UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

Catalyst Development, Its Characterization and Potential Utilization For Industrial Processes

by

Prof. Abdul Rahman Bin Mohamed

Assoc. Prof. Ahmad Zuhairi Bin Abdullah

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Prof. Subhash Bhatia

2011

VERSITI SAINS MALAYSIA

UNIVERSITY RESEARCH GRANT FINAL REPORT
Geran Penyelidikan Universiti Laporan Akhir

TITLE OF RESEARCH:
Tajuk penyelidikan:

CATALYST DEVELOPMENT, ITS CHARACTERIZATION AND POTENTIAL UTILIZATION FOR INDUSTRIAL PROCESSES

PERSONAL PARTICULARS OF RESEARCHER / *MAKLUMAT PENYELIDIK:*

Name of Research Leader:
Nama Ketua Penyelidik:

PROF ABDUL RAHMAN BIN MOHAMED

Name of Co-Researcher
Nama Penyelidik Bersama:
PROF MADYA AHMAD ZUHAIRI BIN ABDULLAH
PROF AZLINA BINTI HARUN@KAMARUDDIN
PROF SUBHASH BHATIA

School/Institute/Centre/Unit :
Pusat Pengajian /Institut/Pusat/Unit :
PUSAT PENGAJIAN KEJURUTERAAN KIMIA

Research Platform (Please tick (/) the appropriate box):
Pelantar Penyelidikan (Sila tanda (/) kotak berkenaan):

[ ]	**A. Life Sciences** *Sains Hayat*
[ ]	**B. Fundamental** *Fundamental*
[/]	**C. Engineering & Technology** *Kejuruteraan & Teknologi*
[ ]	**D. Social Transformation** *Transformasi Sosial*
[ ]	**E. Information & Communications Technology (ICT)** *Teknologi Maklumat & Komunikasi*
[ ]	**F. Clinical Sciences** *Sains Klinikal*
[ ]	**G. Biomedical & Health Sciences** *Bioperubatan Sains Kesihatan*

Tempoh masa penyelidikan ini :

***Duration :** .....3 YEARS.....
Tempoh :

From : 10/10/2007 **To** : 31/7/2011
Dari: *Ke :*

ABSTRACT OF RESEARCH

(An abstract of between 100 and 200 words must be prepared in **Bahasa Malaysia and in English**. This abstract will be included in the Annual Report of the Research and Innovation Section at a later date as a means of presenting the project findings of the researcher/s to the University and the community at large)

In this project, heterogeneous catalysts were synthesized and applied in various catalytic reactions which were biodiesel productions, monoglyceride production, selective catalytic reduction of NO_x, photocatalytic degradation of phenol and productions of carbon nanotubes through simple and versatile method of catalytic chemical vapour deposition (CVD). Characterization of the synthesized catalysts was carried out using surface analyzer, XRD, FTIR, TGA, SEM and TEM. The characteristics of the catalysts were investigated in the selected test reaction and it has been proved that the performance of the new synthesized catalysts were correlated with the specific catalyst behaviors. The catalytic activity of the novel catalysts was assessed in terms of the level of conversion, product yield and selectivity, prior to the optimization of various reaction parameters including reaction temperature, reaction time, types of catalyst and catalyst loading.

Abstrak Penyelidikan

(Perlu disediakan di antara 100 - 200 perkataan di dalam **Bahasa Malaysia dan juga Bahasa Ingge** Abstrak ini akan dimuatkan dalam Laporan Tahunan Bahagian Penyelidikan & Inovasi sebagai satu ca untuk menyampaikan dapatan projek tuan/puan kepada pihak Universiti & masyarakat luar).

Dalam projek ini, mangkin heterogen telah disintesis dan diaplikasikan dalam pelbagai tindak balas dan bertindak sebagai pemangkin untuk tindak balas penghasilan biodiesel, monoglicerida, tindak balas penurunan bermangkin NO_x, fotopemangkinan degradasi fenol serta penghasilan nanotiub karbon melalui kaedah tindak balas penguraian wap kimia bermangkin. Pencirian bagi mangkin yang telah disintesis telah dijalankan dengan menggunakan penganalisis permukaan, XRD, FTIR, TGA, SEM dan TEM. Ciri-ciri dan sifat-sifat mangkin tersebut telah dikenalpasti dalam pelbagai ujikaji tindak balas dan didapati sangat berkait rapat dengan peranan yang dimainkan oleh mangkin tersebut dalam tindak balas yang tertentu. Aktiviti mangkin ini telah dinilai dari segi tahap penguraian, hasil dan produk tindak balas, serta melibatkan proses mendapatkan optimum parameter dalam pelbagai tindak balas termasuklah suhu dan masa tindak balas serta jenis dan jumlah mangkin yang digunakan dalam tindak balas tersebut.

Ringkasan dapatan Projek Penyelidikan

In this project, advanced materials were synthesized and used as heterogeneous catalysts in various catalytic reactions including oleochemical synthesis, biodiesel production, carbon nanotubes productions and environment reactions. These catalysts were characterized for their physical, chemical and catalytic properties and correlations between these properties and their behavior in the selected reaction were established. Significant improvement in the catalytic process was achived using a novel functionalized mesoporous catalyst, ultrasonic-assisted process and certain surfactants. Process parameters involved in the reaction of production of biodiesel, monoglyceride, NO_x reduction, photocatalytic degradation of phenol and production of carbon nanotubes were successfully optimized. The stability of the catalyst materials under various reaction conditions were demonstrated and elucidated.

COMPREHENSIVE TECHNICAL REPORT
Laporan Teknikal Lengkap
Applicants are required to prepare a comprehensive technical report explaining the project.
(This report must be attached separately)
Sila sediakan laporan teknikal lengkap yang menerangkan keseluruhan projek ini.
[Laporan ini mesti dikepilkan]

List the key words that reflectour research:
Senaraikan kata kunci yang mencerminkan penyelidikan anda:

English	Bahasa Malaysia
Carbon Nanotiub	Nanotiub Karbon
Biodiesel Productions	Penghasilan Biodiesel
Catalytic Chemical Vapour Deposition	Penguraian Wap Kimia Bermangkin

a) Results/Benefits of this research
Hasil Penyelidikan

No. *Bil:*	Category/Number: *Kategori/ Bilangan:*	Promised	Achieved
1.	**Research Publications (Specify target journals)** *Penerbitan Penyelidikan (Nyatakan sasaran jurnal)*	**24**	**50**
2.	**Human Capital Development**		
	a. Ph. D Students	**2**	**21**
	b. Masters Students	**16**	**20**
	c. Undergraduates (Final Year Project)	**5**	**8**
	d. Research Officers	**5**	**5**
	e. Research Assisstants	**3**	**4**
	f. Other: Please specify	**2**	**2**
3.	**Patents** *Paten*	**2**	**2**
4.	**Specific / Potential Applications** *Spesifik/Potensi aplikasin*	**4**	**1**
5.	**Networking & Linkages** *Jaringan & Jalinan*	**1**	**2**
6.	**Possible External Research Grants to be Acquired** *Jangkaan Geran Penyelidikan Luar Diperoleh*	**3**	**6**

- Kindly provide copies/evidence for Category 1 to 6.

b) Equipment used for this research.
Peralatan yang telah digunakan dalam penyelidikan ini.

Items *Perkara*	Approved Equipment	Approved Requested Equipment	Location
Specialized Equipment Peralatan khusus	RAMAN SPECTROMETER	RAMAN SPECTROMETER	ROOM 1.22, SCHOOL OF AEROSPACE ENINEERING
	THERMOGRAVIMETRIC ANALYZER (TGA)	THERMOGRAVIMETRIC ANALYZER (TGA)	MTDC LAB, SCHOOL OF AEROSPACE ENINEERING
	WATER BATH	WATER BATH	ENVIRONMENT LAB, SCHOOL OF CHEMICAL ENGINEERING
	HIGH PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC)	HIGH PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC)	THERMODYNAMIC LAB, SCHOOL OF CHEMICAL ENGINEERING
	GAS CHROMATOGRAPHY	GAS CHROMATOGRAPHY	PETROLEUM LAB, SCHOOL OF CHEMICAL ENGINEERING
	CONTINUOUS EMISSION MONITORING SYSTEM/FLAME GAS ANALYZER	CONTINUOUS EMISSION MONITORING SYSTEM/FLAME GAS ANALYZER	ENVIRONMENT LAB, SCHOOL OF CHEMICAL ENGINEERING
	ROTARY EVAPORATOR	ROTARY EVAPORATOR	THERMODYNAMIC LAB, SCHOOL OF CHEMICAL ENGINEERING
	PELLETIZER MANUAL HYDRAULIC PRESS	PELLETIZER MANUAL HYDRAULIC PRESS	ENVIRONMENT LAB, SCHOOL OF CHEMICAL ENGINEERING
	ANALYTICAL BALANCE	ANALYTICAL BALANCE	MTDC LAB, SCHOOL OF AEROSPACE ENINEERING
	HOTPLATE WITH MAGNETIC STIRRER	HOTPLATE WITH MAGNETIC STIRRER	MTDC LAB, SCHOOL OF AEROSPACE ENINEERING
	ULTRASONIC BATH	ULTRASONIC BATH	MTDC LAB, SCHOOL OF AEROSPACE ENINEERING
	pH METER	pH METER	MTDC LAB, SCHOOL OF AEROSPACE ENINEERING
	UNIVERSAL OVEN	UNIVERSAL OVEN	MTDC LAB, SCHOOL OF AEROSPACE ENINEERING
	CONTROLLER & STIRRER	CONTROLLER & STIRRER	ENVIRONMENT LAB, SCHOOL OF CHEMICAL ENGINEERING
Facility Kemudahan			
Infrastructure Infrastruktur			

- Please attach appendix if necessary.

BUDGET / *BAJET*

Perbelanjaan :Expenditure

Project Account No.	: 1001 / PJKIMIA / 814004
Total Approved Budget	: RM 518100
Total Additional Budget	: RM 750000
Grand Total of Approved Budget	: RM 1268100

Yearly Budget Distributed

Year 1	: RM 273700
Year 2	: RM 147700
Year 3	: RM 96700

Additional Budget Approved

Year 1	: RM 500000
Year 2	: RM 250000
	:

Total Expenditure	: RM 1152519.20
Balance	: RM 24,994.77

- **Please attach final account statement from Treasury**

ARahman

Signature of Researcher
Tandatangan Penyelidik

01/08/2011

Date
Tarikh

Professor Dr. Abdul Rahman Bin Mohamed
Ph.D (Chemical Engineering), B.C.N., CEng, FIChemE,
School of Chemical Engineering
Universiti Sains Malaysia
Engineering Campus
14300 Nibong Tebal
Pulau Pinang

General Comments:
Ulasan Umum:

Excellent research output. The research output meets and beyond what has been promised -

2/8/11

Signature and Stamp of Chairperson of PTJ's Evaluation Committee
Tandatangan dan Cop Pengerusi Jawatankuasa Penilaian PTJ

Date : .....
Tarikh :.....

Signature and Stamp of Dean/ Director of PTJ
Tandatangan dan Cop Dekan/ Pengarah PTJ

Date : .....
Tarikh :.....

PROFESOR AZLINA HARUN @ KAMARUDDIN
Dekan
Pusat Pengajian Kejuruteraan Kimia
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Universiti Sains Malaysia, Seri Ampangan
14300 Nibong Tebal, Seberang Perai Selatan
Pulau Pinang.

This research focused on the development of various heterogeneous catalysts system owards its utilizations in numerous field of applications in industrial processes. The erformance of the catalyst was investigated in the selected catalytic reaction. These includes ie production of biodiesel, selective catalytic reduction of NOx and SO_2, synthesis of carbon anotubes (CNTs) and photocatalytic degradation of phenol.

In this project, various catalyst based on MgO, CaO, BaO, SrO and other mesoporous aterial were synthesized at different weight loadings and applied for the production of odiesel. The performance of the new-synthesized catalyst was evaluated through the level of onversion and yield of biodiesel's production. It can be deduced that for the unsupported atalysts, BaO showed the highest basicity and activity in the transesterification reaction. For ie supported catalysts, KOH/SBA-15 produced the highest biodiesel yield due to the high urface area and straight mesoporous channels of the catalyst. The synthesized catalyst were haracterized by using surface analyzer, XRD, FTIR, SEM and TEM. The characteristics of the atalyst were correlated with the specific behaviours of the catalysts in the transesterification eaction. Various process variables such as temperature, catalyst loading and reaction time ere investigated. For this purpose, response surface methology was successfully employed to redict the behavior of different catalyst under various conditions with high degree of accuracy. addition, the effect of applying different analytical method was studied for the improvement in ata accuracy for the conversion and yield in biodiesel production. The comparison between the ffect of mechanical stirring and ultrasonic irradiation was investigated. As a results, ultrasonic adiation was found to improve the yield of biodiesel between 30 – 65%, depending on the talyst. Furthermore, the reaction time needed for achieving 95% yield was reduced from 2 urs to just about 30 min. It was noticed that this problem was originated from the difficulty in tting phase separation after the reaction. The effect of the implementation of ultrasonic adiation on the temperature increase in the reactor was also studied. Utilization of ultrasonic adiation at higher amplitude will cause the higher tempature increase. The higher amplitude l cause the biodiesel yield to be increased to up to 95% in 30 min.

Furthermore, the synthesized heterogeneous catalyst was also tested for the noglyceride production through the esterification of glycerol with lauric acid. Thus, different ase transfer catalyst (PTC) based on clay (montmorillonite) were synthesized. Various

rocess variables including reaction temperature, ratio of glycerol to lauric acid and catalyst ading were investigated towards the conversion and selectivity of monoglyceride productions. or the selective catalytic reduction of NOx, bimetallic catalysts of Cu-Zn/ZSM-5 was developed incorporating copper (Cu) and zinc (Zn) onto ZSM-5 zeolite (Si/Al=40) using two different ethod of impregnation or ion exchange. Different orders of metal loadings which range range etween 2 wt% and 14wt% was employed. Three reaction parameters of reaction temperature, e feed gas mixture of NO and iso-butane concentration was studied. Then, the synthesized metallic catalyst was washcoated onto a 400 cell per square inch (cpsi) ceramic monolith with diameter of 2.0 cm and a length of 6.0 cm. The catalyst were characterized using SEM, XRD, rface analyzer, FTIR and ultrasonic treatment for washcoating adherence of catalyst coating nto the ceramic monolith. As a results, it was found that the best metal incorporations were by npregnating the Cu and ion exchange the Zn with the optimum metal loading of Cu and Zn ere 6wt.% and 8wt.%, respectively. The best operating conditions were obtained from DOE udy showed that the utilization of gas mixture of 900ppm NO, 2000 ppm of iso-butane, 3 v/v of O_2 and N_2 was the optimum inlet gas concentration resulted for the 90% of NO conversion th the used of powdered Cu-Zn/ZSM-5 catalyst with the operating temperature between 300 and 400 °C. Besides showing high catalytic activity, the monolithic catalyst was also stable r up to 72h with an activity drop of only 10% as well as low activation energy of +30.30 kJ/mol as obtained for the reaction.

addition, the objective of this research study is to develop a technology for simultaneous moval of SO_2 and NO_x utilizing activated carbon (AC) synthesized from palm shell (PS). Thus, y-type sorbent (Palm shell activated carbon, PSAC) produced from palm shell for the multaneous removal of SO_2 and NO has been developed. The utilization of this abundant omass waste presents an attractive alternative to the current sorption technologies in the arket. Palm shell was successfully converted into PSAC using physical activation method nsisting of N_2 gas as the carbonization agent and CO_2 gas as the activation agent. The xperimental results of carbonization and activation of PS revealed that CO_2 activation mperature, flow rate and retention time were the most important parameters influencing the haracteristics of SO_2 and NO sorption performance of the prepared PSAC. These three factors owed significant effects on the BET surface area, total pore volume, burn-off, microposity action and carbon yield of PSAC. Regression models were successfully developed to capture e correlation between the PSAC preparation variable to the responses. The models were itable and persistent to predict the responses from the fixed operating variables. As a results,

can be noticed that SO_2 was successfully removed by the prepared PSAC. In the preliminary reparation of PSAC, it was found that the prepared PSAC was not capable of removing NO as simultaneously from the mixed simulated flue gas. Thus, the evaluation of adding various pes of metal oxides to PSAC was done. Four types of metal which are nickel, ferum, anadium and cerium were introduced. It was found PSAC-supported metal oxides exhibits ood result in simultaneous removal of SO_2 and NO from the simulated flue gas. Among the mpregnated metal oxides, PSAC-Ce showed the most promising adsorbent of both SO_2 and O. The major adsorber process parameters affecting SO_2 and NO sorption activity of PSAC-e were studied. These includes feed concentration of SO_2 and NO, relative humidity (RH), pace velocity (SV) and operating temperature. It was found higher SV reduced the SO_2 and O sorption capacity because higher SV means lower adsorbent dosage. RH was also found to nhance SO_2 sorption capacity. This is owing to the reaction of SO_2 with water to produce $_2SO_4$ as by-product. In contrast, the NO sorption capacity dropped badly in the presence of umidity/water vapor in the operating system. This was due to low solubility of NO in water. For perating parameter effect, it was found that NO sorption enhanced as the temperature was ised from 100°C to 250°C. For SO_2, the sorption capacity increased up to 150°C, beyond that e SO_2 soprtion decreased. Small amounts of NO in the feed could improve the sorbent apacities for SO_2, however further increasing the contents of NO in the feed strongly ecreased the removal capacities of SO_2. The same phenomenon was observed for NO when a mall amount of SO_2 was introduced into the feed and vice versa.

In the field of synthesis of carbon nanotubes (CNTs), a fundamental study was nducted in developing effective catalysts for growing carbon nanotubes from natural gas by plying a simple and versatile method of catalytic chemical vapour deposition of methane. is research group has tailor-made various types of carbon nanotubes, such as multi-walled rbon nanotubes (MWNTs), single-walled carbon nanotubes (SWNTs) and Y-junction carbon notubes (Y-CNTs) through the ingenious catalyst development approach. Methane chemical pour decomposition process was studied with three active metal components which are nickel), cobalt (Co) and Iron (Fe). Carbon materials such as carbon molecular sieves (CMS) and ivated carbon (AC) having different surface properties from various sources were utilized as pports with the objective of achieving CH_4 conversion and synthesizing CNTs with different rphologies. CMS materials were considered with the aim of achieving better catalyst ribution over their membrane-like molecular sieve pores to produce CNTs with very thin meter. It was observed from the studies that the impregnation of active metal components

er the AC support led to the formation of CNTs with different morphologies. The catalyst nthesized with AC supports such as Ni/AC, Co/AC and Fe/AC, gave higher methane nversions than CMS-based catalysts. The surface morphological studies confirmed that the etal particles distributions on AC surface was better than CMS. It suggested that the icroporous nature of AC surface was advantageous for the metal particle to accommodate on ıpports surface to facilitate the CH_4 gas molecules to interact and get decomposed to form NTs. Furthermore, it was found that the individual active metal like Fe, Co and Ni components ayed a significant role in methane conversion based on various process parameter such as ılcinations temperature, reduction and reaction temperatures, gas flow ratio (CH_4:N_2) and etal loadings. Different morphologies of CNTs with variation in diameter and thickness were ɔtained utilization of Ni/AC, Co/AC and Fe/AC catalysts.

As mentioned earlier, chemical vapor deposition (CVD) is known to be one of the most romising ways for large-scale and cost effective production of CNTs as compared to other high ɔerating temperature processes. However, with the current commonly used batch-wise CVD ystem, the CNTs production rate is low and it is not cost effective from the economic point of ew. In this research, the problem as aforementioned was overcome through design and brication of a horizontal rotary tubular reactor system which enables the continuous production CNTs. The as-produced carbon deposits collected from the product reservoir were analyzed ith scanning electron microscopy, transmission electron microscopy, thermogravimetric nalysis, and Raman spectroscopy. CNTs were synthesized via catalytic decomposition of ethane over bimetallic Co-Mo/MgO catalyst which was tested earlier to be effective in the atchwise synthesis. In order to meet the increased demand for CNTs nowadays, new reactor nown as rotary tubular reactor was fabricated for continuous production of CNTs. A new ntinuous processing method of CVD was successfully developed for mass production of NTs. The CNTs produced from the rotary tubular reactor possess the diameter distribution of 2.8±4.2nm. The outlet carbon deposits have high purity of 81.7%, high carbon yield of 446.4%, nd high selectivity toward the synthesis of CNTs rather than other kinds of carbon anostructures.

In the area of photocatalysis, nano-TiO_2 supported on activated carbon (AC) and silica el were successfully synthesized by sol gel and hydrothermal methods. The satisfactory results phenol photodegradation were obtained using the supported TiO_2 produced in batch and uidized bed reactor. Modification of TiO_2 photocatalysts by doping technique was also

mployed by immobilization technique to improve the photocatalytic degradation performance of iO_2 photocatalysts. Doping of fluorine (F) and cerium (Ce) was employed to improve the erfomance of TiO_2 synthesized using sol gel and hydrothermal methods. Doping TiO_2 with erium was successfully used on the photocatalytic degradation of phenol under visible light egion in the batch reactor. TiO_2-F photocatalysts performed excellently on the phenol egradation in the fluidized bed reactor. The performance of different nanostructured TiO_2 (TiO_2 anotubes) was also investigated in this project in order to improve the overall photocatalytic fficiency, increase the surface area, and also the interfacial charge transfer rate on the phenol egradation in the batch reactor under UV region. TiO_2-F and TiO_2 nanotubes photocatalysts ere immobilized onto quartz sand and silica gel to overcome the photocatalyst recovery roblem.

PENYATA KUMPULAN WANG
TEMPOH BERAKHIR 7/2011

Tajuk Projek : CATALYST DEVELOPMENT ITS CHARACTERIZATION & POTENTIAL UTILIZATION FOR INDUSTRIAL PROCESSES

Pusat Pengajian : Pusat Pengajian Kejuruteraan Kimia

Penyelidik : ABDULRAHMAN MOHAMED

Status Projek : AKTIF

No Projek (Agensi) :

Tempoh Projek : 2007 / 10 - 2011 / 9

No Akaun : 1001 / 814004

Vot	Keterangan	Peruntukan Asal	Perbelanjaan Tahun Lalu	Peruntukan Semasa	Tanggungan	Belanja	Jumlah Belanja	Baki	%
11000	Gaji	201,600.00	$156,831.16	$0.00	$0.00	$42,612.29	$42,612.29	$2,156.55	0.00
13000	Sumbangan Majikan	0.00	$67.85	$0.00	$0.00	$0.00	$0.00	($67.85)	0.00
15000	Lain-lain Emolumen	0.00	$500.00	$0.00	$0.00	$0.00	$0.00	($500.00)	0.00
		$201,600.00	**$157,399.01**	**0.00**	**$0.00**	**$42,612.29**	**$42,612.29**	**$1,588.70**	0.00
21000	PERJALANAN DAN SARA HIDUP	25,000.00	$30,571.12	$0.00	$1,178.00	$5,731.86	$6,909.86	($12,480.98)	0.00
22000	PENGANGKUTAN BARANG-BARANG	4,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$4,000.00	0.00
23000	PERHUBUNGAN DAN UTILITI	1,500.00	$0.00	$0.00	$0.00	$0.00	$0.00	$1,500.00	0.00
24000	SEWAAN	6,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$6,000.00	0.00
26000	BEKALAN BAHAN MENTAH	5,000.00	$2,995.00	$0.00	$0.00	$0.00	$0.00	$2,005.00	0.00
27000	BEKALAN DAN ALAT PAKAI HABIS	70,000.00	$55,203.83	$0.00	$20,248.69	$13,285.44	$33,534.13	($18,737.96)	0.00
28000	PENYELENGGARAAN DAN PEMBAIKAN KECIL	25,000.00	$14,903.20	$0.00	$13,210.00	$8,240.00	$21,450.00	($11,353.20)	0.00
29000	PERKHIDMATAN IKTISAS DAN HOSPITALITI	30,000.00	$11,371.14	$0.00	$8,490.00	$6,552.00	$15,042.00	$3,586.86	0.00
		$166,500.00	**$115,044.29**	**0.00**	**$43,126.69**	**$33,809.30**	**$76,935.99**	**($25,480.28)**	0.00
35000	HARTA-HARTA MODAL LAIN	900,000.00	$849,995.65	$0.00	$1,118.00	$0.00	$1,118.00	$48,886.35	0.00
		$900,000.00	**$849,995.65**	**0.00**	**$1,118.00**	**$0.00**	**$1,118.00**	**$48,886.35**	0.00

SENARAI NAMA PELAJAR DI BAWAH GERAN RU (814004)

ELAJAR YANG SEDANG MENJALANKAN PENYELIDIKAN-SARJANA

Bil	Nama Pelajar	Sarjana/Doktor Falsafah
1	Seah Choon Ming	Sarjana
2	Norazuwana Shaari	Sarjana
3	Siti Salwa Hashim	Sarjana
4	Afrizal Admiral	Sarjana
5	Razealy Anuar	Sarjana

ELAJAR YANG SEDANG MENJALANKAN PENYELIDIKAN-DOKTOR FALSAFAH

Bil	Nama Pelajar	Sarjana/Doktor Falsafah
1	Lee Zhi Hua	Doktor Falsafah
2	Nurul Aini Md. Razali	Doktor Falsafah
3	Yeoh Wei Ming	Doktor Falsafah
4	Merhnoush Khavarian	Doktor Falsafah
5	Maedahossadat Mohammadi	Doktor Falsafah
6	Tri Yogo Wibowo	Doktor Falsafah
7	Pang Yean Ling	Doktor Falsafah
8	Ali Sabri Badday	Doktor Falsafah
9	Zahra Gholami	Doktor Falsafah
10	Muhammad Ayoub	Doktor Falsafah
11	Atheel Hassan	Doktor Falsafah
12	Nor Hasyimi Rahmat	Doktor Falsafah
13	Lilis Hermida	Doktor Falsafah
14	Hamed Mootabadi	Doktor Falsafah

ELAJAR YANG TELAH MENAMATKAN PENGAJIAN-DOKTOR FALSAFAH

Bil	Nama Pelajar	Sarjana/Doktor Falsafah
1	Chai Siang Piao	Doktor Falsafah
2	Sumathi Suphasethu	Doktor Falsafah
3	Liu Wei Wei	Doktor Falsafah
4	Hossein Mazehari	Doktor Falsafah
5	Irvan Dahalan	Doktor Falsafah
6	Sivakumar	Doktor Falsafah
7	Babak Salamatinia	Doktor Falsafah

LIST OF PATENTS

(1)International Patent Application no: PCT/MY2008/000143 (2008)

-A process for producing Carbon Nanotubes (CNTs)

(2)International Patent Application no : PI 201100 1090 (2011)

- An Apparatus For Production Of Carbon Nanotubes And The Method Thereof

ur Ref: USM/INNOV/200(O)/003

ate: 9 May 2011

Innovations Office
Building J06,
Universiti Sains Malaysia,
11800 USM, Penang, Malaysia.
Tel: 604 653 3888 / 2616 / 3166
Fax: 604 653 4399
http://www.usm.my/r&i

amakrishna Damodharan
ASS International Sdn. Bhd.
uite 8-7-2 Menara Mutiara Bangsar
alan Liku, Off Jalan Riong
9100 Bangsar
uala Lumpur

ear Sir,

ITERNATIONAL APPLICATION NO.: PCT/MY2008/000143
TLE OF INVENTION: A PROCESS FOR PRODUCING CARBON NANOTUBERS (CNTs)

eferring to your letter received dated 4th April 2011, we are pleased to inform you that the niversity has agreed to proceed with the payment for the patent *"A PROCESS FOR RODUCING CARBON NANOTUBERS (CNTs)".*

ne information regarding the product are listed below:

- **APPLICANT** : UNIVERSITI SAINS MALAYSIA
- **AGENT'S FILE REFERENCE** : RD/P1607/USM/08-PCT/SL

ttached is copy of the Purchase Order No: PSJPNP1000000000533 for your action.

/e would be grateful for your immediate response on this matter. Thank you

Ensuring a Sustainable Tomorrow"

ours sincerely,

'ROFESSOR ZAINUL FADZIRUDDIN ZAINUDDIN)
irector
novations Office

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Seberang Perai Selatan

Institute for NanoScience Design
OSAKA University

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1-3 Machikaneyama Toyonaka, Osaka, 560-8531, Japan
Tel:+81-6-6850-6506
E-Mail: itoh@mp.es.osaka-u.ac.jp
26/03/2009

To Prof. Dr. Abdul Rahman Mohamed
School of Chemical Engineering,
Engineering Campus, Universiti Sains Malaysia,
Seri Ampangan, 14300 Nibong Tebal,
Penang, Malaysia.

Dear Prof. Abdul Rahman Mohamed,

I am pleased to inform you on behalf of Institute for NanoScience Design, Osaka University to accept the appointment of Mr. Lee Kim Yang and Mr. Yeoh Wei Ming from 09/05/2009 to 22/05/2009 as visiting researchers. They can work on the TEM study of carbon nanotubes in the institute with our scientific staffs.

We, Institute for NanoScience Design, understand that all expenses incurred in the travel (flight, accommodation, and insurance) will be paid from your research grant. Since you also agree that we will not be accountable to them for any accidents during their stay, we would like to ask them to join some travel insurance during their absence from your university.

We hope that the students obtain good scientific results and enjoy the stay in INSD.

Yours sincerely

Tadashi Itoh

Prof. Tadashi Itoh

Memorandum of Understanding
Between

Universiti Sains Malaysia
11800 USM, Penang, Malaysia
(hereafter referred to as "USM")

And

Institute for NanoScience Design
Osaka University, Osaka 560-0043, Japan
(hereafter referred to as "INSD")

INTENTION OF THE UNDERSTANDING

This understanding is intended to establish the framework for understanding and cooperation between Universiti Sains Malaysia and Institute for NanoScience Design in the areas of staff and student exchanges and the sharing of expertise, knowledge and information.

OBJECTIVES

The objectives of the understanding are as follows:

1 To promote cross-cultural exchanges between staff and students of both institutions;

2 To enrich the academic and campus life of both institutions, as well as to provide support for academic and non-academic activities;

3 To provide opportunities for faculty staff at USM and INSD to undertake joint teaching and research; and

4 To promote the sharing of best practices and experiences.

COMMITMENTS OF USM and INSD

In Respect of Staff Exchange

1 Both institutions will consult on a regular basis, the possibility of staff exchange in areas of teaching, research or administration. The period of the exchange will not exceed a year.

2 Both institutions will ensure that the selected staff meets the appropriate work requirements as determined and agreed upon by the two parties. It is also agreed that the intended exchange be made known to the host institution at least three months in advance.

3 Where an exchange is affected, the salary, travelling and living expenses will be the responsibility of the institutions from which the exchange is made (hereinafter called "*the home institution*") unless otherwise negotiated.

4 The institution in which the exchange is made (hereinafter called "*the host institution*") shall provide accommodation and set working conditions and privileges which are at least equivalent to those accorded to resident staff of that institution.

5 Staff is expected to purchase health and travel insurance as required by the host country; they must present these documents and their translations to the host institution before departure from the home country.

6 Each institution may nominate up to 1 of its staff members per year to participate in the exchange.

7 The host institution will assist the exchange staff in dealing with administrative procedures inclusive of application for visa and other immigration matters.

8 In the case of teaching and research staff members on exchange, advance understanding shall be made between the two institutions with respect to access to special facilities such as laboratories, dedicated equipment, and the like.

9 The institution in which the exchange is made (hereinafter called "*the host institution*") shall not impose any bench fees for the attachment of staff.

In Respect of Associated Matters

1 Both institutions agree to provide on "as needed" basis, orientation of staff in respect of language, culture, customs, and other life skills which may be necessary for the staff to obtain the maximum benefit from the exchange experience.

2 All individuals on exchange under this understanding shall be subject to the laws of the host country and the legislation, in whatever form, governing the affairs of the host institution.

3 Reciprocity will be ensured on a 3-year basis.

4 Both USM and INSD acknowledge that the provision in this understanding represent their mutual intentions and commitment towards staff exchanges and sharing of information and facilities in accordance with the terms and conditions of this understanding, but this understanding is not intended to create any legal binding obligations nor contractual relationship between the parties. In the event that a separate legal understanding needs to be executed in relation to this, both parties may negotiate in good faith on the terms and conditions of a legal understanding to be executed at any other appropriate time.

DURATION AND TERMINATION

1 This understanding shall be in force for a period of 5 years from the date of signatory by both parties and shall be renewable after re-negotiation procedures have been completed.

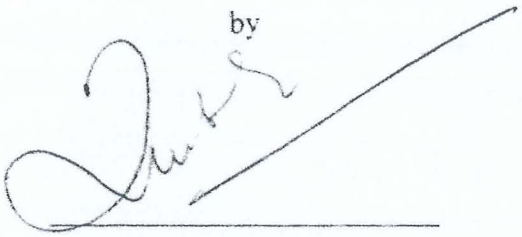
2 Either party shall be competent to terminate the understanding on giving at least six months prior notice to the other party in writing. However, the termination of this agreement shall not affect the implementation of the collaborative activities established under it prior to such termination.

COOPERATION UNDERSTANDING

In Witness Whereof the parties have set their respective hands on this understanding.

UNIVERSITI SAINS MALAYSIA

by



Dzulkifli Abdul Razak

Vice Chancellor

Date

April 15, 2010

INSTITUTE FOR NANOSCIENCE DESIGN
OSAKA UNIVERSITY

by

Tadashi Itoh

Tadashi Itoh

Director

Date

March 17, 2010

USAINS HOLDING SDN BHD (Co. No. 473883-H)
(Wholly owned by Universiti Sains Malaysia, Pulau Pinang, Malaysia)

USAINS 10th ANNIVERSARY A DECADE OF INNOVATION 1999-2009

21 Januari 2011

KEPADA SESIAPA YANG BERKENAAN

Pengesahan Penglibatan Dalam Kerja Perundingan

Dengan hormatnya saya merujuk kepada perkara di atas.

2. Dengan ini saya mengesahkan bahawa Prof. Dr. Abdul Rahman Mohamed daripada Pusat Pengajian Kejuruteraan Kimia, Universiti Sains Malaysia terlibat di dalam kerja perundingan dengan projek syarikat seperti yang berikut:-

Pelanggan	Felda Palm Industries Sdn Bhd
Tajuk	Research and Development of Biogass Scrubbing System Using Activated Carbon From Palm Kernel Shell.
Nilai	RM452,688.65
Tempoh	12 bulan (1/9/10-31/8/11)
Jawatan	Perunding

Sekian, terima kasih.

Yang benar,

Sazali Ahmad
Pengurus Kumpulan
Kewangan & Pembangunan Perniagaan

UNIVERSITI SAINS MALAYSIA

PEJABAT PENGURUSAN DAN KREATIVITI PENYELIDIKAN
RESEARCH CREATIVITY AND MANAGEMENT OFFICE

Ruj. Fail : A1035
Tarikh : 29 Mei 2008

Profesor Abdul Rahman Mohamed
Pusat Pengajian Kejuruteraan Kimia
Universiti Sains Malaysia
Kampus Kejuruteraan
14300 Nibong Tebal
PULAU PINANG

Tuan,

PROJEK PENYELIDIKAN PEMBIAYAAN MALAYSIAN TECHNOLOGY DEVELOPMENT CORPORATION SDN BHD [MTDC]

Dengan segala hormatnya perkara diatas dirujuk.

Sukacita dimaklumkan bahawa projek penyelidikan tuan diatas tajuk *"Single Step Production of Carbon Nanotubes and Hydrogen from Natural Gas"* telah diluluskan geran sebanyak ***RM1,340,000.00*** oleh Malaysian Technology Development Corporation Sdn. Bhd. [MTDC]. Selanjutnya untuk tahun 2008, pihak MTDC telah mengagihkan peruntukan sebanyak RM950,000.00 bagi tuan menjalankan penyelidikan *[Dilampirkan maklumat peruntukan yang diluluskan untuk perhatian tuan]*. Untuk makluman tuan, sejumlah RM100,000.00 telah ditolak daripada peruntukan pertama bagi tujuan *'Market Survey Cost'* dan *'Legal Fee'.* Dengan ini, jumlah pembayaran tahun pertana tuan bernilai **RM850,800.00.** Tempoh projek untuk 36 bulan (3 tahun) mulai 15 Mac 2008 sehingga 14 Mac 2011. Sila kemukakan agihan peruntukan ke RCMO untuk tindakan selanjutnya.

Harap maklum, selaras dengan keputusan Jawatankuasa Eksekutif Naib Canselor pada 17 Mac 2005 yang mana telah dimaklumkan kepada semua melalui memo RCMO bertarikh 13 Julai 2005 bahawa 2.5% daripada **RM850,800.00** atau ***RM21,270.00*** akan dikenakan caj perkhidmatan.

Sila ambil perhatian, akaun projek akan dibuka oleh Jabatan Bendahari dan nombor ini akan dimaklumkan kepada tuan. Sila rujuk tajuk dan nombor projek ini dalam surat menyurat kepada kami.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
"Bersaing di Peringkat Dunia : Komitmen Kita'

LIS SAFINA ISMAIL
Penolong Pendaftar
e-mel: safina@notes.usm.my

s.k. Y. Brs. Profesor Asma Ismail
Timbalan Naib Canselor
[Penyelidikan & Inovasi]

Encik Ismail Jamaluddin
Ketua Penolong Bendahari
Jabatan Bendahari
Kampus Kejuruteraan USM
— *Pohon kerjasama tuan untuk membuka akaun projek*

Puan Ansuya a/p Narhari
Penolong Bendahari
Unit Kumpulan Wang Penyelidikan
Jabatan Bendahari
— *untuk maklumen*

LSI/mwe
Geran Tajaan MTDC

MTDC

Appendix I

UNIVERSITI SAINS MALAYSIA

TLE		Amount Approved (RM)	(a) Year 1 Budget (RM)	(b) Cost of Market Survey (RM)	(c) Legal Fee (RM)	d = a - (Amount front Pay (RM
	Development & Production of Innovative Biomaterial for Developing Countries	5,769,500	3,553,500	95,000	5,000	3,45
	Innovative Technology for the Production of (S)-Ibuprofen	2,987,500	2,149,500	95,000	5,000	2,04
	Development and Production of OilZob – A Novel and Reactive Oil Adsorbent from Various Rubber Wastes	1,989,000	1,290,000	95,000	5,000	1,19
	Enzymatic Deinking a an Environmental Friendly Solution for Recycling of Printed Waste Papers	1,601,500	1,018,000	95,000	5,000	91
	Development & Production of Dense Hydroxyapatite for Bone Graft Substitutes	7,598,500	3,432,480	95,000	5,000	3,33
)	Single-step Production of Carbon Nanotubes and Hydrogen from Natural Gas	1,340,000	950,800	95,000	5,000	85
	Development & Production of Nitrocellulose Membranes	1,625,000	1,149,500	95,000	5,000	1,04
	Development & Production of Bioconjugates	1,440,000	910,000	95,000	5,000	81
OTAL		**24,351,000**	**14,453,780**	**760,000**	**40,000**	**13,65**

MEMORANDUM OF UNDERSTANDING

BETWEEN

FELDA PALM INDUSTRIES SDN BHD

AND

UNIVERSITI SAINS MALAYSIA (USM)

IN REGARDS TO THE RESEARCH & DEVELOPMENT OF BIOGAS SCRUBBING SYSTEM USING ACTIVATED CARBON FROM PALM KERNEL SHELL

This Memorandum of Understanding (**MOU**) is made on 13 September 2010

Between,

FELDA PALM INDUSTRIES SDN. BHD (Company No.359584-V) with its registered address at Level 4, Balai Felda, Jalan Gurney Satu, 54000 Kuala Lumpur, Malaysia ("**FPISB**")

And,

UNIVERSITI SAINS MALAYSIA, which is represented by School of Chemical Engineering, Universiti Sains Malaysia, Engineering Campus , 14300 Nibong Tebal, Pulau Pinang.
("**USM**")

WHEREAS :

1. FPISB is a palm oil mill processing company involved in the milling and processing of fresh oil palm fruits and crude palm oil;

2. USM is a public university with interests in research activities and which functions to carry out and have the charge, conduct and management of any property, project, scheme or enterprise, beneficial and advantageous to USM;

3. FPISB and USM wish to collaborate in the research activities in the area of cleaning and improvement of biogas made from palm oil mill effluent (POME) subject to the terms and conditions appearing hereinafter (the "Collaboration").

NOW IT IS HEREBY UNDERSTOOD AS FOLLOWS:-

1. PRINCIPLES OF COLLABORATION

1.1 This MOU lays the foundation for a broader, co-sponsored program that would improve efficiencies and avoid redundant research activities and expedite the commercialization of university research findings and products, through leveraging resources and capabilities within each organization.

1.2 The principles of the Collaboration center on the following aspects:

a. Research, improve and develop a new technology in the biogas cleaning field with focus on pollution prevention and green engineering;

b. Application of the Research and Development Fund of USM;

c. Exploration of potential commercial uses of the research findings in the field of effluent treatment suitable for POME biogas and new technology that comply with the Environmental Quality Act 1974 and related laws to provide better solutions for the protection of environment and biogas usage; and

d. Identify any potential intellectual property rights which may arise out of or as a result of the Collaboration. For the avoidance of doubt, Parties agree that the details of such intellectual property matters shall be mutually discussed and addressed in a separate definitive agreement.

1.3 Further details in relation to the extent of the Collaboration, the nature, extent and depth of the areas of Collaboration as stated in Clause 1.2 are issues that will be jointly and mutually discussed and agreed upon between USM and FPISB during the course of this Collaboration.

1.4 This MOU intends to set a path for the development of an agreement for more permanent collaboration. The respective rights and obligations of the Parties shall be defined in the future definitive agreement which shall supersede this MOU and all other communications between the Parties with respect to the Collaboration.

1.5 This MOU does not commit any of the Parties to provision of any resources but is a mutual understanding between the Parties to pursue a collaborative and coordinated effort in the specified areas set out in Clause 1.2.

1.6 Notwithstanding Clause 1.5 above, each party shall bear the costs of performing and observing its own obligations under this MOU without charge to the other party.

2. INTENTIONS OF THE PARTIES

The Parties hereby agree that the essential features of the Collaboration shall be:

2.1 The Parties possess the relevant technology and know-how in relation thereto and are willing to provide all such technical and business expertise as may be required for the implementation of the Collaboration.

2.2 The Parties wish to explore business opportunities of mutual interest and in connection with these opportunities, each Party may disclose to the other certain confidential technical and business information which the disclosing party desires the receiving party to treat as confidential.

3. ROLES OF PARTIES

3.1 Roles of FPI are as follows:-

a. Liaise with the MTDC relating to the application of Commercialization Research and Development Fund (CRDF) for Biogas Cleaning Technology;

b. Coordinate all contracts and communications with the MTDC relating to the procurement of the Biogas Cleaning Technology;

c. Provide team members for the procurement of the Biogas Cleaning Technology;

d. Provide a sufficient number of competent personnel to assist in the effective and timely Biogas Cleaning Technology report ("Report") as necessary and to carry out any of the activities undertaken pursuant to this MOU;

e. Ensure the personnel selected are sufficiently competent to conduct the Biogas Cleaning Technology;

f. Engage employees / team members / assistant consultant needed to perform works i.e. collecting data, sampling, literature review etc.;

g. Plan and implement work schedule for the Biogas Cleaning Technology; and

h. Prepare Biogas Cleaning Technology Report.

3.2 Roles of USM are as follows:-

a. Provide registered consultant and related expertise;

b. Provide Guide Assistant Consultants for the Biogas Cleaning Technology;

c. Provide relevant technology for the Biogas Cleaning Technology;

d. Advise FPISB on all elements or aspects of proposal information for Biogas Cleaning Technology;

e. Prepare the scope of work or Term of Reference (TOR) for Biogas Cleaning Technology;

f. Examine and approve the design of the Biogas Cleaning Technology before the submission to the Department of Environment (DOE); and

g. Provide the know-how, knowledge, technical assistant and expertise.

3.3 **The joint roles of FPISB and USM are as follows:-**

a. Attend the Biogas Cleaning Technology approval meeting;

b. Be responsible for and accountable to the Biogas Cleaning Technology design project;

c. Resolve any issues related to the Biogas Cleaning Technology or Report; and

d. Ensure that every action or activity undertaken pursuant to this MOU is conducted according to the laws of Malaysia.

3.4 Each party will appoint an individual to serve as the official contact and coordinate the activities of each Party in the performance of this MOU. The initial appointees of each Party are as follow:-

FPISB:-

For Technical and Management Aspects :

i. Encik Mokhtar Bin Mat Min (IC no: 570309035637)
ii. Encik Zakaria Bin Salam (IC no: 590905055229)
iii. Encik Zainuri Bin Busu (IC no: 730607085077)

For Administrative and Contractual Matters:

Encik Ismail Bin Hasan
(CEO/Senior Executive Director)

USM :-

For Technical Aspects:

i. Prof. Subhash Bhatia (P. no: F9293351)
ii. Prof. Bassim H. Hameed (P. no:G1833936)
iii. Assoc. Prof. Lee Keat Teong (IC no: 770326076031)
iv. Dr. Irvan Dahlan (P. no: R831504)
v. Dr. Sumathi Sethupathi (IC no: 780622085310);

For Administrative and Contractual matters:

Abdul Rahman Mohamed (I/C NO: 640114075779)
(Professor, Universiti Sains Malaysia)

4. RELATIONSHIP OF THE PARTIES

4.1 Nothing in this MOU shall be deemed to constitute, create, give effect to or otherwise recognize a joint venture, partnership, or formal business relationship of any kind, and the rights and obligations of the Parties shall be limited to those expressly set forth herein. Nothing contained in this MOU shall be construed as providing for the sharing of profits or losses arising out of the efforts of either or both Parties.

5. LIMITATION

5.1 This MOU is neither a fiscal nor funds obligation document. Nothing in this MOU authorizes or is intended to obligate the parties to expend, exchange, or reimburse funds, services, or supplies, or transfer or receive anything of value, or to enter into any contract, assistance MOU, inter-agency MOU, or other financial obligation.

5.2 Any endeavor involving reimbursement or contribution of funds between the parties to this MOU will be handled in accordance with applicable laws, regulations, and procedures, and will be subject to separate subsidiary agreements that will be made in writing by representatives/appointee of both parties.

5.3 This MOU in no way restricts either of the parties from participating in any activity with other public or private agencies, organizations, or individuals.

5.4 This MOU does not direct or apply to any person outside FPISB and USM. It is strictly for internal management purposes for each of the parties.

6. CONFIDENTIALITY

6.1 Maintenance of Confidentiality: Each party agrees that it shall take reasonable measures to protect the secrecy of and avoid disclosure and unauthorized use of the Confidential Information of the other party. Without limiting the foregoing, each party shall take at least those measures that it takes to protect its own most highly confidential information and shall ensure that its employees who have access to Confidential Information of the other party have signed a non-use and non-disclosure agreement in content similar to the provisions hereof, prior to any disclosure of Confidential Information to such employees. Neither party shall make any copies of the Confidential Information of the other party unless the same are previously approved in writing by the other party. Each party shall reproduce the other party's proprietary rights notices on any such approved copies, in the same manner in which such notices were set forth in or on the original.

6.2 No Warranty: All confidential information is provided "As Is". Each party makes no warranties, express, implied or otherwise, regarding its accuracy, completeness or performance.

6.3 Return of Materials: All documents and other tangible objects containing or representing Confidential Information which have been disclosed by either party to the other party, and all copies thereof which are in the possession of the other party, shall be and remain the property of the disclosing party and shall be promptly returned to the disclosing party upon the disclosing party's written request.

7. TERM AND TERMINATION

7.1 The term of this MOU is for a period of three (3) years from the effective date of this MOU unless otherwise terminated pursuant to Clause 7.2 below.

7.2 Either party may terminate this MOU by giving a thirty (30) days written notice to the other party without penalties or liabilities.

8. VARIATION

Any provision of this MOU may be amended or modified by mutual consent between the Parties and such amendment/modification shall be in writing and signed by the duly authorised representative of the Parties.

IN WITNESS WHEREOF this Memorandum of Understanding has been executed by the Parties the day and year first abovestated

Signed by)
for and on behalf of)
FELDA PALM INDUSTRIES SDN BHD)

.....

Ismail Bin Hasan
(CEO/Senior Executive Director)

Witnessed by:

.....

Name: Zainuri Bin Busu
NRIC No.: 730607085077

Signed by)
for and on behalf of)
Universiti Sains Malaysia)

.....

Professor Tan Sri Dato' Dzulkifli Abdul Razak
(Vice-Chancellor, Universiti Sains Malaysia)

Witnessed by:

.....

Name: **Professor Abdul Rahman Mohamed**
NRIC No.: 640114075779

SCOPE OF WORK

1. Palm shell activated carbon (PSAC) made from steam activation will be prepared and tested as a comparative to CO_2 activated PSAC. The steam activated PSAC is tested for future production of PSAC in the current palm oil plant.

2. A lab scale adsorption experimental set-up for the removal of H_2S from a simulated biogas will be designed.

3. The lab scale adsorption experimental set-up will be fabricated and modified accordingly to fit the existing flue gas experimental rig.

4. The feasibility of the prepared PSAC made from CO_2 and steam activation will be tested to remove H_2S from biogas.

5. Modification will be done onto the PSAC to further enhance the removal of H_2S from biogas if needed.

6. The process parameters for H_2S removal using PSAC will be optimized.

7. A complete characterization will be done onto the optimized PSAC.

8. Finally a complete design of biogas cleaning pilot plant (blue print) using PSAC as an adsorbent for the removal of H_2S from POME biogas will be proposed.
    a. Technical advice will be given regarding the design proposed.
    b. Technical guidance will be given to the contractors during the construction of the plant.
    c. Technical support will be given during the commissioning of the plant.

ITINERARY

Activity 1: Literature review
Activity 2: Modification and establishing equipment
Activity 3: Equipment set-up and preliminary experimental work
Activity 4: Experimental work and data collection
Activity 5: Analysis of experimental results
Activity 6: Pilot plant design and research report

Description	Month (September 2010 – September 2011)											
	1	2	3	4	5	6	7	8	9	10	11	12
Activity 1												
Activity 2												
Activity 3												
Activity 4												
Activity 5												
Activity 6												

EXPECTED BUDGET RELEASE FROM FELDA

Month	Amount Released (RM)	Total Relesed (RM)
1 – 3	200,000.00	200,000.00
4 – 6	100,000.00	300,000.00
7 – 9	100,000.00	400,000.00
10 – 12	52,688.65	452,688.65

UNIVERSITI SAINS MALAYSIA

Pejabat Pengurusan Dan Kreativiti Penyelidikan
Research Creativity and Management Office

Canselori

Universiti Sains Malaysia
Aras 6, Bangunan Canselori
11800, USM Pulau Pinang
T : (6)04-653 3108/3178/3988/5019
F : (6)04-656 6466/8470
: (6)04-653 2350
L : www.research.usm.my

Tarikh : 22 Mac 2011

Profesor Abdul Rahman Mohamed
Pusat Pengajian Kejuruteraan Kimia
Universiti Sains Malaysia
Kampus Kejuruteraan
14300 Nibong Tebal
Pulau Pinang

Tuan,

KEPUTUSAN PERMOHONAN SKIM GERAN PENYELIDIKAN FUNDAMENTAL (FRGS)

Penyelidik Utama	Profesor Abdul Rahman Mohamed	PTJ	Pusat Pengajian Kejuruteraan Kimia
Penyelidik Bersama	1. Prof. Madya Dr. Lee Keat Teong 2. Dr. Chai Siang Piao	PTJ	1. Pusat Pengajian Kejuruteraan Kimia 2. School of Engineering, Monash University, Malaysia
Tajuk Projek	Synthesis And Growth Study Of Aligned Carbon Nanotubes Produced From Spin Coated Catalyst		
Pelantar	Sains Fundamental		
No. Akaun	203/PJKIMIA/6071204	Jumlah Geran	RM 41,480.00
Tempoh Geran	24 bulan		
Tarikh Mula	01 April 2011	Tarikh Tamat	31 Mac 2013

2. Kerjasama tuan untuk mengembalikan Borang Perakuan Geran seperti di **Lampiran A** dan Borang Agihan Peruntukan seperti di **Lampiran B** dalam tempoh **2 minggu** dari tarikh surat ini amatlah dihargai. Jika tiada maklum balas dalam tempoh tersebut, Bahagian Penyelidikan & Inovasi menganggap tuan tidak berminat untuk menerima tawaran geran ini. Bersama-sama ini disertakan garis Panduan Umum Geran Penyelidikan Fundamental (FRGS) seperti di **Lampiran C** untuk makluman dan tindakan tuan selanjutnya.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
'Memastikan Kelestarian Hari Esok'

Yang menjalankan tugas,

(AMRA OTHMAN)
Penolong Pendaftar
Unit Pengurusan Geran & Kontrak

t Development, Its Characterization and Potential Utilization for Industrial Processes (1001/PJKIMIA/814004)
May 2011

SES CATEGORY	TOTAL APPROVED BUDGET (RM)	TOTAL CUMULATIVE EXPENDITURE (RM)	BALANCE OF THE GRANT (RM)	REMARKS
00-Salary & Allowance (Gaji & Upahan)				
Elaun (Staf Projek)	201,600.00	199,800.00	1,800.00	
l	201,600.00	199,800.00	1,800.00	
00- Travelling Expenses (Perbelanjaan Perjalanan & Sara Hidup)				
gkutan/Hotel/Sara Hidup	25,000.00	40,000.00	-15,000.00	
l	**25,000.00**	**40,000.00**	-15,000.00	
00- Transportation (Pengangkutan Barang-barang)				
gkutan Barang-Barang	4,000.00	0.00	4,000.00	
l	4,000.00	**0.00**	4,000.00	
00-Communication and Utilities (Perhubungan dan Utiliti)				
lefon, Faksimili	1,500.00	0.00	1,500.00	
l	1,500.00	**0.00**	1,500.00	
00- Rentals (Sewaan)				
	6,000.00	0.00	6,000.00	
l	6,000.00	**0.00**	6,000.00	
00- (Bekalan Bahan Mentah)				
Bahan Mentah	5,000.00	2,995.00	2,005.00	
l	**5,000.00**	**2,955.00**	2,005.00	
00- Consumables & Supplies for Research (Bekalan Bahan untuk Penyelidikan)				
& Alat Pakai Habis	70,000.00	73,339.25	-3,339.25	
l	**70,000.00**	**73,339.25**	-3,339.25	
00- Maintenance & Repairs (Upah Penyelengaraan & Pembaikan Kecil)				
kan Kecil	25,000.00	34,033.20	-9,033.20	
l	**25,000.00**	**34,033.20**	-9,033.20	
00-Special/Professional Services/Other Services & Hospitality (Perkhidmatan Ikhtisas & Perkhidmatan Lain yang Dibeli dan Hospitaliti)				
matan Iktisas, Perkhidmatan Hospitaliti	30,000.00	18,173.14	11,826.86	
l	**30,000.00**	**18,173.14**	11,826.86	
00- Equipments (Harta Modal- Harta ang lain)				
odal	900,000.00	851,113.65	48,886.35	
l	**900,000.00**	**851,113.65**	48,886.35	
	1,268,100.00	**1,219,454.20**	**50,677.95**	

67.85)
500.00)
em (2,600.00)

UNIVERSITI SAINS MALAYSIA

LAPORAN PRESTASI GERAN UNIVERSITI PENYELIDIKAN
PROGRESS REPORT OF RESEARCH UNIVERSITY GRANT (SESSION 1/2008)

Maklumat Projek :: Project Identification

Tajuk Projek *Project Title*	: Catalyst Development, Its Characterization And Potential Utilization for Industrial Processes
Pelantar Penyelidikan *Research Platform*	: PELANTAR PENYELIDIKAN KEJURUTERAAN & TEKNOLOGI
Tempoh Projek (ttbbhh) *Project Duration (yymmdd)*	: **001200**
Tarikh Mula *Start Date*	: 10 / 10 / 2007
Tarikh Dijangka Tamat *End Date*	: 9 / 9 / 2010
Tarikh Lanjutan Pertama	: 9 / 9 / 2011
Tarikh Tamat	: 9 / 9 / 2011
Ketua Projek *Project Leader*	: PROFESOR ABDUL RAHMAN BIN MOHAMED
Ahli Projek *Project Members (including GRA)*	: PROF MADYA AHMAD ZUHAIRI BIN ABDULLAH PROFESOR AZLINA BINTI HARUN @ KAMARUDDIN PROFESOR SUBHASH BHATIA

Peratusan Prestasi :: Achievement Percentage

Prestasi projek mengikut penanda aras yang telah dicapai sehingga tempoh ini:
Project progress according to milestones achieved up to this period:

0-25%

Masalah/ Kekangan :: Problems/ Constraints

1) Laboratory modification at School of Chemical Engineering USM caused a delay of up to 2 months to research work.
2) Difficulty in getting the optimum conditions for biodiesel production as the error in the analysis was rather large.
3) Minor modification was needed on the ultrasonic reactor of biodiesel production unit as leakage occurred at several parts. Few weeks of delay occurred as the reactor was sent back to supplier for repair and modification. It was back in operation end of March 2008.
4) Difficulty in the analysis of the characteristics of the mesoporous catalysts. Unreliable results caused some of the sample need to be retested.

Pembangunan Sumber Manusia :: Human Capital Development

Human Capital	Number	
	On-Going	Graduated
Pelajar Doktor Falsafah *PhD Student*	1	1
Pelajar Sarjana *MSc Student*	5	1

Pelajar Tahun Akhir - Sarjana Muda *Undergraduate Final Year Project*	4	4
Pegawai Penyelidik *Temporary Research Officer*	0	
Pembantu Penyelidik *Temporary Research Assistant*	1	
Lain-lain (Sila nyatakan) *Others (please specify):*		
Jumlah *Total*	**17**	

Output Penyelidikan :: Research Output

Journal (Jurnal)

Pengarang Utama (*Main Author*) : 790310-08-62 - Chai Siang Piao

Pengarang Bersama (*Co Author*) : 640114-07-57 - Abdul Rahman Bin Mohamed

Tajuk Artikel (*Title of Article*) : The Examination Of Nio And CoOx Catalysts Supported On Ai203 and SIO2 For Carbon Nanotubes Production By Catalytic Chemical Vapor Deposition Of Methane.

Nama Jurnal (*Name of Journal*) : Carbon-Science And Technology

Peringkat (*Level*) : Antarabangsa (International)

Jenis Jurnal (*Type of Journal*) : Berwasit (Referred)

Faktor Impak (*Impact Factor*) : 0

Bulan Penerbitan (*Month of Publication*) : January

Tahun Penerbitan (*Year of Publication*) : 2008

Jilid (*Volume*) : 1

Bilangan (*Issue*) :

Muka surat (*Page Number*) : 24-29

Penerbit (*Publisher*) : Applied Science Innovations Pvt.Ltd,India

fail berkaitan *related file* :

Pengarang Utama (*Main Author*) : F9293351 - Subhash Bhatia

Pengarang Bersama (*Co Author*) : 710914-11-51 - Ahmad Zuhairi Abdullah

Tajuk Artikel (*Title of Article*) : A Dsorption Of Butyl Acetate In Air Over Silver-Loaded Y And ZSM-5 Zeolites:Experimental And Modelling Studies.

Nama Jurnal (*Name of Journal*) : Journal Of Hazardous Materials.

Peringkat (*Level*) : Antarabangsa (International)

Jenis Jurnal (*Type of Journal*) : Berwasit (Referred)

Faktor Impak (*Impact Factor*) : 0

Bulan Penerbitan (*Month of Publication*) : January

Tahun Penerbitan (*Year of Publication*) : 2008

Jilid (*Volume*) :

(Issue)	.
Muka surat *(Page Number)*	: 1-9
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	:

Pengarang Utama *(Main Author)*	: F9293351 - Subhash Bhatia
Pengarang Bersama *(Co Author)*	: 710914-11-51 - Ahmad Zuhairi Abdullah
Tajuk Artikel *(Title of Article)*	: Catalytic Oxidation Of Butyl Acetate Over Silver-Loaded Zeolites.
Nama Jurnal *(Name of Journal)*	: Journal Of Hazardous Materials.
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	:
Bilangan *(Issue)*	: 157
Muka surat *(Page Number)*	: 480-489
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	:

Pengarang Utama *Main Author)*	: - Ahmad Zuhairi Abdullah
Tajuk Artikel *Title of Article)*	: Improved loose contact diesel soot oxidation by synergic effects between metal oxides in K2O-V2o5/zsm-5 catalyst
Nama Jurnal *Name of Journal)*	: Catalyst Communication
Peringkat *Level)*	: Antarabangsa (International)
enis Jurnal *Type of Journal)*	: Berwasit (Referred)
aktor Impak *mpact Factor)*	: 2.394
ulan Penerbitan *Month of Publication)*	: January
ahun Penerbitan *ear of Publication)*	: 2008
lid *olume)*	: 6
langan *ssue)*	: 31
uka surat *age Number)*	: 1196-1200
nerbit *ublisher)*	: Publisher Elsevier
il berkaitan *ated file*	:

Pengarang Utama *(Main Author)*	: - Ahmad Zuhairi Abdullah
Tajuk Artikel *(Title of Article)*	: Selective catalytic reduction of nitric oxide in diesel engine exhaust over monolithic catalysts washcoated with bimetallic Cu-Zn/ZSM-5
Nama Jurnal *(Name of Journal)*	: Environment Asia Journal
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	:
Bilangan *(Issue)*	:
Muka surat *(Page Number)*	:
Penerbit *(Publisher)*	: Thai Society iof Higher Education Institutes on Environment, Thailand.
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Development of synergical mixed metal oxides catalysts for the storage of nitric oxide (NO) from diesel engine exhaust.
Nama Jurnal *(Name of Journal)*	: Journal of Hazardous Materials
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	:
Bilangan *(Issue)*	:
Muka surat *(Page Number)*	:
Penerbit *(Publisher)*	:
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Biocatalytic esterification of citronellol with lairic acid by immobilized lipase on aminopropyl-graphted mesoporous SBA-15 matrix.
Nama Jurnal *(Name of Journal)*	: Biochemical Engineering Journal
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0

Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	:
Bilangan *(Issue)*	:
Muka surat *(Page Number)*	:
Penerbit *(Publisher)*	:
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Characterization and catalytic activity for selective catalytic reduction (SCR) of nitrogen oxides in diesel exhaust.
Nama Jurnal *(Name of Journal)*	: Journal of Hazardous Materials
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	:
Bilangan *(Issue)*	:
Muka surat *(Page Number)*	:
Penerbit *(Publisher)*	:
fail berkaitan *related file*	:

oceeding (Kertas Persidangan - Prosiding)

Nama Seminar *Name of Seminar)*	: Proceedings of The International Conferences on Environmental Research and Technology ICERT 2008
Tajuk Kertas Kerja *Title of Paper Work)*	: ENERGY BALANCE IN PRODUCTION OF BIODIESEL.
Peringkat *Level)*	: Antarabangsa (International)
Tempat Persidangan *Place of Conference)*	: Pulau Pinang
Negara *Country)*	: MALAYSIA
Tarikh Mula Persidangan *Start Date)*	: 5/28/2008
Tarikh Tamat Persidangan *End Date)*	: 5/30/2008
Muka surat *Page Number)*	:
ail berkaitan *elated file*	:

ama Seminar *Name of Seminar)*	: Proceedings of the International Conferences of Environmental Research and Technology

Tajuk Kertas Kerja *(Title of Paper Work)*	: Proposed Biodiesel Production and Development Policy in Malaysia
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 5/28/2008
Tarikh Tamat Persidangan *(End Date)*	: 5/30/2008
Muka surat *(Page Number)*	:
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceedings of the International Conferences and Exhibition on Composited Material and Nano-structure
Tajuk Kertas Kerja *(Title of Paper Work)*	: Synthesis and Characterization of Oragnic-Inorganic Mesoporous Silica Prepared Through Silanation and graphted on Surface Silons
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Malacca
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 8/5/2008
Tarikh Tamat Persidangan *(End Date)*	: 9/7/2008
Muka surat *(Page Number)*	:
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceedings of 2nd Penang International Conferences For Young Chemists In Conjuction With 2nd
Tajuk Kertas Kerja *(Title of Paper Work)*	: The Effect of Ultrasonic Irradiation on The Heterogeneous Catalysts For Biodiesel Production From Palm Oil
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 6/20/2008
Muka surat *(Page Number)*	:
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Penang International Conference For Young Chemists In Conjunction with 2nd
Tajuk Kertas Kerja *(Title of Paper Work)*	: Comparison and Characterization of Different Solid based catalysts for biodiesel production of palm oil
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA

Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 6/20/2008
Muka surat *(Page Number)*	:
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceedings of the International Symposium on Environmental Management.
Tajuk Kertas Kerja *(Title of Paper Work)*	: Selective Catalytic Reduction (SCR) of nitric oxides in diesel exhaust over ZSM-5 washcoated seramic monolic catalyts
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Thailand
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 9/22/2008
Tarikh Tamat Persidangan *(End Date)*	: 9/23/2008
Muka surat *(Page Number)*	:
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceeding Of the 2nd Penang International Conferences For Young Chemists In Conjunction With 2nd
Tajuk Kertas Kerja *(Title of Paper Work)*	: Mesoporous Silica Supported KOH as heterogeneous Solid base catalyst in Transesterification process
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 9/20/2008
Muka surat *(Page Number)*	:
fail berkaitan *Related file*	:

stract (Kertas Persidangan - Abstrak)

Entry/Tiada Rekod

ster (Kertas Persidangan - Poster)

engarang Bersama *Co Author)*	: 60106086708 - Dr. Azlina Harun @ Kamarudin
ain-lain *Others)*	: - Umi Natrah Abdol Karim
lama Seminar *Name of Seminar)*	: Penang International Conference For Young Chemists
ajuk Kertas Kerja *Title of Paper Work)*	: Potential of Carbon Nanotubes as a Biocatalysts Support : A Review
eringkat *Level)*	: Antarabangsa (International)
empat Persidangan *Place of Conference)*	: USM

Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 6/20/2008
Fail berkaitan *Related file*	:

ook (Buku)

o Entry/Tiada Rekod

hapter in Books (Bab dalam Buku)

o Entry/Tiada Rekod

hesis (Tesis)

Tajuk Tesis *(Title of Thesis)*	: Catalytic Decomposition Of Methane Into Carbon Nanotubes And COx- Free Hydrogen In a Single Step Process
Tahun dikeluarkan *(Year of Publication)*	: 2008
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 1/1/1900
Universiti *(University)*	: USM
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Dr. Abdul Rahman Bin Mohamed
Penyelia Bersama *(Co-Supervisor)*	: Dr. Syarif Hussein Syarif Zein
Fail berkaitan *Related file*	:

Tajuk Tesis *(Title of Thesis)*	: Bimetallic Monolithic Catalyst for Selective Catalytic Reduction of NOx in Diesel Engine Exhaust
Tahun dikeluarkan *(Year of Publication)*	: 2008
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 8/14/2008
Universiti *(University)*	: USM
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Dr. Ahmad Zuhairi
Penyelia Bersama *(Co-Supervisor)*	: Prof. Subash Bhatia
Fail berkaitan *Related file*	:

ublicity Material (Bahan Media)

o Entry/Tiada Rekod

rticle in Mass Media (Artikel dalam Media Massa)

o Entry/Tiada Rekod

erbelanjaan :: Expenditure

No. Akaun Projek	: 1001 / PJKIMIA / 814004
Penaja	: USM (RU)
Ketegori Penaja	: USM
Peruntukan Diluluskan (1)	: RM 518100

Pecahan Mengikut Tahun

Tahun 2007 : RM 273700

Tahun 2008 : RM 147700

Tahun 2009 : RM 96700

Peruntukan Tambahan (2) : RM 750000

Pecahan Mengikut Tahun

Tahun 2008 : RM 500000

Tahun 2009 : RM 250000

Jumlah Peruntukan Keseluruhan (1) + (2) : RM 1268100
Jumlah Peruntukan yang Telah Diterima Hingga Kini (3) : RM 1268100

Jumlah Perbelanjaan (4) : RM 1163132
Baki (3) - (4) : RM 104968

Jumlah Perbelanjaan (3) : RM 1163132
Baki (2) - (3) : RM 104968

Pecahan Geran Mengikut Vot

Vot	**Butiran Vot** *(Vot Details)*	**(A) Bajet yang diluluskan** *Total Approved Budget* **(RM)**	**(B) Tambahan** *Total* **(RM)**	**(C) Bajet yang dibelanjakan** *Total Budget Spent* **(RM)**	**(A + B) - C Baki** *(Total)*
11000	Gaji Dan Upahan	201600	0	173127	28473
21000	Perbelanjaan Perjalanan Dan Sara Hidup	25000	0	36889	-11889
22000	Pengangkutan Barang-barang	4000	0	0	4000
23000	Perhubungan Utiliti	1500	0	0	1500
24000	Sewaan	6000	0	0	6000
26000	Bekalan Bahan Mentah Dan Bahan Untuk Penyelenggaraan	5000	0	2995	2005
27000	Bekalan Dan Bahan-bahan Lain	70000	0	60668	9332
28000	Penyelenggaraan Dan Pembaikan Kecil Yang Dibeli	25000	0	22903	2097
29000	Perkhidmatan Iktisas Dan Perkhidmatan Lain Yang Dibeli Dan Hospitaliti	30000	0	15986	14014
35000	Harta Modal - Harta Modal Lain	150000	500000	849996	-199996
Jumlah Keseluruhan *(Grand Total)*		**(A)** 1268100	**(B)** 750000	**(C)** 1163132	**(3) - (4)** 104968

***Maklumat perbelanjaan (Bajet yang dibelanjakan) diperolehi daripada Jabatan Bendahari (Sehingga 30 April 2011)**
Information (Total Budget Spent) taken from Bursary (Up to April 30th 2011)

ingkasan Penemuan Projek Penyelidikan :: Summary of Research Findings

Catalysts for biodiesel production based on MgO, CaO, BaO, SrO and mesoporous materials were synthesized at different weight oadings loadings.

!) Characterization of those catalysts using surface analyzer, XRD, FTIR, SEM and TEM.

:) Finalize the experimental design using response surface methodology (RSM) to minimize the number of experimental runs to letermine conditions for biodiesel production using ultrasonic reactor. Process variables such as temperature (50-90 ℃), catalyst oading (1-5 %) and reaction time (30-120 min) were investigated while the conversion and biodiesel yield were the process arameter.

4) Identification of analytical method for improved data accuracy for conversion and yield in biodiesel production. The problem originated from the difficulty in getting phase separation after the reaction.

Monoglyceride production

1) Synthesis of different phase transfer catalysts (PTC) based on clay (Montmorillonite). Different PTCs were used such as sodium, tributyl ammonium, cetyltrimethyl ammonium and tributyl ammonium.

2) Process study for the esterification of glycerol with lauric acid for monoglyceride production. Process variables used were temperature (100-150 C), glycerol:lauric acid ratio (1-6) and catalyst loading (0.5 g) while the conversion and selectivity were the process parameters.

Esterification of Glycerol with Lauric Acid over various catalyst

Catalyst Operating Condition Conversion of lauric acid Selectivity of Monolaurate
Temperature of Reaction, C Mol ratio gly/lauric acid Cat loading,g Time of reaction, hours
NaMMT 130 6 0.5 8 76.1301 67.2676
K10MMT 130 6 0.5 8 80.8350 68.7206
TBK10 130 6 0.5 8 72.9806 68.8878
CTMMT 130 6 0.5 8 66.6783 71.5928
TBMMT 130 6 0.5 8 79.5832 71.4733
TBMMT 120 6 0.5 8 41.5577 70.3882
TBMMT 100 6 0.5 8 7.4941 75.7297
TBMMT, US 150 6 0.5 8 77.3536 62.0474
TBMMT, US 130 6 0.5 8 49.4572 49.4572
Amberlyst 16 120 6 0.5 8 65.0488 76.8511
TBMMT 130 1 0.4 8 53.8826 48.7973

Notes :
NaMMT : SodiumMontmorillonite
K10MMT : Montmorillonite K10
TBK10 : Tributhyl Ammonium – K10
CTMMT : Cethyl trimethyl Ammonium – Montmorillonite
TBMMT : Tributhyl Ammonium – Montmorillonite
US : Using Ultrasonic

Selective catalytic reduction of NOx

1) Bimetallic catalysts (Cu-Zn/ZSM-5) was developed by incorporating copper (Cu) and zinc (Zn) onto ZSM-5 zeolite (Si/Al=40) using either impregnation or ion exchange in different orders with metal loadings range between 2 wt. % and 14 wt. %. Then, the bimetallic catalyst was washcoated onto a 400 cell per square inch (cpsi) ceramic monolith with a diameter of 2.0 cm and a length of 6.0 cm.

2) The catalyst were characterized using SEM, XRD, surface analyzer, FTIR and ultrasound treatment for washcoating adherence of catalyst coating onto the ceramic monolith.

3) The activity study was performed in a glass reactor 15 mm and 25.4 mm internal diameter for powdered and structured catalysts, respectively. It was operated between 200 ⁰C and 550 ⁰C at 13,000 h-1 of GHSV. The feed gas mixture was 1,000 ppm of NO, 1,500 ppm of iso-butane, 3 v/v % O2 and N2 balance.
4) The design of experiment with 3 parameters was studied whereby the NO and iso-butane concentration were between 900 and 2,000 ppm and the temperature between 300 ⁰C and 400 ⁰C.

The best metal incorporation methods were by impregnating the Cu and ion exchange the Zn while the optimum metals loading were 6 wt. % and 8 wt. % of Cu and Zn, respectively. The best operating conditions were obtained from DOE study whereby a mixture of 900 ppm of NO, 2,000 ppm of iso-butane, 3 v/v % of O2 and N2 balance as the inlet gas should be used to result in 90 % of NO conversion for powdered Cu-Zn/ZSM-5 catalyst at between 300 ⁰C and 400 ⁰C. 1.8 g of Cu-Zn/ZSM-5 catalyst with 6 wt. % of Cu and 8 wt. % of Zn obtained by 2 time of washcoating step onto the ceramic monolith showed about 88 % conversion of NO in the same operating conditions. Besides showing high catalytic activity, the monolithic catalyst was also stable for up to 72 h with an activity drop of only 10 %. Furthermore, low activation energy of +30.30 kJ/mol was obtained for the reaction.

ail yang dimuat-naik :: Uploaded File

UNIVERSITI SAINS MALAYSIA

LAPORAN PRESTASI GERAN UNIVERSITI PENYELIDIKAN
PROGRESS REPORT OF RESEARCH UNIVERSITY GRANT (SESSION 1/2009)

Maklumat Projek :: Project Identification

Tajuk Projek *Project Title*	: Catalyst Development, Its Characterization And Potential Utilization for Industrial Processes
Pelantar Penyelidikan *Research Platform*	: PELANTAR PENYELIDIKAN KEJURUTERAAN & TEKNOLOGI
Tempoh Projek (ttbbhh) *Project Duration (yymmdd)*	: **001200**
Tarikh Mula *Start Date*	: 10 / 10 / 2007
Tarikh Dijangka Tamat *End Date*	: 9 / 9 / 2010
Tarikh Lanjutan Pertama	: 9 / 9 / 2011
Tarikh Tamat	: 9 / 9 / 2011
Ketua Projek *Project Leader*	: PROFESOR ABDUL RAHMAN BIN MOHAMED
Ahli Projek *Project Members (including GRA)*	: PROF MADYA AHMAD ZUHAIRI BIN ABDULLAH PROFESOR AZLINA BINTI HARUN @ KAMARUDDIN PROFESOR SUBHASH BHATIA

Peratusan Prestasi :: Achievement Percentage

Prestasi projek mengikut penanda aras yang telah dicapai sehingga tempoh ini:
Project progress according to milestones achieved up to this period:

51-75%

Masalah/ Kekangan :: Problems/ Constraints

1) Laboratory modification at School of Chemical Engineering USM caused a delay of up to 2 months to research work.

2) Difficulty in the analysis of the characteristics of the catalysts. Surface analysis generally takes about 2-3 months due to long queue. Unreliable results caused some of the sample need to be retested.

3) Purchase of equipment takes long time.

Pembangunan Sumber Manusia :: Human Capital Development

Human Capital	Number	
	On-Going	Graduated
Pelajar Doktor Falsafah *PhD Student*	7	1
Pelajar Sarjana *MSc Student*	10	3

Pelajar Tahun Akhir - Sarjana Muda *Undergraduate Final Year Project*	0	9
Pegawai Penyelidik *Temporary Research Officer*	0	
Pembantu Penyelidik *Temporary Research Assistant*	8	
Lain-lain (Sila nyatakan) *Others (please specify):*		
Jumlah *Total*	**38**	

utput Penyelidikan :: Research Output

urnal (Jurnal)

Pengarang Utama *(Main Author)*	: 640114075779 - Abdul Rahman Mohamed
Tajuk Artikel *(Title of Article)*	: Utilization of Oil Palm as a Source of Renewable Energy in Malaysia
Nama Jurnal *(Name of Journal)*	: Renewable and Sustainaible Energy Reviews
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 4.075
Bulan Penerbitan *(Month of Publication)*	: September
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 1
Bilangan *(Issue)*	: 9
Muka surat *(Page Number)*	: 2404-2421
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	: 2008(8).pdf

Tajuk Artikel *(Title of Article)*	: Optimazation of Microporous Palm Shell Activated Carbon Production for Flue Gas Desulphurization
Nama Jurnal *(Name of Journal)*	: Journal of Bioresource Technology
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 3.103
Bulan Penerbitan *(Month of Publication)*	: September
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 100
Bilangan *(Issue)*	: 24
Muka surat *(Page Number)*	: 1614-1621
Penerbit *(Publisher)*	: Elsevier

Fail berkaitan *related file*	: Optimization 9.pdf

Tajuk Artikel *(Title of Article)*	: Removal SO2 and NO Over Rice Husk Ash (RHA)/CaO-Supported Metal Oxides.
Nama Jurnal *(Name of Journal)*	: Journal of Engineering Science Technology
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 1.884
Bulan Penerbitan *(Month of Publication)*	: September
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 3(2)
Bilangan *(Issue)*	: 24
Muka surat *(Page Number)*	: 109-116
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Recent Patent on Photocatalysis over Nanosized Titanium Dioxide
Nama Jurnal *(Name of Journal)*	: Recent Patent on Chemical Engineering
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: September
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 1
Bilangan *(Issue)*	: 2
Muka surat *(Page Number)*	: 209-219
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Production Carbon Nanotubes via Catalytic Decomposition of Methane
Nama Jurnal *(Name of Journal)*	: ASM Science
Peringkat *(Level)*	: Kebangsaan (National)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)

Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: October
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 2
Bilangan *(Issue)*	: 10
Muka surat *(Page Number)*	: 57-64
Penerbit *(Publisher)*	: ASM Science
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Evaluation of Various Additives on the Preparation of Rice Husk Ash (RHA)/CaO-Based Sorbent for Flue Gas Desulfurization (FGD) at Low Temperature
Nama Jurnal *(Name of Journal)*	: Journal of Hazardous Materials
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.975
Bulan Penerbitan *(Month of Publication)*	: October
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 161
Bilangan *(Issue)*	: 33
Muka surat *(Page Number)*	: 570-574
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	: 2008(5).pdf

Tajuk Artikel *(Title of Article)*	: Effect of FeOX Loaded on CoOX/ Al2 O3 Catalyst for the Formation of Thin-Walled Carbon Nanotubes.
Nama Jurnal *(Name of Journal)*	: Materials Letters
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 1.748
Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 63
Bilangan *(Issue)*	: 30
Muka surat *(Page Number)*	: 1428-1430

Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	: Effect of Feox.pdf

Tajuk Artikel *(Title of Article)*	: Effect of FeOx,CoOx, and NiO Catalysts and Calcination Temperatures on the Synthesis of Single-walled Carbon Nanotubes Through Chemical Vapor Deposition of Methane
Nama Jurnal *(Name of Journal)*	: Journal of Alloy and Compounds
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 1.455
Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 477
Bilangan *(Issue)*	: 42
Muka surat *(Page Number)*	: 785-788
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Selection of Metal Oxides in the Preparation of Rice Husk Ash (RHA) / CaO Sorbent for Simultaneous SO2 and NO Removal
Nama Jurnal *(Name of Journal)*	: Journal Hazardous Materials
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.975
Bulan Penerbitan *(Month of Publication)*	: April
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 166
Bilangan *(Issue)*	: 33
Muka surat *(Page Number)*	: 1556-1559
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	: Selection.pdf

Tajuk Artikel *(Title of Article)*	: Synthesis of High Purity Multi- Walled Carbon Nanotubes over Easily Purified Co-Mo/MgO Catalyst via Catalytic Chemical Vapor Deposition of Methane
Nama Jurnal *(Name of Journal)*	: New Carbon Material Journal
Peringkat *(Level)*	: Antarabangsa (International)

enis Jurnal *Type of Journal)*	: Berwasit (Referred)
aktor Impak *Impact Factor)*	: 0
ulan Penerbitan *Month of Publication)*	: June
ahun Penerbitan *Year of Publication)*	: 2009
ilid *Volume)*	: 24(2)
ilangan *Issue)*	: 4
uka surat *Page Number)*	: 1-5
enerbit *Publisher)*	: Elsevier
ail berkaitan *elated file*	:

ajuk Artikel *Title of Article)*	: Continuous Biosynthesis of Biodiesel from Waste Cooking Palm Oil in a Packed Bed Reactor: Optimazation using Response Surface Methodology (RSM) and Mass Transfer Studies
ama Jurnal *Name of Journal)*	: Bioresource Technology
eringkat *Level)*	: Antarabangsa (International)
enis Jurnal *Type of Journal)*	: Berwasit (Referred)
aktor Impak *Impact Factor)*	: 3.103
ulan Penerbitan *Month of Publication)*	:
ahun Penerbitan *Year of Publication)*	: 0
ilid *Volume)*	: 100
ilangan *Issue)*	: 24
uka surat *Page Number)*	: 710-716
enerbit *Publisher)*	: Elsevier
ail berkaitan *elated file*	:

ajuk Artikel *Title of Article)*	: Catalytic Studies of Lipaseon FAME Production From Waste Cooking Palm Oil in a Tert Butanol System
ama Jurnal *Name of Journal)*	: Process Biochemistry
eringkat *Level)*	: Universiti (University)
enis Jurnal *Type of Journal)*	: Berwasit (Referred)
aktor Impak *Impact Factor)*	: 0
ulan Penerbitan *Month of Publication)*	: December
ahun Penerbitan *Year of Publication)*	: 2008
ilid *Volume)*	: 43
ilangan *Issue)*	: 12

Muka surat *(Page Number)*	: 1436-1439
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Effect of Catalyst Additives on the Production of Biofuels from Palm Oil Cracking in a Transport Riser Reactor
Nama Jurnal *(Name of Journal)*	: Bioresource Technology
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 3.103
Bulan Penerbitan *(Month of Publication)*	: September
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 100
Bilangan *(Issue)*	: 9
Muka surat *(Page Number)*	: 2540-2545
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Hydrodynamic Study of Zeolite Based Composite Cracking Catalyst in a Transport Riser Reactor
Nama Jurnal *(Name of Journal)*	: Chemical Engineering Research and Design
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: January
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 87
Bilangan *(Issue)*	: 6
Muka surat *(Page Number)*	: 771-779
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Improved Loose Contact Diesel Soot Oxidation by Synergic Effects Between Metal Oxides in K2O-V2O5/ZSM-5 Catalyst
Nama Jurnal *(Name of Journal)*	: Catalysis Communications

Peringkat *Level)*	: Antarabangsa (International)
Jenis Jurnal *Type of Journal)*	: Berwasit (Referred)
Faktor Impak *Impact Factor)*	: 2.394
Bulan Penerbitan *Month of Publication)*	: March
Tahun Penerbitan *Year of Publication)*	: 2009
Jilid *Volume)*	: 6
Bilangan *Issue)*	: 31
Muka surat *Page Number)*	: 1196-1200
Penerbit *Publisher)*	: Elsevier
Fail berkaitan *Related file*	:

Tajuk Artikel *Title of Article)*	: Selective Catalytic Reduction of Nitric Oxide in Diesel Engine Exhaust over Monolithic Catalysts Washcoated with Bimetallic Cu-Zn/ZSM-5
Nama Jurnal *Name of Journal)*	: Environment Asia Journal
Peringkat *Level)*	: Antarabangsa (International)
Jenis Jurnal *Type of Journal)*	: Berwasit (Referred)
Faktor Impak *Impact Factor)*	: 0
Bulan Penerbitan *Month of Publication)*	:
Tahun Penerbitan *Year of Publication)*	: 2009
Jilid *Volume)*	: 0
Bilangan *Issue)*	: 0
Muka surat *Page Number)*	: 0
Penerbit *Publisher)*	: Thai Society of Higher Education Institutes On Environment, Thailand
Fail berkaitan *Related file*	:

Tajuk Artikel *Title of Article)*	: Biocatalytic Esterification of Citronellol with Lauric Acid by Immobilized Lipase on Aminopropyl-Graphted Mesoporous SBA-15 Matrix
Nama Jurnal *Name of Journal)*	: Biochemical Engineering Journal
Peringkat *Level)*	: Antarabangsa (International)
Jenis Jurnal *Type of Journal)*	: Berwasit (Referred)
Faktor Impak *Impact Factor)*	: 1.872
Bulan Penerbitan *Month of Publication)*	:
Tahun Penerbitan *Year of Publication)*	: 2009
Jilid *Volume)*	: 44

Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 263-270
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Broad Bundles of Single-Walled Carbon Nanotube Synthesized over Fe2O3/MgO Via Chemical Vapor Deposition of Methane
Nama Jurnal *(Name of Journal)*	: NANO
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	: June
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 4
Bilangan *(Issue)*	: 2
Muka surat *(Page Number)*	: 77-81
Penerbit *(Publisher)*	: World Scienctific
fail berkaitan *related file*	: Broad Bundles.pdf

Tajuk Artikel *(Title of Article)*	: Performance of an Activated Carbon Made From Waste Palm Shell in Simultaneous Adsorption of SOx and NOx of Flue Gas at Low Temperature
Nama Jurnal *(Name of Journal)*	: Science in China Series E Technological Science
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0.376
Bulan Penerbitan *(Month of Publication)*	: April
Tahun Penerbitan *(Year of Publication)*	: 2008
Jilid *(Volume)*	: 52
Bilangan *(Issue)*	: 1
Muka surat *(Page Number)*	: 198-203
Penerbit *(Publisher)*	: Springer
fail berkaitan *related file*	:

oceeding (Kertas Persidangan - Prosiding)

Nama Seminar *(Name of Seminar)*	: Collaborative Research and Development in Chemical Engineering among Academe, Industry, and Government in the ASEAN Region, Manila, Philppines
Tajuk Kertas Kerja *(Title of Paper Work)*	: Selection of Metal Oxides in the Preparation if Rice Husk Ask (RHA) /CaO Sorbent For Simultaneous SO2 and NO Removal
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Manila, Philippines
Negara *(Country)*	: FILIPINA
Tarikh Mula Persidangan *(Start Date)*	: 1/22/2009
Tarikh Tamat Persidangan *(End Date)*	: 1/23/2009
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Removal of SO2 over RHA-Based Sorbent: Effect of
Tajuk Kertas Kerja *(Title of Paper Work)*	: Sorbent Particle Size and Sorption Capacity of Various Starting Materials
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Manila, Philippines
Negara *(Country)*	: FILIPINA
Tarikh Mula Persidangan *(Start Date)*	: 2/2/2009
Tarikh Tamat Persidangan *(End Date)*	: 3/2/2009
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceeding in International Symposium on Clean Energy Technology 2007 (ISCET 2007) in Conjunction with 3rd International Symposium on Bioenergy and Bioprocess Engineering (ISBBE 2007
Tajuk Kertas Kerja *(Title of Paper Work)*	: Comparison Studies on Methanolysis of Refined Palm Oil and Waste Cooking Palm Oil in tert-Butanol as Reaction Medium.
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Shanghai, China
Negara *(Country)*	: CHINA
Tarikh Mula Persidangan *(Start Date)*	: 11/21/2007
Tarikh Tamat Persidangan *(End Date)*	: 11/23/2007
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: The 2nd Penang International Conferences for Young Chemists, ICYC
Tajuk Kertas Kerja *(Title of Paper Work)*	: Optimal Continuous Biosynthesis of Biodiesel by a Packed Bed Bioreactor and mass Transfer Modelling
Peringkat *(Level)*	: Kebangsaan (National)

Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 6/20/2009
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Symposium of Chemical Engineers, SOMche
Tajuk Kertas Kerja *(Title of Paper Work)*	: Studies of Reaction Parameters on Transesterification of Waste Cooking Oil.
Peringkat *(Level)*	: Universiti (University)
Tempat Persidangan *(Place of Conference)*	: Kuala Lumpur
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 12/12/2007
Tarikh Tamat Persidangan *(End Date)*	: 12/14/2007
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: The 237th ACS National Meeting, Salt Like City, UT
Tajuk Kertas Kerja *(Title of Paper Work)*	: Biogasoline Production from Catalytic Cracking of Vegetable Oil in Biorefinery
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Salt Like City, UT
Negara *(Country)*	: AUSTRALIA
Tarikh Mula Persidangan *(Start Date)*	: 3/22/2009
Tarikh Tamat Persidangan *(End Date)*	: 3/26/2009
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: 4th International Conference on Recent Advances in Materials, Minerals & Environment and 2nd Asian Symposium on Materials and Processing, Batu Ferringhi, Penang, Malaysia
Tajuk Kertas Kerja *(Title of Paper Work)*	: Synthesis and Characterization of Nanocrystalline Zeolite ZSM-5
Peringkat *(Level)*	: Kebangsaan (National)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/1/2009
Tarikh Tamat Persidangan *(End Date)*	: 6/3/2009

Muka surat : 0
(Page Number)

fail berkaitan :
Related file

Nama Seminar : International Conference on Environmental Research and Technology (ICERT 2008
(Name of Seminar)

Tajuk Kertas Kerja : Energy balance in production of biodiesel
(Title of Paper Work)

Peringkat : Antarabangsa (International)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 5/28/2009
(Start Date)

Tarikh Tamat Persidangan : 5/30/2009
(End Date)

Muka surat : 0
(Page Number)

fail berkaitan :
Related file

Nama Seminar : International Conference on Environmental Research and Technology (ICERT 2008)
(Name of Seminar)

Tajuk Kertas Kerja : Proposed biodiesel production and development policy in Malaysia
(Title of Paper Work)

Peringkat : Antarabangsa (International)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 5/28/2009
(Start Date)

Tarikh Tamat Persidangan : 5/30/2009
(End Date)

Muka surat : 0
(Page Number)

fail berkaitan :
Related file

Nama Seminar : International Conference and Exhibition on Composite Materials and Nano-structure
(Name of Seminar)

Tajuk Kertas Kerja : Synthesis and characterization of organic-inorganic mesoporous silica prepared through silanation and graphted on surface silanols
(Title of Paper Work)

Peringkat : Antarabangsa (International)
(Level)

Tempat Persidangan : Melaka
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 8/5/2008
(Start Date)

Tarikh Tamat Persidangan : 8/7/2008
(End Date)

Muka surat : 0
(Page Number)

fail berkaitan :
Related file

Nama Seminar : 2nd. Penang International Conference for Young Chemists in conjunction with 2nd. USM Penang International Postgraduate Convention 2008
(Name of Seminar)

Tajuk Kertas Kerja *(Title of Paper Work)*	: The effect of ultrasonic irradiation on the heterogeneous catalysts for biodiesel production from palm oil
Peringkat *(Level)*	: Universiti (University)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 6/20/2008
Muka surat *(Page Number)*	: 0
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: 2nd. Penang International Conference for Young Chemists in conjunction with 2nd. USM Penang International Postgraduate Convention 2008
Tajuk Kertas Kerja *(Title of Paper Work)*	: Comparison and characterization of different solid based catalysts for biodiesel production out of palm oil
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 6/20/2008
Muka surat *(Page Number)*	: 0
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceedings of the 2nd. Penang International Conference for Young Chemists in conjunction with 2nd. USM Penang International Postgraduate Convention 2008
Tajuk Kertas Kerja *(Title of Paper Work)*	: Mesoporous silica supported KOH as heterogeneous solid base catalyst in transesterification process
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Pulau Pinang
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 6/18/2008
Tarikh Tamat Persidangan *(End Date)*	: 6/20/2008
Muka surat *(Page Number)*	: 0
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceedings of the International Symposium on Environmental Management: Hazardous-Environmental Management Towards Sustainability, Nakorn Nayok, Thailand
Tajuk Kertas Kerja *(Title of Paper Work)*	: Selective catalytic reduction (SCR) of nitric oxide in diesel exhaust over ZSM-5 washcoated ceramic monolith catalyst
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Thailand
Negara *(Country)*	: THAILAND

Tarikh Mula Persidangan *(Start Date)*	: 9/22/2008
Tarikh Tamat Persidangan *(End Date)*	: 9/23/2009
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceedings of the Seminar Minyak dan Lemak 2008 (SMILE 2008), Kuantan
Tajuk Kertas Kerja *(Title of Paper Work)*	: Optimization of process parameters for alkaline-catalyzed transesterification of palm oil using response surface methodology
Peringkat *(Level)*	: Kebangsaan (National)
Tempat Persidangan *(Place of Conference)*	: Kuantan
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 11/17/2008
Tarikh Tamat Persidangan *(End Date)*	: 11/19/2008
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: Proceedings of the 15th Regional Symposium on Chemical Engineering (RSCE 2008) in conjunction with 22nd Symposium of Malaysia Chemical Engineers (SOMChE 2008)
Tajuk Kertas Kerja *(Title of Paper Work)*	: Dependence of mesoporous silica (SBA-15) characterisitcs synthesized using nonionic triblock copolymers on synthesis gel composition
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Kuala Lumpur
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 12/2/2008
Tarikh Tamat Persidangan *(End Date)*	: 12/3/2008
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: MRS International Materials Research Conference
Tajuk Kertas Kerja *(Title of Paper Work)*	: Performance of an activated carbon made from Waste Palm Shell in Simultaneous Adsorption of SOx and NOx of Flue Gas at Low Temperature
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Chongqing, China
Negara *(Country)*	: CHINA
Tarikh Mula Persidangan *(Start Date)*	: 6/9/2008
Tarikh Tamat Persidangan *(End Date)*	: 12/6/2008
Muka surat *(Page Number)*	: 0
Fail berkaitan *Related file*	:

Entry/Tiada Rekod

oster (Kertas Persidangan - Poster)

Entry/Tiada Rekod

ook (Buku)

Entry/Tiada Rekod

hapter in Books (Bab dalam Buku)

Entry/Tiada Rekod

hesis (Tesis)

Tajuk Tesis *(Title of Thesis)*	: Bimetallic Monolithic Catalyst for Selective Catalytic Reduction of NOx in Diesel Engine Exhaust
Tahun dikeluarkan *(Year of Publication)*	: 2008
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 8/14/2008
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Dr. Ahmad Zuhairi Abdullah
Penyelia Bersama *(Co-Supervisor)*	: Prof. Subhash Bhatia
Fail berkaitan *Related file*	:

Tajuk Tesis *(Title of Thesis)*	: Synthesis, characterization and application of mesoporous base catalysts in biodiesel production process
Tahun dikeluarkan *(Year of Publication)*	: 2008
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 1/1/2009
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Dr. Ahmad Zuhairi Abdullah
Penyelia Bersama *(Co-Supervisor)*	: Dr. Lee Keat Teong
Fail berkaitan *Related file*	:

Tajuk Tesis *(Title of Thesis)*	: Removal of SO^2 and No From Flue Gas Using Sorbent Prepared From Rice Husk Ash)Rha)
Tahun dikeluarkan *(Year of Publication)*	: 2009
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 6/18/2009
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Abdul Rahman Bin Mohamed
Penyelia Bersama *(Co-Supervisor)*	: Dr. Lee Keat Teong
Fail berkaitan *Related file*	:

blicity Material (Bahan Media)

		Budget **(RM)**		*Spent* **(RM)**	
11000	Gaji Dan Upahan	201600	0	173127	28473
21000	Perbelanjaan Perjalanan Dan Sara Hidup	25000	0	36889	-11889
22000	Pengangkutan Barang-barang	4000	0	0	4000
23000	Perhubungan Utiliti	1500	0	0	1500
24000	Sewaan	6000	0	0	6000
26000	Bekalan Bahan Mentah Dan Bahan Untuk Penyelenggaraan	5000	0	2995	2005
27000	Bekalan Dan Bahan-bahan Lain	70000	0	60668	9332
28000	Penyelenggaraan Dan Pembaikan Kecil Yang Dibeli	25000	0	22903	2097
29000	Perkhidmatan Iktisas Dan Perkhidmatan Lain Yang Dibeli Dan Hospitaliti	30000	0	15986	14014
35000	Harta Modal - Harta Modal Lain	150000	500000	849996	-199996
Jumlah Keseluruhan *(Grand Total)*		**(A)** 1268100	**(B)** 750000	**(C)** 1163132	**(3) - (4)** 104968

Maklumat perbelanjaan (Bajet yang dibelanjakan) diperolehi daripada Jabatan Bendahari (Sehingga 30 April 2011)
nformation (Total Budget Spent) taken from Bursary (Up to April 30th 2011)

ngkasan Penemuan Projek Penyelidikan :: Summary of Research Findings

odiesel production using ultrasonic reactor

Catalysts for biodiesel production based on MgO, CaO, BaO, SrO and mesoporous materials were synthesized at different eight loadings loadings. For the unsupported catalysts, BaO showed the highest basicity and activity in the transesterification action. For the supported catalysts, KOH/SBA-15 produced the highest biodiesel yield due to high surface area and straight esoporous channels of the catalyst.

Characterization of those catalysts using surface analyzer, XRD, FTIR, SEM and TEM. The characteristics of the catalysts were orrelated with the specific catalytic behaviors of the catalysts in the transesterification reaction.

Finalize the experimental design using response surface methodology (RSM) to minimize the number of experimental runs to etermine conditions for biodiesel production using ultrasonic reactor. Process variables such as temperature (50-90 ⊠C), catalyst ading (1-5 %) and reaction time (30-120 min) were investigated while the conversion and biodiesel yield were the process arameter. For this purpose, response surface methodology was successfully employed to predict the behavior of different atalysts under various conditions with high degree of accuracy.

Identification of analytical method for improved data accuracy for conversion and yield in biodiesel production. The problem riginated from the difficulty in getting phase separation after the reaction.

Comparison between the effect of mechanical stirring and ultrasonic irradiation in the transesterification process. Ultrasonic adiation was demonstrated to improve the yield of biodiesel between 30-65 %, depending on the catalyst. The reaction time to chieve 95 % yield was reduced from about 2 h to just about 30 min.

Study on the effect of ultrasonic irradiation on the temperature increase in the reactor. Various catalyst to oil ratios were tested. trasonic irradiation at higher amplitude caused higher temperature increase (up to 65 ⊠C). The effect was more pronounced hen smaller volume of reactants was used. Higher amplitude also caused the increase in biodiesel yield to up to 95 % in 30 min.

The reusability of the catalyst for up to 3 cycles of operation was also tested. Minimal loss of activity was demonstrated by the atalyst (20 %w/w KOH/SBA-15) but further use resulted in about 30 % loss of activity due to leaching.

il yang dimuat-naik :: Uploaded File

NIVERSITI SAINS MALAYSIA

LAPORAN PRESTASI GERAN UNIVERSITI PENYELIDIKAN
PROGRESS REPORT OF RESEARCH UNIVERSITY GRANT (SESSION 1/2010)

aklumat Projek :: Project Identification

ajuk Projek *roject Title*	: Catalyst Development, Its Characterization And Potential Utilization for Industrial Processes
elantar Penyelidikan *esearch Platform*	: PELANTAR PENYELIDIKAN KEJURUTERAAN & TEKNOLOGI
empoh Projek (ttbbhh) *roject Duration (yymmdd)*	: **001200**
arikh Mula *tart Date*	: 10 / 10 / 2007
arikh Dijangka Tamat *nd Date*	: 9 / 9 / 2010
arikh Lanjutan Pertama	: 9 / 9 / 2011
arikh Tamat	: 9 / 9 / 2011
Ketua Projek *roject Leader*	: PROFESOR ABDUL RAHMAN BIN MOHAMED
Ahli Projek *roject Members (including GRA)*	: PROF MADYA AHMAD ZUHAIRI BIN ABDULLAH PROFESOR AZLINA BINTI HARUN @ KAMARUDDIN PROFESOR SUBHASH BHATIA

eratusan Prestasi :: Achievement Percentage

restasi projek mengikut penanda aras yang telah dicapai sehingga tempoh ini:
roject progress according to milestones achieved up to this period:

1-75%

asalah/ Kekangan :: Problems/ Constraints

ada

embangunan Sumber Manusia :: Human Capital Development

Human Capital	Number	
	On-Going	Graduated
Pelajar Doktor Falsafah *PhD Student*	9	2
Pelajar Sarjana *MSc Student*	9	5
Pelajar Tahun Akhir - Sarjana Muda *Undergraduate Final Year Project*	6	7
Pegawai Penyelidik *Temporary Research Officer*	4	
Pembantu Penyelidik *Temporary Research Assistant*	7	
Lain-lain (Sila nyatakan) *Others (please specify):*	0	

Jumlah *Total*	**49**

utput Penyelidikan :: Research Output

urnal (Jurnal)

Tajuk Artikel *Title of Article)*	: Selection of best Impregnated palm Shell Activated Carbon (PSAC) for Simultaneous Removal of SO2 and NOx
Nama Jurnal *Name of Journal)*	: Journal of Hazardous Materials
Peringkat *Level)*	: Antarabangsa (International)
Jenis Jurnal *Type of Journal)*	: Berwasit (Referred)
Faktor Impak *Impact Factor)*	: 2.975
Bulan Penerbitan *Month of Publication)*	: February
Tahun Penerbitan *Year of Publication)*	: 2010
Jilid *Volume)*	: 24
Bilangan *Issue)*	: 1
Muka surat *Page Number)*	: 1093-1096
Penerbit *Publisher)*	: Elsevier Science BV
Fail berkaitan *Related file*	: selection of best.pdf

Tajuk Artikel *Title of Article)*	: Preparation of Carbon Molecular Sieve from Lignocellulosic Biomass: A Review
Nama Jurnal *Name of Journal)*	: Renewable and Sustainable Energy Reviews
Peringkat *Level)*	: Antarabangsa (International)
Jenis Jurnal *Type of Journal)*	: Berwasit (Referred)
Faktor Impak *Impact Factor)*	: 4.075
Bulan Penerbitan *Month of Publication)*	: January
Tahun Penerbitan *Year of Publication)*	: 2010
Jilid *Volume)*	: 14
Bilangan *Issue)*	: 6
Muka surat *Page Number)*	: 1591-1599
Penerbit *Publisher)*	: PERGAMON-ELSEVIER SCIENCE LTD
Fail berkaitan *Related file*	: preparation_maedah1.pdf

Tajuk Artikel *Title of Article)*	: Subcritical Water Liquefaction of Oil Palm Fruit Press Fiber for the Production of Bio-Oil : Effect of Catalysts
Nama Jurnal *Name of Journal)*	: Bioresources Technology

Level)	: Antarabangsa (International)
enis Jurnal *Type of Journal)*	: Berwasit (Referred)
aktor Impak *Impact Factor)*	: 4.453
ulan Penerbitan *Month of Publication)*	: February
ahun Penerbitan *Year of Publication)*	: 2010
ilid *Volume)*	: 101
ilangan *Issue)*	: 2
uka surat *Page Number)*	: 745-751
enerbit *Publisher)*	: Elsevier
ail berkaitan *elated file*	: Subcritical Water1.pdf

ajuk Artikel *Title of Article)*	: Investigations on the effects of CoOx to MoOx ratio and CoOx–MoOx loading on methane decomposition into carbon nanotubes
lama Jurnal *Name of Journal)*	: Journal of Alloys and Compounds
eringkat *Level)*	: Antarabangsa (International)
enis Jurnal *Type of Journal)*	: Berwasit (Referred)
aktor Impak *Impact Factor)*	: 1.15
ulan Penerbitan *Month of Publication)*	: August
ahun Penerbitan *Year of Publication)*	: 2009
ilid *Volume)*	: 488
ilangan *Issue)*	: 1
luka surat *Page Number)*	: 294-299
enerbit *Publisher)*	: Elsevier
il berkaitan *lated file*	: 2009.pdf

ajuk Artikel *itle of Article)*	: SO2 and NO Simultaneous Removal from Flue Gas over Cerium Supported Palm Shell Activated Carbon at Lower Temperatures Role of Cerium on NO Removal
ama Jurnal *lame of Journal)*	: Energy Fuel
eringkat *evel)*	: Antarabangsa (International)
nis Jurnal *ype of Journal)*	: Berwasit (Referred)
ktor Impak *mpact Factor)*	: 2.056
lan Penerbitan *onth of Publication)*	: February
hun Penerbitan *ear of Publication)*	: 2010
d *olume)*	: 24

Bilangan *(Issue)*	: 1
Muka surat *(Page Number)*	: 427-431
Penerbit *(Publisher)*	: AMER CHEMICAL SOC
Fail berkaitan *(related file*	: SO2 and NO.pdf

Tajuk Artikel *(Title of Article)*	: Optimization of Carbon Nanotubes Synthesis via Methane Decomposition over Alumina-Based Catalyst
Nama Jurnal *(Name of Journal)*	: Accepted by Fullerenes, Nanotubes and Carbon Nanostructures
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0.68
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: TAYLOR & FRANCIS INC
Fail berkaitan *(related file*	: Optimization.jpg

Tajuk Artikel *(Title of Article)*	: Synthesis of Carbon Molecular Sieve from Palm Shell using Deposition of Polyfurfuryl Alcohol
Nama Jurnal *(Name of Journal)*	: Accepted by Korean Journal Chemical Engineering
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0.83
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Korean INST Chemical Engineers
Fail berkaitan *(related file*	: synthesis.pdf

Tajuk Artikel *(Title of Article)*	: Sub/Supercritical Liquefaction of Oil Palm Fruit Press Fiber for the Production of Bio-Oil: Effect of Solvents

Nama Jurnal *(Name of Journal)*	: Accepted by Bioresources Technology
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 4.453
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Elsevier Science Ltd
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Cerium Impregnated Palm Shell Activated Carbon (Ce/PSZC) Sorbent for Simultaneous Removal of SO2 and NO-Process Study
Nama Jurnal *(Name of Journal)*	: Accepted by Chemical Engineering Journal
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.813
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Elsevier Science SA.
fail berkaitan *related file*	: cerium.pdf

Tajuk Artikel *(Title of Article)*	: Adsorption Isotherm Models and Properties of SO2 and NO Removal by Palm Shell Activated Carbon Supported with Cerium (Ce/PSAC)
Nama Jurnal *(Name of Journal)*	: Accepted by Chemical Engineering Journal
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.813
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0

Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Elsevier Science SA.
Fail berkaitan *related file*	: adsorption.pdf

Tajuk Artikel *(Title of Article)*	: Performance of Palm Shell Activated Carbon Impregnated with CeO2 and V2O5 Catalyst in Simultaneous Removal SO2 and NO
Nama Jurnal *(Name of Journal)*	: Accepted by Journal of Applied Science-Special Issue
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	: Performance5.pdf

Tajuk Artikel *(Title of Article)*	: Role of Reaction & Factors on Carbon Nanotubes Growth in Chemical Vapour Decomposition Process using Methane - A Highlight
Nama Jurnal *(Name of Journal)*	: Journal of Materials
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0.688
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Hindawi Publishing Corporation
fail berkaitan *related file*	: role.pdf

Tajuk Artikel *(Title of Article)*	: Optimized Parameters for Carbon Nanotubes Synthesis over Fe and Ni Catalysts via Methane CVD
Nama Jurnal *(Name of Journal)*	: Accepted by Reviews and Advanced Materials Science
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0.891
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 0
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Inst. Problems Mechanical Engineering-Russian Acad Sciences
fail berkaitan *related file*	: Optimized Parameters.pdf

Tajuk Artikel *(Title of Article)*	: Optimization of K/SBA-15 Catalyzed Transesterification of Palm Oil using Response Surface Methodology
Nama Jurnal *(Name of Journal)*	: Fuel Processing Technology
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.066
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 90
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 958-964
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Heat treatment Effects on the Characteristics and Performance of TiO2 Sonocatalyst in the Degradation of Organic Dyes in Aqueous Effluent
Nama Jurnal *(Name of Journal)*	: Journal of Hazardous Matarials
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.975
Bulan Penerbitan *(Month of Publication)*	: January

Tahun Penerbitan *(Year of Publication)*	: 2010
Jilid *(Volume)*	: 173
Bilangan *(Issue)*	: 1-3
Muka surat *(Page Number)*	: 159-167
Penerbit *(Publisher)*	: Elsevier
Fail berkaitan *(related file*	:

Tajuk Artikel *(Title of Article)*	: Optimization of Process Parameters for Alkaline-Catalyzed Transesterification of Palm Oil using Response Surface Methodogy
Nama Jurnal *(Name of Journal)*	: Accepted by Sains Malaysiana
Peringkat *(Level)*	: Kebangsaan (National)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 2010
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Malaysia
Fail berkaitan *(related file*	:

Tajuk Artikel *(Title of Article)*	: Influence of Silica to Surfactant Ratio and Synthesis pH on the Characteristics of Mesoporous SBA-15
Nama Jurnal *(Name of Journal)*	: Accepted by Journal of Physical Science
Peringkat *(Level)*	: Kebangsaan (National)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 2010
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Universiti Sains Malaysia
Fail berkaitan *(related file*	:

Tajuk Artikel *(Title of Article)*	: Recent Progress on Innovative and Potential Technologies for Glycerol Transformation into Fuel Additives : A Critical Review
Nama Jurnal *(Name of Journal)*	: Renewable & Sustainable Energy Review
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 4.075
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 14
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 987-1000
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Optimization of Ultrasonic-Assisted Heterogeneous Biodiesel Production from Palm oil : A Response Surface Methodology Approach
Nama Jurnal *(Name of Journal)*	: Fuel Processing Technology
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.066
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 2009
Jilid *(Volume)*	: 91
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 441-448
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	:

Tajuk Artikel *(Title of Article)*	: Ultrasonic-Assisted Biodiesel Production Process from Palm Oil using Alkaline Earth Oxides as the heterogeneous Catalyst
Nama Jurnal *(Name of Journal)*	: Fuel
Peringkat *(Level)*	: Antarabangsa (International)
Jenis Jurnal *(Type of Journal)*	: Berwasit (Referred)
Faktor Impak *(Impact Factor)*	: 2.536

Bulan Penerbitan *Month of Publication)*	:
Tahun Penerbitan *Year of Publication)*	: 2009
Jilid *Volume)*	: 89
Bilangan *Issue)*	: 0
Muka surat *Page Number)*	: 1818-1825
Penerbit *Publisher)*	: Elsevier
Fail berkaitan *related file*	:

Tajuk Artikel *Title of Article)*	: Cationic Surfactant-Modified Clay Catalysts for the Synthesis of Monoglyceride Through the Esterification of Glycerol and Lauric Acid
Nama Jurnal *Name of Journal)*	: International journal of science Engineering and Technology
Peringkat *Level)*	: Antarabangsa (International)
Jenis Jurnal *Type of Journal)*	: Berwasit (Referred)
Faktor Impak *Impact Factor)*	: 0
Bulan Penerbitan *Month of Publication)*	:
Tahun Penerbitan *Year of Publication)*	: 2009
Jilid *Volume)*	: 2
Bilangan *Issue)*	: 1
Muka surat *Page Number)*	: 47-53
Penerbit *Publisher)*	: ILRAM Publisher
Fail berkaitan *related file*	:

Tajuk Artikel *Title of Article)*	: Composites as Cracking Catalysts in the Production of Biofuel From Palm Oil : Deactivation Studies
Nama Jurnal *Name of Journal)*	: Chemical Engineering Journal
Peringkat *Level)*	: Antarabangsa (International)
Jenis Jurnal *Type of Journal)*	: Berwasit (Referred)
Faktor Impak *Impact Factor)*	: 2.813
Bulan Penerbitan *Month of Publication)*	:
Tahun Penerbitan *Year of Publication)*	: 2009
Jilid *Volume)*	: 155
Bilangan *Issue)*	: 0
Muka surat *Page Number)*	: 347-354
Penerbit *Publisher)*	: Elsevier Science SA.

Fail berkaitan :
related file

Tajuk Artikel : Catalytic Technology for Carbon Dioxide Reforming of Methane to Synthesis Gas
(Title of Article)

Nama Jurnal : ChemCatChem
(Name of Journal)

Peringkat : Antarabangsa (International)
(Level)

Jenis Jurnal : Berwasit (Referred)
(Type of Journal)

Faktor Impak : 0
(Impact Factor)

Bulan Penerbitan :
(Month of Publication)

Tahun Penerbitan : 2009
(Year of Publication)

Jilid : 1
(Volume)

Bilangan : 2
(Issue)

Muka surat : 192-208
(Page Number)

Penerbit : Elsevier Science SA.
(Publisher)

fail berkaitan :
related file

Tajuk Artikel : Effect of Mass Transfer and Enzyme Loading on the Biodiesel Yield and Reaction Rate in the Enzymatic Transesterification of Crude Palm Oil
(Title of Article)

Nama Jurnal : Energy and Fuels
(Name of Journal)

Peringkat : Antarabangsa (International)
(Level)

Jenis Jurnal : Berwasit (Referred)
(Type of Journal)

Faktor Impak : 0
(Impact Factor)

Bulan Penerbitan :
(Month of Publication)

Tahun Penerbitan : 2009
(Year of Publication)

Jilid : 23
(Volume)

Bilangan : 0
(Issue)

Muka surat : 4651-4658
(Page Number)

Penerbit : Elsevier
(Publisher)

fail berkaitan :
related file

Tajuk Artikel : Biodiesel (FAME) Productivity Catalytic Efficiency and Thermal Stability of Lipozyme TL IM for Crude Palm Oil Transesterification with Methanol
(Title of Article)

Nama Jurnal : Journal of the American Oil Chemists
(Name of Journal)

Peringkat : Antarabangsa (International)
(Level)

Jenis Jurnal : Berwasit (Referred)
(Type of Journal)

Faktor Impak *(Impact Factor)*	: 0
Bulan Penerbitan *(Month of Publication)*	:
Tahun Penerbitan *(Year of Publication)*	: 2010
Jilid *(Volume)*	: 0
Bilangan *(Issue)*	: 0
Muka surat *(Page Number)*	: 0
Penerbit *(Publisher)*	: Elsevier
fail berkaitan *related file*	:

roceeding (Kertas Persidangan - Prosiding)

Nama Seminar *(Name of Seminar)*	: Cambridge-CNT Symposium 2009
Tajuk Kertas Kerja *(Title of Paper Work)*	: Single and Multi-Wall CNT Growth over Fe/Carbon Catalyst by Thermal CVD of Methane
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Cambridge, U.K
Negara *(Country)*	: AUSTRALIA
Tarikh Mula Persidangan *(Start Date)*	: 11/13/2009
Tarikh Tamat Persidangan *(End Date)*	: 11/13/2009
Muka surat *(Page Number)*	: -
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: International Conference of Nanotechnology Research and Commercialisation (ICONT 2009)
Tajuk Kertas Kerja *(Title of Paper Work)*	: Optimization of Carbon Nanotubes Synthesis via Methane Decomposition overAlumina-Based Catalyst
Peringkat *(Level)*	: Kebangsaan (National)
Tempat Persidangan *(Place of Conference)*	: Langkawi, Kedah
Negara *(Country)*	: MALAYSIA
Tarikh Mula Persidangan *(Start Date)*	: 8/12/2009
Tarikh Tamat Persidangan *(End Date)*	: 8/14/2009
Muka surat *(Page Number)*	: -
fail berkaitan *Related file*	:

Nama Seminar *(Name of Seminar)*	: International Conference on Nanotechnology Research and Commercialisation (ICONT 2009)
Tajuk Kertas Kerja *(Title of Paper Work)*	: Identification of the Effect of Activate Metal Contents on Large Scale Synthesis of High Quality Carbon
Peringkat *(Level)*	: Antarabangsa (International)
Tempat Persidangan *(Place of Conference)*	: Langkawi, Kedah

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 12/14/2009
(Start Date)

Tarikh Tamat Persidangan : 12/17/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : International Conference on Green Technology and Engineering
(Name of Seminar)

Tajuk Kertas Kerja : Selective Cationic Surfactant-Modified Clay Catalyst for the Synthesis of Monoglyceride Through the Esterification of Glycerol and Lauric Acid
(Title of Paper Work)

Peringkat : Antarabangsa (International)
(Level)

Tempat Persidangan : Bandar Lampung
(Place of Conference)

Negara : INDONESIA
(Country)

Tarikh Mula Persidangan : 4/15/5009
(Start Date)

Tarikh Tamat Persidangan : 4/17/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : International Conference on Chemical, Biological and Environmental Engineering (CBEE 2009)
(Name of Seminar)

Tajuk Kertas Kerja : Sonocatalytic Degradation of Various Dyes in Wastewater over Heat-Treated TiO2 Catalysts and Assisted by Hydrogen Peroxide
(Title of Paper Work)

Peringkat : Antarabangsa (International)
(Level)

Tempat Persidangan : Singapore
(Place of Conference)

Negara : SINGAPURA
(Country)

Tarikh Mula Persidangan : 10/9/2009
(Start Date)

Tarikh Tamat Persidangan : 10/11/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Colloquium 2009
(Name of Seminar)

Tajuk Kertas Kerja : Comparative Study of SBA-15 Functionalized with Different Acid Stes as Solid Acid Catalysts for Esterification of Glycerol Towards Monolaurine Production
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 10/31/2009
(Start Date)

Tarikh Tamat Persidangan : 11/1/2009
(End Date)

Muka surat : -
(Page Number)

---

fail berkaitan :
Related file

Nama Seminar : Colloquium 2009
(Name of Seminar)

Tajuk Kertas Kerja : Effectof Ultrasonic Energy on the Temperature Behavior of the Heterogeneous Catalyzed Biodiesel Production Process
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 10/31/2009
(Start Date)

Tarikh Tamat Persidangan : 11/1/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Colloquium 2009
(Name of Seminar)

Tajuk Kertas Kerja : A Short Review : Degradation of Organic Dyes in Wastewater by Ultrasonic Irradation Enhanced by Fentons Reagent
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 10/31/2009
(Start Date)

Tarikh Tamat Persidangan : 11/1/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Symposium of Malaysian Chemical Engineers
(Name of Seminar)

Tajuk Kertas Kerja : Comparison of Sonocatalytic Activities on the Degradation of Rhodamine B in the Presence of TiO2 Powder and Nanotubes
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Kuala Lumpur
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 7/1/2010
(Start Date)

Tarikh Tamat Persidangan : 7/1/2010
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Colloquium 2009
(Name of Seminar)

Tajuk Kertas Kerja : Ultrasonic Assisted Fast Transesterification of Palm Oil using Strontium Oxide as Heterogeneous Catalyst
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 10/31/2009
(Start Date)

Tarikh Tamat Persidangan : 11/1/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Seminar Tahun kelima Biasiswa Penyelidikan National Science Fellowship
(Name of Seminar)

Tajuk Kertas Kerja : Enzymatic Transesterification of Palm Oil to FAME in Non-Organic Phase System : Process Optimization and Modelling Studies
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Universiti Putra Malaysia, Serdang Selangor
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 11/19/2009
(Start Date)

Tarikh Tamat Persidangan : 11/20/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Colloquium 2009
(Name of Seminar)

Tajuk Kertas Kerja : Production of Biodiesel using Cerbera Odollam (Sea Mango) Oil with Different Type of Solvents and Enzyme
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 10/31/2009
(Start Date)

Tarikh Tamat Persidangan : 11/1/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Regional Engineering Postgraduate Conference 2009
(Name of Seminar)

Tajuk Kertas Kerja : Crude Palm Oil Transesterification at room Temperature: Process Optimization
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Putrajaya
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 10/20/2009
(Start Date)

Tarikh Tamat Persidangan : 10/21/2009
(End Date)

Muka surat : -
(Page Number)

fail berkaitan :
Related file

Nama Seminar : Colloquium 2009
(Name of Seminar)

Tajuk Kertas Kerja : Kinetic Studies on Enzymatic Transesterification of Crude Palm Oil in Homogeneous Phase Mixtures
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Pulau Pinang
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 10/31/2009
(Start Date)

Tarikh Tamat Persidangan : 11/1/2009
(End Date)

Muka surat : -
(Page Number)

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Related file

Nama Seminar : International Conference for Technical Postgraduates 2009
(Name of Seminar)

Tajuk Kertas Kerja : Thermodynamic Studies on Activity and Stability of Immobilized Thermomyces Lanuginosus in Producing Fatty Acid Methyl Ester (FAME)
(Title of Paper Work)

Peringkat : Kebangsaan (National)
(Level)

Tempat Persidangan : Kuala Lumpur
(Place of Conference)

Negara : MALAYSIA
(Country)

Tarikh Mula Persidangan : 12/14/2009
(Start Date)

Tarikh Tamat Persidangan : 12/15/2009
(End Date)

Muka surat : -
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esis (Tesis)

Tajuk Tesis : Removal of SO2 and NO From Simultaned Flue Gas using Cerium-Modified Palm Shell Activated Carbon
(Title of Thesis)

Tahun dikeluarkan : 2010
(Year of Publication)

Tarikh Penganugerahan Ijazah : 4/7/2010
(Date of Convocation)

(University)	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Dr. Abdul Rahman Bin Mohamed
Penyelia Bersama *(Co-Supervisor)*	: Prof. Dr. Subhash Bhatia
Fail berkaitan *Related file*	:

Tajuk Tesis *(Title of Thesis)*	: Production of Biofuel From Oil Palm Biomass using Subcritical and Supercritical Liquefaction
Tahun dikeluarkan *(Year of Publication)*	: 2010
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 6/22/2010
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Dr. Abdul Rahman Bin Mohamed
Penyelia Bersama *(Co-Supervisor)*	: Prof. Dr. Subhash Bhatia
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Tajuk Tesis *(Title of Thesis)*	: Effect of Cacination on the Performance of TiO2 in Sonocatalytic Degradation on Dyes in Wastewater
Tahun dikeluarkan *(Year of Publication)*	: 2009
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 9/1/2009
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Madya Dr. Zuhairi
Penyelia Bersama *(Co-Supervisor)*	:
Fail berkaitan *Related file*	:

Tajuk Tesis *(Title of Thesis)*	: Development of Ultrasonic Assisted Biodiesel Production Process from Palm Oil using Heterogeneous Catalysts
Tahun dikeluarkan *(Year of Publication)*	: 2010
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 5/1/2009
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Madya Dr. Zuhairi
Penyelia Bersama *(Co-Supervisor)*	:
Fail berkaitan *Related file*	:

Tajuk Tesis *(Title of Thesis)*	: Synthesis Characterization of Mesoporous Base Catalyst for Transesterification of Palm Oil
Tahun dikeluarkan *(Year of Publication)*	: 2009

Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 9/1/2009
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Madya Dr. Zuhairi Abdullah
Penyelia Bersama *(Co-Supervisor)*	:
Fail berkaitan *Related file*	:

Tajuk Tesis *(Title of Thesis)*	: Synthesis Characterization and Evaluation of Catalytic Activity of Fe (III)TiO2 in the Removal of Reactive Dye in Aqueous System Under Ultrasonic Irradation
Tahun dikeluarkan *(Year of Publication)*	: 2010
Tarikh Penganugerahan Ijazah *(Date of Convocation)*	: 6/1/2009
Universiti *(University)*	: Universiti Sains Malaysia
Pusat Pengajian *(School)*	: P P KEJ KIMIA
Penyelia *(Supervisor)*	: Prof. Madya Dr. Zuhairi Abdullah
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erbelanjaan :: Expenditure

No. Akaun Projek : 1001 / PJKIMIA / 814004

Penaja : USM (RU)

Ketegori Penaja : USM

Peruntukan Diluluskan (1) : RM 518100

Pecahan Mengikut Tahun

Tahun 2007 : RM 273700

Tahun 2008 : RM 147700

Tahun 2009 : RM 96700

Peruntukan Tambahan (2) : RM 750000

Pecahan Mengikut Tahun

Tahun 2008 : RM 500000

Tahun 2009 : RM 250000

Jumlah Peruntukan Keseluruhan (1) + (2) : RM 1268100

Jumlah Peruntukan yang Telah Diterima Hingga Kini (3) : RM 1268100

Jumlah Perbelanjaan (4) : RM 1163132

Baki (3) - (4) : RM 104968

Jumlah Perbelanjaan (3) : RM 1163132
Baki (2) - (3) : RM 104968

Pecahan Geran Mengikut Vot

Vot	Butiran Vot *(Vot Details)*	(A) Bajet yang diluluskan *Total Approved Budget* (RM)	(B) Tambahan *Total* (RM)	(C) Bajet yang dibelanjakan *Total Budget Spent* (RM)	(A + B) - C Baki *(Total)*
11000	Gaji Dan Upahan	201600	0	173127	28473
21000	Perbelanjaan Perjalanan Dan Sara Hidup	25000	0	36889	-11889
22000	Pengangkutan Barang-barang	4000	0	0	4000
23000	Perhubungan Utiliti	1500	0	0	1500
24000	Sewaan	6000	0	0	6000
26000	Bekalan Bahan Mentah Dan Bahan Untuk Penyelenggaraan	5000	0	2995	2005
27000	Bekalan Dan Bahan-bahan Lain	70000	0	60668	9332
28000	Penyelenggaraan Dan Pembaikan Kecil Yang Dibeli	25000	0	22903	2097
29000	Perkhidmatan Iktisas Dan Perkhidmatan Lain Yang Dibeli Dan Hospitaliti	30000	0	15986	14014
35000	Harta Modal - Harta Modal Lain	150000	500000	849996	-199996
Jumlah Keseluruhan *(Grand Total)*		**(A)** 1268100	**(B)** 750000	**(C)** 1163132	**(3) - (4)** 104968

***Maklumat perbelanjaan (Bajet yang dibelanjakan) diperolehi daripada Jabatan Bendahari (Sehingga 30 April 2011)**
Information (Total Budget Spent) taken from Bursary (Up to April 30th 2011)

Ringkasan Penemuan Projek Penyelidikan :: Summary of Research Findings

Advanced materials have been synthesized and used as heterogeneous catalysts in many reactions. Particular focus is given to mesoporous materials and their functionalization into various types of catalysts including acid and base. These catalysts have been tested for catalytic reactions covering oleochemical synthesis, biodiesel Production and environmental reactions.
The catalysts have been characterized for its physical, chemical and catalytic properties and correlations between the properties and their behavior in the reaction have been established. Significant improvement in the catalytic process have been achieved by means a novel functionalized mesoporous catalyst, an ultrasonic-assisted process and the use of certain surfactant. Process conditions in the production of biodiesel, NOx reduction, monoglyceride have been successfully optimized. The stability of the catalyst materials under various reaction conditions has been demonstrated and elucidated.

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ARTICLE

The Examination of NiO and CoO_x Catalysts Supported on Al_2O_3 and SiO_2 for Carbon Nanotubes Production via CCVD of Methane

Siang-Piao Chai, Sivakumar VM, Sharif Hussein Sharif Zein, Abdul Rahman Mohamed *

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The effects of catalyst components on the synthesis of carbon nanotubes (CNTs) are always the concern of many. The aim of this work is to examine the dependence of the morphology of CNTs formed on the nature of NiO and CoO_x catalysts supported on Al_2O_3 and SiO_2 at two different synthesis temperatures, i.e. 550°C and 700°C, respectively. Catalytic chemical vapor deposition (CCVD) of methane was adopted for synthesizing the nanotubes materials. The developed catalysts were characterized by X-ray diffraction (XRD) and temperature programmed reduction (TPR). The morphology of the produced carbon nanostructures was analyzed by transmission electron microscopy (TEM). The experimental result shows that CNTs were presence on the surfaces of most of the tested catalysts. The yield of the CNTs produced over these catalysts was calculated. It was found that the yield decreased in the order of NiO/SiO_2>CoO_x/SiO_2>CoO_x/Al_2O_3>NiO/Al_2O_3 for the reaction at 550°C and in the order of NiO/SiO_2>CoO_x/Al_2O_3>CoO_x/SiO_2>NiO/Al_2O_3 at 700°C. The morphological analysis reveals that the structure of the CNTs depends upon the effects of metal-support interaction (MSI) and the synthesis temperature.

1. Introduction :

Carbon nanotubes (CNTs), exhibiting superior unique structural, mechanical, optical and electrical properties [1], have great potential applications in advance technologies, such as quantum wires, field-effect transistors, field emitters, diodes, etc. [2-5]. Since their discovery in 1991 [6], research in the field of CNTs has undergone an exponential growth. In general, there are three principal methods adopted in producing CNTs: laser ablation, electric-arc-discharge and catalytic chemical vapor deposition (CCVD). By comparison, CCVD method is of great interest since it produces CNTs at a lower temperature, higher yield and at relatively low cost.

Different carbon-containing molecules, including methane, acetylene, ethylene, propylene, benzene, toluene, hexane, alcohol and acetone have been used as carbon feedstock in synthesizing CNTs [7,8]. Among these hydrocarbons, methane was used in this study, concerning methane is the primary composition of natural gas which is cheap and highly abundant worldwide. Furthermore, methane has high stability at elevated temperatures in preventing self-pyrolysis [9,10]. Self-pyrolysis of hydrocarbons will lead to the formation of amorphous carbon which is the impurity of the nanotubes product. Previously, we have reported that TiO_2 supported NiO catalyst records the lowest activation energy in methane decomposition into CNTs and hydrogen [11]. In this paper, we will further examine the roles of metal oxides (CoO_x and NiO) and catalysts supports (alumina and silica) as well as the effect of synthesis temperatures on the morphologies and the yield of the CNTs produced via CCVD of methane.

2. Experimental :

2.1 Preparation of supported catalysts :

All the catalysts used in this study were prepared by conventional impregnation method. $Ni(NO_3)_2.6H_2O$ (supplied by Aldrich) and $Co(NO_3).6H_2O$ (supplied by Aldrich) were used as the metal sources of NiO and CoO_x with each loading amount adjusted to 10 wt% for all the prepared catalyst samples. Both metals in nitrate form were first dissolved in distilled water and then impregnated onto SiO_2 powders (Cab-osil, supplied by RdH) and Al_2O_3 (supplied by Ajax), respectively. The impregnated samples were dried at 105°C for 12 hours and calcined in air at 600°C for 5 hours. The catalysts were then sieved to a size of 425-600 μm. The synthesized catalysts were tested in the reaction without a preceding reduction in hydrogen flow.

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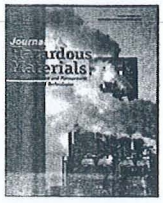

ption of butyl acetate in air over silver-loaded Y and ZSM-5 zeolites: imental and modelling studies

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ABSTRACT

Adsorption behaviours of butyl acetate in air have been studied over silver-loaded Y (Si/Al = 40) and ZSM-5 (Si/Al = 140) zeolites. The silver metal was loaded into the zeolites by ion exchange (IE) and impregnation (IM) methods. The adsorption study was mainly conducted at a gas hourly space velocity (GHSV) of 13,000 h^{-1} with the organic concentration of 1000 ppm while the desorption step was carried out at a GHSV of 5000 h^{-1}. The impregnated silver-loaded adsorbents showed lower uptake capacity and shorter breakthrough time by about 10 min, attributed to changes in the pore characteristics and available surface for adsorption. Silver exchanged Y (AgY(IE)) with lower hydrophobicity showed higher uptake capacity of up to 35%, longer adsorbent service time and easier desorption compared to AgZSM-5(IE). The presence of water vapour in the feed suppressed the butyl acetate adsorption of AgY(IE) by 42% due to the competitive adsorption of water on the surface and the effect was more pronounced at lower GHSV. Conversely, the adsorption capacity of AgZSM-5(IE) was minimally affected, attributed to the higher hydrophobicity of the material. A mathematical model is proposed to simulate the adsorption behaviour of butyl acetate over AgY(IE) and AgZSM-5(IE). The model parameters were successfully evaluated and used to accurately predict the breakthrough curves under various process conditions with root square mean errors of between 0.05 and 0.07.

uction

e organic chemicals (VOCs) are emitted as gases from lids or liquids which contain organic compounds. Paints, , and wax all contain organic solvents, as do many clean- fecting, cosmetic and degreasing products. All of these can release organic compounds while using them, and, degree, when they are stored. When these organic com- eleased to atmosphere, they become a key contributor of nation. Smog is hazardous because it decreases visibility. pent-based processes for the separation of multi- nt gaseous mixtures are becoming increasingly popular. generation of synthetic and more selective adsorbents d in recent years has enabled the adsorption-based tech- compete successfully with the traditional gas-separation es, such as cryogenic distillation [1]. Adsorption technol- days is being implemented successfully for its commercial ons in the removal of VOCs. For example, the BOWSORB® nology, based on the pressure-swing adsorption princi- oped and patented by Dow Chemical Company in 1987, has been installed as an economical alternative for the recovery of VOCs [2].

The adsorbent acts as a separation medium for the process. The primary requirements of an absorbent are the selectivity, in which it determines the preferential adsorption of one or more component based upon equilibrium and/or kinetic mechanisms. Besides, a good adsorbent gave the maximum possible loading of VOC on the adsorbent and it must be chemical and physical stable under various operating conditions. Activated carbons are generally used in many adsorption processes due to their higher adsorption capacity and lower price. However, their regeneration is very difficult because of their thermal and chemical instabilities that may cause significant safety problems [3]. As an alternative to activated carbon, high silica zeolites have several advantages. It is reported that at relatively high humidity, carbon takes up appreciable quantities of moisture thereby limiting their effectiveness for VOC uptake [4]. A part of that, zeolites are inorganic and hence, they can be regenerated in air subject to flammability considerations. The use of hydrophobic zeolites is attracting more and more attention due to their resistance to high thermal operation and their high adsorption affinity for VOC in humid conditions [4].

The common operating experimental variables in the adsorption studies are the gas flow rate, VOC concentration and the type of VOC. Additional variables are the amount of adsorbent and the

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Catalytic oxidation of butyl acetate over silver-loaded zeolites

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rmance of silver-loaded zeolite (HY and HZSM-5) catalysts in the oxidation of butyl acetate as a model volatile organic compound tudied. The objective was to find a catalyst with superior activity, selectivity towards deep oxidation product and stability. The catalyst measured under excess oxygen condition in a packed bed reactor operated at gas hourly space velocity (GHSV) = 15,000–32,000 h^{-1}, perature between 150 and 500 °C and butyl acetate inlet concentration of 1000–4000 ppm. Both AgY and AgZSM-5 catalysts exhibited in the oxidation of butyl acetate. Despite lower silver content, AgY showed better activity, attributed to better metal dispersion, surface es and acidity, and its pore system. Total conversion of butyl acetate was achieved at above 400 °C. The oxidation of butyl acetate imple power law model. The reaction orders, n and m were evaluated under differential mode by varying the VOC partial pressure 04 and 0.018 atm and partial pressure of oxygen between 0.05 and 0.20 atm. The reaction rate was independent of oxygen concentration der with respect to VOC concentration. The activation energies were 19.78 kJ/mol for AgY and 32.26 kJ/mol for AgZSM-5, respectively.

tyl acetate; Silver; Zeolites; Catalysis; Characterization; Activity; Kinetic

ction

ce of the volatile organic compound (VOC) emission echnique depends on the characteristics of the effluent eated, such as the nature of VOC, its concentration rate [1]. Catalytic oxidation that can be effectively wide range of VOCs concentrations and waste gas presents an interesting solution for VOCs elimination e catalytic process permits the oxidation reaction to ignificantly lower temperature than that required by dation processes. There are two types of catalysts used in catalytic oxidation, i.e. metal oxides and oble metals [2,3–5]. The selection between a metal noble metal is generally influenced by several factors the nature of the gaseous stream to be treated and e of contaminants. However, it is generally accepted netals are more active than metal oxides but the latter resistant to poisoning [6]. Pt and Pd are the most ble metals used for total oxidation of VOCs [7] and are supported on an oxide such as Al_2O_3 or SiO_2.

In general, platinum exhibits higher activity than palladium for the total oxidation of VOCs [8].

Oxides of transition metals such as copper, chromium, manganese and nickel can tolerate higher levels of poisons but the activity shown by these oxides are usually lower than that of noble metal-based catalyst [4]. Silver has recently gained much interest for low temperature NOx reduction [9] and CO oxidation [10]. Thus, it could be a suitable catalyst for many redox reactions like VOC oxidation. Pioneering works by Cordi and Falconer [11] led to the conclusion that Ag/Al_2O_3 catalyst was very active for the complete oxidation of VOC to CO_2 and H_2O. VOC was hypothesized to diffuse along the alumina surface and reacted at the silver sites, where oxygen is adsorbed. As the oxidation occurred at high temperatures, VOC reacted in parallel on silver and alumina sites. Recently, Beak et al. [12] studied various transition metals such as Mn, Fe, Co, Ni, Cu, Zn and Ag for catalytic oxidation of toluene and methyl ethyl ketone and silver showed the best activity among the tested catalysts. Thus, it is of great scientific interest to study the performance of this metal in the complete oxidation of a wider range of organic substances.

The choice of the support is also important with γ-alumina being the most widely investigated. An important property pointed out by several researchers is that the hydrophobicity of

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provement of loose contact diesel soot oxidation by synergic ffects between metal oxides in K_2O–V_2O_5/ZSM-5 catalysts

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ot oxidation in loose contact with 15 wt% CuO/, V_2O_5/, Fe_2O_3/ and K_2O–V_2O_5/ZSM-5 catalysts at a ratio of 9:1 was stud-SM-5 was the most active with a peak activity at 450 °C. Further improvement was achieved with the incorporation of O, attributed to the mobility of potassium upon melting. Chemical interactions between the K_2O and extra framework sil- in potassium silicate formation. Sintering of oxides towards the end of the oxidation process resulted in a delay in the com-ot oxidation.

ese; soot; Oxidation; K_2O–V_2O_5/ZSM-5; Loose contact; Synergic effect

tion

nany other types of pollutants emitted diesel ually emit significant amount of soot and nitro- (NOx). To protect the environment, the two have to be removed from the exhaust gas. As ions on diesel engine emissions becoming more he engine modification and the exhaust after re needed. While NOx can be removed by cat-ction processes [1], soot particulates are com-lected on a catalytic filter and periodically CO_2 [2]. The catalyst in the trap must be suffi-ve to oxidize the soot within the exhaust gas es (300–400 °C) [3]. The catalysts' activity and e key factors in determining its applicability in ial scale.

s investigated for soot filter are such as noble transition metals [4], perovskites [5] and alkali nd the soot-catalyst contact appears to be the rtant problem [2]. Soot oxidation mainly initiate from areas that have contact with the catalyst. This contact will involve in various pathways for the local transport of reactive oxygen species from the active catalytic species to the soot [7]. The nature of the contact (loose or tight) can therefore affect the relative effectiveness of a catalyst in promoting soot oxidation. Loose contact always shows reduced activity compared to tight contact for all compositions, but the degree of degradation varies from compound to compound [6]. Hinot et al. [2] stressed that soot particles could not be effectively oxidized unless the catalyst is deposited uniformly in the soot clusters. However, some benefit could also be obtained from loose contact as oxygen diffusion is facilitated. Therefore, soot particles embedded deep into the soot-catalyst mass could simultaneously undergo oxidation with those exposed to the oxygen at the external surface.

As loose contact between the catalyst and soot always leads to lower oxidation activity than the tight contact, active catalytic formulations should also include other components with high mobility [6]. Potassium has been proposed to increase the effective contact with the soot due to its high mobility [6,8]. However, report on the combination of transition metal and potassium as the soot

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Utilization of oil palm as a source of renewable energy in Malaysia

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Abstract

Malaysia is currently the world's largest producer and exporter of palm oil. Malaysia produces about 47% of the world's supply of palm oil. Malaysia also accounts the highest percentage of global vegetable oils and fats trade in year 2005. Besides producing oils and fats, at present there is a continuous increasing interest concerning oil palm renewable energy. One of the major attentions is bio-diesel from palm oil. Bio-diesel implementation in Malaysia is important because of environmental protection and energy supply security reasons. This palm oil bio-diesel is biodegradable, non-toxic, and has significantly fewer emissions than petroleum-based diesel (petro-diesel) when burned. In addition to this oil, palm is also a well-known plant for its other sources of renewable energy, for example huge quantities of biomass by-products are developed to produce value added products such as methane gas, bio-plastic, organic acids, bio-compost, ply-wood, activated carbon, and animal feedstock. Even waste effluent; palm oil mill effluent (POME) has been converted to produce energy. Oil palm has created many opportunities and social benefits for the locals. In the above perspective, the objective of the present work is to give a concise and up-to-date picture of the present status of oil palm industry enhancing sustainable and renewable energy. This work also aims to identify the prospects of Malaysian oil palm industry towards utilization of oil palm as a source of renewable energy.

Keywords: Oil palm; Energy; Palm oil; Bio-diesel; Biomass

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talytic esterification of citronellol with lauric acid by immobilized lipase on ɔpropyl-grafted mesoporous SBA-15

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ABSTRACT

Mesoporous SBA-15 was synthesized under acidic condition at 40 °C with a non-ionic triblock copolymer (P123) as the template. The synthesis gel composition used was 1 SiO_2:0.017 P123:2.9 HCl:202.6 H_2O. Functionalization of SBA-15 with 3-aminopropyltriethoxysilane (APTES) by post-synthesis method was performed under reflux for 2 h. The mesoporous samples were characterized using Fourier transform infrared (FT-IR), nitrogen adsorption, transmission electron microscopy (TEM) and scanning electron microscopy (SEM). They were then utilized as supports for the immobilization of lipase to be subsequently used for the esterification of citronellol and lauric acid. Leaching and reusability tests were also conducted on the immobilized enzymes. Functionalization resulted in about 10% improvement in enzyme loading, leading to higher activity. The immobilized enzyme was also more stable to low pH and high temperature while showing better retention (up to 95%) of enzyme molecules. Immobilized lipase maintained 90% of its esterification activity in non-aqueous system even after 4 cycles of use. The improvements were associated with enhanced surface hydrophobicity, changes in pore shapes and stronger enzyme–support interactions with minimal effects to the enzymatic activity.

duction

es are one of the enzymes of considerable physiological strial significance [1,2]. However, they are unstable and very from the reaction mixture is usually difficult. The zation of these enzymes within mineral hosts is a pop- challenging approach to design new biocatalysts with d future applications [3,4]. The immobilized lipases have vantages over soluble counterparts in terms of stability, ty and applicability to continuous processing. They also tter stability to pH while having low substrate-inhibition]. The handling of immobilized lipases is relatively easy as ally strongly bind to a solid phase and easy to be separated reaction mixture [6]. The stability of the immobilization pends on the immobilization method and type of sup- refore, it is important to choose the most suitable support bilize enzymes so that the enhancement of thermal and nal stabilities, the minimization operating cost and the ty of the enzyme can be achieved [2].

ed mesoporous silicas, in particular SBA-15, have been be promising host matrixes for immobilization of enzymes e research works on various conversions have been initiated by several research groups [3,7]. SBA-15 has a BET surface areas of between 690 and 1040 m^2/g, large pore sizes of between 50 and 100 Å and unusually large pore volumes of up to 2.5 cm^3/g. Its silica wall thickness ranges from 3.1 to 6.4 nm [3]. In addition, the pore size of SBA-15 can be easily tuned by employing different swelling agents and the functionalization of its surface could render it suitable for specific catalytic applications [8]. All these characteristics make the materials potential candidates to act as suitable support materials for large molecules like enzymes. In our earlier work, a highly porous SBA-15 material with well-organized array of straight channels and narrow pore size distribution has been developed [9]. The correlations between its surface characteristics and the synthesis conditions have also been successfully elucidated.

Though SBA-15 support has been demonstrated to protect the enzyme from aggregation [10], the insufficient strength of interaction between enzyme and the mesoporous support causes significant enzyme leaching from the support [3]. Thus, surface modification of mesoporous silicas with organofunctionalities was actively investigated to reduce the degree of enzyme leaching [2,3,8]. Through organic functionalization of the internal surface, certain functional groups can be attached to the surface of the mesoporous material to strengthen interactions with the enzyme. In addition, the surface functionalization also partially reduces the pore openings, especially at the external surface. This will 'trap' the enzyme molecules within the pores but still allowing reactant and product molecules to diffuse in and out of the pores [3].

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talytic esterification of citronellol with lauric acid by immobilized lipase on opropyl-grafted mesoporous SBA-15

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ABSTRACT

Mesoporous SBA-15 was synthesized under acidic condition at 40 °C with a non-ionic triblock copolymer (P123) as the template. The synthesis gel composition used was 1 SiO_2:0.017 P123:2.9 HCl:202.6 H_2O. Functionalization of SBA-15 with 3-aminopropyltriethoxysilane (APTES) by post-synthesis method was performed under reflux for 2 h. The mesoporous samples were characterized using Fourier transform infrared (FT-IR), nitrogen adsorption, transmission electron microscopy (TEM) and scanning electron microscopy (SEM). They were then utilized as supports for the immobilization of lipase to be subsequently used for the esterification of citronellol and lauric acid. Leaching and reusability tests were also conducted on the immobilized enzymes. Functionalization resulted in about 10% improvement in enzyme loading, leading to higher activity. The immobilized enzyme was also more stable to low pH and high temperature while showing better retention (up to 95%) of enzyme molecules. Immobilized lipase maintained 90% of its esterification activity in non-aqueous system even after 4 cycles of use. The improvements were associated with enhanced surface hydrophobicity, changes in pore shapes and stronger enzyme–support interactions with minimal effects to the enzymatic activity.

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Though SBA-15 support has been demonstrated to protect the enzyme from aggregation [10], the insufficient strength of interaction between enzyme and the mesoporous support causes significant enzyme leaching from the support [3]. Thus, surface modification of mesoporous silicas with organofunctionalities was actively investigated to reduce the degree of enzyme leaching [2,3,8]. Through organic functionalization of the internal surface, certain functional groups can be attached to the surface of the mesoporous material to strengthen interactions with the enzyme. In addition, the surface functionalization also partially reduces the pore openings, especially at the external surface. This will 'trap' the enzyme molecules within the pores but still allowing reactant and product molecules to diffuse in and out of the pores [3].

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ization of microporous palm shell activated carbon production e gas desulphurization: Experimental and statistical studies

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ABSTRACT

Optimizing the production of microporous activated carbon from waste palm shell was done by applying experimental design methodology. The product, palm shell activated carbon was tested for removal of SO_2 gas from flue gas. The activated carbon production was mathematically described as a function of parameters such as flow rate, activation time and activation temperature of carbonization. These parameters were modeled using response surface methodology. The experiments were carried out as a central composite design consisting of 32 experiments. Quadratic models were developed for surface area, total pore volume, and microporosity in term of micropore fraction. The models were used to obtain the optimum process condition for the production of microporous palm shell activated carbon useful for SO_2 removal. The optimized palm shell activated carbon with surface area of 973 m^2/g, total pore volume of 0.78 cc/g and micropore fraction of 70.5% showed an excellent agreement with the amount predicted by the statistical analysis. Palm shell activated carbon with higher surface area and microporosity fraction showed good adsorption affinity for SO_2 removal.

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ed carbon is one of the most effective adsorbents, be-
ts well-developed porous structures, large active surface
good mechanical properties. Activated carbons have been
many adsorption processes ranging from liquid to gas
1999). Commercial activated carbons can be manufac-
m a variety of carbonaceous precursors such as lignite,
d, and various agricultural and forest by-products, by
hysical or steam-pyrolysis or chemical method. In phys-
sses gases such N_2 and CO_2 will be used whereas for
processes the starting materials are impregnated with a
ng agent (example $ZnCl_2$, H_3PO_4 and KOH). Steam-pyro-
one using high-temperature steam (Zhang et al., 2004;
and Zabaniotou, 2007).
tly interests are growing in the use of low-cost and abun-
ailable lignocellulosic material as the precursor for the
n of activated carbon. One of these is oil palm fruit waste
m shell which is abundantly available from the palm oil
g mills in Malaysia. Despite its wide use already for bio-
production, there is still much to be done to optimize
tion of biomass for cogeneration in Malaysia (Sumathi
8).

Palm shell (also known as endocarp) has been used as starting material for preparing activated carbon for various applications (Sumathi et al., 2008; Lua and Guo, 1998; Lua et al., 2006). Guo and Lua (2002, 2003) have studied the adsorption of SO_2 with and without impregnation. However, there is no report in the literature referring to an optimum production of microporous palm shell activated carbon (PSAC) to remove SO_2, particularly from flue gas by using response surface methodology (RSM) approach.

Removal of SO_2 from flue gas has gained the interest of many researchers. This is because SO_2 is one of the main precursors of acid rain and human fatalities (De Nevers, 2000). Most of the global productions of SO_2 come from combustion of fossil fuels such as coal and oil. To minimize the adverse impacts, many efforts have been taken to eliminate the SO_2 emission. One of the most promising existing flue gas desulphurization technologies is dry removal of SO_2 using activated carbon. This method has been reported by many researchers as a capable approach to remove SO_2 from flue gas (Qiang et al., 2005; Tseng et al., 2003).

Hence, in this study, RSM optimization has been applied to prepare PSAC. RSM is a collection of statistical and mathematical techniques useful for developing, improving and optimizing processes. RSM was originally developed by Box and Wilson (1951). Researches related to RSM applications performed for optimization of activated carbon production are very rare. In the present work, the preparation of microporous activated carbon from palm shell and its potential for flue gas desulphurization were focused. This preparation procedure involves many factors. Thus, in assessing

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REMOVAL OF SO_2 AND NO OVER RICE HUSK ASH (RHA)/CaO-SUPPORTED METAL OXIDES

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Abstract

The activity of rice husk ash (RHA)/CaO-based sorbent supported with various metal oxides for the removal of SO_2 and NO from simulated flue gas of combustion process has been studied. In this study, RHA/CaO-based sorbents were impregnated with an appropriate metal nitrates solution followed by drying and calcinations, which resulted in the sorbent having the following active phases; MgO, MnO, CoO, ZnO, Al_2O_3, Fe_2O_3, and CeO_2. The sorbent-catalysts were tested in a fixed bed reactor by passing mixture gas consisting of SO_2 (2000 ppm), NO (500 ppm), O_2 (10 %), water vapor (50%) and N_2 as a balance at a total flow rate of 150 mL/min and reaction temperature of 87°C. The results showed that RHA/CaO sorbents impregnated with CeO_2 displayed the highest sorption capacity among other impregnated metal oxides for the simultaneous removal of SO_2 and NO. Infrared spectroscopic results indicate the formation of both sulfate (SO_4^{2-}) and nitrate (NO_3^-) species due to a catalytic role played by CeO_2.

Keywords: Rice husk ash (RHA), Metal oxides, Sorbent-catalysts, SO_2, NO.

1. Introduction

It is well known that acid rain is one of the most serious environmental issues related to large-scale fossil fuel combustion, especially in urban areas. Sulfur oxides (SO_x) and nitric oxides (NO_x) are the main anthropogenic acid gases that not only lead to formation of acid precipitation, but also impose adverse effects on human health, aquatic ecosystems, crops and manmade materials. Typically, SO_x and NO_x in flue gases consist of more than 98% of sulfur dioxide (SO_2) [1]

A Review on Carbon Nanotubes Production via Catalytic Methane Decomposition

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ABSTRACT

Methane decomposition is a promising approach to produce high purity, high yield and perfect orientation of carbon nanotubes and is viable for scaling up its production at a relatively low cost. The current research of methane decomposition is widely focusing on the aptness of catalyst system and the reaction conditions for optimizing the production of carbon nanotubes. The appropriate interaction of metal-support is vital in improving the catalyst activity, deactivation rate and selectivity of the carbon nanotubes for lower activation energy consumption. In this case, the traditional catalysts, iron group metals (Fe, Ni, Co) supported on silica, alumina, magnesia, titania, zirconia and graphite are extensively used. Methane decomposition is an attractive process in view of its potentiality in producing single-walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWNTs), depending on the specific range of reaction temperature and a particular catalyst system in use. Therefore, selectivity of SWNTs and MWNTs is possible to be achieved by altering the composition of metal and support in a catalytic process. Large-scale production of carbon nanotubes remains a question due to the lack of comprehensive knowledge of the carbon nanotubes growth mechanism. The catalytic process and the morphology of the carbon nanotubes formed can be vividly revealed if the carbon nanotubes growth mechanism is well understood. Three main growth mechanisms have been reported, including base growth model, tips growth model and base-tips growth model. Conversely, the growth mechanism is an arguable issue that needs further investigation to clarify it. This paper reviews the catalysis for the production of carbon nanotubes via methane decomposition, the morphology of carbon nanotubes produced and the proposed growth mechanisms, in order to create more understanding on carbon nanotubes and their related studies.

Keywords: Carbon nanotubes, catalytic filamentous carbon, catalytic methane decomposition, catalysis

1.0 INTRODUCTION

Carbon nanotubes have been receiving fabulous research interest from scientists worldwide, since it was first discovered by Sumio Iijima in 1991 (Iijima, 1991), to explore their application and to develop the efficient carbon nanotubes synthesis system. Carbon nanotubes have structure similar to graphene sheet rolled into a cylinder form with a diameter ranging from 0.8 to 300 nm. Carbon nanotubes can be categorized into single-walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWNTs) depending on the number of graphene layer. SWNTs consist of single layer graphene sheet and MWNTs consist of several layers of graphene sheets rolled into a cylinder.

Along the years, various synthesis processes such as electric-arc-discharge (Iijima, 1991; Iijima et al., 1993; Bethune et al., 1993) and laser ablation (Thess et al., 1996) have been used in the production of carbon nanotubes. However, all these processes have significant drawbacks and limitations. Electric-arc-discharge method, a technique used to synthesize fullerene, is reported to yield significantly less carbon nanotubes with large amount of undesirable carbonaceous byproducts. Laser ablation is the most recent achievement in producinghigh ly pure carbon nanotubes. but the high cost of operation and equipment as well as low production rate limit the plausible scaling up in the production of nanotubes.

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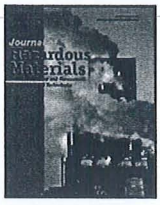

communication

uation of various additives on the preparation ce husk ash (RHA)/CaO-based sorbent for flue desulfurization (FGD) at low temperature

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ABSTRACT

This paper examines the effectiveness of 10 additives toward improving SO_2 sorption capacities (SSC) of rice husk ash (RHA)/lime (CaO) sorbent. The additives examined are NaOH, $CaCl_2$, LiCl, $NaHCO_3$, NaBr, $BaCl_2$, KOH, K_2HPO_4, $FeCl_3$ and $MgCl_2$. Most of the additives tested increased the SSC of RHA/CaO sorbent, whereby NaOH gave highest SSC (30 mg SO_2/g sorbent) at optimum concentration (0.25 mol/l) compared to other additives examined. The SSC of RHA/CaO sorbent prepared with NaOH addition was also increases from 17.2 to 39.5 mg SO_2/g sorbent as the water vapor increases from 0% RH to 80% RH. This is probably due to the fact that most of additives tested act as deliquescent material, and its existence increases the amount of water collected on the surface of the sorbent, which played an important role in the reaction between the dry-type sorbent and SO_2. Although most of the additives were shown to have positive effect on the SSC of the RHA/CaO sorbent, some were found to have negative or insignificant effect. Thus, this study demonstrates that proper selection of additives can improve the SSC of RHA/CaO sorbent significantly.

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rain and the acidification of the environment has emerged ious global problem during recent decades. Sulfur diox-), represents 98% of the sulfur oxide pollutants generated from large-scale fossil fuel combustion, is commonly l as the most important precursor to acid rain [1,2]. The of SO_2-containing gasses has received considerable atten-ecent decades due to a variety of effects caused by this t. Dry sorbent injection control technologies is among the nethod which has been widely accepted by reason of being vith less equipment, lower capital and operating costs, lim-ndary waste generation, and fewer problems of corrosion ng-up [3–5]. Nevertheless, acid gas sorption capacities are y lower than those achieved with wet control technologies. e, enhancing the sorption capacities of dry sorbent toward been an important issue for dry-type methods applica-

are a number of dry-type sorbents that have been con-in the literature for usage in desulfurization process. ly, we have reported the preparation of siliceous/calcium sorbents prepared from coal fly ash [6,7], oil palm ash [8,9] and rice husk ash [10]. It was found that, those prepared sorbent have higher SO_2 sorption capacity (SSC) relating to higher surface areas due to the fact that coal fly ash, oil palm ash and rice husk ash are a pozzolanic material (mainly consist of SiO_2/Al_2O_3). These pozzolanic materials can react with Ca-based in the presence of water to form calcium silicate hydrates (near-amorphous/poorly crystallized compounds) which have a very high surface area. Apart from that, the structural properties and sorption capacities of these types of sorbents are also affected by siliceous material/Ca-based ratio and the hydration conditions. Among those sorbents prepared, rice husk ash (RHA)/CaO sorbent shows highest SSC. However, our recent study on RHA/CaO sorbent [11] revealed that higher SSC did not show any correlation with specific surface area. On the other hand, many studies indicate that relative humidity has the greatest impact on the SSC of dry Ca-based sorbents at low temperature [12–17]. The relative humidity is consecutively connected to moisture content of the solids. In addition, some additives have been employed to alter the moisture content on the prepared sorbent surface in equilibrium with a gas phase of a given relative humidity [18–23]. Thus, the use of additive would then be expected to improve the sorbent SSC in desulfurization processes in the way of altering the sorbent particle's physical/chemical properties. Therefore, the scope of this work is to evaluate the effectiveness of various additives in the preparation of RHA-based sorbent for desulfurization process at low temperature.

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of FeO_x loaded on CoO_x/Al_2O_3 catalyst for the formation of thin-walled n nanotubes

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ABSTRACT

Effects of FeO_x loaded on CoO_x/Al_2O_3 catalyst on the yield and morphology of the produced carbon nanotubes were studied. The findings showed that the addition of a small amount of FeO_x on the CoO_x/Al_2O_3 catalyst provoked the formation of carbon nanotubes with a thin wall structure. The results also revealed that an increase in FeO_x content decreased the yield of carbon nanotubes. An optimized weight ratio of CoO_x to FeO_x was found to be 8:2 (w/w) whereby the catalyst of this composition grew carbon nanotubes with a thin wall structure and not of diminutive carbon yield.

uction

n nanotubes have created an active area of current research of their unique structural, mechanical, and electrical proper- hey are generally considered as promising building blocks for e devices. Several nanoelectronics devices based on carbon es such as quantum wires, field effect transistors, field and diodes have been demonstrated [2–5]. It is well accepted properties of carbon nanotubes, including electrical and al properties depend strongly on their chirality, diameter, thickness [6–8]. The interaction or coupling between the nt graphene layers for carbon nanotubes with thick walls n their physical and chemical properties being more ted. On the other hand, carbon nanotubes with smaller s and thinner walls are much needed in the miniaturization onic applications due to their excellent electronic and properties.

evious results showed that the NiO/TiO_2 catalyst was effective in g carbon nanotubes from methane and the activation energy for ss was one of the lowest ever reported in the literature [9]. the produced carbon nanotubes possessed a larger diameter (~40 nm) and a thick wall morphology. We had also demonstrated that FeO_x might induce the formation of carbon nanotubes with a thin wall structure [10]. Nevertheless, no further study was carried out to investigate the influence of FeO_x on the morphology of nanotubes grown. Hence, this letter is aimed at reporting the effect of FeO_x loaded on the CoO_x/Al_2O_3 catalyst on carbon yield and morphology of the carbon nanotubes synthesized via methane decomposition.

2. Experimental

$Co(NO_3)_2.6H_2O$ (supplied by Aldrich) and $Fe(NO_3)_2.9H_2O$ (supplied by Merck) were used as metal sources for the preparation of CoO_x and FeO_x. Alumina (supplied by Ajax) was used as a catalyst support. All the catalysts used in this study were prepared using a conventional impregnation method. The experimental setup and the catalyst preparation procedures had been reported previously [10–12]. The synthesis of carbon nanotubes was carried out at atmospheric pressure in a stainless steel fixed-bed reactor at a temperature of 700 °C. The product gases were analyzed using on-line gas chromatography (Hewlett-Packard Series 6890, USA). Carbon nanotubes deposited on the catalysts were analyzed using a transmission electron microscope (TEM) (Philips, CM12) and a scanning electron microscopy (SEM) image of the catalyst particles was taken using LEO Supra 50 VP FESEM. An X-ray diffraction (XRD) pattern of the catalyst after reaction was measured by Bruker D8 Advance Powder Diffractometer. Intensity was measured by step scanning in the 2θ range of 20–70° with a step of 0.02° and a measuring time of 2 s/point.

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ts of FeO_x, CoO_x, and NiO catalysts and calcination temperatures on the nesis of single-walled carbon nanotubes through chemical vapor sition of methane

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ABSTRACT

The oxides of cobalt, iron, and nickel catalysts were tested in chemical vapor deposition (CVD) of methane in synthesizing single-walled carbon nanotubes (SWNTs). All catalysts used in this study were prepared using impregnation method and calcined at temperatures ranging from 300 to 850 °C. The catalyst samples after CVD of methane were characterized using transmission electron microscopy (TEM). The TEM study elucidates that iron oxide serves as an effective catalyst for growing SWNTs. The presence of SWNTs on the catalyst was confirmed in the Raman study.

duction

since the discovery of carbon nanotubes (CNTs) by Iijima [1], the innovative materials have been one of the most studied fields nowadays. The firstly discovered CNTs were alled CNTs (MWNTs). Two years later, in 1993, single-NTs (SWNTs) were synthesized by Iijima and Ichihashi [2] une et al. [3]. The unique electronic and mechanical prop-SWNTs have made them suitable for several applications have become the most welcome of all CNTs. For instance, re very useful in the miniature electronics applications [4]. everal methods such as laser ablation, arc-discharge and chemical vapor deposition (CCVD) have been effectively d in growing SWNTs [5]. Nevertheless, laser ablation and arge have significant drawbacks for large-scale production s, resulted from their intensive power requirement and the d nature of CNTs produced from both methods which make of purification and application of the samples difficult [6]. rally accepted that CCVD is a promising method for pro-WNTs on a larger scale for the reasons that CCVD method is not only simple and economical, but it is also efficient to give rise to the production of high purity CNTs.

It is known that the choice of metal plays a determinant factor in the formation of SWNTs [7]. Previously, our studies showed that catalyst calcination temperature has significantly influenced the morphology of the grown CNTs [8]. We also reported that alumina is a suitable catalyst support for growing SWNTs [9]. In continuation of the previous studies, the present work is aimed at examining the effects of the three most commonly used metal oxides, viz. cobalt, iron, and nickel oxides, supported on alumina and their calcination temperatures on selectively synthesizing SWNTs.

2. Experimental

The synthesis of SWNTs was carried out at atmospheric pressure in a fixed bed quartz reactor that was inserted into a stainless steel tube at a reaction temperature of 950 °C. The diameter and length of the quartz tube reactor were 19 and 690 mm, respectively. The detailed experimental setup and catalyst preparation procedure were reported previously [8–10]. The loading amount of cobalt, iron, and nickel oxides, denoted as CoO_x, FeO_x, and NiO, respectively, was adjusted to 5 wt% with respect to the total catalyst weight. The dried catalyst samples were calcined in air at 300, 600, and 850 °C. The CCVD process was carried out for 30 min. The carbon deposited on the catalyst was analyzed via a transmission electron microscopy (TEM) system (Philips, model CM12) for studying the morphology of the deposited carbon. The presence of SWNTs was further identified using Raman spectroscopy (Jobin Yvon Horiba HR800UV)

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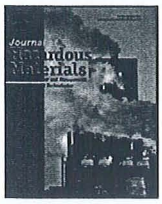

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tion of metal oxides in the preparation of rice husk ash (RHA)/CaO nt for simultaneous SO_2 and NO removal

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ABSTRACT

In this work, the removal of SO_2 and NO from simulated flue gas from combustion process was investigated in a fixed-bed reactor using rice husk ash (RHA)/CaO-based sorbent. Various metal precursors were used in order to select the best metal impregnated over RHA/CaO sorbents. The results showed that RHA/CaO sorbents impregnated with CeO_2 had the highest sorption capacity among other impregnated metal oxides for the simultaneous removal of SO_2 and NO. Infrared spectroscopic results indicated the formation of both sulfate (SO_4^{2-}) and nitrate (NO_3^-) species due to the catalytic role played by CeO_2. Apart from that, the catalytic activity of the RHA/CaO/CeO_2 sorbent was found to be closely related to its physical properties (specific surface area, total pore volume and average pore diameter).

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ain has been identified as one of the most serious threats obal environment ever faced in human history. Undoubt- most dominant air pollutants contributing to acid rain are des (SO_x) and nitric oxides (NO_x). The major sources of SO_x emission by human activities are from the combustion of s, mainly in electric power plant. The SO_x and NO_x formed released into the environmental together with the boiler Typically, SO_x and NO_x in flue gases consists of more than lfur dioxide (SO_2) [1] and over 90–95% of nitric oxide (NO) equently, considerable attention has been given to removal d NO from flue gas combustion system. Nevertheless, the mon technology used to date still uses two separate sys- emove these pollutants. For example, the SNOX process of psoe which combine the wet-gas sulfuric acid process for val and the selective catalytic reduction (SCR) process for val of NO [3].

pts have been made to find a suitable method for the f SO_2 and NO simultaneously. Dry sorption method is now d to be the most attractive way to treat waste gases con- O_2 and NO. These methods have the advantages of being ith less equipment, lower capital and operating costs, and condary waste generation [4,5]. At the moment, there are reports on removal SO_2 and NO simultaneously by the dry method. Some of these reports include: Ca-based sorbent [6,7], Ca-based with fly ash [8], natural manganese ore [9], activated carbon [10–12], activated carbon-impregnated catalyst [13–15] and metal catalyst [16–19]. Apart from these, the simultaneous removal of SO_2 and NO at low temperature using sorbent prepared from siliceous materials are also very limited, especially using rice husk ash (RHA). RHA is an agricultural waste material that available abundantly in rice-producing countries such as Malaysia. It was estimated that more than 22.8 million metric tons of RHA is produced annually worldwide, of which Malaysia alone produces more than 77,000 metric tons of RHA annually [20].

Previously, we had reported the sorption characteristics of SO_2 by RHA/CaO sorbent [21–25]. However, this sorbent was unable to remove NO gases. Currently, a wide range of metals/metal oxides have been reported to have good activities for NO removal from waste gases. In this work, RHA/CaO sorbent has been prepared by employing impregnation method with various metal oxides. This was done with a view to improve its ability to capture SO_2 and NO from simulated flue gas. The experiments were performed in a fixed-bed reactor at low temperature.

2. Experimental

2.1. Preparation of sorbent

The raw rice hush ash (RHA) used in this work was collected directly without any pretreatment from Kilang Beras & Minyak Sin Guan Hup Sdn. Bhd., Nibong Tebal, Malaysia and the CaO was obtained from BDH Laboratories, England. Prior to use, the RHA

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RESEARCH PAPER

nthesis of high purity multi-walled carbon nanotubes er Co-Mo/MgO catalyst by the catalytic chemical vapor position of methane

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bstract: Nearly uniform diameter multi-walled carbon nanotubes (MWCNTs) were synthesized over a magnesia supported Co-Mo imetallic catalyst through the catalytic chemical vapor deposition of methane. The bimetallic catalyst with a composition of o:Mo:MgO=5:20:75 (mass ratio) was prepared by a sol-gel method. Thermagravimetric analysis shows that MWCNTs were synthe-zed in high yield. The selectivity of the catalyst for MWCNTs over undesired amorphous carbon was 91.17%. Transmission electron icroscopy indicates that the MWCNTs grown on the catalyst have an average diameter of 6.2 ± 0.5 nm (mean ± standard deviation). hrough simple purification by mild acid treatment, the catalyst residue for the purified samples was reduced to 0.72%.

ey Words: Catalysis, Multi-walled carbon nanotubes, Easily purified catalyst, Catalytic chemical vapor deposition

ntroduction

Carbon nanotubes (CNTs), discovered by Sumio Iijima in [1], have attracted much attention from the research nunity owing to their superior physical and chemical rties[2], such as high tenacity, high electron conductivity, ior surface property, excellent field emission property, , and semiconductor properties[3-4]. These properties of render them to have potential applications in the areas ctronic, energy storage, nanocomposites, and medical [5-10].

The common strategies for synthesizing CNTs can be di- into the following categories: arc-discharge, laser abla- and chemical vapor deposition (CVD) methods[11-13]. ischarge and laser ablation methods require high tem- ures, i.e., above 1000℃, to synthesize CNTs. Although processes enable the production of high quality CNTs, ace the limitations of mass and cost-effective production. method is relatively simple, economical, and easy to up. CVD has been widely used, owing to its potential to ce large amount of CNTs of high purity and the ease of olling reaction conditions to produce the desired type of a nanostructures.

t is expected that CNTs with high purity and uniform y are of high market demand with the applications of expanded. After the CVD process, the as-produced are required to be purified in order to remove catalyst from CNTs. One of the criteria for catalyst is its ease to be removed from the raw product to simplify the purification procedure. The properties of CNTs depend strongly on their chirality that is closely related to CNT diameters [14-16]. Therefore, the only way to obtain CNTs with uniform properties for their application purposes is to synthesize CNTs with uniform diameter in high purity and yield.

Previously, we have reported that MWCNTs with narrow diameter distribution were grown on Co-Mo/Al_2O_3 through the control of calcination and reduction temperature [17-18]. However, alumina support is a very stable material that is inert to both mild acid and alkali, which make the purification process of CNTs difficult. In the present study, MgO was chosen as support material for Co-Mo catalyst, which was prepared by sol-gel method. After the CVD, the as-synthesized CNTs were purified by a simple mild acid treatment. The CNTs before and after purification were characterized by TEM and TGA. The findings are reported and discussed in this article.

2 Experimental

2.1 Preparation of Co-Mo/MgO catalyst

A mixture of $Co(NO_3)_2 \cdot 6H_2O$, $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$, and $Mg(NO_3)_2 \cdot 6H_2O$ was dissolved in distilled water to prepare Co-Mo/MgO catalyst with a mass ratio of Co:Mo:MgO=5:20:75. Citric acid with 3 times weight of the

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inuous biosynthesis of biodiesel from waste cooking palm oil packed bed reactor: Optimization using response surface nodology (RSM) and mass transfer studies

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ABSTRACT

This study aimed to develop an optimal continuous procedure of lipase-catalyzes transesterification of waste cooking palm oil in a packed bed reactor to investigate the possibility of large scale production further. Response surface methodology (RSM) based on central composite rotatable design (CCRD) was used to optimize the two important reaction variables packed bed height (cm) and substrate flow rate(ml/min) for the transesterification of waste cooking palm oil in a continuous packed bed reactor. The optimum condition for the transesterification of waste cooking palm oil was as follows: 10.53 cm packed bed height and 0.57 ml/min substrate flow rate. The optimum predicted fatty acid methyl ester (FAME) yield was 80.3% and the actual value was 79%. The above results shows that the RSM study based on CCRD is adaptable for FAME yield studied for the current transesterification system. The effect of mass transfer in the packed bed reactor has also been studied. Models for FAME yield have been developed for cases of reaction control and mass transfer control. The results showed very good agreement compatibility between mass transfer model and the experimental results obtained from immobilized lipase packed bed reactor operation, showing that in this case the FAME yield was mass transfer controlled.

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rnative fuel source are currently of interest as crude oil soar to record high. Biodiesel, also known as fatty acid ester (FAME), has become more attractive as an alternative ource because of its environmental benefit such as biodee, nontoxic and low emission profiles (Canakci, 2007; tti et al., 2007; Lara Pizarro and Park, 2003). Presently ial production of biodiesel from waste cooking oil is per- by chemical alkaline or acidic processes. However, chemiısesterification has some unavoidable drawbacks such as nergy and methanol consumption, difficulty in glycerol y, and a large amount of alkaline wastewater from the catde et al., 2008; Haas et al., 2003; Lu et al., 2007).

ently, enzymatic methanolysis using lipases has become ttractive in biodiesel production, since it is considered to effective way to overcome the drawbacks involved in the al process. Particularly, the by-product, glycerol, can be easovered without complex treatment (Ha et al., 2007). The roblem of enzyme catalyzed process is the high cost of the used as catalyst and the cost of raw material which accounts for about 70% of the total cost (Wang et al., 2008). Therefore, researchers are always looking for other effort to reduce the cost of biodiesel production. Waste cooking oil, originated from restaurants and household disposals, is creating serious problems of environmental control. Production of biodiesel with waste cooking oil as feedstock not only could reduce disposal problems, but, more importantly, would decrease the cost of biodiesel (Chen et al., 2005). Several studies showed that enzymatic methanolysis with waste cooking oil was a promising alternative as a feedstock for biodiesel production (Wang et al., 2008; Watanabe et al., 2001; Nie et al., 2006; Li et al., 2006). The key step in enzymatic process lies in the successful immobilization of the enzyme, which allows for its easy recovery and reused (Modi et al., 2007). High operational stability of the immobilized enzyme was reported in several studies (Watanabe et al., 2001; Nie et al., 2006; Li et al., 2006; Shimada et al., 2002; Royon et al., 2007), making it possible in a batch system, or its long use in a continuous one, which reduces the incidence of catalyst cost.

Although lipase catalyzed transesterification has significant benefits, the industrial application technology has been slow. For widespread industrial use to occur the process has to be technically and economically feasible. The packed bed reactor (PBR) has been extensively investigated by several researchers for use in industrial scale application (Watanabe et al., 2001; Nie et al., 2006; Royon et al., 2007). The packed bed reactor is one of the most

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uous biosynthesis of biodiesel from waste cooking palm oil cked bed reactor: Optimization using response surface dology (RSM) and mass transfer studies

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ABSTRACT

This study aimed to develop an optimal continuous procedure of lipase-catalyzes transesterification of waste cooking palm oil in a packed bed reactor to investigate the possibility of large scale production further. Response surface methodology (RSM) based on central composite rotatable design (CCRD) was used to optimize the two important reaction variables packed bed height (cm) and substrate flow rate(ml/min) for the transesterification of waste cooking palm oil in a continuous packed bed reactor. The optimum condition for the transesterification of waste cooking palm oil was as follows: 10.53 cm packed bed height and 0.57 ml/min substrate flow rate. The optimum predicted fatty acid methyl ester (FAME) yield was 80.5% and the actual value was 79%. The above results shows that the RSM study based on CCRD is acceptable for FAME yield studied for the current transesterification system. The effect of mass transfer in the packed bed reactor has also been studied. Models for FAME yield have been developed for cases of reaction control and mass transfer control. The results showed very good agreement compatibility between mass transfer model and the experimental results obtained from immobilized lipase packed bed reactor operation, showing that in this case the FAME yield was mass transfer controlled.

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Although lipase catalyzed transesterification has significant benefits, the industrial application technology has been slow. For widespread industrial use to occur the process has to be technically and economically feasible. The packed bed reactor (PBR) has been extensively investigated by several researchers for use in industrial scale application (Watanabe et al., 2001; Nie et al., 2006; Royon et al., 2007). The packed bed reactor is one of the most

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ic studies of lipase on FAME production from waste cooking palm *tert*-butanol system

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ABSTRACT

In this present work, fatty acid methyl ester (FAME) was produced from waste cooking palm oil (WCPO) by lipase-catalyzed reaction. The catalytic activities of several commercial lipases and different organic solvent were screened. Novozyme 435 was found to be more effective in catalyzing the transesterification of WCPO with methanol. *tert*-Butanol was used as the reaction medium, which eliminated both negative effect caused by excessive methanol and glycerol as the byproduct. Several variables such as effect of methanol/oil molar ratio, effect of lipase quantity and effect of agitation speed (rpm) were examined in a batch system. Transesterification of WCPO can reach up to 88% FAME yield under optimum condition (methanol/oil molar ratio 4:1, 4% Novozyme 435 based on oil weight, 200 rpm and 12 h reaction time). Kinetics of lipase-catalyzed transesterification of WCPO in *tert*-butanol system was also investigated. A model based on Ping Pong Bi Bi with only inhibition by methanol was found to fit the initial rate data and the kinetics parameters were evaluated by non-linear regression analysis.

tion

wn that there is finite amount of fossil fuels and the served could be depleted in less than 50 years at the of consumption [1]. Developing renewable resources therefore necessary. Biodiesel, also known as fatty acid r (FAME) has become more attractive as an alternative ce because of its environmental benefit such as le, nontoxic and low emission profiles [2–4].

, the industrial production of biodiesel fuel is by transesterification of waste oil using alkaline nlike the conventional chemical routes for synthesis els, biocatalytic route permits one to carry out the cation of a wide variety of oil feed stocks in the present purities, such as free fatty acids (FFA). Separation and of the biodiesel fuels produced enzymatically is easier he absence of soap byproduct [5].

, crude palm oil (CPO) has been chosen as the raw the biodiesel production as Malaysia is the largest palm oil in the world. Malaysia currently accounts for d palm oil production and 62% of world exports, and nd 22% of the world total production and exports of , respectively (unpublished data from Malaysian Palm Oil Board). Palm oil is the most productive oil bearing plant species. Palm oil has the highest yield of around 4000 kg per hectare compared to that of other vegetable oils [6]. Furthermore palm oil is less susceptible to the vagaries of weather compare to other crops. Therefore, it would be economically intuitive to consider palm oil as a favorable feed stock for biodiesel production [7].

However the CPO current price is RM3198/tonne which is too expensive and has limited the CPO use as diesel (unpublished data from Malaysian Palm Oil Boards). Waste cooking palm oil (WCPO) from restaurants and household is inexpensive compared to CPO, thus it is a promising alternative to CPO for biodiesel production. Reducing the cost of the feed stocks is necessary for biodiesel to be commercially viable to compete with the petroleum diesel, currently priced at RM2400/tonne (unpublished data from National Economic Council Malaysia).

Lipase observed high synthesis activity and good stability in the hydrophobic solvent like hexane but the hydrophilic compounds used as substrate (alcohol) or obtained as product (glycerol) are immiscible in hydrophobic reaction medium. Problem of solubilization results in the absorption of polar molecules onto the hydrophilic support leading to low transesterification rate [8]. To solve this problem, *tert*-butanol was used as an ideal solvent. With a certain amount of *tert*-butanol as the reaction medium, both methanol and byproduct glycerol are soluble, so the negative effect caused by methanol and glycerol on lipase catalytic activity could be totally eliminated [9].

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ct of catalyst additives on the production of biofuels from palm oil cracking transport riser reactor

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ABSTRACT

Catalytic cracking of crude palm oil (CPO) and used palm oil (UPO) were studied in a transport riser reactor for the production of biofuels at a reaction temperature of 450 °C, with residence time of 20 s and catalyst-to-oil ratio (CTO) of 5 g g^{-1}. The effect of HZSM-5 (differrent Si/Al ratios), beta zeolite, SBA-15 and AlSBA-15 were studied as physically mixed additives with cracking catalyst Rare earth-Y (REY). REY catalyst alone gave 75.8 wt% conversion with 34.5 wt% of gasoline fraction yield using CPO, whereas with UPO, the conversion was 70.9 wt% with gasoline fraction yield of 33.0 wt%. HZSM-5, beta zeolite, SBA-15 and AlSBA-15 as additives with REY increased the conversion and the yield of organic liquid product. The transport riser reactor can be used for the continuous production of biofuels from cracking of CPO and UPO over REY catalyst.

oduction

uel is defined as liquid or gaseous fuel for transport purpose n be produced from the utilization of biomass substrates or urce (Stocker, 2008). The increasing interest for biofuels ion is due to the depletion of fossil fuel. Plant oils, espealm oil has attracted attention of researchers to develop ronmentally friendly and high quality fuel, which is free gen and sulfur (Tamunaidu, 2006). In recent years, there en several studies on the production of hydrocarbons (i.e. l, biogasoline) from plant oils such as castor, soybean, catton (Albuquerque et al., 2009), algal oil (Sharif Hossain 008) and palm oil (Twaiq et al., 1999; Yean-Sang et al., using types of catalysts.

ytic cracking is one of the routes for obtaining liquid fuels tain linear and cyclic paraffins, olefins, aldehydes, ketones oxylic acids (Chew and Bhatia, 2008). Different reaction have been described for studying catalytic cracking on ratory-scale. One of the most common systems used for cracking studies of gas oil and palm oil is the fixed bed mi-ity test or MAT unit (Tamunaidu and Bhatia, 2007). There ral studies reported on the production of biofuels from lm oil (CPO), used palm oil (UPO) and palm oil-based fatty ture (FAM), using zeolites as a cracking catalyst in a micro-Twaiq et al., 1999; Yean-Sang et al., 2004a,b). The gasoline, kerosene and diesel fractions obtained from CPO, UPO or FAM were similar in compositions to the commercial petroleum products as determined from gas chromatography analysis (Yean-Sang et al., 2004a).

Li et al. (2009) studied the catalytic cracking of cottonseed oil in a fixed-fluidized bed reactor. In the presence of fluidized catalytic cracking (FCC) equilibrium catalyst (zeolite), liquid product rich in gasoline and diesel fraction was produced. The maximum yield of light fuel oil (65.6 wt% at 360 °C) and gasoline fraction (33.7 wt% at 205 °C) were obtained at optimum condition. Lappas et al. (2008) was able to obtain conversions higher than 85 wt% for catalytic cracking of wax performed in a bench scale automated fixed bed unit using commercially available FCC catalysts.

Various catalysts are reported for cracking of triglycerides. The choice of the catalyst plays an important role in the cracking of triglyceride. Since zeolites are extremely active, therefore it has been tested extensively for catalytic cracking, especially of vegetable oil by several researchers (Twaiq et al., 1999; Yean-Sang et al., 2004a). The common zeolites are H–Y, H-Beta, H-mordenite, Ultra-stable Y (USY) and HZSM-5. There are also studies of catalytic cracking of palm oil over various mesoporous catalysts such as MCM-41 and SBA-15 (Twaiq et al., 2003a,b, 2004; Yean-Sang et al., 2004c) beside microporous zeolite catalysts. Different catalysts will lead to different product distribution of catalytic cracking (Chew and Bhatia, 2008). Corma et al. (2007) studied catalytic cracking of glycerol and sorbitol, in the presence of 6 different catalysts, including a fresh FCC catalyst, an equilibrium FCC catalyst with metal impurities (ECat), a mesoporous Al_2O_3, a USY zeolite (Y), a ZSM5-based

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Hydrodynamic study of zeolite-based composite cracking catalyst in a transport riser reactor

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ABSTRACT

A composite catalyst containing H-Y zeolite and kaolin suitable for catalytic cracking of palm oil for the production of biofuels was synthesized by sol–gel–sieve method. In this study, we report the results of the hydrodynamic studies using a composite catalyst in a transport riser reactor. The hydrodynamic study confirms that the pressure difference across the transport riser reactor varies with the superficial gas velocity and it becomes significant at the bend section of the reactor. The pressure buildup occurs when the superficial fluid velocity reaches bubbling fluidization velocity. A model incorporating different dimensionless groups correlated with the pressure difference in transport riser reactor at different operating conditions. The proposed model predicted the pressure drop within an average error of ±20% in a transport riser reactor.

Keywords: Composite cracking catalyst; Transport riser reactor; Hydrodynamic studies; Pressure drop; Superficial gas velocity

1. Introduction

The depletion of crude oil has attracted researchers to explore the alternative energy source. Palm oil is one of the alternative feedstock which can be used to produce an environmental friendly and high quality biofuels that are free of nitrogen and sulfur (Ooi et al., 2004b; Tamunaidu and Bhatia, 2007). Currently, a substantial amount of the crude palm oil is used to produce biodiesel by reacting crude palm oil with methanol to convert it into methyl esters. However, biodiesel cannot be used in gasoline engines and there is a need to develop a direct process to convert palm oil into bio-gasoline suitable for gasoline engines. Zeolites as the cracking catalyst for palm oil could effectively produce variety of liquid hydrocarbon fuels (Twaiq et al., 2003a,b; Ooi et al., 2004a,b; Wachter, 2005; Tamunaidu and Bhatia, 2007). The catalytic cracking process could take place at lower temperature compared to thermal cracking and the coke is deposited on the catalyst during cracking process leading to catalyst deactivation. Hence, the removal of coke in the catalyst is done in separate reactor by burning the coke in the presence of air and the regenerated catalyst is recycled back to the cracking reactor.

Fluid catalytic cracking (FCC) process has been used in the refinery for the production of gasoline, kerosene, diesel and olefins from gas oil. Transport riser reactor is an integral part of the catalytic cracking process. Our past research has shown that the catalytic cracking of palm oil for the production of biofuels could be carried out in transport riser reactor (Tamunaidu and Bhatia, 2007). However, there is a need of suitable cracking catalyst to be used in a transport riser reactor for obtaining reasonable yield of bio-gasoline in order to make the process economical. The activity of the catalyst increased with the increasing of alumina content up to an optimum level then decreased with the further increase of alumina content due to the decreasing of the crystallinity (Twaiq et al., 2003b). Extensive works have been done in developing the cracking catalyst for bio-gasoline production (Twaiq et al., 2003c; Ooi et al., 2004a,b).

The hydrodynamic plays an important role in the design of transport riser reactor. The full scale-up of circulating fluidized beds requires at least five dimensionless groups, four groups are required in the inertial limit and three groups are sufficient for similarity (Van der Meer et al., 1999). The riser diameter influences in opposite manner for Geldart A par-

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Improvement of loose contact diesel soot oxidation by synergic effects between metal oxides in K_2O–V_2O_5/ZSM-5 catalysts

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sel soot oxidation in loose contact with 15 wt.% CuO/, V_2O_5/, Fe_2O_3/ and K_2O–V_2O_5/ZSM-5 catalysts at a ratio of 9:1 was stud-O_5/ZSM-5 was the most active with a peak activity at 450 °C. Further improvement was achieved with the incorporation of % K_2O, attributed to the mobility of potassium upon melting. Chemical interactions between the K_2O and extra framework sil-sulted in potassium silicate formation. Sintering of oxides towards the end of the oxidation process resulted in a delay in the com- of soot oxidation.

ds: Diesel soot; Oxidation; K_2O–V_2O_5/ZSM-5; Loose contact; Synergic effect

oduction

ide many other types of pollutants emitted, diesel s usually emit significant amount of soot and nitro-ides (NOx). To protect the environment, the two ants have to be removed from the exhaust gas. As gulations on diesel engine emissions becoming more nt, the engine modification and the exhaust after ent are needed. While NOx can be removed by cat-reduction processes [1], soot particulates are com- collected on a catalytic filter and periodically d to CO_2 [2]. The catalyst in the trap must be suffi- active to oxidize the soot within the exhaust gas atures (300–400 °C) [3]. The catalysts' activity and y are key factors in determining its applicability in nercial scale.

alysts investigated for soot filter are such as noble [2], transition metals [4], perovskites [5] and alkali [6] and the soot-catalyst contact appears to be the nportant problem [2]. Soot oxidation would initiate from areas that have contact with the catalyst. This contact will involve in various pathways for the local transport of reactive oxygen species from the active catalytic species to the soot [7]. The nature of the contact (loose or tight) can therefore affect the relative effectiveness of a catalyst in promoting soot oxidation. Loose contact always shows reduced activity compared to tight contact for all compositions, but the degree of degradation varies from compound to compound [6]. Hinot et al. [2] stressed that soot particles could not be effectively oxidized unless the catalyst is deposited uniformly in the soot clusters. However, some benefit could also be obtained from loose contact as oxygen diffusion is facilitated. Therefore, soot particles embedded deep into the soot-catalyst mass could simultaneously undergo oxidation with those exposed to the oxygen at the external surface.

As loose contact between the catalyst and soot always leads to lower oxidation activity than the tight contact, active catalytic formulations should also include other components with high mobility [6]. Potassium has been proposed to increase the effective contact with the soot due to its high mobility [6,8]. However, report on the combination of transition metal and potassium as the soot

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Selective Catalytic Reduction of Nitric Oxide in Diesel Engine Exhaust over Monolithic Catalysts Washcoated with Bimetallic Cu-Zn/ZSM-5

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bstract

Selective catalytic reduction (SCR) of nitric oxide (NO) in diesel engine exhaust over Cu-Zn/ZSM-5 washcoated ramic monolithic catalysts is reported. The washcoat component was prepared by ion-exchanging ZSM-5 (Si/Al=40) th zinc while copper was incorporated through impregnation. The dispersed washcoat component was then incorporated to 400 cpsi ceramic monolith through a dipping process with the final loadings between 19.6 wt. % and 31.4 wt. %. The CR process was studied with a feed comprising of 900 ppm NO, 2,000 ppm iso butane and 3 % oxygen at gas hourly space locities (GHSV) between 5,000 and 13,000 h^{-1}. NO conversion increased until a loading of 23.6 wt. % to give a conversion 88 % at 400 °C. The activity dropped at higher loadings due to the partial blockage of cell openings and diffusion nitations while unstable washcoating adherence was also demonstrated. After an initial deactivation of about 10 % in the st 48 h, this catalyst showed stable residual activity. Between 325 and 375 °C, minimal effect on the activity was detected nen the space time was reduced from 0.94 s to 0.24 s, suggesting the absence of external mass transfer limitations for up a GHSV of 16,000 h^{-1}.

eywords: NO; selective catalytic reduction; ZSM-5; ceramic monolith; performance.

Introduction

Diesel engine owes its popularity to its high fuel ficiency, reliability, durability and relatively low fuel ice. This engine is run under oxygen excess condition a so called lean-burn operation. However, the peration increases the production of toxic gas e.g. tric oxides (NO) which cause severe environmental d health problems. Catalytic processes have been idely investigated for NO_x removal and selective talytic reduction (SCR) being the most popular one olis *et al.*, 2001; Pisarello *et al.*, 2002; Bennici *et* , 2005). The SCR technology is still immature and veral drawbacks are yet to be satisfactorily dressed.

For a deNO_x unit, pressure drop is a key issue denbrand *et al.*, 1999; Makkee *et al.*, 2002). In a r exhaust or a power plant flue gas system, the essure drop should ideally be below 10-20 mbar eijger *et al.*, 2001). Additional demands comprise w sensitivity to dust and resistance to thermal shock. ructured packings, like monolithic are gaining interest r application in NO_x reduction (Zamaro *et al.*, 2005; ueno-Lopez *et al.*, 2005) as the pressure drop in ese catalysts is significantly lower than that of ndomly packed bed catalysts (Cybulski *et al.*, 1999). mong various types of monolith, ceramic monoliths ing the most widely used substrate material, mainly because of its relatively low manufacturing costs and high thermal stability (Heck *et al.*, 2001). However, the specific surface of most structured supports is below 1 m^2/g, which is way too low for catalytic purposes. The specific surface area can be enhanced up to about 40 m^2/g by washcoating with suitable microporous or mesoporous materials. As zeolites have a specific surface area of 300-700 m^2/g, a monolayer of zeolite may serve the need for surface area and porosity (Seijger *et al.*, 2001). The ZSM-5 washcoated ceramic monolith catalysts provide interesting advantage in the SCR of NO_x starts receiving attention among researchers (Zamaro *et al.*, 2005; Li *et al.*, 2008). ZSM-5 possesses high surface area of about 370 m^2/g and has been demonstrated to have high hydrothermal stability and suitability in many environmental catalysis applications in our earlier works (Deeng *et al.*, 2004; Abdullah *et al.*, 2003; Abdullah *et al.*, 2006).

Among metals studied as the active component of the catalyst are Cu (Deeng *et al.*, 2004), Pt (Ismail *et al.*, 2002) and Co (Ren *et al.*, 2002). By reviewing the results, Cu should provide superiority on the basis of high activity, high stability, low toxicity and low cost. Therefore, it was used in this study. Recently, the bimetallic catalysts have created particular interest due to the promoting effect between metal species (Ismail *et al.*, 2002). The second metal should be able to

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BROAD BUNDLES OF SINGLE-WALLED CARBON NANOTUBE SYNTHESIZED OVER Fe_2O_3/MgO VIA CHEMICAL VAPOR DEPOSITION OF METHANE

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SWCNTs are important materials in manufacturing advanced devices like field effect transistor and field emitters. Fe_2O_3/MgO catalyst was developed to grow SWCNTs and was used in chemical vapor deposition (CVD) of methane. The catalyst was prepared by mixing iron powder (Fe_2O_3) with MgO at the prescribed stoichiometry ratio. The findings show that SWCNTs in bundle form were grown over the catalyst. Most of the observed bundles are broad with each bundle constitutes more than 20 individual SWCNTs. Raman analysis indicates that these nanotubes possessed highly graphitized structure. Comparing with other catalyst preparation methods, this approach creates better efficiency in the synthesis and reproducibility of SWCNTs in the methane CVD.

Keywords: Single-walled carbon nanotubes; chemical vapor deposition; electron microscopy; Raman spectroscopy.

1. Introduction

The discovery of single-walled carbon nanotubes (SWCNTs) by Iijima and Ichihashi[1] in 1993 had attracted many researchers to investigate the properties and the potential applications of this ultra-small tube. SWCNTs have been proven to be a good interconnection and active component in nanoscale electronic devices.[2] Recent researches also demonstrated that SWCNTs are important materials for manufacturing nanodevices, such as

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erformance of an activated carbon made from waste alm shell in simultaneous adsorption of SO_x and NO_x f flue gas at low temperature

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is study examined the individual and simultaneous adsorption of SO_x (SO_2) and NO_x (NO-NO_2) on tivated carbon prepared from waste palm shell. The adsorption process was examined in a fixed bed actor at low temperatures (100—300℃). For individual adsorption without any catalytic activation, O_x showed good adsorption whereas NO_x was very much poor. In the simultaneous adsorption of SO_x d NO_x, SO_x showed greater adsorption affinity than NO_x. For palm shell activated carbon (PSAC) im-egnated with metal catalyst (Ni and Ce) the concentration adsorbed profile showed that the amount of O_x adsorbed decreased regularly, while the amount of the adsorbed NO_x increased irregularly. The operties of the pure and impregnated PSAC were analyzed by BET, SEM and EDX. These investiga-ns indicated that PSAC impregnated with metal catalyst is the determining factor in the adsorption of O_x and NO_x simultaneously.

m shell, activated carbon, flue gas, SO_x, NO_x

Introduction

nissions of sulfur dioxide (SO_x) and nitrogen oxide O_x) from the progressive industrialization of power nt flue gases may cause many environmental hazards, rticularly acid rain and ground-layer ozone formation. ue to its high toxicity and negative impact on the obal environment, interest in reducing these emissions nultaneously has been increasing lately. Among the nous reducing methods are flue gas desulphurization GD) and selective catalytic reduction (SCR). The lit-atures show that CuO/Al_2O_3-based catalysts and acti-ted carbon-based catalyst are active for simultaneous noval[1−4], but the purpose of this study is to remove O_x and NO_x gases simultaneously at low temperature. is is because flue gas temperatures at stack burners nge from 120 to 250℃. Earlier studies revealed that ivated carbon (AC) showed promising future to re-ve SO_x and NO_x gas simultaneously[5,6]. Therefore, activated carbon-based catalysts which are active for this purpose in the temperature range of below 100℃ were developed[7].

The AC adsorption process is known to have high adsorption capacities for variety of toxic gases because of its high surface area and micro-porous structure. In addition to this, its content of acidic and basic surface sites[8−10] and the presence of suitable metal derivatives favor the process of adsorption of certain chemical gas adsorption[11,12]. Some first series transition metals were used as catalyst for NO_x and SO_x removal by AC[13].

Palm shell activated carbon (PSAC) made from waste palm shell can be used as an alternative to the existing commercially available AC for this study purpose. Previous studies discovered that PSAC can be used to remove SO_2 and H_2S gas[14−16] but none have been reported to remove either NO_x or the simultaneous removal of NO_x

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ction of best impregnated palm shell activated carbon (PSAC) for ıltaneous removal of SO_2 and NOx

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ABSTRACT

This work examines the impregnated carbon-based sorbents for simultaneous removal of SO_2 and NOx from simulated flue gas. The carbon-based sorbents were prepared using palm shell activated carbon (PSAC) impregnated with several metal oxides (Ni, V, Fe and Ce). The removal of SO_2 and NOx from the simulated flue gas was investigated in a fixed-bed reactor. The results showed that PSAC impregnated with CeO_2 (PSAC-Ce) reported the highest sorption capacity among other impregnated metal oxides for the simultaneous removal of SO_2 and NOx. PSAC-Ce showed the longest breakthrough time of 165 and 115 min for SO_2 and NOx, respectively. The properties of the pure and impregnated PSAC were analyzed by BET, FTIR and XRF. The physical–chemical features of the PSAC-Ce sorbent indicated a catalytic activity in both the sorption of SO_2 and NOx. The formation of both sulfate (SO_4^{2-}) and nitrate (NO^{3-}) species on spent PSAC-Ce further prove the catalytic role played by CeO_2.

oduction

ldwide, air pollution is a growing threat to human health natural environment. One of the major effects of air pols acid rain and it is caused by sulfur dioxides (SOx) and n oxides (NOx) gases. Fuel combustion processes and power re the largest contributor of these gases in the form of flue ypical composition of coal-fired power plant flue gas conout 500–2000 ppm of SO_2 and over 125 ppm of NOx [1]. ts high toxicity and negative impact on the global environıajor effect has been taken to reduce both these emissions neously.

ng the widely used reducing methods are flue gas desulfurFGD) and selective catalytic reduction (SCR). The literatures ıat CuO/Al_2O_3-based catalysts and activated carbon-based are active for simultaneous removal of both the toxic gases part from these, the simultaneous removal of SO_2 and NOx r temperatures are preferred comparatively because flue ıperatures at stack burners range at lower temperature, ı 120 to 250 °C. Earlier studies revealed that activated car-) showed a promising future to remove SO_x and NOx gas ıeously [6,7] however these studies are done at elevated ıtures (300 °C and above).

One of the latest types of AC in the current market is biomass based AC [8]. Currently in Malaysia palm shell based AC is gradually finding its way out for a useful utilization [9]. Hence it can be very handful as well as economical to use palm shell activated carbon (PSAC) as an alternative to the existing commercially available AC for this study.

Previous studies discovered that the locally made PSAC can be used to remove SO_2 and H_2S gas [10–12] but none have been reported to remove NOx or the simultaneous removal of both NOx and SO_2. Presently there are a number of studies that report the usage of metal oxides for simultaneous removal of SO_2 and NOx [13–15]. Prior to this study we had also reported the sorption characteristics of PSAC to remove SO_2 and NOx [16]. However PSAC was unable to remove NOx gas. Thus in this work the usage of PSAC as a modified (impregnated with various metal oxides) sorbent were tested for its possibility in capturing both SO_2 and NOx simultaneously from a simulated coal-fired power plant flue gas at low temperature.

2. Experimental

2.1. Preparation of sorbent

The PSAC used in this work was prepared by physical activation using CO_2 gas. The details of the preparation method can be seen elsewhere [16]. Prior to the impregnation process the PSAC was sieved to a size of 1 mm. The PSAC was subjected to pore volume impregnation by metal oxides. First the PSAC was impregnated with metal nitrate of an appropriate con-

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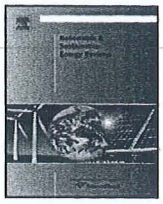

aration of carbon molecular sieve from lignocellulosic biomass: A review

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ABSTRACT

A literature review on preparation of carbon molecular sieve (CMS) from lignocellulosic biomass is presented. The effect of various operation parameters such as pyrolytic temperature, flow rate of the carbonizing agent and time of pyrolysis on the carbonization of the lignocellulosic biomass as a carbon precursor was reviewed. Various physical and chemical processes for the activation of the biomass-based char and their effects on textural properties of the activated char were discussed. Conversion of activated chars to CMS as the final stage of the preparation process through different techniques of chemical vapor deposition (CVD) and controlled pyrolysis was assessed. Survey of literature revealed that production of CMS with BET surface area of 1247 m^2/g and micropore volume of 0.51 cm^3/g, under appropriate conditions has been reported. Also, maximum selectivity of 7.6 and 400 for separation of O_2/N_2 and CO_2/CH_4 was devoted to palm shell and coconut shell-based CMS, respectively.

duction

ration and purification of gaseous mixtures is an important the chemical and petrochemical industries. Nowadays, a growing demand for high purity products which boosts ortance of gas separation processes. Gas adsorption as a treatment technique is proved to be effective in processes which involve the gas separation and purification [1,2]. Although adsorption may be a costly method however, utilizing low cost materials as adsorbent makes the adsorption process cost effective. Lignocellulosic biomasses are attractive materials as precursors for preparation of carbonaceous materials used in adsorption processes [3,4].

Biomass is the only renewable source of carbon which can be converted to solid, liquid and gaseous product through various conversion processes. Currently, biomass provides about 14% of the word's energy consumption [5], but still large quantities of biomass have no specific use. They are burned in open air or dumped which generate pollutants including dust and acid rain gases such as sulfur dioxide and nitrogen oxides. According to the

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ocritical water liquefaction of oil palm fruit press fiber for the production bio-oil: Effect of catalysts

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ABSTRACT

Decomposition of oil palm fruit press fiber (FPF) to various liquid products in subcritical water was investigated using a high-pressure autoclave reactor with and without the presence of catalyst. When the reaction was carried in the absence of catalyst, the conversion of solid to liquid products increased from 54.9% at 483 K to 75.8% at 603 K. Simultaneously, the liquid yield increased from 28.8% to 39.1%. The liquid products were sub-categorized to bio-oil (benzene soluble, diethylether soluble, acetone soluble) and water soluble. When 10% $ZnCl_2$ was added, the conversion increased slightly but gaseous products increased significantly. However, when 10% Na_2CO_3 and 10% NaOH were added independently, the solid conversion increased to almost 90%. In the presence of catalyst, the liquid products were mainly bio-oil compounds. Although solid conversion increased at higher reaction temperature, but the liquid yield did not increase at higher temperature.

roduction

wadays, the world is facing multiple problems such as global ing, acid rain and depletion of energy resources. All these ems are directly related to the high dependency of world y source on non-renewable fossil fuels such as petroleum, al gas, and coal. Therefore, there is an urgent need to develop ative, new, cheap, clean, and renewable energy resources, have the potential to solve the environment problems men- above. There are various alternative energy resources avail- ncluding hydro, biomass, wind, solar, hydrogen and nuclear, ver biomass has been receiving considerable attention lately. ass is popular because it is widely available in many parts of orld. Using indigenous source of biomass for energy supply void the domination by certain countries. Furthermore, the biomass as a substitute for fossil fuels can reduce the carbon nt in the atmosphere as carbon dioxide is absorbed by plant otosynthesis during growth (Demirbas, 2001).

mass can generally be divided to four wide categories: (i) y waste and residues, including mill wood waste, tree and waste, thinning and urban wood waste, bark and sawdust. ergy crops, including short rotation woody crops, herbaceous crops, grasses and starch crops. (iii) Aquatic biomass such as eds. (iiii) Agricultural residues and waste biomass, such as wastes derived from cultivation of crops, municipal solid animal waste, food processing waste and etc. (Demirbas, 2001, 2007; LÉDÉ, 1999; Meng et al., 2006). Malaysia, being a country that actively promotes agricultural activities has abundant biomass wastes. Oil palm is the most important agriculture crop in Malaysia, since Malaysia is one of the main palm oil producing and exporting countries in the world. In year 2008, 4.88 million hectares of land in Malaysia is covered by oil palm cultivation which produces 90.40 million tonnes of fresh fruit bunches (FFB). The amount of oil palm biomass produced by these oil palm plantations in year 2008 is estimated to be about 37.0 million tons, consisting of 22% empty fruit bunch (EFB), 13.5% fruit press fiber (FPF) and 5.5% shell (Malaysia Palm Oil Council (MPOC), 2004 and Malaysia Palm oil Board (MPOB) January, 2009). Indiscriminate disposal of these wastes will cause serious environmental problems. On the other hand, lately, it has been proven that biomass sources can become an economical source of renewable energy. Therefore, developing new technologies for converting oil palm biomass to energy sources (liquid or gas) becomes an attractive research area.

Biomass conversion to energy could be divided into three main approaches: direct combustion processes (e.g. burning wood for heating and cooking, etc.), biochemical processes (such as methane fermentation and alcoholic fermentation, etc.), and thermochemical processes. Thermochemical processes may be further subdivided into pyrolysis, gasification and liquefaction (high-pressure liquefaction, sub to supercritical fluid (SCF)). These processes convert waste biomass into energy rich products. Each technology has its own advantages, depending on the type of biomass source and the form of energy needed (Mirza et al., 2008). For instance, pyrolysis and gasification has the advantage of non requirement of high

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gations on the effects of CoO_x to MoO_x ratio and CoO_x–MoO_x loading on ne decomposition into carbon nanotubes

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ABSTRACT

The effects of CoO_x to MoO_x ratio and loading amount of CoO_x–MoO_x for Al_2O_3 supported catalysts on methane decomposition into carbon nanotubes (CNTs) were investigated. The reaction was performed in a fixed-bed vertical reactor at 700 °C. It has been shown that a small amount of molybdenum added brought about considerable increases in carbon yield. The highest carbon yield was recorded for the catalyst CoO_x:MoO_x with weight ratio of 8:2. The examination of catalyst activity and carbon morphology reveals that an increase in the molybdenum content reduced the carbon yield and formed CNTs of smaller diameter and narrower diameter distribution. The study also shows that CoO_x–MoO_x loading determines the yield of carbon and the diameter of CNTs. The yield of carbon reached the maximum at 30 wt% loading, and subsequent increases in the loading amount decreased the yield. In addition, severe agglomeration of CoO_x–MoO_x alloy particles for high loaded CoO_x–MoO_x-containing catalysts led to the formation of larger alloy clusters that grew CNTs with comparatively larger diameters.

ction

insic properties of carbon nanotubes (CNTs) make them tial applications in fields such as quantum wires, field-sistors, field emitters, diodes, gas sensor, electric power d conductive polymers [1]. The versatility of CNTs has tudies not only in growing this structure, but also on w CNTs with specific architectures. After the catalytic CNTs was first reported by Yacaman et al. in 1993 been generally accepted that catalytic method holds ntages over other synthesis methods, such as laser abla-c-discharge, for large-scale production of CNTs. This ble to catalytic growth which involves simple equip-p, lower reaction temperature and higher nanotube

re many articles which reported the influences of catalyst ts on effective cracking of hydrocarbon gases into CNTs compatibility of the catalyst components in growing ding the active metal, promoter and support, is indeed nsition metals, such as Co, Ni or Fe, are commonly used the growth of CNTs in catalytic chemical vapor deposi-ell known that catalyst promoters play role in increasing rbon yield and the selectivity for the formation of the specific nanotube morphology, all of which are lacking in individual metals. Possible promoters, including Fe, Co, Mn, Mg, Al, Ni, Mo, Cu, Pd, Pt, etc., have been studied in decomposition process for CNTs production [3,6–14]. In our previous findings, MoO_x was found to be an effective promoter for CoO_x used for producing CNTs of better morphology and yield [15]. Particularly relevant to the current work, the significance of Co–Mo catalysts supported on various oxides for the synthesis of CNTs has also been reported by other research groups lately [16–22]. Co–Mo catalysts have effectively been used to grow single-walled carbon nanotubes from carbon monoxide [20,21] or alcohol [22]. It is known that a promoter can alter the morphology of active metal to suit the growth of CNTs or anticipate in enhancing or weakening metal–support interaction of the catalyst system, indirectly participating in the catalytic growth of CNTs. For this reason, the ratio of active metal to promoter is crucial and it is believed that an optimum ratio will give the highest rate of CNTs formation [9]. On the other hand, it is also widely accepted that active metal is the main component of catalyst that controls the diameter of the CNTs and the loading amount of the metal determines the size distribution of the active metal [23,24]. Thus, the influence of metal loading on the size of CNTs is identified as an important parameter to be optimized in CNTs synthesis.

Our previous studies also divulge that calcination and reduction temperature for CoO_x–MoO_x/Al_2O_3 catalysts has significant effects on carbon yield, quality and morphology of the CNTs obtained from methane decomposition and the suitable calcination and reduction

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$_2$ and NO Simultaneous Removal from Simulated Flue Gas over Cerium-Supported Palm Shell Activated at Lower Temperatures—Role of Cerium on NO Removal

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Cerium (Ce) supported on palm-shell-activated carbon (PSAC) has been found to significantly increase its activity in simultaneous removal SO_2 and NO from simulated flue gas. In the present study, the role of Ce on SO_2 and NO removal was studied through reaction adsorption. The catalyst was characterized using BET, EDAX, and SEM. It was found that PSAC could remove SO_2 only without the addition of Ce, and NO could be removed in the presence of Ce loaded over PSAC. The experimental results showed Ce10/PSAC catalyst at 100 °C yield the best breakthrough time for simultaneous removal of NO and SO_2. NO removal lasted for 115 min, whereas SO_2 for 165 min. As the Ce content was increased from 5 to 12%, NO conversion increased significantly, but dropped with further increase in Ce content. Higher temperatures do not encourage the simultaneous adsorption of SO_2 and NO. It was found that SO_2 and NO create competitive phenomenon toward the active sites of PSAC and Ce/PSAC. SO_2 removal was not affected by the addition of Ce because PSAC played an important role of SO_2 adsorption and Ce presences promoted the adsorption rate.

Introduction

rrently in Malaysia, it is estimated that the power ns flue gas emission load is about 16% from the total llutant.[1] SO_2 and NO are the 2 major contributors of r stations flue gas. Hence serious efforts have to be taken der to curb this problem before it diversifies. Among us emission control technologies available today, cal- based flue gas desulphurization and selective catalytic tion (SCR) by NH_3 are the most effective technologies O_2 and NO removal, respectively.[2−5] However, in order ver the capital cost of equipment and operating cost, it is ble to remove SO_2 and NO simultaneously in a single

rrently, catalysts supported over activated carbon (AC) sorbents are well-known for their potential of removing nd NO simultaneously. There are mainly two types of st-sorbents, activated carbon/coke (all termed AC) at ratures of 140−150 °C[6,7] and CuO/Al_2O_3 to be used at ratures of 350−400 °C[8,9] are reported. The AC-based ology is profitable because of its readiness of being retrofitted into current boiler systems, which reduces the equipment costs and warrants higher boiler efficiencies. Normally in this technology, SO_2 is removed first at the lower part of the reactor then NO is removed by SCR. Recently metal oxides supported over AC have drawn interest because it could do the job simultaneously in a single-step process. Many types of metal oxides have been studied, including Fe, Mn, Ca, V, Cu, and Cr oxides in comparison to AC alone[10−13] but so far none have reported the usage of Cerium (Ce). In Malaysia, palm shell biomass generated during the palm oil refining process can be utilized in the production of activated carbon. Hence in this research, palm-shell-activated carbon (PSAC) has been successfully supported with Ce metal oxide to remove SO_2 and NO gases. The reaction mechanism presented the role of Ce supported over PSAC in simultaneous removal of SO_2 and NO.

2. Experimental Section

2.1. Catalyst Preparation. The AC used is a palm-shell-derived product made from physical activation with N_2 and CO_2 gas. The details and quality of the PSAC has been reported elsewhere.[14] The Ce/PSAC catalyst was prepared through a conventional pore volume impregnation procedure using an appropriate aqueous solution of cerium nitrate ($Ce(NO_3)3\cdot 6H_2O$). After the impregnation, the sample was dried in air at 110 °C for 12 h and calcined in Argon gas at 500 °C for 4 h. The Ce/PSAC samples prepared are termed

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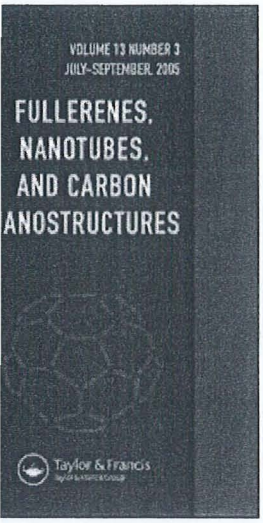

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Optimization of Carbon Nanotubes Synthesis via Methane Decomposition over Alumina-Based Catalyst

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Polyfurfuryl 알코올 증착에 의한 야자껍질로부터 탄소분자 체의 합성

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(접수 2009. 12. 2; 수정 2010. 3. 11; 게재확정 2010. 3. 30)

Synthesis of Carbon Molecular Sieve from Palm Shell Using Deposition of Polyfurfuryl Alcohol

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약. 이 연구에서는 야자껍질로부터 이상적인 sieving 특성을 갖는 탄소 분자 체(CMS)의 합성을 시도하였다. 그 과정은 세 계로 이루어지는데 탄소화 과정, 이산화 탄소 활성화 과정, 그리고 polyfurfuryl 알코올 고분자 증착 과정이다. 이산화 탄소 성화에 의해 야자 껍질로부터 만들어진 활성탄(CA)은 CMS의 합성을 위한 원료 물질로 사용되었다. 야자껍질로부터 만들 진 AC를 준비한 다음 AC에 대한 최적의 furfuryl 알코올 과 포름 알데히드 비를 결정하였다. AC에 polyfurfuryl 알코올의 증 을 탄소화 과정에 앞서 수행하였다. 이렇게 고분자가 증착된 AC는 불활성 환경 조건과 700 - 900 °C온도에서 탄소화 과정을 친다. 모든 미세세공 물질은 micrometric사의 ASAP/2020을 이용하여 분석되었다. 결과로 AC에 대한 최적의 furfuryl 알코 과 포름 알데히드 비는 1:2.5로 결정 되었다. 7 Å 이하의 미세세공은 700 °C, 800 °C 그리고 900 °C 에서 1.5시간 동안 고분자 증착된 AC에 형성 되었다. 1.5시간 동안 900 °C 에서 탄소화 온도는 CMS합성을 위한 최적의 조건으로 밝혀졌다. 이러한 건하에서 생성된 CMS는 5. 884 Å의 구멍 크기를 갖는다.

제어: 탄소 분자체, 활성 탄소, 고분자 증착 방법, polyfurfuryl 알코올

BSTRACT. In this work, an intention to synthesize the carbon molecular sieve (CMS) with ideal sieving properties from palm ell has been attempted. The process includes three main stages: carbonization, carbon dioxide activation and polymer position using polyfurfuryl alcohols. Palm shell based activated carbon (AC) produced by carbon dioxide activation was used raw material in synthesis of CMS. After preparing palm shell based AC, optimum concentration ratio of furfuryl alcohols and rmaldehyde to AC for CMS synthesis was obtained in this study. Deposition of polyfurfuryl alcohols on the palm shell based C was then carried out prior to carbonization. These polymer deposited AC was subjected to carbonization at 700-900°C under ert condition. All the microporous materials were analyzed using micromeritics ASAP/2020. The results show that optimum ncentration ratio of furfuryl alcohol and formaldehyde to AC is 1:2.5. The micropore with pore width less than 7 Å was med on the polymer deposited AC at 700°C, 800°C and 900°C for 1.5 hours. Carbonization temperature at 900°C for 1.5 hours is found to be optimum for CMS synthesis. The CMS produced under this condition has pore width of 5.884 Å.

ywords: Carbon Molecular Sieve, Activated Carbon, Polymer deposition method, polyfurfuryl alcohol

INTRODUCTION

Over the last four decades, Malaysia has become the rld largest palm oil producer and currently the industry considered as backbone of agriculture in Malaysia occupy- ; about 60% of the total cultivated land in the country.[1] ese oil palm mills produce a lot of by-products, such as m shell. Palm shell has high carbon content, especially after carbonization process. It is a good precursor for production of AC with high porosity. These activated carbons can possibly be converted into CMS through deposition method.[2-5]

CMS can be defined as substances with discrete pore structures that can differentiate between molecules on the basis of size. CMS have most of the pores in the molecular size range allowing separation and purification of gas mixture

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/supercritical liquefaction of oil palm fruit press fiber for the production of -oil: Effect of solvents

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ABSTRACT

Thermal decomposition of oil palm fruit press fiber (FPF) with sub/supercritical methanol, ethanol, acetone, and 1,4-dioxane treatments were investigated using a high-pressure autoclave reactor. When FPF was decomposed with methanol, ethanol, and acetone from 483 to 603 K, the highest degree of conversion obtained were 81.5%, 77.8%, and 67.9% while the highest liquid product yield (LP) obtained were 38.0%, 36.9%, and 38.5%, respectively. For the case of 1,4-dioxane, the conversion of FPF increased from 18.30% to 80.00%, while LP yield increased dramatically from 13.30% to 50.90% (consisting of 42.3% bio-oil compounds) when the reaction temperature was increased from 483 to 563 K. However, the conversion of FPF and LP yield decreased to 69.60% and 24.10%, respectively, when the temperature was further increased to 603 K. Comparison between all the solvents, subcritical 1,4-dioxane treatment was found very effective in the degradation of FPF to produce bio-oil component.

roduction

m oil is the most important Malaysian agriculture crop. It is ıted that around 4.88 million hectares of land in Malaysia sed for palm oil cultivation in 2008. Malaysia is one of the palm oil producing and exporting countries in the world produces about 37.00 million tones of palm oil biomasses ting five million tons oil palm fruit pressed fiber (FPF) in Mazaheri et al., 2010). In the past two decades, in spite of ıg energy resources such as hydro, wind, solar and nuclear , biomass has been regarded as a new energy resource be- it is very cheap, clean and abundantly available in many of the world (Demirbas, 2001). Besides, the damages resulted sing fossil fuel such as air pollution, green house effect, toxic global warming and acid rain on one part, and increasing day of the crude oil price on the other part, makes it important : for a new energy resource such as biomass and the conver- ıethods for utilizing it. Furthermore rising consumption of s kinds of energy such as gas, oil and coal and limitation in uel resources have increased the importance of this subject ofold. Therefore, it seems that finding a new method for con- g the huge biomass energy resources to useable energy is ıble.

rmochemical treatment is one of the potential ways to t biomass to biofuel. Under the umbrella of thermochemi- atment, recently sub/supercritical fluid has (SCF) attracted more attention than other processes because the process is environmentally friendly and can be carried out at relatively lower temperature. A fluid is named supercritical when its temperature and pressure goes higher than the critical pressure (P_C) and critical temperature (T_C) that indicates the end of the vapor liquid coexistence curve as well as gases and liquids are indistinguishable fluids and any difference between liquid and gaseous phases disappears. In fact, matter that exists in the region above the critical points (e.g., T_C and P_C), which is a new phase, is called supercritical fluid (SCF). Supercritical fluids have liquid like properties such as high density that means more dissolving power properties which allow the solvation of many compounds in supercritical fluids. Besides, supercritical fluids also have gas like properties such as high diffusivity and low viscosity which enhance mass transfer rates of reactants to the active biomass's molecules and readily penetrate porous and fibrous solids. Therefore, reactions which are limited by the rates of diffusion, rather than natural kinetics, will proceed faster in supercritical fluids than in liquids. These drastic changes mean that SCF is adjustable for different applications (Tucker, 1999). Since it is well-known that the dielectric constant, viscosity, and other physical properties of SCF are functions of density, and since density varies with pressure, these properties are also strongly pressure-dependent. In other words, small changes in pressure lead to significant changes in density, which in turn alters all density dependent solvent properties such as dielectric constant and thermal conductivity. The ability to change the physical properties of the solvent by simply manipulating the pressure or temperature is unique to supercritical systems (Jessop et al., 1999).

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um impregnated palm shell activated carbon (Ce/PSAC) sorbent for ıltaneous removal of SO_2 and NO—Process study

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ABSTRACT

The simultaneous removal of SO_2 and NO from simulated flue gas by cerium oxide supported over palm shell activated carbon (Ce/PSAC) was studied in a fixed bed adsorber. The effects of adsorber temperature, presence of humidity, feed gas concentration and space velocity were studied as the process parameter. The results were illustrated as sorption breakthrough curves. From the experimental results, it was found that at higher space velocity, the SO_2 and NO sorption capacity was reduced. Humidity enhanced the SO_2 sorption capacity but deterred the NO sorption at percentage more than 15%. Temperature played an important role in the simultaneous removal of SO_2 and NO by cerium supported over PSAC. The maximum simultaneous sorption capacity of SO_2 and NO was achieved at temperature 150 °C with 121.7 and 3.5 mg/g, respectively. This study shows that cheap biomass based activated carbon can be a potential sorbent for simultaneous removal of SO_2 and NO from flue gas.

oduction

acidification of land and water through air pollution has d extra attention in recent years due to its growing threat an health and nature. One of the prominent contributors ollution is fuel combustion process with stationary and sources. The most widespread and dangerous outputs of cess are oxides of nitrogen (NOx) and oxides of sulfur (SOx) re are a number of technologies available to remove these pollutants. The literatures show that calcium based flue ılfurization, selective catalytic reduction (SCR) by NH_3 and O_3-based catalysts are the most effective technologies for NO removal [2–5]. However in order to lower the capital quipment and operating cost, it is desirable to remove SO_2 simultaneously in a single unit with a cheap sorbent. One ood choices is via activated carbon (AC).

e are many types of AC prepared from various carbona- aterials and impregnated with a variety of additives. Some AC have been used to remove NOx and SOx simultane- esearchers reported that metal oxides supported over AC ıwn interest because it could do the job simultaneously in a ep process. Many types of metal oxides have been studied, g Fe, Mn, Ca, V, Cu and Cr oxides in comparison to AC alone ır none have reported on cerium (Ce) [6–13].

Currently interests are growing in the use of low-cost and abundantly available lignocellulosic material as the precursor for the preparation of AC. One alike is palm shell activated carbon (PSAC) made from oil palm fruit waste, *i.e.* palm shell which is abundantly available from the palm oil processing mills in Malaysia [14]. Palm shell based AC with and without impregnation have been used to remove SO_2 [15–18], however none have reported on NO removal or simultaneous removal of NO and SO_2.

In the present work, the potential of PSAC as a modified (impregnated with cerium oxide) sorbent was tested for its possibility in sorbing both SO_2 and NO gas simultaneously from a simulated flue gas at different process operating conditions.

2. Experimental

2.1. Preparation of sorbent

The PSAC was first prepared by thermal charring of the palm shell. Then it is followed by a physical activation using CO_2 gas at temperature 1100 °C. Details of the preparation method are reported elsewhere [17]. Prior to the impregnation process, PSAC was sieved to a size of 1 mm. The PSAC was subjected to pore volume impregnation by cerium nitrate. First, the PSAC was impregnated with cerium nitrate ($Ce(NO_3)_3{\cdot}6H_2O$) of an appropriate concentration to obtain around 10 wt% of metal content per gram of PSAC (10 ml of 10 wt% metal solution/gram of PSAC). In this study cerium nitrate from Fluka was used as the metal precursor. During the impregnation, the solution of metal nitrate was continuously mixed with PSAC for 5 h. Then the samples were heated

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ɔtion isotherm models and properties of SO_2 and NO removal by palm shell ed carbon supported with cerium (Ce/PSAC)

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ABSTRACT

The adsorption of SO_2 and NO onto palm shell activated carbon supported with cerium oxide (Ce/PSAC) was studied in a fixed bed adsorber. This paper reports the adsorption equilibrium of SO_2 and NO in a simulated flue gas on Ce/PSAC. The experimental results show that within the experimental conditions at different inlet concentration of SO_2/NO, the adsorption capacities of Ce/PSAC can be well fitted by Langmuir compared to Freundlich adsorption isotherms. The binary mixtures of SO_2 and NO at different initial concentration can be well-correlated by the extended Jain and Snoeyink (JS) Langmuir model compared to extended Langmuir model. The physical properties of Ce/PSAC were calculated and it was consistent with the isotherm parameters obtained from the adsorption results. The adsorption was controlled by physisorption.

ction

tion processes and its emission *i.e.* flue gas has been a setback to nature as well as human kind. It has been hat SO_2 and NO contained in flue gas are the primary ponsible for the acid rain and ground-layer ozone for- e to these factors, interest in reducing these emissions usly has been increasing lately to save the global health. famous reducing methods are dry-type methods such catalytic reduction, adsorption and flue gas desulphur- 5].

ed carbon as an agent for adsorption has been used ears in many field. Gas-phase adsorption by activated separation process in which adsorbate molecules are to the pore surface of solid activated carbon [6]. Acti- on is predominantly amorphous material that has large a and pore volume. Activated carbons are made from tarting material [7]. For gaseous removal, activated car- from bituminous coal and coconut are the prominent rrently palm shell-based activated carbon is introduced se applications because it has similar property as coconut

cussions were made in the literature about adsorption f SO_2, O_2, CO_2, N_2, CH_4 and H_2S on palm shell acti- on (PSAC) [10–14]. However none have been reported on NO removal or simultaneous removal of SO_2 and NO. Moreover these researchers did not study the adsorption kinetics using model isotherms. Bae and Lee [15], examined the adsorption kinetics of 8 different gases (O_2, H_2, N_2, Ar, CO, CO_2, SO_2 and CH_4) on a carbon molecular sieve using three different isotherms, *i.e.* Dubunin–Radushkevich (DR), Langmuir and Freundlich–Langmuir (LF). Juray et al. [16] developed a transient kinetic model using Langmuir ideal surface and Elovich real surface model for simultaneous adsorption of NO and SO over Na/γ-AlO sorbent.

In this study, the most commonly used adsorption isotherm equations *i.e.* Langmuir and Freundlich were used to describe single gas adsorption of SO_2 and NO over Ce/PSAC. A modified extended Langmuir (MEL) was used to predict the binary mixture. Different inlet concentrations (*i.e.* 1000–2500 mg/l of SO_2 and 100–700 mg/l of NO) and equilibrium temperatures (*i.e.* 100–300 °C) were used to describe the adsorption isotherm and heat of adsorption.

2. Materials and methods

2.1. Preparation of sorbent

The PSAC was prepared by physical activation using CO_2 gas. The details of the preparation method are reported elsewhere [17]. Prior to the impregnation process, PSAC was sieved to a size of 1 mm. The PSAC was subjected to pore volume impregnation by cerium metal nitrate. First the PSAC was impregnated with cerium metal nitrate ($Ce(NO_3)_3{\cdot}6H_2O$) of an appropriate concentration to obtain around 10 wt% of metal content per gram of PSAC (10 ml of 10 wt% metal solution/g of PSAC). In this study cerium nitrate from Fluka was used as the metal precursors. During the impreg-

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Performance of Palm Shell Activated Carbon Impregnated with CeO_2 and V_2O_5 Catalyst in Simultaneous Removal of SO_2 and NO

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Abstract: This study examined the SO_2 and NO sorption capacity of modified Palm Shell Activated Carbon (PSAC). The PSAC was modified using vanadium and cerium metal oxides and the effects were studied for simultaneous removal of SO_2 and NO at temperatures of 100-300°C. The weight percentage of metal added and their calcination temperature were also analyzed. It was found that cerium based PSAC showed a higher sorption capacity compared to vanadium. Calcination procedure plays an important role in provoking the oxide formation from the impregnated metal nitrates. A 10% loading of Ce onto PSAC resulted in 121.7 mg g^{-1} of SO_2 and 3.5 mg g^{-1} of NO sorption capacity g^{-1} of Ce/PSAC at temperature 150°C compared to vanadium which shows a much lower sorption capacity. Lower temperatures are favorable for the SO_2 removal and higher temperature are favorable for NO reduction.

Key words: Palm shell, SO_2, NO, simultaneous, cerium, vanadium

INTRODUCTION

Emissions from combustion processes such as sulfur dioxide (SO_2) and Nitrogen Oxide (NO) has been causing many environmental hazards, particularly acid rain and ground layer ozone formation. Reducing these emissions simultaneously has been a target for many environmentalists. Among the famous methods and technologies, dry sorption is still considered to be one of the most attractive ways to treat waste gases containing SO_2 and NO. This method has the advantage of being simple with less equipment, lower capital and operating costs and limited secondary waste generation (Ishizuka *et al*., 2000; Lin *et al*., 2003). At present, there are only a limited number of reports on simultaneous removal of SO_2 and NO by dry method. Some of latest reports include: Ca-based sorbent (Nimmo *et al*., 2004; Pisupati and Bhalla, 2008; Dahlan, 2008), CuO based catalyst (Liu *et al*., 2009; Rodas-Grapain *et al*., 2005), pure activated carbon (Zhu *et al*., 2005; Qiang *et al*., 2005), activated carbon impregnated catalyst (Ma *et al*., 2008), Activated Carbon Fiber (ACF) (Mochida *et al*., 2000) and honeycomb catalyst (Wang *et al*., 2004; Yanli *et al*., 2004).

Activated carbon seems to be one of the most promising bases for simultaneous removal because the system can run at temperatures below 200°C and space velocities lower than 1000 h^{-1} (Nishijima *et al*., 1980). Any cheap material with high carbon content, low in in-organics can be used as a raw material for the production of activated carbon (Ioannidou and Zabaniotou, 2007). One of the latest types of activated carbon is activated carbon made from waste oil palm biomasses. Palm shell has been used to produce activated carbon and its product has been widely used for many applications in particularly to remove gaseous pollutant such as SO_2, CO_2 and H_2S (Guo and Lua, 2002a; Guo *et al*., 2007; Lua and Guo, 2001). Aroua *et al*. (2008) have reported the usage of carbon molecular sieve produced from palm shell to remove CO_2, O_2 and N_2. Up to the date, PSAC have not been reported on NO removal nor simultaneous removal of SO_2 and NO by other researchers.

Hence, the aim of this investigation is to study the simultaneous adsorption of SO_2 and NO from simulated flue gas on PSAC by varying: (1) type of metal support, (2) effect of calcination, (3) weight percentage of metal support and (4) effect of adsorber temperature. Vanadium and cerium were chosen as the metal catalysts. Productive results could promote the use of palm shell made activated carbon in desulphurization and denitrification processes simultaneously, since the calcium-based sorbents systems have shown some severe limitations.

MATERIALS AND METHODS

Preparation of activated carbon catalysts: An activated carbon prepared by physical activation with CO_2 gas from palm shell was used in this study. Details of the

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le of Reaction and Factors of Carbon Nanotubes owth in Chemical Vapour Decomposition Process Using thane—A Highlight

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One of the remarkable achievements in the field of nanotechnology is Carbon Nanotubes (CNT) synthesis. Since their discovery in 1991 by Iijima, CNTs have attracted much attention across the world. The CNTs are broadly classified into single-walled carbon nanotubes (SWNTs) and multiwalled carbon nanotubes (MWNTs). The most distinguished features of SWNTs and MWNTs are their electrical, mechanical, chemical, and electronic properties which in turn find their potential applications in almost all fields of science, engineering, and technology. Based on the previous research studies to till date, chemical vapour deposition (CVD) is considered to be the simplest method with high energy efficiency and precise control of reaction parameters compared to other different methods for synthesizing CNTs. Since production of CNTs is becoming the most important factor in the applications point of view, most industries today are opting for the CVD technique. This paper reviewed the synthesis of CNT by CVD especially focusing on methane CVD. Various parameters influencing the reaction and CNT growth were also discussed. A detailed review was made over the different types of CVD process, influence of metal, supports, metal-support interaction, effect of promoters, and reaction parameters role in CNTs growth.

troduction

on nanotubes (CNTs) are sheets of graphite rolled tubes and possess excellent properties due to their netric structure [1]. They are broadly classified into -walled carbon nanotubes (SWNTs) and multiwalled n nanotubes (MWNTs). Among them SWNTs are the naterials to the emerging field of nanotechnology [2]. have reached the forefront of many industrial research cts nowadays. Due to their high strength, stiffness, and ical conductivity [3], CNTs are designated as one of nost attractive materials for reinforcing the material mposites [4, 5] and for nanoelectronics applications. retical and experimental elastic modulus (1TPa) and e strength of these materials are in the range of tens Pa, respectively [6]. In general, CNTs can be produced by carbon arc discharge method (CA) [7], chemical vapour deposition method (CVD) [8], pulsed laser vaporization technique (PLV) [9], and high-pressure carbon monoxide conversion (HiPco) process [10]. In CA and PLV methods, although high quality materials can be produced, the high temperature employed for evaporating the carbon atoms from solid carbon sources (over 3000 K) make them difficult to scale up the process in a cost-effective way. Hence, chemical vapour decomposition (CVD) has gained importance owing to its easiest and economic way of production in a larger scale [11]. CVD method is believed as the most suitable synthesis method in terms of product quality and quantity [12]. A review by Baddour and Briens, 2005, concluded that catalytic technique such as CVD is simple, inexpensive, energy-efficient and can produce high purity CNTs in high yield (>75%) [13]. As the applications for CNTs range from

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treatment effects on the characteristics and sonocatalytic performance of in the degradation of organic dyes in aqueous solution

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A B S T R A C T

The ambient sonocatalytic degradation of congo red, methyl orange, and methylene blue by titanium dioxide (TiO_2) catalyst at initial concentrations between 10 and 50 mg/L, catalyst loadings between 1.0 and 3.0 mg/L and hydrogen peroxide (H_2O_2) concentrations up to 600 mg/L is reported. A 20 kHz ultrasonic processor at 50 W was used to accelerate the reaction. The catalysts were exposed to heat treatments between 400 and 1000 °C for up to 4 h to induce phase change. Sonocatalysts with small amount of rutile phase showed better sonocatalytic activity but excessive rutile phase should be avoided. TiO_2 heated to 800 °C for 2 h showed the highest sonocatalytic activity and the degradation of dyes was influenced by their chemical structures, chemical phases and characteristics of the catalysts. Congo red exhibited the highest degradation rate, attributed to multiple labile azo bonds to cause highest reactivity with the free radicals generated. An initial concentration of 10 mg/L, 1.5 g/L of catalyst loading and 450 ppm of H_2O_2 gave the best congo red removal efficiency of above 80% in 180 min. Rate coefficients for the sonocatalytic process was successfully established and the reused catalyst showed an activity drop by merely 10%.

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ntly, it is estimated that about 10,000 different types of cial dyes and pigments exist and over 700,000 tones are d annually [1,2]. About 10–20% of the total world produc- yes is lost during the dyeing process and is released into ents [3]. Industrial dyestuffs constitute one of the largest f organic compounds that cause an increasing environ- oncern [4]. Therefore, a lot of studies have been dedicated is wastewater by using advanced oxidation process which hydroxyl (•OH) radicals to mineralize the organic com- Different degrees of success have been reported but the could subject to some common drawbacks like high capi- nning costs, the needs for toxic chemicals and low removal , especially at low concentrations. Photocatalytic degra- another plausible method but its practicality is generally ith heavily colored effluent, high photocatalyst loading volume operation due to low penetration of the UV light

plication of ultrasounds in water with a frequency range n 18 and 100 MHz can result the phenomenon of acoustic . It involves the formation, growth and collapse of cav- es that entrapped dissolved gases or vapors surrounding water [5,6,7]. Subsequently, many local hot spots with extremely high temperature (up to 5000 K) and high pressure (up to 1000 atm) are generated to consequently induce the dissociation of water (Eqs. (1)–(4)), oxygen molecules (Eqs. (5)–(8)) and hydrogen peroxide (H_2O_2) (Eq. (9)) in the case of its addition into the effluent [5,7,8].

$$H_2O \xrightarrow[TiO_2]{))))} \cdot OH + H\cdot \quad (1)$$

$$^{\bullet}OH + H^{\bullet} \rightarrow H_2O \quad (2)$$

$$2\,^{\bullet}OH \rightarrow H_2O_2 \quad (3)$$

$$2\,^{\bullet}OH \rightarrow H_2O^{\bullet} + O^{\bullet} \quad (4)$$

$$O_2 \xrightarrow[TiO_2]{))))} 2O\cdot \quad (5)$$

$$^{\bullet}O + H_2O \rightarrow 2\,^{\bullet}OH \quad (6)$$

$$O_2 + H^{\bullet} \rightarrow {}^{\bullet}O_2H \quad (7)$$

$$^{\bullet}O_2H + {}^{\bullet}O_2H \rightarrow H_2O_2 + O_2 \quad (8)$$

$$H_2O_2 \xrightarrow[TiO_2]{))))} 2 \cdot OH \quad (9)$$

As a semiconductor material, TiO_2 is characterized by a filled valence band and an empty conduction band [3,4]. In the presence of suitable energy source, the excitation of electron from the valence band to the conduction band could occur. With the presence of UV light or ultrasonic irradiation as the energy source,

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ation of mesoporous K/SBA-15 catalyzed transesterification of palm oil using e surface methodology

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ABSTRACT

K/SBA 15 was investigated for the transesterification of palm oil. The influence of temperature, reactants' ratio, catalyst loading and reaction time on the biodiesel yield was studied using a Central Composite Design (CCD). The process optimization using Response Surface Methodology (RSM) was performed and the interactions between the operational variables were elucidated. The optimum conditions were found to be 70 °C for the reaction temperature, 11.6 mol/mol for methanol to oil ratio, 3.91 wt.% for the catalyst loading and 5 h for the reaction time to achieve 93% of biodiesel yield. High catalytic activity was attributed to high surface area of the catalyst and the relatively easy diffusion of reactants in the mesopores. The effect of catalyst loading and reaction time was relatively more dominant in affecting the biodiesel yield. High potential of SBA-15 as catalyst for biodiesel production was demonstrated.

ion

onal fossil energy resources are limited and greenhouse s are becoming a greater concern, research is now being vards the use of alternative renewable fuels that are fulfilling an increasing energy demand. Biodiesel, an iesel fuel, is a promising, non-toxic and eco-friendly fuel entionally produced by transesterification process of oils presence of catalysts in the process plays an important roving in the reaction rate and yield [2]. Due to al problem, easier catalyst separation, and economic rrent research trend in catalysis has been focusing on the on of homogeneous catalytic system into heterogeneous It should be noted that biodiesel needs to have full with either ASTM D6751-07 or EN 14214:2003 standards s a fuel. The compliance is basically influenced by many as the purity of the fatty acid methyl esters content, the ne purification process, the original constituents in the etc. [2].

numerous heterogeneous catalysts currently available that the transesterification reactions. A great variety of catalysts ine-earth metals oxides and hydroxides [4], alkali metals ydroxides or salts supported on alumina [1,5,6], zeolites [7], , as well as some solid acids [2] have been investigated s reaction conditions and with a variable degrees of success. turn the salts into more stable forms that can better resist leaching during the reaction. Zeolites are one of the catalyst supports that have attracted strong attention in the field of catalysis due to their unique pore system, high surface area and high stability. However, these materials present severe limitations when large reactant molecules are involved, especially in liquid-phase systems as is frequently the case in the synthesis of fine chemicals. It is due to the fact that mass transfer limitations are very severe for the microporous materials [8]. Similarly, catalysts with small pores are not suitable for biodiesel production because of the diffusion limitation of the large fatty acid molecules (triglyceride). Therefore, many researchers now turn into with mesoporous materials instead of zeolites to be applied as the catalyst support in order to overcome this limitation.

The advantage of using ordered mesoporous solids in catalysis are the relatively large pores which facilitate mass transfer and the very high surface area which allows high concentration of active sites per mass of material [8]. Mesoporous SBA-15 possesses a high surface area (600–1000 m^2/g) and is formed by a hexagonal array of uniform tubular channels with tunable pore diameters (5–30 nm) and thicker pore walls (3–6 nm) [9]. It has high thermal stability which promises great opportunity for the application as catalysts or catalytic supports [10]. However, the process of transesterification is affected by various factors, depending upon the reaction condition used. Some of the effects are free fatty acid and moisture of the source of oil, type of oil, catalyst type and loading, molar ratio of alcohol to oil, type of alcohol, reaction time and temperature, mixing intensity and effect of solvents [11]. Recent studies have also revealed that functionalized mesoporous silica, such as tin oxide-modified mesoporous SBA-15 [12], titanium-grafted mesoporous silica [13] and Mg–MCM-41 [14] appeared to be very promising in catalyzing various transesterification reactions. Despite highly promising catalyst reported for various

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Optimization of Process Parameters for Alkaline-Catalysed Transesterification of Palm Oil Using Response Surface Methodology

(Pengoptimuman Parameter Proses untuk Transesterifikasi Minyak Sawit Bermangkin Alkali Menggunakan Kaedah Sambutan)

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ABSTRACT

Biodiesel (fatty acid methyl esters) was synthesized from direct transesterification of vegetable oils, where the corresponding triglycerides react with methanol in the presence of a suitable catalyst. The alkali catalysts are the most common catalyst used in biodiesel industry because the process proves faster and the reaction conditions are moderate compared to the acid catalyst. In the present study, biodiesel production using heterogeneous alkaline-catalysed transesterification process (KOH supported on SBA 15) was proposed. The influence of reaction temperature x_1 (50 - 90°C), ratio of methanol to oil, x_2 (6:1 – 14:1 mol/mol), amount of catalyst, x_3 (1 – 5wt.%), and reaction time, x_4(2 - 6h) to the reaction was studied. These four conditions were studied using design of experiment (DOE), based on four-variable central composite design (CCD) with $\alpha = 2$. The process variables were optimised using the Response Surface Methodology (RSM) in obtaining the maximum yield of biodiesel. This method was also applied to determine the significance and interaction of the variables affecting the biodiesel production. The biodiesel produced in the experiment was analysed by gas chromatography, which considered five major fatty acid methyl esters. The optimal conditions of response were found to be 70°C for reaction temperature, 11.6 wt/wt of ratio methanol to oil, 3.91wt.% of weight of catalyst and 5 h for reaction time with 93% of biodiesel yield for predicted value and 87.3% from experimental.

Keywords: Base catalyst; biodiesel; response surface methodology

ABSTRAK

Biodiesel telah disintesis daripada transesterifikasi langsung minyak sayuran yang melibatkan trigliserida bertindak balas dengan metanol dengan kehadiran mangkin yang sesuai. Mangkin beralkali adalah mangkin yang biasanya digunakan di dalam industri biodiesel kerana proses terbukti lebih cepat dan keadaan tindak balas sederhana berbanding dengan mangkin berasid. Dalam kajian ini, penghasilan biodiesel menggunakan proses transesterifikasi bermangkinkan heterogen beralkali (KOH disokong di atas SBA-15) telah dikaji. Kesan suhu tindak balas, x_1 (50 - 90°C), nisbah metanol kepada minyak, x_2 (6:1 – 14:1 mol/mol), berat mangkin, x_3 (1 – 5wt.%), dan masa, x_4(2 - 6 h) terhadap tindak balas dikaji. Empat keadaan ini telah dikaji menggunakan reka bentuk eksperimen (DOE) berdasarkan kepada empat pembolehubah reka bentuk gabungan berpusat (CCD) dengan $\alpha = 2$. Pembolehubah proses telah dioptimumkan menggunakan kaedah sambutan permukaan (RSM) dalam mendapatkan hasil biodiesel yang maksimum. Kaedah ini juga digunakan untuk menentukan kepentingan dan interaksi pembolehubah-pembolehubah yang mempengaruhi hasil biodiesel. Biodiesel yang dihasilkan telah dianalisis melalui kromatografi yang mengambilkira lima metil ester asid lemak utama. Keadaan optimum sambutan didapati pada suhu tindak balas 70°C, nisbah metanol kepada minyak 11.6 mol/mol, berat mangkin 3.91 wt.% dan 5 jam masa tindak balas dengan 93% hasil biodiesel keluaran untuk nilai jangkaan dan 87.3% daripada eksperimen.

Kata kunci: Biodiesel; kaedah sambutan permukaan; mangkin beralkali

INTRODUCTION

Due to environmental, green chemistry and economic concerns, current research trend in catalysis has been focused on the transformation of homogeneous catalytic system into heterogeneous systems. The replacement of homogeneous catalysts by heterogeneous catalysts would have various advantages, most important being the application of easier working up procedures, the easy catalyst separation from the reaction mixture and the reduction of environment pollutants (Venkatesan et al. 2004). Besides that, the process of transesterification is affected by various factors depending upon the reaction condition used. Some of the effects are free fatty acid and moisture of the source of oil, type of oil, catalyst type and concentration, molar ratio of alcohol to oil, type of alcohol, reaction time and temperature, mixing intensity and effect of solvents (Lopez et al. 2005; Meher et al. 2004) The economic and environmental interest in using oil and fats are also involved in the production of biodiesel.

The objective of this study was to optimize process variables of transesterification. The process variables studied were reaction temperature, ratio of methanol to

Influence of the Silica-to-Surfactant Ratio and the pH of Synthesis on the Characteristics of Mesoporous SBA-15

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Abstract: *Mesoporous silica SBA-15 was synthesised with two different sets of synthesis conditions and was characterised using nitrogen adsorption, X-ray diffraction (XRD), transmission electron microscopy (TEM) and scanning electron microscopy (SEM). The effects of the ratio of tetraethylorthosilicate/triblockcopolymer (TEOS/TCP) (1.52–3.38) and pH (1.3–3.0) were particularly studied. Well-ordered hexagonal mesoporous silicas were formed at a TEOS/TCP ratio of 2.25 and a pH above 2. The highest surface area and an intense XRD pattern were shown by those synthesised at a ratio of 1.52 (669 m^2/g and 0.5 cc/g). A high TEOS amount disturbed the condensation of the silica network, causing failure in the formation of the Si-O-Si network.*

Keywords: mesoporous, SBA-15, TEOS/TCP ratio, pH, characteristics

Abstrak: *Silika mesoliang SBA-15 telah dihasilkan melalui dua set keadaan sintesis yang berbeza dan dicirikan menggunakan kaedah penjerapan nitrogen, pembelauan sinar X (XRD), mikroskop elektron transmisi (TEM) dan mikroskop electron imbasan (SEM). Kesan nisbah tetraetilortosilikat/kopolimer triblok (TEOS/TCP) (1.52–3.38) dan pH (1.3–3.0) telah dikaji secara khusus. Silika heksagon mesoliang yang teratur telah terbentuk pada nisbah TEOS/TCP 2.25 dan pH melebihi 2. Luas permukaan tertinggi dan pola XRD paling kuat ditunjukkan oleh silica yang disintesis pada nisbah 1.52 (669 m^2/g dan 0.5 cc/g). Amaun TEOS yang terlampau tinggi mengganggu kondensasi jaringan silika menyebabkan kegagalan dalam pembentukan jaringan Si-O-Si.*

Katakunci: mesoliang, SBA-15, nisbah TEOS/TCP, pH, ciri-ciri

1. INTRODUCTION

The presence of ordered nanoporous materials has been known for more than a century.[1] Since the discovery of M41S mesoporous materials in 1992, there has been an increasing interest in the design of novel porous materials tailored with various pore organisations and dimensions for potential applications in separation, catalysis, chemical sensing and optical coating.[2,3] The use of mesoporous materials of MCM-41 as carriers for basic guest species has been

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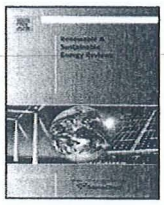

nt progress on innovative and potential technologies for glycerol formation into fuel additives: A critical review

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ABSTRACT

Glycerol emerges as a significant worth chemical that can be converted into high value products. In the prospect of biorefinery industries and great demand towards renewable sources, glycerol has proved to have tremendous potential to be transformed, thus supersede conventional petroleum derived fuel additive. Various types of oxygenated biocomponents and rigorous studies of glycerol transformation into fuel additives are presented in this review paper. Particular focus is given to etherification, acetylation and acetalation processes with specific behaviors in the respective reaction system.

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evelopment and commercial use of biodiesel has been ingly and rapidly expanding in Europe and US for over 10 e prominent superiority of biodiesel over petroleum vards health and environment (free sulfur content, low f harmful emission, e.g. particulate matter, HC, CO, etc., better lifecycle of CO_2 for global warming alleviation) as well as engine performance (enhance lubricity, high cetane number for complete combustion) [1,2] has enticed Asia to use biodiesel as alternative fuels and innovative solution to curb the polluted air emitted from growing vehicle population [3].

Despite the rapid pace of biodiesel development and commercialization, there are several key challenges emerging and these must be addressed efficiently. One key problem that is being ultimate focused is the inevitable low value production of glycerol as co-product of biodiesel from transesterification and esterification of vegetable oil [4]. Stoichiometrically, glycerol is produced by

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ization of ultrasonic-assisted heterogeneous biodiesel production from palm oil: ponse surface methodology approach

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ABSTRACT

The use of ultrasonic processor in the heterogeneous transesterification of palm oil for biodiesel production has been investigated. Response surface methodology was employed to statistically evaluate and optimize the biodiesel production process catalyzed by two alkaline earth metal oxide catalysts i.e. BaO and SrO. SEM, surface analysis, AAS analysis and the Hammett indicator methods were used for characterization of the catalysts. Four different variables including reaction time (10–60 min), alcohol to oil molar ratio (3:1–15:1), catalyst loading (0.5–3.0 wt.%) and ultrasonic amplitude (25–100%) were optimized. Mathematical models were developed and used to predict the behavior of the process. The models were able to accurately predict the biodiesel yield with less than 5% error for both catalysts. The basic strength of the catalysts was the main reason of their high activities. This study confirmed that the ultrasonic significantly improved the process by reducing the reaction time to less than 50 min and the catalyst loading to 2.8 wt.% to achieve biodiesel yields of above 95%. The optimum alcohol to oil ratio was found to be at 9:1 while the best amplitudes were ~70 and ~80% for the BaO and SrO catalysts, respectively.

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y, particular focus is been given on global warming and n of non-renewable resources. These problems are primarily to the heavy consumption of fossil fuels. Much attention has n to biomass resources as alternatives for energy sources. The diesel fuel is produced by the transesterification of vegetable w alcohol in the presence of homogeneous base-catalyst such NaOH [1]. Transesterification can occur in the absence of a t it can be effectively intensified by the use of suitable catalyst ver, for the satisfactory use of the product as diesel fuel, the ust be removed from the product mixture and this requires ne purification processes while huge amount of wastewater d at the same time [3].

geneous catalytic process is expected to be future biodiesel process. This process lowers the cost and minimizes the ental impacts due to the simpler production steps and n processes which are normally carried out under very mild . The heterogeneous catalysts capable to be used are such as, ilicates [4], alkaline earth metal compounds and hydroxides alkali metal hydroxides or salts supported on γ-alumina [7–9], [10]. The common problem associated with the heteroge- iesel production process is its low reaction rate due to poor between the oil and alcohol during the reaction due to their miscibility [4,5].

The demand for biodiesel in the world is sharply increasing. Thus, increasing the production rate for biodiesel in order to meet the demand seems to be essential. Therefore, new accelerating technologies are of great interest among researchers in this area. Ultrasonic radiations can accelerate the biodiesel production rate with homogenous catalyst [1,11]. Hanh et al. [2] found that the methanolysis of oil in aqueous catalyst solutions (e.g. NaOH, KOH) can be accelerated by low frequency ultrasound which led to the intensification of the overall process. Reports on the beneficial use of ultrasound for homogeneous catalytic process for biodiesel production are also published very recently [1,2,12]. Despite widely investigated for accelerating homogeneous reaction systems, heterogeneous biodiesel production process has never been intensified using ultrasonic energy. The benefit offered to the homogeneous process is theoretically possible in the case of heterogeneous process in a similar manner. However, report on the use of ultrasonic-assisted heterogeneous process for the production of this renewable fuel is still hardly found in the literature.

Fig. 1 shows the five step reaction mechanism generally proposed for the role of metal oxide catalyst in the transesterification reaction. Steps 1 and 2 describe the adsorption of alcohol and fatty acid on two neighboring free catalytic sites, respectively. In step 3, the two adsorbed groups react to form a surface intermediates. These surface intermediates will further decompose in step 4 and finally desorb (step 5). According to Hattori et al. [13], the rate-determining step of this mechanism with catalysts having a higher basicity, such as BaO and SrO, is the surface reaction step. Forward reaction promotes the formation of esters to result in high biodiesel yield. In this respect, higher alcohol

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onic-assisted biodiesel production process from palm oil using alkaline metal oxides as the heterogeneous catalysts

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ABSTRACT

The ultrasonic-assisted transesterification of palm oil in the presence of alkaline earth metal oxide catalysts (CaO, SrO and BaO) was investigated. Batch process assisted by 20 kHz ultrasonic cavitation was carried out to study the effect of reaction time (10–60 min), alcohol to palm oil molar ratio (3:1–15:1), catalysts loading (0.5–3%) and varying of ultrasonic amplitudes (25–100%). The activities of the catalysts were mainly related to their basic strength. The catalytic activity was in the sequence of CaO < SrO < BaO. At optimum conditions, 60 min was required to achieve 95% yield compared to 2–4 h with conventional stirring. Also, the yields achieved in 60 min increased from 5.5% to 77.3% (CaO), 48.2% to 95.2% (SrO), and 67.3% to 95.2 (BaO). Fifty percentage amplitude of ultrasonic irradiation was deemed the most suitable value and physical changes on the catalysts after the ultrasonic-assisted reaction were successfully elucidated. BaO catalyst underwent relatively more severe activity drop in the catalyst reusability test. Catalysts dissolution was found to be mainly responsible for activity drop of the reused catalysts, especially with BaO catalyst.

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el is an eco-friendly and alternative energy source for ines that can be synthesized by transesterification of oil or animal fat with alcohols [1]. The reaction can be by alkalis, acids, or enzymes [2]. Alkali-catalyzed transe- n is much faster than acid-catalyzed transesterification st often used commercially [1]. Nevertheless, the alkali mpounds have some drawbacks, i.e. they must be neu- ter the reaction, thus, eliminating the possibility for ility of the catalyst [3,4]. The neutralization process also arge amount of wastewater that deserves treatment, to ant increase in the production costs [5].

eneous catalysis have many advantages: they are rela- corrosive, environmentally benign and present fewer oblems. They are also much easier to be separated from ucts and can be designed to give higher activity, selec- onger catalyst lifetimes [6]. Alkaline-earth metals oxi- droxides [7–9], alkali metals (Na and K) hydroxides or rted on γ-alumina [3,10–11], zeolites [12], hydrotalcites been investigated with a variable degree of success. mponent alkaline earth metal oxides (BaO, SrO, CaO, h have higher basicity, lower solubility in alcohol and producing higher biodiesel yield have also been reported [9]. However, complete behavior of these catalysts in the transesterification process is yet to be fully understood [9,14].

As oil and methanol are not completely miscible, the mixing efficiency can affect the course of the transesterification reaction. The reaction can only occur in the interfacial region between the methanol, oil and catalyst and the alkaline earth oxide catalysts are essentially insoluble in the two phases. Continuous and vigorous mixing is then required to increase the area of contact between the three phases [15,16]. The mixing process generally increases energy input for biodiesel production process, yet the biodiesel yield is generally lower then that in the homogeneous process [9].

Low frequency ultrasound is theoretically seen as an efficient, time saving and economically functional method to accelerate biodiesel production process [17]. Ultrasonic mixing can produce smaller droplets of the reacting phases than conventional agitation, leading to a drastic increase in the interfacial area and improved mass transfer [18]. As a result, the mixing requirement during the process is also significantly lowered, translating in reduced energy consumption [15]. Ultrasonic can also 'grind' the catalyst into smaller particles to create new active sites for the subsequent reaction. Thus, the solid catalyst is expected to last longer in the ultrasonic-assisted process.

The main aim of this study was to characterize the effects of ultrasonic energy in presence of alkaline earth metal oxides as heterogeneous catalysts. As reported in literature, most of the transesterification processes for biodiesel production use some oils other than palm oil such as rapeseed oil [19] and soybean oil [4,8,10]. As

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osites as cracking catalysts in the production of biofuel from palm oil: ivation studies

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ABSTRACT

Composite catalysts HZSM-5/alumina (CZA) and Al-MCM-41/alumina (CMA) were synthesized and tested for their catalytic cracking activity in the production of biofuel from palm oil. Both composite catalysts were characterized for their structure, acidity and surface morphology. The addition of alumina in the composite catalysts improved their hydrothermal stability due to the changes in the surface morphology. The deactivation of the catalysts was studied by obtaining time on stream data by varying the palm oil to catalyst ratio of 8–16. The deactivation data were analyzed using different activity models and the deactivation parameters were determined.

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oduction of biofuel from palm oil has been extensively sing zeolites as the cracking catalysts [1–8]. Zeolite ZSM- arkable properties and performance in FCC process [9], -41 mesoporous material are reported as promising and atalysts [2,3] for biofuel production in the catalytic crack- m oil due to higher diffusivity of bulky molecules [1–8]. ntional catalyst for gas oil cracking contains zeolite that he major surface area as well as active sites and thus is the onent that controls catalyst activity and selectivity [10]. disperse zeolite in the matrix and to increase its thermal thermal stabilities, alumina is added as a binder with- emical bonds between matrix and zeolite. The presence and macropores in the catalyst is desired to increase the electivity during catalytic cracking [11].

/MCM-41 [4] and Beta/MCM-41 [8] as composite cata- also been reported in the palm oil cracking because of ng interest in the ordered porous materials with com- ro- and mesopores due to their significant supplementary s. A significant improvement in the selectivity of products ved. However, one of the major barriers of solid acid cata- in the catalytic cracking reaction is the rapid deactivation alyst. Most of the reactions involving oil fractions, the eactivates by active site coverage due to coke formation, on the catalyst age. The deactivation could be expressed in terms of process time or the deactivating agent i.e., coke on the catalyst, without explicit link to the operating conditions.

The effect of coke could be suppressed by changing the operating parameters of reaction process, for example by increasing pressure and decreasing the cracking conversion/temperature ratio [10]. However, the changes in these process parameters have limitations. Therefore the development of catalyst resistance to coking is an alternative solution to this problem. The understanding of catalyst deactivation allows the development of improved catalysts being less sensitive to the deactivation and perform better.

Since composite catalysts have been investigated for the production of biofuel from palm oil in terms of products selectivity [4,8], therefore it will be interesting to study their catalyst deactivation (stability). The composites composed of low crystalline materials like alumina could help in this respect. In the present study, the catalytic activity, hydrothermal stability and deactivation of the composite catalysts containing HZSM-5, and Al-MCM-41 with alumina as binder in the production of biofuel from palm oil cracking are reported. The effect of time on stream (TOS) on catalyst deactivation is reported and deactivation parameters are obtained using different activity models.

2. Experimental

2.1. Catalyst preparation

2.1.1. Alumina

2 M Al_2O_3 (boehmite sol) was prepared following Yoldas process [12] with some modifications. This method describes a direct preparation of the high-concentration boehmite sol. 21.1 g of aluminum

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ect of Mass Transfer and Enzyme Loading on the Biodiesel Yield and Reaction Rate in the Enzymatic Transesterification of Crude Palm Oil

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Efforts in minimizing mass transfer effects in enzymatic transesterification of crude palm oil in a biphasic system have always been the compromise between enzyme loading and agitation speed. Therefore, effect of enzyme loading and agitation speed on fatty acid methyl ester (FAME) productivity in terms of intrinsic and external mass transfer limitations and the effective reaction time were determined using factorial design. FAME yield response was significantly affected by agitation speed, enzyme loading and reaction time, whereas initial reaction rate was solely dependent on the enzyme loading. Graphical plots of experimental results revealed that the mass transfer effect for the transport of reactant from bulk liquid to immobilized lipase and within the intraparticle of immobilized lipase were absent at 150 rpm and 6.65% enzyme loading. Optimization conditions for a kinetically controlled domain proposed by the response surface methodology established 100% FAME yield in 4 h reaction time at initial reaction rate of 2.77% FAME yield per min.

Introduction

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Table 1. Designated Candidate Points for Process Variables with Corresponding Studied Ranges

factorial design: four levels − three factors		study levels			
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[a] The percentage of enzyme quantities used in weight per unit weight of CPO.

Hexane, petroleum ether, acetone, and other organic solvent have been adopted to dissolve hydrophobic vegetable oil into methanol for homogeneous reaction mixture in addition to removing byproduct glycerol periodically. Consequently, lipase inactivation caused by insoluble methanol and byproduct glycerol can be omitted. However, these hydrophobic organic solvents were unable to completely dilute both methanol and glycerol. Thus, lipase still exhibits poor stability in such reaction media. The use of moderate polarity *tert*-butanol (log $P = 0.35$) dissolves completely the hydrophilic methanol and glycerol together with the hydrophobic vegetable oil when all components are present in equilibrium state. Thus, both the negative effects caused by excessive methanol and byproduct glycerol could be totally eliminated.[14] The application of *tert*-butanol as reaction medium have resulted in high biodiesel yield of 95% catalyzed by the combined Lipozyme TL IM and Novozym 435, and

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GINAL PAPER

diesel (FAME) Productivity, Catalytic Efficiency Thermal Stability of Lipozyme TL IM for Crude Palm Oil nsesterification with Methanol

ıey Sim · Azlina Harun Kamaruddin · ısh Bhatia

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act Crude palm oil (CPO) transesterification with nol at room temperature is an important factor for zing biodiesel processing costs with respect to energy in addition, good stability of expensive lipase activity nsured and is reported in this study. The enzyme g, agitation speed and reaction time at a constant ing temperature of 30 °C were studied to find rable operational conditions using a factorial design. ical analysis was used to assist the enzymatic sterification so that a reduced mass transfer effect was ed to obtain high FAME yields. The combination of um enzyme loading of 6.67 wt% and 150 rpm agitapeed for the system at 30 °C gave 81.73% FAME t 4 h and a production rate of 85.86% FAME yield/h. gh viscosity of CPO observed at 30 °C compared to hindered the achievement of 96.15% FAME yield at temperature. It was found that an increase of 10 °C ably deactivated the lipase, but was compensated by hanced FAME production rate with 96.15% FAME after only 4 h reaction time. Thus, 40 °C was con- the most suitable operating temperature for lipoTL IM to catalyze CPO transesterification.

ords Transesterification · acid methyl ester (FAME) · Lipase · Temperature · ical analysis · Biodiesel · Palm oil · Mass transfer

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Introduction

The use of refined edible vegetable oil as a feedstock for biodiesel production allows for a simple conversion method and promises the highest conversion rate through the transesterification reaction. The sustainable cultivation of edible vegetable oil guarantees that the oil supply is sufficient for food consumption, consumer products as well as biodiesel production. Crude palm oil (CPO; *Elaeis guineensis*) is currently one of the most attractive feedstocks for renewable energy production. This is mainly because it is the least expensive of the vegetable oils and has a high yield of CPO, with 4.2 tonnes per hectare produced annually. Malaysia is well known as the world's largest producer and exporter of palm oil, with CPO production increasing dramatically from 8.3 million tonnes in 1998 to 15.8 million tonnes in 2009 [1]. The large availability of palm oil is attributed to the high oil palm yield per area of land, with the palm oil possessing the highest fossil energy balance and the lowest production costs relative to other energy crops [2]. For biodiesel to be commercially viable, the cost of the feedstocks must be inexpensive. It is therefore logical to use cheap CPO in the transesterification reaction as it conforms to the process requirement of low production costs.

Refined palm oil has given better results than CPO in terms of biodiesel production. However, in addition to the free fatty acid and water content, refined palm oil and CPO also differ in their phospholipid contents. Phospholipids as the main component of oil gum actually contribute to the high viscosity in CPO and thus lead to a significant mass transfer effect [3]. The methanolysis of refined palm oil without phospholipids progresses faster with Novozym 435, 4.65 (g biodiesel/h/g lipase), by more than half compared to unrefined palm oil, 2.02 (g biodiesel/h/g lipase)

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OPTIMIZED PARAMETERS FOR CARBON NANOTUBES SYNTHESIS OVER Fe AND Ni CATALYSTS VIA METHANE CVD

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Abstract. Multi walled carbon nanotubes (MWNTs) were synthesized via methane chemical vapor decomposition using low-cost activated carbon (AC) as support for Fe and Ni catalyst. Maximum methane conversions of 98% and 42% were observed on Fe and Ni catalysts respectively at reaction temperature of 750 °C by on-line gas chromatography. Bundles of MWNTs with an average internal dia ~ 20nm at 850 °C over Ni catalyst and thin-walled CNTs (dia ~ 8 nm) formed over Fe catalysts were confirmed by morphological studies by transmission electron microscopy. CNTs formed over Fe catalyst illustrated a typical *tip-growth phenomenon*. The formation of MWNTs was further supported with the data obtained from thermogravimetric analysis. The ideal condition for CNT growth was noticed under N_2/CH_4 gas flow ratio of 2:1 rather than H_2/CH_4 atmosphere.

1. INTRODUCTION

Carbon nanotubes (CNTs) are a new form of carbon molecules with many outstanding properties which makes them potentially useful in various applications such as electronic, mechanical, composite, medical, etc., [1-5]. In general, CNTs has been classified either as metallic or semi-conducting that depends strongly on their chirality and diameter. Among CNT synthesis methods, chemical vapour decomposition (CVD) is the most suitable method at low temperatures when compared with other techniques [6]. In this process, various inorganic porous materials such as alumina [7], silica [8], magnesium oxide [9] and Zeolites [10] were investigated as support materials by numerous researchers in producing various diameter ranges of single-walled carbon nanotubes (SWNTs) and MWNTs [11]. However, while considering high quantity and lower production cost of CNTs, it is necessary to trace a new support material to overcome current drawbacks like higher production cost and purification issues. In recent years, carbon itself finds more importance in catalytic reactions either as a catalyst or as supports owing to its fascinating physical and chemical characteristics. The potential use of carbon as catalyst support has not yet been fully exploited, even though there is considerable volume of literature devoted to this field in last 20 years [12-14]. Since malaysia being the leading producer of activated carbon from its palm industry, there is abundant resource for its cheaper availability. Hence, our present study was focused on using low-cost AC (derived from wood base material) as support for Fe and Ni catalysts with the aim to grow CNTs of different morphologies.

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Optimizing photocatalytic degradation of phenol by TiO_2/GAC using response surface methodology

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(Received 8 March 2010 • accepted 3 May 2010)

Abstract–TiO_2 deposited on granular activated carbon (TiO_2/GAC) was used for photocatalytic degradation of phenol. The effects of photocatalyst loading, initial substrate concentration and addition of an oxidizing agent as H_2O_2 were investigated using a one-factor-at-a-time experiment. Central composite design, an experimental design for response surface methodology (RSM), was used for the modelling and optimization of the phenol degradation. Analysis of variance (ANOVA) indicated that the proposed quadratic model was in agreement with the experimental case with R^2 and R^2_{adj} correlation coefficients of 0.9760 and 0.9544, respectively. Accordingly, the optimum conditions for phenol degradation were a photocatalyst loading of two layers, initial phenol concentration of 34.44 mg L^{-1} and H_2O_2 concentration of 326.90 mg L^{-1}. The TiO_2/GAC was used for five cycles with phenol degradation efficiency still higher than 90%. Finally, the phenol that remained adsorbed on GAC was able to migrate to TiO_2 and then photocatalytically be degraded.

Key words: TiO_2, Granular Activated Carbon, Phenol, Photocatalytic Degradation, Response Surface Methodology

INTRODUCTION

ntamination of water by phenol and its derivatives is a seri-oblem experienced by nations throughout the developed and ping countries. Phenols have been widely used by many indus-uch as petrochemical, petroleum refineries, phenolic resin manu-ng, textile, paint, plastic, paper-making and iron smelting [1]. leases of these untreated organic pollutants into the environment high priority concern since they are harmful to organisms at oncentrations and many of them have been listed as hazard-ollutants by both the US Environmental Protection Agency ne European Commission [2,3]. The ingestion of such con-ated water into the human body also can cause paralysis of ntral nervous system and damage the kidney, liver and pan-[4]. Due to their high toxicity and recalcitrant nature, the re- to innocuous levels is an arduous process for many biologi-ysical and chemical processes [5,6]. Therefore, suitable and nt wastewater treatment methods for removing the phenols he wastewater must be considered.

e use of the heterogeneous photocatalysis for the oxidation of c and inorganic pollutants in both water and air has been ac- studied in the past 20 years [2,5,7-12]. The preferential use O_2 for the photocatalytic degradation of organic pollutants is on its low cost, non-toxicity and photochemical stability. This ss is based on the formation of nonselective and highly reac-adicals such as hydroxyl radicals (•OH), which can attack a range of organic pollutants by converting them into carbon le, water and other associated inorganic salts. However, fine powder is generally accompanied by complications arising he need for separation of the powder from the treated pollut-ants, which prevents the large-scale applications of this promising method.

Several efforts have been adopted to enhance the separation performance of TiO_2, such as immobilization of TiO_2 onto various supports [11-18]. But the photocatalytic efficiency of pollutant degradation is usually decreased due to the mass transfer limitation when some materials without adsorption ability, such as glass and stainless steel are used as supports [13,14]. To enhance the mass transfer, some sorbents as the supporter of photocatalyst have drawn the attention of researchers. These sorbents used often contain silica gel [15], zeolite [11,17] and activated carbon (AC) [12,16,18]. Among them, AC is most commonly employed as catalyst support for TiO_2 due to its unique characteristics such as large specific surface area, highly developed porosity, strong adsorption capacity and superiority of low cost. Ao et al. [16] have prepared nanocrystal anatase TiO_2 particles deposited on AC at low temperature by sol-gel method. Their work showed that phenol pollutants were adsorbed by AC, and then migrated continuously onto the surface of TiO_2 for subsequent photocatalytic degradation. In the same vein, Ravichandran et al. [18] investigated the photocatalytic activity of immobilized commercial TiO_2 (Degussa P25) onto AC. Their results also indicated that there was a synergistic effect and a common interface, in which the adsorbed pollutants on AC were transferred to TiO_2-P25. Hence, when combining the roles of both adsorption and photocatalytic degradation, TiO_2/AC is expected to be a promising photocatalyst for the removal of organic pollutants from aqueous solution.

Furthermore, it was stated that the photocatalytic degradation efficiency of this process is dependent on numerous process parameters such as photocatalyst loading, initial substrate concentration, pH value, light intensity, air flow rate and presence of added oxidant species; working conditions are case-specific and need to be carefully optimized. The majority of recent studies concerned with the effects of these process parameters on the photocatalytic degradation

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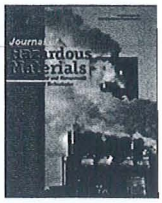

communication

ption of SO_2 and NO from simulated flue gas over rice husk ash A)/CaO/CeO_2 sorbent: Evaluation of deactivation kinetic parameters

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ABSTRACT

In this study, the kinetic parameters of rice husk ash (RHA)/CaO/CeO_2 sorbent for SO_2 and NO sorptions were investigated in a laboratory-scale stainless steel fixed-bed reactor. Data experiments were obtained from our previous results and additional independent experiments were carried out at different conditions. The initial sorption rate constant (k_0) and deactivation rate constant (k_d) for SO_2/NO sorptions were obtained from the nonlinear regression analysis of the experimental breakthrough data using deactivation kinetic model. Both the initial sorption rate constants and deactivation rate constants increased with increasing temperature, except at operating temperature of 170 °C. The activation energy and frequency factor for the SO_2 sorption were found to be 18.0 kJ/mol and 7.37×10^5 cm^3/(g min), respectively. Whereas the activation energy and frequency factor for the NO sorption, were estimated to be 5.64 kJ/mol and 2.19×10^4 cm^3/(g min), respectively. The deactivation kinetic model was found to give a very good agreement with the experimental data of the SO_2/NO sorptions.

roduction

aning flue gases from sulfur oxides (SO_x) and nitric oxides has become an issue of great importance to governmental tory agencies and general public due to their negative effect ls the environment and human health. Normally SO_x and /hich consists of more than 98% of sulfur dioxide (SO_2) [1] er 90–95% of nitric oxide (NO) [2], are generated mainly from nbustion of fossil fuels in power stations as well as chemical and metallurgy processes. Attempts have been made to find a e method for the removal of SO_2 and NO simultaneously. Dry on method is now considered to be the most attractive way t waste gases containing SO_2 and NO due to the drawbacks sorption methods [3,4]. There are several dry-type sorbents ve been considered in the previous study for simultaneous al of SO_2 and NO.

A, which is produced from the burning of rice husk, has been in this study as a raw material in the preparation of dry-type t since it is available abundantly in rice-producing countries alaysia. RHA also contains high amount of silica. However, as low sorption capacity when used alone to remove acidic Therefore, this agricultural waste-siliceous starting material to be activated with other materials and the silica in RHA plays an important role in the formation of reactive species which is responsible for high sorption capacity [5,6].

Previously, we had reported the sorption characteristics of SO_2 and NO over rice husk ash (RHA)-based sorbent at low temperature [5–11]. Nevertheless, our previous reports only dealt with activity measurement related to sorbent preparation conditions and effects of reactor operating conditions. Our previous results also showed that the highest sorption capacity for the simultaneous removal of SO_2 and NO was obtained using RHA/CaO/CeO_2 sorbent. Currently, the optimum preparative parameters for this kind of sorbent had also been reported [12]. On the other hand, the reaction between the siliceous/calcium dry-type sorbents and SO_2/NO is very scarcely reported. The reaction between this siliceous/calcium dry-type sorbents and SO_2/NO are very complicated due to the complex composition of the sorbent. The sorption of these pollutant gases (SO_2/NO) on the sorbents is not a simple physical sorption processes, but also may be described as chemisorption or as gas–solid non-catalytic reactions.

There are various kinetic models that have been employed to estimate kinetic parameters in gas–solid reaction, mainly involves single component sorbent (such as CaO, $Ca(OH)_2$ and $CaCO_3$) and it was carried out mainly at high operating temperature. These kinetics models included shrinking unreacted core model [13], changing grain size model [14] and random pore model [15]. Most of these models contain large number of adjustable parameters related to the pore structure, to the product layer and pore diffusion resistances as well as the surface sorption rate parameters. In addition,

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MESOPOROUS FUNCTIONALIZED ACID CATALYSTS AND THEIR USE AS ENVIRONMENTALY FRIENDLY CATALYSTS IN ESTERIFICATION OF GLYCEROLS FOR MONOGLYCERIDE PRODUCTION

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ABSTRACT

Monoglycerides are valuable compounds with wide applications as emulsifiers in food, pharmaceutical and cosmetic industries. They can be produced by esterification of glycerols with fatty acids. Traditional homogeneous catalysts are usually used in the reaction for commercial scale productions. The processes utilizing homogeneous catalysts possess some drawbacks due to environmental aspect, such as corrosiveness, hazards of waste catalysts, etc. Because of simplicity in catalysts removal and minimization of the amount of waste formed, the utilization of heterogeneous or solid acid catalysts, as an alternative for this process, is an emerging topic on the aspect of the green–chemical processes. However, diffusion limitation of liquids within porous solids dictates that the use of mesoporous materials with pore diameter ranging from 20°A to 100°A is expected to be successful in liquid-phase reactions. The discovery of a family of ordered mesoporous silicas opens up new possibilities for preparing heterogeneous catalysts for liquid phase reactions. This review highlights on recent developments in the synthesis of mesoporous functionalized acid catalysts, for esterification of glycerols by fatty acids to produce monoglycerides.

Keywords: Monoglycerides; Esterification; Glycerol; Mesoporous Functionalized Acid Catalysts

INTRODUCTION

Monoglycerides are valuable compounds that are used as emulsifiers in food, pharmaceutical and cosmetic industries. Monoglycerides are composed of a hydrophilic head and hydrophobic tail. This composition gives them detergency characteristics. They increase permeability of skin and thus make drug absorptions easy [1].

Currently, the commercial scale production of monoglyceride is through direct esterification of glycerols with fatty acids [Fig. 1] that generally relies on traditional homogeneous catalysts using strong mineral acids, such as sulfuric acid and phosphoric acid [1, 2, 3]. However, this technology possesses severe drawbacks, such as the generation

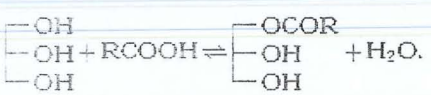

Figure 1: Direct Esterification of Glycerols and Fatty Acid [1]

of large amount of by products, high energy demand and environmental aspects. Techniques for the purification of monoglycerides e.g., distillation are limited to food applications as such process steps are expensive [4]. The replacement of homogeneous catalysts by heterogeneous

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ct of Mass Transfer and Enzyme Loading on the Biodiesel Yield and Reaction Rate in the Enzymatic Transesterification of Crude Palm Oil

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Efforts in minimizing mass transfer effects in enzymatic transesterification of crude palm oil in a biphasic system have always been the compromise between enzyme loading and agitation speed. Therefore, effect of enzyme loading and agitation speed on fatty acid methyl ester (FAME) productivity in terms of intrinsic and external mass transfer limitations and the effective reaction time were determined using factorial design. FAME yield response was significantly affected by agitation speed, enzyme loading and reaction time, whereas initial reaction rate was solely dependent on the enzyme loading. Graphical plots of experimental results revealed that the mass transfer effect for the transport of reactant from bulk liquid to immobilized lipase and within the intraparticle of immobilized lipase were absent at 150 rpm and 6.65% enzyme loading. Optimization conditions for a kinetically controlled domain proposed by the response surface methodology established 100% FAME yield in 4 h reaction time at initial reaction rate of 2.77% FAME yield per min.

Introduction

ısesterification is the reaction of a fat or oil with an l to form esters and glycerol. Enzymatic transesterifica- r fatty acid methyl ester (FAME) production with mild ng conditions and high specificity in product synthesis vents several difficulties arising during chemical pro- . There are two principal considerations in the econo- biodiesel production: (a) the costs of feed (oil and acyl l) and (b) the process operation cost.[1−5] Expenses on ed are attributed to 60−75% of transesterification tion cost.[6−8]

aysia is known as the largest palm oil producers with illion tons of crude palm oil (CPO) production. t becomes a great incentive to promote the develop- of biodiesel production from CPO.[13] The cost for CPO resulted from palm oil extraction is relatively low compared to refined vegetable oil that undergoes process degumming, bleaching, deoderization, and hydrogenation. Besides, CPO contains high triglycerides, that is, over 96%, and low free fatty acid is also another added advantage.

Hexane, petroleum ether, acetone, and other organic solvent have been adopted to dissolve hydrophobic vegetable oil into methanol for homogeneous reaction mixture in addition to removing byproduct glycerol periodically. Consequently, lipase inactivation caused by insoluble methanol and byproduct glycerol can be omitted. However, these hydrophobic organic solvents were unable to completely dilute both methanol and glycerol. Thus, lipase still exhibits poor stability in such reaction media. The use of moderate polarity *tert*-butanol (log $P = 0.35$) dissolves completely the hydrophilic methanol and glycerol together with the hydrophobic vegetable oil when all components are present in equilibrium state. Thus, both the negative effects caused by excessive methanol and byproduct glycerol could be totally eliminated.[14] The application of *tert*-butanol as reaction medium have resulted in high biodiesel yield of 95% catalyzed by the combined Lipozyme TL IM and Novozym 435, and

Table 1. Designated Candidate Points for Process Variables with Corresponding Studied Ranges

factorial design: four levels − three factors		study levels			
dependent variables	independent variables	1	2	3	4
FAME yield	*A*: agitation speed (rpm):	150	175	200	225
initial reaction rate	*B*: enzyme loading (%):	2.5[a]	5.0[a]	7.5[a]	10.0[a]
	C: reaction time (h):	0.00	2.00	4.00	6.00

[a] The percentage of enzyme quantities used in weight per unit weight of CPO.

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nic-assisted biodiesel production process from palm oil using alkaline netal oxides as the heterogeneous catalysts

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ABSTRACT

The ultrasonic-assisted transesterification of palm oil in the presence of alkaline earth metal oxide catalysts (CaO, SrO and BaO) was investigated. Batch process assisted by 20 kHz ultrasonic cavitation was carried out to study the effect of reaction time (10–60 min), alcohol to palm oil molar ratio (3:1–15:1), catalysts loading (0.5–3%) and varying of ultrasonic amplitudes (25–100%). The activities of the catalysts were mainly related to their basic strength. The catalytic activity was in the sequence of CaO < SrO < BaO. At optimum conditions, 60 min was required to achieve 95% yield compared to 2–4 h with conventional stirring. Also, the yields achieved in 60 min increased from 5.5% to 77.3% (CaO), 48.2% to 95.2% (SrO), and 67.3% to 95.2 (BaO). Fifty percentage amplitude of ultrasonic irradiation was deemed the most suitable value and physical changes on the catalysts after the ultrasonic-assisted reaction were successfully elucidated. BaO catalyst underwent relatively more severe activity drop in the catalyst reusability test. Catalysts dissolution was found to be mainly responsible for activity drop of the reused catalysts, especially with BaO catalyst.

tion

is an eco-friendly and alternative energy source for ıes that can be synthesized by transesterification of l or animal fat with alcohols [1]. The reaction can be ' alkalis, acids, or enzymes [2]. Alkali-catalyzed transe- is much faster than acid-catalyzed transesterification often used commercially [1]. Nevertheless, the alkali ıpounds have some drawbacks, i.e. they must be neu- :r the reaction, thus, eliminating the possibility for .ty of the catalyst [3,4]. The neutralization process also rge amount of wastewater that deserves treatment, to nt increase in the production costs [5].

neous catalysis have many advantages: they are rela- orrosive, environmentally benign and present fewer blems. They are also much easier to be separated from cts and can be designed to give higher activity, selec- nger catalyst lifetimes [6]. Alkaline-earth metals oxi- roxides [7–9], alkali metals (Na and K) hydroxides or :ed on γ-alumina [3,10–11], zeolites [12], hydrotalcites been investigated with a variable degree of success. ıonent alkaline earth metal oxides (BaO, SrO, CaO, have higher basicity, lower solubility in alcohol and producing higher biodiesel yield have also been reported [9]. However, complete behavior of these catalysts in the transesterification process is yet to be fully understood [9,14].

As oil and methanol are not completely miscible, the mixing efficiency can affect the course of the transesterification reaction. The reaction can only occur in the interfacial region between the methanol, oil and catalyst and the alkaline earth oxide catalysts are essentially insoluble in the two phases. Continuous and vigorous mixing is then required to increase the area of contact between the three phases [15,16]. The mixing process generally increases energy input for biodiesel production process, yet the biodiesel yield is generally lower then that in the homogeneous process [9].

Low frequency ultrasound is theoretically seen as an efficient, time saving and economically functional method to accelerate biodiesel production process [17]. Ultrasonic mixing can produce smaller droplets of the reacting phases than conventional agitation, leading to a drastic increase in the interfacial area and improved mass transfer [18]. As a result, the mixing requirement during the process is also significantly lowered, translating in reduced energy consumption [15]. Ultrasonic can also 'grind' the catalyst into smaller particles to create new active sites for the subsequent reaction. Thus, the solid catalyst is expected to last longer in the ultrasonic-assisted process.

The main aim of this study was to characterize the effects of ultrasonic energy in presence of alkaline earth metal oxides as heterogeneous catalysts. As reported in literature, most of the transesterification processes for biodiesel production use some oils other than palm oil such as rapeseed oil [19] and soybean oil [4,8,10]. As

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alytic Technology for Carbon Dioxide Reforming of :hane to Synthesis Gas

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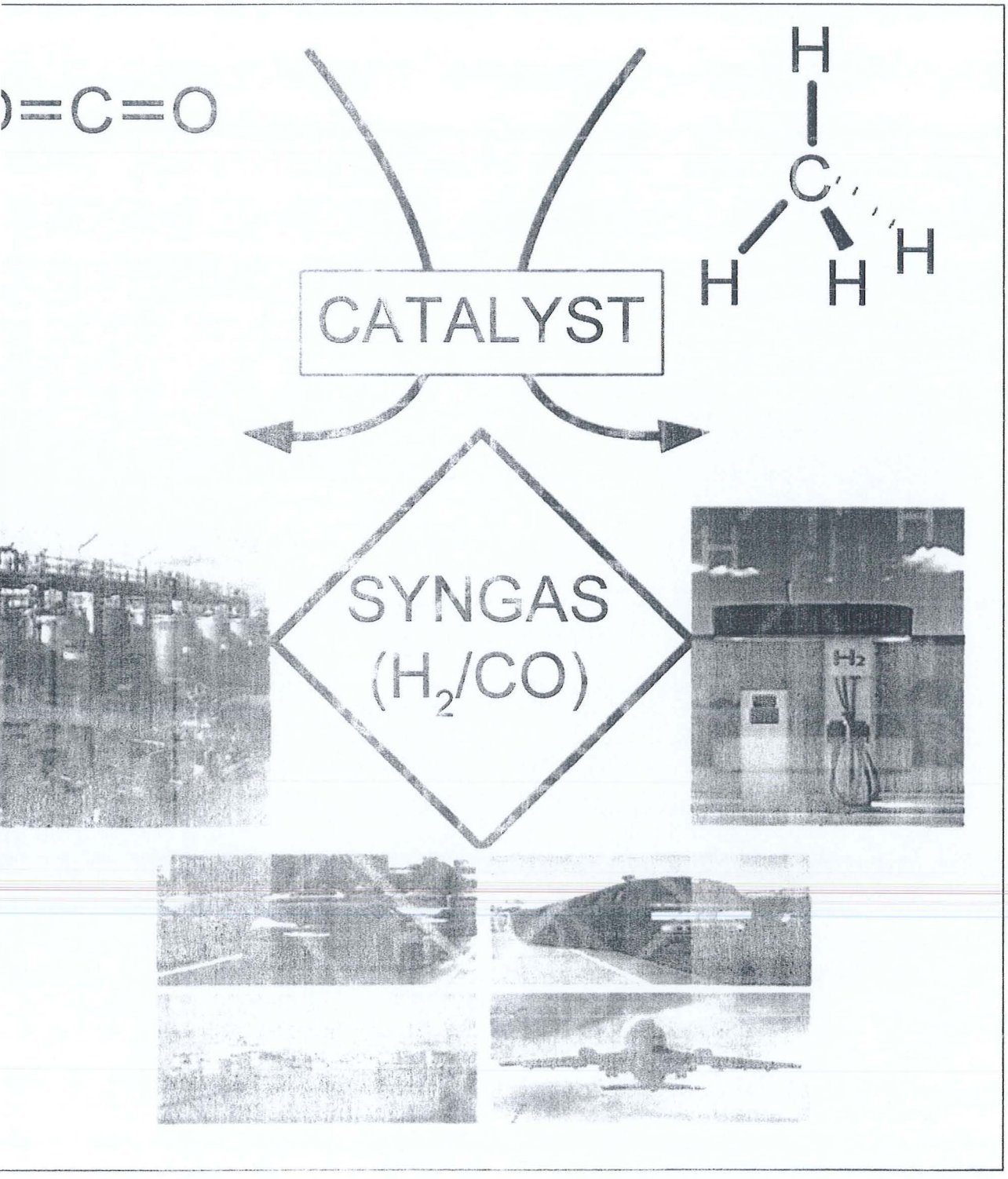

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ıtalytic Technology for Carbon Dioxide Reforming of ethane to Synthesis Gas

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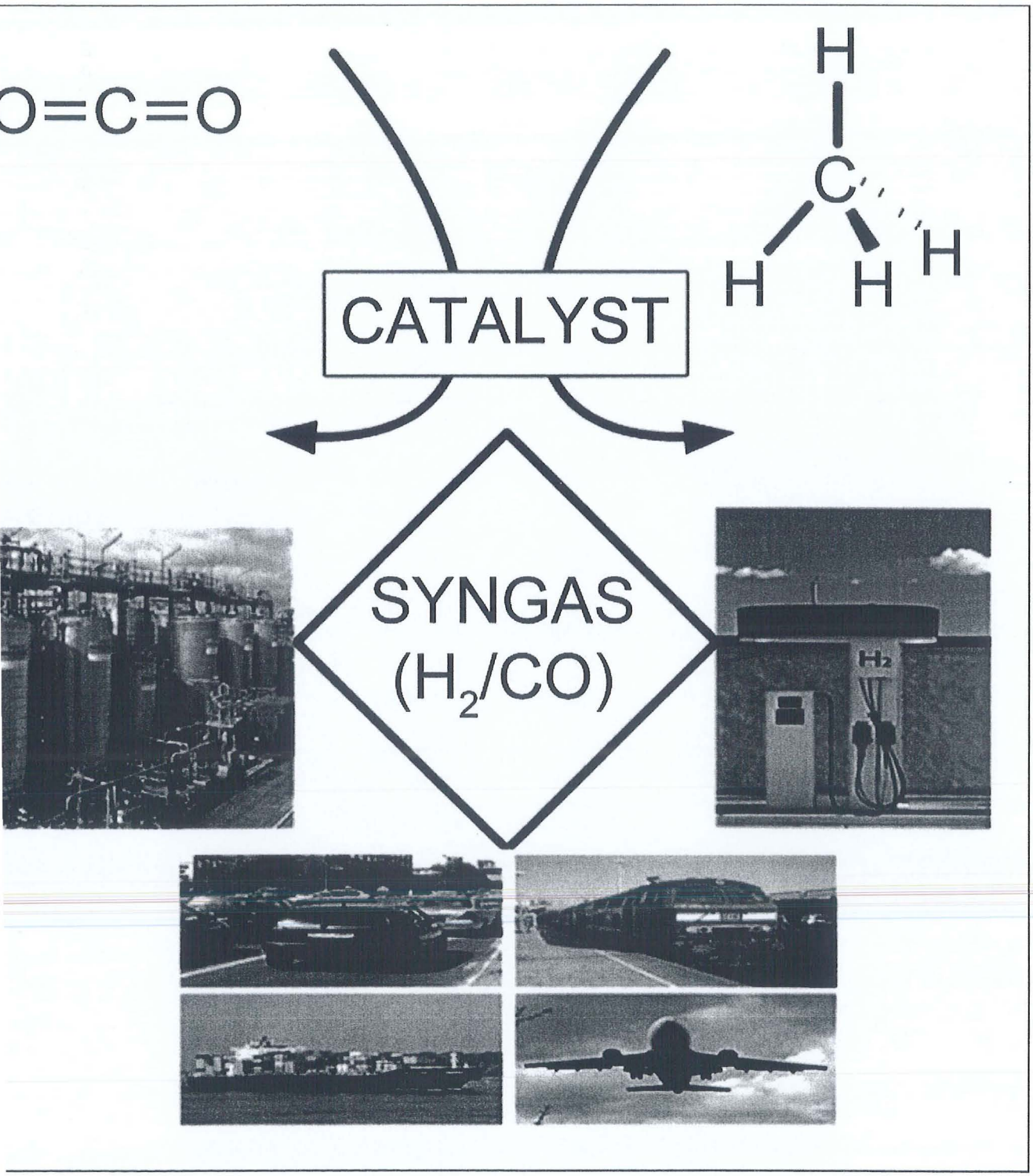

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treatment effects on the characteristics and sonocatalytic performance of n the degradation of organic dyes in aqueous solution

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ABSTRACT

The ambient sonocatalytic degradation of congo red, methyl orange, and methylene blue by titanium dioxide (TiO_2) catalyst at initial concentrations between 10 and 50 mg/L, catalyst loadings between 1.0 and 3.0 mg/L and hydrogen peroxide (H_2O_2) concentrations up to 600 mg/L is reported. A 20 kHz ultrasonic processor at 50 W was used to accelerate the reaction. The catalysts were exposed to heat treatments between 400 and 1000 °C for up to 4 h to induce phase change. Sonocatalysts with small amount of rutile phase showed better sonocatalytic activity but excessive rutile phase should be avoided. TiO_2 heated to 800 °C for 2 h showed the highest sonocatalytic activity and the degradation of dyes was influenced by their chemical structures, chemical phases and characteristics of the catalysts. Congo red exhibited the highest degradation rate, attributed to multiple labile azo bonds to cause highest reactivity with the free radicals generated. An initial concentration of 10 mg/L, 1.5 g/L of catalyst loading and 450 ppm of H_2O_2 gave the best congo red removal efficiency of above 80% in 180 min. Rate coefficients for the sonocatalytic process was successfully established and the reused catalyst showed an activity drop by merely 10%.

uction

tly, it is estimated that about 10,000 different types of ial dyes and pigments exist and over 700,000 tones are annually [1,2]. About 10–20% of the total world produces is lost during the dyeing process and is released into nts [3]. Industrial dyestuffs constitute one of the largest organic compounds that cause an increasing environncern [4]. Therefore, a lot of studies have been dedicated is wastewater by using advanced oxidation process which ydroxyl (•OH) radicals to mineralize the organic comifferent degrees of success have been reported but the could subject to some common drawbacks like high capinning costs, the needs for toxic chemicals and low removal , especially at low concentrations. Photocatalytic degranother plausible method but its practicality is generally ith heavily colored effluent, high photocatalyst loading volume operation due to low penetration of the UV light

plication of ultrasounds in water with a frequency range n 18 and 100 MHz can result the phenomenon of acoustic . It involves the formation, growth and collapse of cavs that entrapped dissolved gases or vapors surrounding water [5,6,7]. Subsequently, many local hot spots with extremely high temperature (up to 5000 K) and high pressure (up to 1000 atm) are generated to consequently induce the dissociation of water (Eqs. (1)–(4)), oxygen molecules (Eqs. (5)–(8)) and hydrogen peroxide (H_2O_2) (Eq. (9)) in the case of its addition into the effluent [5,7,8].

$$H_2O \xrightarrow[TiO_2]{))))} \cdot OH + H\cdot \quad (1)$$

$$^{\bullet}OH + H^{\bullet} \rightarrow H_2O \quad (2)$$

$$2^{\bullet}OH \rightarrow H_2O_2 \quad (3)$$

$$2^{\bullet}OH \rightarrow H_2O^{\bullet} + O^{\bullet} \quad (4)$$

$$O_2 \xrightarrow[TiO_2]{))))} 2O\cdot \quad (5)$$

$$^{\bullet}O + H_2O \rightarrow 2^{\bullet}OH \quad (6)$$

$$O_2 + H^{\bullet} \rightarrow {}^{\bullet}O_2H \quad (7)$$

$$^{\bullet}O_2H + {}^{\bullet}O_2H \rightarrow H_2O_2 + O_2 \quad (8)$$

$$H_2O_2 \xrightarrow[TiO_2]{))))} 2\cdot OH \quad (9)$$

As a semiconductor material, TiO_2 is characterized by a filled valence band and an empty conduction band [3,4]. In the presence of suitable energy source, the excitation of electron from the valence band to the conduction band could occur. With the presence of UV light or ultrasonic irradiation as the energy source,

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Optimization of Process Parameters for Alkaline-Catalysed Transesterification of Palm Oil Using Response Surface Methodology

(Pengoptimuman Parameter Proses untuk Transesterifikasi Minyak Sawit Bermangkin Alkali Menggunakan Kaedah Sambutan)

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ABSTRACT

iodiesel (fatty acid methyl esters) was synthesized from direct transesterification of vegetable oils, where the corresponding riglycerides react with methanol in the presence of a suitable catalyst. The alkali catalysts are the most common catalyst sed in biodiesel industry because the process proves faster and the reaction conditions are moderate compared to the cid catalyst. In the present study, biodiesel production using heterogeneous alkaline-catalysed transesterification process KOH supported on SBA 15) was proposed. The influence of reaction temperature x_1 (50 - 90°C), ratio of methanol to oil, $_2$ (6:1 – 14:1 mol/mol), amount of catalyst, x_3 (1 – 5wt.%), and reaction time, x_4(2 - 6h) to the reaction was studied. hese four conditions were studied using design of experiment (DOE), based on four-variable central composite design CCD) with $\alpha = 2$. The process variables were optimised using the Response Surface Methodology (RSM) in obtaining the aximum yield of biodiesel. This method was also applied to determine the significance and interaction of the variables ffecting the biodiesel production. The biodiesel produced in the experiment was analysed by gas chromatography, which onsidered five major fatty acid methyl esters. The optimal conditions of response were found to be 70°C for reaction emperature, 11.6 wt/wt of ratio methanol to oil, 3.91wt.% of weight of catalyst and 5 h for reaction time with 93% of iodiesel yield for predicted value and 87.3% from experimental.

eywords: Base catalyst; biodiesel; response surface methodology

ABSTRAK

iodiesel telah disintesis daripada transesterifikasi langsung minyak sayuran yang melibatkan trigliserida bertindak balas engan metanol dengan kehadiran mangkin yang sesuai. Mangkin beralkali adalah mangkin yang biasanya digunakan i dalam industri biodiesel kerana proses terbukti lebih cepat dan keadaan tindak balas sederhana berbanding dengan angkin berasid. Dalam kajian ini, penghasilan biodiesel menggunakan proses transesterifikasi bermangkinkan heterogen eralkali (KOH disokong di atas SBA-15) telah dikaji. Kesan suhu tindak balas, x_1 (50 - 90°C), nisbah metanol kepada inyak, x_2 (6:1 – 14:1 mol/mol), berat mangkin, x_3 (1 – 5wt.%), dan masa, x_4(2 - 6 h) terhadap tindak balas dikaji. Empat eadaan ini telah dikaji menggunakan reka bentuk eksperimen (DOE) berdasarkan kepada empat pembolehubah reka bentuk ubungan berpusat (CCD) dengan $\alpha = 2$. Pembolehubah proses telah dioptimumkan menggunakan kaedah sambutan ermukaan (RSM) dalam mendapatkan hasil biodiesel yang maksimum. Kaedah ini juga digunakan untuk menentukan pentingan dan interaksi pembolehubah-pembolehubah yang mempengaruhi hasil biodiesel. Biodiesel yang dihasilkan lah dianalisis melalui kromatografi yang mengambilkira lima metil ester asid lemak utama. Keadaan optimum sambutan dapati pada suhu tindak balas 70°C, nisbah metanol kepada minyak 11.6 mol/mol, berat mangkin 3.91 wt.% dan 5 jam asa tindak balas dengan 93% hasil biodiesel keluaran untuk nilai jangkaan dan 87.3% daripada eksperimen.

ata kunci: Biodiesel; kaedah sambutan permukaan; mangkin beralkali

INTRODUCTION

ue to environmental, green chemistry and economic ncerns, current research trend in catalysis has been cused on the transformation of homogeneous catalytic stem into heterogeneous systems. The replacement homogeneous catalysts by heterogeneous catalysts ould have various advantages, most important being e application of easier working up procedures, the easy talyst separation from the reaction mixture and the duction of environment pollutants (Venkatesan et al. 04). Besides that, the process of transesterification is affected by various factors depending upon the reaction condition used. Some of the effects are free fatty acid and moisture of the source of oil, type of oil, catalyst type and concentration, molar ratio of alcohol to oil, type of alcohol, reaction time and temperature, mixing intensity and effect of solvents (Lopez et al. 2005; Meher et al. 2004) The economic and environmental interest in using oil and fats are also involved in the production of biodiesel.

The objective of this study was to optimize process variables of transesterification. The process variables studied were reaction temperature, ratio of methanol to

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upercritical liquefaction of oil palm fruit press fiber for the production of l: Effect of solvents

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ABSTRACT

Thermal decomposition of oil palm fruit press fiber (FPF) with sub/supercritical methanol, ethanol, acetone, and 1,4-dioxane treatments were investigated using a high-pressure autoclave reactor. When FPF was decomposed with methanol, ethanol, and acetone from 483 to 603 K, the highest degree of conversion obtained were 81.5%, 77.8%, and 67.9% while the highest liquid product yield (LP) obtained were 38.0%, 36.9%, and 38.5%, respectively. For the case of 1,4-dioxane, the conversion of FPF increased from 18.30% to 80.00%, while LP yield increased dramatically from 13.30% to 50.90% (consisting of 42.3% bio-oil compounds) when the reaction temperature was increased from 483 to 563 K. However, the conversion of FPF and LP yield decreased to 69.60% and 24.10%, respectively, when the temperature was further increased to 603 K. Comparison between all the solvents, subcritical 1,4-dioxane treatment was found very effective in the degradation of FPF to produce bio-oil component.

action

il is the most important Malaysian agriculture crop. It is that around 4.88 million hectares of land in Malaysia for palm oil cultivation in 2008. Malaysia is one of the n oil producing and exporting countries in the world duces about 37.00 million tones of palm oil biomasses five million tons oil palm fruit pressed fiber (FPF) in zaheri et al., 2010). In the past two decades, in spite of nergy resources such as hydro, wind, solar and nuclear omass has been regarded as a new energy resource be- very cheap, clean and abundantly available in many e world (Demirbas, 2001). Besides, the damages resulted g fossil fuel such as air pollution, green house effect, toxic al warming and acid rain on one part and increasing day he crude oil price on the other part, makes it important a new energy resource such as biomass and the conver- ods for utilizing it. Furthermore rising consumption of nds of energy such as gas, oil and coal and limitation in resources have increased the importance of this subject l. Therefore, it seems that finding a new method for con- e huge biomass energy resources to useable energy is

ochemical treatment is one of the potential ways to omass to biofuel. Under the umbrella of thermochemi- ent, recently sub/supercritical fluid has (SCF) attracted more attention than other processes because the process is environmentally friendly and can be carried out at relatively lower temperature. A fluid is named supercritical when its temperature and pressure goes higher than the critical pressure (P_C) and critical temperature (T_C) that indicates the end of the vapor liquid coexistence curve as well as gases and liquids are indistinguishable fluids and any difference between liquid and gaseous phases disappears. In fact, matter that exists in the region above the critical points (e.g., T_C and P_C), which is a new phase, is called supercritical fluid (SCF). Supercritical fluids have liquid like properties such as high density that means more dissolving power properties which allow the solvation of many compounds in supercritical fluids. Besides, supercritical fluids also have gas like properties such as high diffusivity and low viscosity which enhance mass transfer rates of reactants to the active biomass's molecules and readily penetrate porous and fibrous solids. Therefore, reactions which are limited by the rates of diffusion, rather than natural kinetics, will proceed faster in supercritical fluids than in liquids. These drastic changes mean that SCF is adjustable for different applications (Tucker, 1999). Since it is well-known that the dielectric constant, viscosity, and other physical properties of SCF are functions of density, and since density varies with pressure, these properties are also strongly pressure-dependent. In other words, small changes in pressure lead to significant changes in density, which in turn alters all density dependent solvent properties such as dielectric constant and thermal conductivity. The ability to change the physical properties of the solvent by simply manipulating the pressure or temperature is unique to supercritical systems (Jessop et al., 1999).

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Selective Catalytic Reduction of Nitric Oxide in Diesel Engine Exhaust over Monolithic Catalysts Washcoated with Bimetallic Cu-Zn/ZSM-5

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ostract

Selective catalytic reduction (SCR) of nitric oxide (NO) in diesel engine exhaust over Cu-Zn/ZSM-5 washcoated ramic monolithic catalysts is reported. The washcoat component was prepared by ion-exchanging ZSM-5 (Si/Al=40) th zinc while copper was incorporated through impregnation. The dispersed washcoat component was then incorporated o 400 cpsi ceramic monolith through a dipping process with the final loadings between 19.6 wt. % and 31.4 wt. %. The R process was studied with a feed comprising of 900 ppm NO, 2,000 ppm iso butane and 3 % oxygen at gas hourly space ocities (GHSV) between 5,000 and 13,000 h^{-1}. NO conversion increased until a loading of 23.6 wt. % to give a conversion 88 % at 400 °C. The activity dropped at higher loadings due to the partial blockage of cell openings and diffusion itations while unstable washcoating adherence was also demonstrated. After an initial deactivation of about 10 % in the t 48 h, this catalyst showed stable residual activity. Between 325 and 375 °C, minimal effect on the activity was detected en the space time was reduced from 0.94 s to 0.24 s, suggesting the absence of external mass transfer limitations for up a GHSV of 16,000 h^{-1}.

ywords: NO; selective catalytic reduction; ZSM-5; ceramic monolith; performance.

Introduction

Diesel engine owes its popularity to its high fuel ficiency, reliability, durability and relatively low fuel ce. This engine is run under oxygen excess condition a so called lean-burn operation. However, the eration increases the production of toxic gas e.g. ric oxides (NO) which cause severe environmental d health problems. Catalytic processes have been dely investigated for NO_x removal and selective alytic reduction (SCR) being the most popular one olis *et al.*, 2001; Pisarello *et al.*, 2002; Bennici *et* 2005). The SCR technology is still immature and veral drawbacks are yet to be satisfactorily dressed.

For a deNO_x unit, pressure drop is a key issue denbrand *et al.*, 1999; Makkee *et al.*, 2002). In a exhaust or a power plant flue gas system, the ssure drop should ideally be below 10-20 mbar ijger *et al.*, 2001). Additional demands comprise sensitivity to dust and resistance to thermal shock. uctured packings, like monolithic are gaining interest application in NO_x reduction (Zamaro *et al.*, 2005; eno-Lopez *et al.*, 2005) as the pressure drop in se catalysts is significantly lower than that of domly packed bed catalysts (Cybulski *et al.*, 1999). ong various types of monolith, ceramic monoliths ng the most widely used substrate material, mainly because of its relatively low manufacturing costs and high thermal stability (Heck *et al.*, 2001). However, the specific surface of most structured supports is below 1 m^2/g, which is way too low for catalytic purposes. The specific surface area can be enhanced up to about 40 m^2/g by washcoating with suitable microporous or mesoporous materials. As zeolites have a specific surface area of 300-700 m^2/g, a monolayer of zeolite may serve the need for surface area and porosity (Seijger *et al.*, 2001). The ZSM-5 washcoated ceramic monolith catalysts provide interesting advantage in the SCR of NO_x starts receiving attention among researchers (Zamaro *et al.*, 2005; Li *et al.*, 2008). ZSM-5 possesses high surface area of about 370 m^2/g and has been demonstrated to have high hydrothermal stability and suitability in many environmental catalysis applications in our earlier works (Deeng *et al.*, 2004; Abdullah *et al.*, 2003; Abdullah *et al.*, 2006).

Among metals studied as the active component of the catalyst are Cu (Deeng *et al.*, 2004), Pt (Ismail *et al.*, 2002) and Co (Ren *et al.*, 2002). By reviewing the results, Cu should provide superiority on the basis of high activity, high stability, low toxicity and low cost. Therefore, it was used in this study. Recently, the bimetallic catalysts have created particular interest due to the promoting effect between metal species (Ismail *et al.*, 2002). The second metal should be able to

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f catalyst additives on the production of biofuels from palm oil cracking nsport riser reactor

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ABSTRACT

Catalytic cracking of crude palm oil (CPO) and used palm oil (UPO) were studied in a transport riser reactor for the production of biofuels at a reaction temperature of 450 °C, with residence time of 20 s and catalyst-to-oil ratio (CTO) of 5 g g^{-1}. The effect of HZSM-5 (different Si/Al ratios), beta zeolite, SBA-15 and AlSBA-15 were studied as physically mixed additives with cracking catalyst Rare earth-Y (REY). REY catalyst alone gave 75.8 wt% conversion with 34.5 wt% of gasoline fraction yield using CPO, whereas with UPO, the conversion was 70.9 wt% with gasoline fraction yield of 33.0 wt%. HZSM-5, beta zeolite, SBA-15 and AlSBA-15 as additives with REY increased the conversion and the yield of organic liquid product. The transport riser reactor can be used for the continuous production of biofuels from cracking of CPO and UPO over REY catalyst.

on

defined as liquid or gaseous fuel for transport purpose roduced from the utilization of biomass substrates or Stocker, 2008). The increasing interest for biofuels due to the depletion of fossil fuel. Plant oils, espeil has attracted attention of researchers to develop entally friendly and high quality fuel, which is free nd sulfur (Tamunaidu, 2006). In recent years, there veral studies on the production of hydrocarbons (i.e. gasoline) from plant oils such as castor, soybean, ca- (Albuquerque et al., 2009), algal oil (Sharif Hossain and palm oil (Twaiq et al., 1999; Yean-Sang et al., types of catalysts.

racking is one of the routes for obtaining liquid fuels inear and cyclic paraffins, olefins, aldehydes, ketones ic acids (Chew and Bhatia, 2008). Different reaction e been described for studying catalytic cracking on y-scale. One of the most common systems used for king studies of gas oil and palm oil is the fixed bed mi- est or MAT unit (Tamunaidu and Bhatia, 2007). There tudies reported on the production of biofuels from l (CPO), used palm oil (UPO) and palm oil-based fatty (FAM), using zeolites as a cracking catalyst in a micro- q et al., 1999; Yean-Sang et al., 2004a,b). The gasoline, kerosene and diesel fractions obtained from CPO, UPO or FAM were similar in compositions to the commercial petroleum products as determined from gas chromatography analysis (Yean-Sang et al., 2004a).

Li et al. (2009) studied the catalytic cracking of cottonseed oil in a fixed-fluidized bed reactor. In the presence of fluidized catalytic cracking (FCC) equilibrium catalyst (zeolite), liquid product rich in gasoline and diesel fraction was produced. The maximum yield of light fuel oil (65.6 wt% at 360 °C) and gasoline fraction (33.7 wt% at 205 °C) were obtained at optimum condition. Lappas et al. (2008) was able to obtain conversions higher than 85 wt% for catalytic cracking of wax performed in a bench scale automated fixed bed unit using commercially available FCC catalysts.

Various catalysts are reported for cracking of triglycerides. The choice of the catalyst plays an important role in the cracking of triglyceride. Since zeolites are extremely active, therefore it has been tested extensively for catalytic cracking, especially of vegetable oil by several researchers (Twaiq et al., 1999; Yean-Sang et al., 2004a). The common zeolites are H–Y, H-Beta, H-mordenite, Ultra-stable Y (USY) and HZSM-5. There are also studies of catalytic cracking of palm oil over various mesoporous catalysts such as MCM-41 and SBA-15 (Twaiq et al., 2003a,b, 2004; Yean-Sang et al., 2004c) beside microporous zeolite catalysts. Different catalysts will lead to different product distribution of catalytic cracking (Chew and Bhatia, 2008). Corma et al. (2007) studied catalytic cracking of glycerol and sorbitol, in the presence of 6 different catalysts, including a fresh FCC catalyst, an equilibrium FCC catalyst with metal impurities (ECat), a mesoporous Al_2O_3, a USY zeolite (Y), a ZSM5-based

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ydrodynamic study of zeolite-based composite cracking talyst in a transport riser reactor

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ABSTRACT

A composite catalyst containing H-Y zeolite and kaolin suitable for catalytic cracking of palm oil for the production of biofuels was synthesized by sol–gel–sieve method. In this study, we report the results of the hydrodynamic studies using a composite catalyst in a transport riser reactor. The hydrodynamic study confirms that the pressure difference across the transport riser reactor varies with the superficial gas velocity and it becomes significant at the bend section of the reactor. The pressure buildup occurs when the superficial fluid velocity reaches bubbling fluidization velocity. A model incorporating different dimensionless groups correlated with the pressure difference in transport riser reactor at different operating conditions. The proposed model predicted the pressure drop within an average error of ±20% in a transport riser reactor.

Keywords: Composite cracking catalyst; Transport riser reactor; Hydrodynamic studies; Pressure drop; Superficial gas velocity

Introduction

depletion of crude oil has attracted researchers to explore lternative energy source. Palm oil is one of the alterna- eedstock which can be used to produce an environmental dly and high quality biofuels that are free of nitrogen and r (Ooi et al., 2004b; Tamunaidu and Bhatia, 2007). Cur- y, a substantial amount of the crude palm oil is used to uce biodiesel by reacting crude palm oil with methanol nvert it into methyl esters. However, biodiesel cannot be in gasoline engines and there is a need to develop a direct ss to convert palm oil into bio-gasoline suitable for gaso- ngines. Zeolites as the cracking catalyst for palm oil could ively produce variety of liquid hydrocarbon fuels (Twaiq , 2003a,b; Ooi et al., 2004a,b; Wachter, 2005; Tamunaidu Bhatia, 2007). The catalytic cracking process could take at lower temperature compared to thermal cracking and oke is deposited on the catalyst during cracking process ng to catalyst deactivation. Hence, the removal of coke in atalyst is done in separate reactor by burning the coke presence of air and the regenerated catalyst is recycled to the cracking reactor.

Fluid catalytic cracking (FCC) process has been used in the refinery for the production of gasoline, kerosene, diesel and olefins from gas oil. Transport riser reactor is an integral part of the catalytic cracking process. Our past research has shown that the catalytic cracking of palm oil for the production of biofuels could be carried out in transport riser reactor (Tamunaidu and Bhatia, 2007). However, there is a need of suitable cracking catalyst to be used in a transport riser reactor for obtaining reasonable yield of bio-gasoline in order to make the process economical. The activity of the catalyst increased with the increasing of alumina content up to an optimum level then decreased with the further increase of alumina content due to the decreasing of the crystallinity (Twaiq et al., 2003b). Extensive works have been done in developing the cracking catalyst for bio-gasoline production (Twaiq et al., 2003c; Ooi et al., 2004a,b).

The hydrodynamic plays an important role in the design of transport riser reactor. The full scale-up of circulating fluidized beds requires at least five dimensionless groups, four groups are required in the inertial limit and three groups are sufficient for similarity (Van der Meer et al., 1999). The riser diameter influences in opposite manner for Geldart A par-

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provement of loose contact diesel soot oxidation by synergic ffects between metal oxides in K_2O–V_2O_5/ZSM-5 catalysts

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esel soot; Oxidation; K_2O–V_2O_5/ZSM-5; Loose contact; Synergic effect

ion

nany other types of pollutants emitted, diesel ally emit significant amount of soot and nitro- (NOx). To protect the environment, the two nave to be removed from the exhaust gas. As ons on diesel engine emissions becoming more he engine modification and the exhaust after re needed. While NOx can be removed by cat-ction processes [1], soot particulates are com-ected on a catalytic filter and periodically CO_2 [2]. The catalyst in the trap must be suffi-ve to oxidize the soot within the exhaust gas es (300–400 °C) [3]. The catalysts' activity and key factors in determining its applicability in al scale.

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As loose contact between the catalyst and soot always leads to lower oxidation activity than the tight contact, active catalytic formulations should also include other components with high mobility [6]. Potassium has been proposed to increase the effective contact with the soot due to its high mobility [6,8]. However, report on the combination of transition metal and potassium as the soot

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Selective Catalytic Reduction of Nitric Oxide in Diesel Engine Exhaust over Monolithic Catalysts Washcoated with Bimetallic Cu-Zn/ZSM-5

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stract

Selective catalytic reduction (SCR) of nitric oxide (NO) in diesel engine exhaust over Cu-Zn/ZSM-5 washcoated amic monolithic catalysts is reported. The washcoat component was prepared by ion-exchanging ZSM-5 (Si/Al=40) h zinc while copper was incorporated through impregnation. The dispersed washcoat component was then incorporated o 400 cpsi ceramic monolith through a dipping process with the final loadings between 19.6 wt. % and 31.4 wt. %. The R process was studied with a feed comprising of 900 ppm NO, 2,000 ppm iso butane and 3 % oxygen at gas hourly space ocities (GHSV) between 5,000 and 13,600 h^{-1}. NO conversion increased until a loading of 23.6 wt. % to give a conversion 88 % at 400 °C. The activity dropped at higher loadings due to the partial blockage of cell openings and diffusion itations while unstable washcoating adherence was also demonstrated. After an initial deactivation of about 10 % in the t 48 h, this catalyst showed stable reaction activity. Between 325 and 375 °C, minimal effect on the activity was detected en the space time was reduced from 0.94 s to 0.24 s, suggesting the absence of external mass transfer limitations for up GHSV of 16,000 h^{-1}.

ywords: NO; selective catalytic reduction; ZSM-5; ceramic monolith; performance.

Introduction

Diesel engine owes its popularity to its high fuel ficiency, reliability, durability and relatively low fuel ce. This engine is run under oxygen excess condition a so called lean-burn operation. However, the eration increases the production of toxic gas e.g. ric oxides (NO) which cause severe environmental l health problems. Catalytic processes have been ely investigated for NO_x removal and selective alytic reduction (SCR) being the most popular one lis *et al.*, 2001; Pisarello *et al.*, 2002; Demicci *et* 2005). The SCR technology is still immature and eral drawbacks are yet to be satisfactorily ressed.

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Among metals studied as the active component of the catalyst are Cu (Deeng *et al.*, 2004), Pt (Ismail *et al.*, 2002) and Co (Ren *et al.*, 2002). By reviewing the results, Cu should provide superiority on the basis of high activity, high stability, low toxicity and low cost. Therefore, it was used in this study. Recently, the bimetallic catalysts have created particular interest due to the promoting effect between metal species (Ismail *et al.*, 2002). The second metal should be able to

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Recent Patents on Photocatalysis over Nanosized Titanium Dioxide

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Abstract: The concern over increasing presence of complex refractory compounds in the wastewater streams, the conventional treatment method cannot be used for complete treatment of the effluent. These current problems have provided incentives to develop newer technologies to improve performance of existing technologies. In this paper, photocatalytic process (belonging to the class of advanced oxidation processes) is presented to show the potential of nanosized TiO_2 semiconductor photocatalysis towards the refractory compounds into less harmful molecules. The work highlights the basics of this process including the various nanosized TiO_2 synthesis methods and a description of the attempts and possibilities to improve its reactivity in the recent years. Besides, information on the photocatalytic reactor design, other aspects with a complete overview of the various applications to wastewater treatment is also provided. The present review paper seeks to offer an overview of the dramatic trend in the use of the nanosized TiO_2 photocatalysis for the remediation and decontamination of wastewater, report on recent work done, important achievement and problems. The present article discusses the useful patents in the field of photocatalysis over nanosized titanium dioxide

Keywords: Photocatalysis, organic contaminants degradation, nanosized titanium dioxide, photoreactor.

1. INTRODUCTION

New developments in the variety of fields to meet the ever-increasing requirements of human beings have also led to the presence of new compounds in the effluent streams of processing plants, which are not readily degraded by the conventional effluent treatment methods [1-3]. The focus on waste minimization and water conservation in recent years has also resulted in the production of concentrated or toxic residues. It is of utmost importance to dispose off these residues in a proper manner as well as to keep the concentration of chemicals in the effluent stream to a certain minimum level in order to comply with the environmental laws, which are becoming more stringent these days. As a response, the research into more efficient waste water treatment technologies so as to degrade the complex refractory molecules into simpler molecules is vital to combat the deteriorating water quality.

Advance oxidation processes (AOPs) are one example of an environmental friendly approach for treating the effluent containing the new toxic chemicals, refractory and biodegradable compounds. Typically AOPs are ambient temperature and pressure process that involve *in situ* generation of highly reactive species such as hydroxyl radical ($^{\bullet}OH$). The $^{\bullet}OH$ radicals are powerful oxidizing reagents with an oxidation potential of 2.80 V and exhibits faster rates of oxidation reactions as compared to that using conventional oxidants like hydrogen peroxide or $KMnO_4$ [4]. Among AOPs, photocatalytic oxidation (PCO) has proved to be of real interest as efficient tool for degrading aquatic organic contaminants. PCO involves the acceleration of photoreaction in presence of semiconductor photocatalyst. One of the major applications of PCO is heterogeneous ph catalysis to effect total mineralization of liquid phase org contaminants. The term "photocatalytic degradation" usu refers to complete photocatalytic oxidation or ph mineralization, essentially to CO_2, H_2O, NO_3^-, PO_4^{3-} halides ions [5, 6].

Titania photocatalysis also referred to as the "Hon Fujishima effect" was first unfolded by the pioneer research of Fujishima and Honda in 1972. These auth revealed the possibility of water splitting by ph electrochemical cell having an inert cathode and rutile tit anode. As a consequence, the application of titania ph catalysis extended to environmental frontiers. Ever si 1977, when Frank and Bard first examined the possibili of using TiO_2 to decompose cyanide in water under sunli there has been increasing interest in environme applications. By far, titania has played a much larger rol this scenario compared to other semiconductor ph catalysts due to its cost effectiveness, inert nature photostability. Extensive literature analysis has shown m possibilities of improving the efficiency of photodegradat over titania by manipulating the TiO_2 structures at na scale to increase intrinsic activity and selectivity [7, Recent research results on improving TiO_2 photocatal activities such as metal doping and integrated with adsorb for water and air pollution controls are used to show h novel catalytic properties can be discovered by uni photocatalytic oxidation process but common materials at nano-scale.

As part of the dawn, there is general agreement that important in the development of highly efficient ph catalytic reactors to realize nanosized TiO_2 intri performance. This is particularly true in the context of sca photocatalytic reactors processing large volumes of wa generated with the present level of knowledge about th reactors. Many researchers have stressed that several asp

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Catalytic oxidation of butyl acetate over silver-loaded zeolites

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performance of silver-loaded zeolite (HY and HZSM-5) catalysts in the oxidation of butyl acetate as a model volatile organic compound was studied. The objective was to find a catalyst with superior activity, selectivity towards deep oxidation product and stability. The catalyst y was measured under excess oxygen condition in a packed bed reactor operated at gas hourly space velocity (GHSV) = 15,000–32,000 h^{-1}, n temperature between 150 and 500 °C and butyl acetate inlet concentration of 1000–4000 ppm. Both AgY and AgZSM-5 catalysts exhibited ctivity in the oxidation of butyl acetate. Despite lower silver content, AgY showed better activity, attributed to better metal dispersion, surface teristics and acidity, and its pore system. Total conversion of butyl acetate was achieved at above 400 °C. The oxidation of butyl acetate ed a simple power law model. The reaction orders, *n* and *m* were evaluated under differential mode by varying the VOC partial pressure en 0.004 and 0.018 atm and partial pressure of oxygen between 0.05 and 0.20 atm. The reaction rate was independent of oxygen concentration gle order with respect to VOC concentration. The activation energies were 19.78 kJ/mol for AgY and 32.26 kJ/mol for AgZSM-5, respectively.

ds: Butyl acetate; Silver; Zeolites; Catalyst; Characterization; Activity; Kinetic

troduction

e choice of the volatile organic compound (VOC) emission nent technique depends on the characteristics of the efflu- be treated, such as the nature of VOC, its concentration s flow rate [1]. Catalytic oxidation that can be effectively d in a wide range of VOCs concentrations and waste gas ates presents an interesting solution for VOCs elimina- ']. The catalytic process permits the oxidation reaction to at a significantly lower temperature than that required by al oxidation processes. There are two types of catalysts an be used in catalytic oxidation, i.e. metal oxides and ted noble metals [2,3–5]. The selection between a metal or a noble metal is generally influenced by several fac- ch as the nature of the gaseous stream to be treated and sence of contaminants. However, it is generally accepted ble metals are more active than metal oxides but the lat- more resistant to poisoning [6]. Pt and Pd are the most on noble metals used for total oxidation of VOCs [7] and , they are supported on an oxide such as Al_2O_3 or SiO_2. In general, platinum exhibits higher activity than palladium for the total oxidation of VOCs [8].

Oxides of transition metals such as copper, chromium, manganese and nickel can tolerate higher levels of poisons but the activity shown by these oxides are usually lower than that of noble metal-based catalyst [4]. Silver has recently gained much interest for low temperature NOx reduction [9] and CO oxidation [10]. Thus, it could be a suitable catalyst for many redox reactions like VOC oxidation. Pioneering works by Cordi and Falconer [11] led to the conclusion that Ag/Al_2O_3 catalyst was very active for the complete oxidation of VOC to CO_2 and H_2O. VOC was hypothesized to diffuse along the alumina surface and reacted at the silver sites, where oxygen is adsorbed. As the oxidation occurred at high temperatures, VOC reacted in parallel on silver and alumina sites. Recently, Beak et al. [12] studied various transition metals such as Mn, Fe, Co, Ni, Cu, Zn and Ag for catalytic oxidation of toluene and methyl ethyl ketone and silver showed the best activity among the tested catalysts. Thus, it is of great scientific interest to study the performance of this metal in the complete oxidation of a wider range of organic substances.

The choice of the support is also important with γ-alumina being the most widely investigated. An important property pointed out by several researchers is that the hydrophobicity of

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nprovement of loose contact diesel soot oxidation by synergic effects between metal oxides in K_2O–V_2O_5/ZSM-5 catalysts

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Diesel soot; Oxidation; K_2O–V_2O_5/ZSM-5; Loose contact; Synergic effect

uction

e many other types of pollutants emitted, diesel usually emit significant amount of soot and nitro-les (NOx). To protect the environment, the two ts have to be removed from the exhaust gas. As lations on diesel engine emissions becoming more , the engine modification and the exhaust after t are needed. While NOx can be removed by cat-duction processes [1], soot particulates are com-collected on a catalytic filter and periodically to CO_2 [2]. The catalyst in the trap must be suffi-ctive to oxidize the soot within the exhaust gas tures (300–400 °C) [3]. The catalysts' activity and are key factors in determining its applicability in ercial scale.

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Selective Catalytic Reduction of Nitric Oxide in Diesel Engine Exhaust over Monolithic Catalysts Washcoated with Bimetallic Cu-Zn/ZSM-5

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Abstract

Selective catalytic reduction (SCR) of nitric oxide (NO) in diesel engine exhaust over Cu-Zn/ZSM-5 washcoated ceramic monolithic catalysts is reported. The washcoat component was prepared by ion-exchanging ZSM-5 (Si/Al=40) with zinc while copper was incorporated through impregnation. The dispersed washcoat component was then incorporated into 400 cpsi ceramic monolith through a dipping process with the final loadings between 19.6 wt. % and 31.4 wt. %. The SCR process was studied with a feed comprising of 900 ppm NO, 2,000 ppm iso butane and 3 % oxygen at gas hourly space velocities (GHSV) between 5,000 and 13,000 h^{-1}. NO conversion increased until a loading of 23.6 wt. % to give a conversion of 88 % at 400 °C. The activity dropped at higher loadings due to the partial blockage of cell openings and diffusion limitations while unstable washcoating adherence was also demonstrated. After an initial deactivation of about 10 % in the first 48 h, this catalyst showed stable residual activity. Between 325 and 375 °C, minimal effect on the activity was detected when the space time was reduced from 0.94 s to 0.24 s, suggesting the absence of external mass transfer limitations for up to a GHSV of 16,000 h^{-1}.

Keywords: NO; selective catalytic reduction; ZSM-5; ceramic monolith; performance.

1. Introduction

Diesel engine owes its popularity to its high fuel efficiency, reliability, durability and relatively low fuel price. This engine is run under oxygen excess condition in a so called lean-burn operation. However, the operation increases the production of toxic gas e.g. nitric oxides (NO) which cause severe environmental and health problems. Catalytic processes have been widely investigated for NO_x removal and selective catalytic reduction (SCR) being the most popular one (Solis *et al.*, 2001; Pisarello *et al.*, 2002; Bennici *et al.*, 2005). The SCR technology is still immature and several drawbacks are yet to be satisfactorily addressed.

For a deNO_x unit, pressure drop is a key issue (Odenbrand *et al.*, 1999; Makkee *et al.*, 2002). In a car exhaust or a power plant flue gas system, the pressure drop should ideally be below 10-20 mbar (Seijger *et al.*, 2001). Additional demands comprise low sensitivity to dust and resistance to thermal shock. Structured packings, like monolithic are gaining interest for application in NO_x reduction (Zamaro *et al.*, 2005; Bueno-Lopez *et al.*, 2005) as the pressure drop in these catalysts is significantly lower than that of randomly packed bed catalysts (Cybulski *et al.*, 1999). Among various types of monolith, ceramic monoliths being the most widely used substrate material, mainly because of its relatively low manufacturing costs and high thermal stability (Heck *et al.*, 2001). However, the specific surface of most structured supports is below 1 m^2/g, which is way too low for catalytic purposes. The specific surface area can be enhanced up to about 40 m^2/g by washcoating with suitable microporous or mesoporous materials. As zeolites have a specific surface area of 300-700 m^2/g, a monolayer of zeolite may serve the need for surface area and porosity (Seijger *et al.*, 2001). The ZSM-5 washcoated ceramic monolith catalysts provide interesting advantage in the SCR of NO_x starts receiving attention among researchers (Zamaro *et al.*, 2005; Li *et al.*, 2008). ZSM-5 possesses high surface area of about 370 m^2/g and has been demonstrated to have high hydrothermal stability and suitability in many environmental catalysis applications in our earlier works (Deeng *et al.*, 2004; Abdullah *et al.*, 2003; Abdullah *et al.*, 2006).

Among metals studied as the active component of the catalyst are Cu (Deeng *et al.*, 2004), Pt (Ismail *et al.*, 2002) and Co (Ren *et al.*, 2002). By reviewing the results, Cu should provide superiority on the basis of high activity, high stability, low toxicity and low cost. Therefore, it was used in this study. Recently, the bimetallic catalysts have created particular interest due to the promoting effect between metal species (Ismail *et al.*, 2002). The second metal should be able to

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inuous biosynthesis of biodiesel from waste cooking palm oil packed bed reactor: Optimization using response surface nodology (RSM) and mass transfer studies

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ABSTRACT

This study aimed to develop an optimal continuous procedure of lipase-catalyzes transesterification of waste cooking palm oil in a packed bed reactor to investigate the possibility of large scale production further. Response surface methodology (RSM) based on central composite rotatable design (CCRD) was used to optimize the two important reaction variables packed bed height (cm) and substrate flow rate(ml/min) for the transesterification of waste cooking palm oil in a continuous packed bed reactor. The optimum condition for the transesterification of waste cooking palm oil was as follows: 10.53 cm packed bed height and 0.57 ml/min substrate flow rate. The optimum predicted fatty acid methyl ester (FAME) yield was 80.3% and the actual value was 79%. The above results shows that the RSM study based on CCRD is adaptable for FAME yield studied for the current transesterification system. The effect of mass transfer in the packed bed reactor has also been studied. Models for FAME yield have been developed for cases of reaction control and mass transfer control. The results showed very good agreement compatibility between mass transfer model and the experimental results obtained from immobilized lipase packed bed reactor operation, showing that in this case the FAME yield was mass transfer controlled.

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native fuel source are currently of interest as crude oil oar to record high. Biodiesel, also known as fatty acid ester (FAME), has become more attractive as an alternative ource because of its environmental benefit such as biode-, nontoxic and low emission profiles (Canakci, 2007; ti et al., 2007; Lara Pizarro and Park, 2003). Presently al production of biodiesel from waste cooking oil is per- by chemical alkaline or acidic processes. However, chemi- sesterification has some unavoidable drawbacks such as ergy and methanol consumption, difficulty in glycerol ', and a large amount of alkaline wastewater from the cat- e et al., 2008; Haas et al., 2003; Lu et al., 2007).

ntly, enzymatic methanolysis using lipases has become tractive in biodiesel production, since it is considered to ffective way to overcome the drawbacks involved in the l process. Particularly, the by-product, glycerol, can be eas- vered without complex treatment (Ha et al., 2007). The oblem of enzyme catalyzed process is the high cost of the used as catalyst and the cost of raw material which accounts for about 70% of the total cost (Wang et al., 2008). Therefore, researchers are always looking for other effort to reduce the cost of biodiesel production. Waste cooking oil, originated from restaurants and household disposals, is creating serious problems of environmental control. Production of biodiesel with waste cooking oil as feedstock not only could reduce disposal problems, but, more importantly, would decrease the cost of biodiesel (Chen et al., 2005). Several studies showed that enzymatic methanolysis with waste cooking oil was a promising alternative as a feedstock for biodiesel production (Wang et al., 2008; Watanabe et al., 2001; Nie et al., 2006; Li et al., 2006). The key step in enzymatic process lies in the successful immobilization of the enzyme, which allows for its easy recovery and reused (Modi et al., 2007). High operational stability of the immobilized enzyme was reported in several studies (Watanabe et al., 2001; Nie et al., 2006; Li et al., 2006; Shimada et al., 2002; Royon et al., 2007), making it possible in a batch system, or its long use in a continuous one, which reduces the incidence of catalyst cost.

Although lipase catalyzed transesterification has significant benefits, the industrial application technology has been slow. For widespread industrial use to occur the process has to be technically and economically feasible. The packed bed reactor (PBR) has been extensively investigated by several researchers for use in industrial scale application (Watanabe et al., 2001; Nie et al., 2006; Royon et al., 2007). The packed bed reactor is one of the most

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OPTIMIZED PARAMETERS FOR CARBON NANOTUBES SYNTHESIS OVER Fe AND Ni CATALYSTS VIA METHANE CVD

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Abstract. Multi walled carbon nanotubes (MWNTs) were synthesized via methane chemical vapor decomposition using low-cost activated carbon (AC) as support for Fe and Ni catalyst. Maximum methane conversions of 98% and 42% were observed on Fe and Ni catalysts respectively at reaction temperature of 750 °C by on-line gas chromatography. Bundles of MWNTs with an average internal dia ~ 20nm at 850 °C over Ni catalyst and thin-walled CNTs (dia ~ 8 nm) formed over Fe catalysts were confirmed by morphological studies by transmission electron microscopy. CNTs formed over Fe catalyst illustrated a typical *tip-growth phenomenon*. The formation of MWNTs was further supported with the data obtained from thermogravimetric analysis. The ideal condition for CNTs growth was noticed under N_2/CH_4 gas flow ratio of 2:1 rather than H_2/CH_4 atmosphere.

1. INTRODUCTION

Carbon nanotubes (CNTs) are a new form of carbon molecules with many outstanding properties which makes them potentially useful in various applications such as electronic, mechanical, composite, medical, etc., [1-5]. In general, CNTs has been classified either as metallic or semi-conducting that depends strongly on their chirality and diameter. Among CNTs synthesis methods, chemical vapour decomposition (CVD) is the most suitable method at low temperatures when compared with other techniques [6]. In this process, various inorganic porous materials such as alumina [7], silica [8], magnesium oxide [9] and Zeolites [10] were investigated as support materials by numerous researchers in producing various diameter ranges of single-walled carbon nanotubes (SWNTs) and MWNTs [11]. However, while considering high quantity and lower production cost of CNTs, it is necessary to trace a new support material to overcome current drawbacks like higher production cost and purification issues. In recent years, carbon itself finds more importance in catalytic reactions either as a catalyst or as supports owing to its fascinating physical and chemical characteristics. The potential use of carbon as catalyst support has not yet been fully exploited, even though there is considerable volume of literature devoted to this field in last 20 years [12-14]. Since malaysia being the leading producer of activated carbon from its palm industry, there is abundant resource for its cheaper availability. Hence, our present study was focused on using low-cost AC (derived from wood base material) as support for Fe and Ni catalysts with the aim to grow CNTs of different morphologies.

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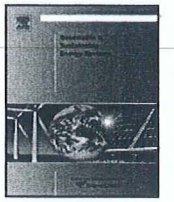

nt progress on innovative and potential technologies for glycerol formation into fuel additives: A critical review

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ABSTRACT

Glycerol emerges as a significant worth chemical that can be converted into high value products. In the prospect of biorefinery industries and great demand towards renewable sources, glycerol has proved to have tremendous potential to be transformed, thus supersede conventional petroleum derived fuel additive. Various types of oxygenated biocomponents and rigorous studies of glycerol transformation into fuel additives are presented in this review paper. Particular focus is given to etherification, acetylation and acetalation processes with specific behaviors in the respective reaction system.

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levelopment and commercial use of biodiesel has been gingly and rapidly expanding in Europe and US for over 10 ne prominent superiority of biodiesel over petroleum wards health and environment (free sulfur content, low of harmful emission, e.g. particulate matter, HC, CO, etc., better lifecycle of CO_2 for global warming alleviation) as well as engine performance (enhance lubricity, high cetane number for complete combustion) [1,2] has enticed Asia to use biodiesel as alternative fuels and innovative solution to curb the polluted air emitted from growing vehicle population [3].

Despite the rapid pace of biodiesel development and commercialization, there are several key challenges emerging and these must be addressed efficiently. One key problem that is being ultimate focused is the inevitable low value production of glycerol as co-product of biodiesel from transesterification and esterification of vegetable oil [4]. Stoichiometrically, glycerol is produced by

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mization of ultrasonic-assisted heterogeneous biodiesel production from palm oil: sponse surface methodology approach

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ABSTRACT

The use of ultrasonic processor in the heterogeneous transesterification of palm oil for biodiesel production has been investigated. Response surface methodology was employed to statistically evaluate and optimize the biodiesel production process catalyzed by two alkaline earth metal oxide catalysts i.e. BaO and SrO. SEM, surface analysis, AAS analysis and the Hammett indicator methods were used for characterization of the catalysts. Four different variables including reaction time (10–60 min), alcohol to oil molar ratio (3:1–15:1), catalyst loading (0.5–3.0 wt.%) and ultrasonic amplitude (25–100%) were optimized. Mathematical models were developed and used to predict the behavior of the process. The models were able to accurately predict the biodiesel yield with less than 5% error for both catalysts. The basic strength of the catalysts was the main reason of their high activities. This study confirmed that the ultrasonic significantly improved the process by reducing the reaction time to less than 50 min and the catalyst loading to 2.8 wt.% to achieve biodiesel yields of above 95%. The optimum alcohol to oil ratio was found to be at 9:1 while the best amplitudes were ~70 and ~80% for the BaO and SrO catalysts, respectively.

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ıtly, particular focus is been given on global warming and on of non-renewable resources. These problems are primarily d to the heavy consumption of fossil fuels. Much attention has en to biomass resources as alternatives for energy sources. The iodiesel fuel is produced by the transesterification of vegetable low alcohol in the presence of homogeneous base-catalyst such or NaOH [1]. Transesterification can occur in the absence of a but it can be effectively intensified by the use of suitable catalyst ever, for the satisfactory use of the product as diesel fuel, the must be removed from the product mixture and this requires ome purification processes while huge amount of wastewater ted at the same time [3].

ogeneous catalytic process is expected to be future biodiesel on process. This process lowers the cost and minimizes the nental impacts due to the simpler production steps and on processes which are normally carried out under very mild ıs. The heterogeneous catalysts capable to be used are such as, -silicates [4], alkaline earth metal compounds and hydroxides d alkali metal hydroxides or salts supported on γ-alumina [7–9] es [10]. The common problem associated with the heteroge- odiesel production process is its low reaction rate due to poor on between the oil and alcohol during the reaction due to their nmiscibility [4,5].

The demand for biodiesel in the world is sharply increasing. Thus, increasing the production rate for biodiesel in order to meet the demand seems to be essential. Therefore, new accelerating technologies are of great interest among researchers in this area. Ultrasonic radiations can accelerate the biodiesel production rate with homogenous catalyst [1,11]. Hanh et al. [2] found that the methanolysis of oil in aqueous catalyst solutions (e.g. NaOH, KOH) can be accelerated by low frequency ultrasound which led to the intensification of the overall process. Reports on the beneficial use of ultrasound for homogeneous catalytic process for biodiesel production are also published very recently [1,2,12]. Despite widely investigated for accelerating homogeneous reaction systems, heterogeneous biodiesel production process has never been intensified using ultrasonic energy. The benefit offered to the homogeneous process is theoretically possible in the case of heterogeneous process in a similar manner. However, report on the use of ultrasonic-assisted heterogeneous process for the production of this renewable fuel is still hardly found in the literature.

Fig. 1 shows the five step reaction mechanism generally proposed for the role of metal oxide catalyst in the transesterification reaction. Steps 1 and 2 describe the adsorption of alcohol and fatty acid on two neighboring free catalytic sites, respectively. In step 3, the two adsorbed groups react to form a surface intermediates. These surface intermediates will further decompose in step 4 and finally desorb (step 5). According to Hattori et al. [13], the rate-determining step of this mechanism with catalysts having a higher basicity, such as BaO and SrO, is the surface reaction step. Forward reaction promotes the formation of esters to result in high biodiesel yield. In this respect, higher alcohol

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ɔnic-assisted biodiesel production process from palm oil using alkaline netal oxides as the heterogeneous catalysts

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ABSTRACT

The ultrasonic-assisted transesterification of palm oil in the presence of alkaline earth metal oxide catalysts (CaO, SrO and BaO) was investigated. Batch process assisted by 20 kHz ultrasonic cavitation was carried out to study the effect of reaction time (10–60 min), alcohol to palm oil molar ratio (3:1–15:1), catalysts loading (0.5–3%) and varying of ultrasonic amplitudes (25–100%). The activities of the catalysts were mainly related to their basic strength. The catalytic activity was in the sequence of CaO < SrO < BaO. At optimum conditions, 60 min was required to achieve 95% yield compared to 2–4 h with conventional stirring. Also, the yields achieved in 60 min increased from 5.5% to 77.3% (CaO), 48.2% to 95.2% (SrO), and 67.3% to 95.2 (BaO). Fifty percentage amplitude of ultrasonic irradiation was deemed the most suitable value and physical changes on the catalysts after the ultrasonic-assisted reaction were successfully elucidated. BaO catalyst underwent relatively more severe activity drop in the catalyst reusability test. Catalysts dissolution was found to be mainly responsible for activity drop of the reused catalysts, especially with BaO catalyst.

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l is an eco-friendly and alternative energy source for nes that can be synthesized by transesterification of il or animal fat with alcohols [1]. The reaction can be y alkalis, acids, or enzymes [2]. Alkali-catalyzed transe- is much faster than acid-catalyzed transesterification t often used commercially [1]. Nevertheless, the alkali mpounds have some drawbacks, i.e. they must be neuer the reaction, thus, eliminating the possibility for lity of the catalyst [3,4]. The neutralization process also arge amount of wastewater that deserves treatment, to ant increase in the production costs [5].

eneous catalysis have many advantages: they are relacorrosive, environmentally benign and present fewer oblems. They are also much easier to be separated from ucts and can be designed to give higher activity, seleconger catalyst lifetimes [6]. Alkaline-earth metals oxidroxides [7–9], alkali metals (Na and K) hydroxides or rted on γ-alumina [3,10–11], zeolites [12], hydrotalcites been investigated with a variable degree of success. ponent alkaline earth metal oxides (BaO, SrO, CaO, h have higher basicity, lower solubility in alcohol and producing higher biodiesel yield have also been reported [9]. However, complete behavior of these catalysts in the transesterification process is yet to be fully understood [9,14].

As oil and methanol are not completely miscible, the mixing efficiency can affect the course of the transesterification reaction. The reaction can only occur in the interfacial region between the methanol, oil and catalyst and the alkaline earth oxide catalysts are essentially insoluble in the two phases. Continuous and vigorous mixing is then required to increase the area of contact between the three phases [15,16]. The mixing process generally increases energy input for biodiesel production process, yet the biodiesel yield is generally lower then that in the homogeneous process [9].

Low frequency ultrasound is theoretically seen as an efficient, time saving and economically functional method to accelerate biodiesel production process [17]. Ultrasonic mixing can produce smaller droplets of the reacting phases than conventional agitation, leading to a drastic increase in the interfacial area and improved mass transfer [18]. As a result, the mixing requirement during the process is also significantly lowered, translating in reduced energy consumption [15]. Ultrasonic can also 'grind' the catalyst into smaller particles to create new active sites for the subsequent reaction. Thus, the solid catalyst is expected to last longer in the ultrasonic-assisted process.

The main aim of this study was to characterize the effects of ultrasonic energy in presence of alkaline earth metal oxides as heterogeneous catalysts. As reported in literature, most of the transesterification processes for biodiesel production use some oils other than palm oil such as rapeseed oil [19] and soybean oil [4,8,10]. As

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SYNTHESIS AND CHARACTERIZATION OF MESOPOROUS BASE CATALYST FOR TRANSESTERIFICATION OF PALM OIL

by

NORAINI BINTI RAZALI

Thesis submitted in fulfillment of the
requirements for the degree of
Master of Science

SEPTEMBER 2009

REMOVAL OF SO_2 AND NO FROM SIMULATED FLUE GAS USING RICE HUSK ASH/CaO/CeO_2 SORBENT

by

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Thesis submitted in fulfillment of the requirements
for the degree of
Doctor of Philosophy

March 2009

REMOVAL OF SO_2 AND NO FROM SIMULATED FLUE GAS USING CERIUM-MODIFIED PALM SHELL ACTIVATED CARBON

SUMATHI SETHUPATHI

UNIVERSITI SAINS MALAYSIA

2010

PRODUCTION OF BIOFUEL FROM OIL PALM BIOMASS USING SUBCRITICAL AND SUPERCRITICAL LIQUEFACTION

by

HOSESEIN MAZAHERI

Thesis submitted in fulfillment of the requirements
for the degree of
Doctor of Philosophy

SYNTHESIS OF IMMOBILIZED NANO-TiO_2 FOR PHOTOCATALYTIC DEGRADATION OF PHENOL

by

NOR FAUZIAH BINTI ZAINUDIN

Thesis submitted in fulfillment of the requirements
for the degree of
Master of Science

May 2010

DEVELOPMENT OF CARBON NANOTUBES USING FLOATING IRON-BASED CATALYSTS

by

MEHRNOUSH KHAVARIAN

Thesis Submitted in Fulfilment of the Requirements
for the Degree
of Master of Science

October 2010

PHOTOCATALYTIC DEGRADATION OF PHENOL IN A FLUIDIZED BED REACTOR USING TiO_2 PREPARED BY A HYDROTHERMAL METHOD IMMOBILIZED ON GRANULAR ACTIVATED CARBON

by

SIN JIN CHUNG

Thesis submitted in fulfillment of the
requirements for the degree
of Master of Science

MAY 2010

Nanotechnology: a big future for the small world!

Nano technology

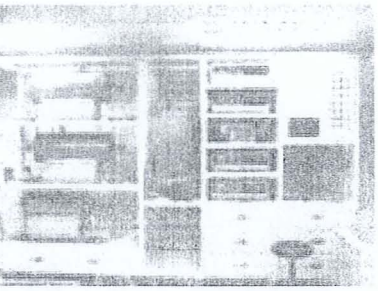
Nanotechnology is the sixth truly revolutionary technology introduced in the modern world following the Industrial Revolution of the mid-1700s, the Nuclear Energy Revolution of the 1940s, the Green Revolution of the 1960s, the Information Revolution of the 1980s and the Bio Technology Revolution of the 1990s. Nanotechnology offers the tools to control the production of materials and the function of devices at the atomic and molecular level. With this level of control, the possibilities of creating new materials and new devices are limitless.

In sync with the current advancements in technology, three research groups at USM have been exploring the boundless possibilities of nanotechnology. Advances in nanotechnology have led to the discovery of many new materials and inventions of novel applications. For example, the Carbon Nanotube Research Group, led by Professor Abdul Rahman Mohamed, has had a major breakthrough in methane catalytic vapour deposition (CVD) technology thus placing USM at the forefront of nanoscience and nanotechnology. Another group of researchers from the USM's School of Dental Sciences has invented NanoSeal Plus, the world's first endodontic or root canal sealer treatment using nanotechnology. At USM's Institute for Research in Molecular Medicine (INFORMM), a group called NanoBiotechnology Research and Innovation (NanoBRI) is focusing its energy on the design and development of nanoparticles, nanocochlea, reagents design, drugs and molecules carrier design and development, cellular imaging and diagnostic platforms. Unlike the rest of us, these researchers are unperturbed to be accused of living in a small world. The small world that they live in promises a big future to the rest of us.

Carbon nanotube technology

The Carbon Nanotube Research Group focuses on the technology to produce carbon nanotubes (CNTs) on a large scale and CNT applied products. CNTs have emerged as one of the most important components of nanotechnology. These tiny tubes have diameters as small as to 0.4 nm, while their lengths can extend up to a million times their diameter. CNTs have been said to be the most innovative materials of the 21st century due to their extraordinary properties and their enormous potential applications. Most fascinating is the fact that nanotubes could either be semiconducting or metallic depending on their structural orientation. In addition, CNTs are lighter than aluminum and 25 times stronger than steel alloys. CNTs can carry electric current 1,000 times better than that of copper and have a heat transmission of 1.8 times better than that of the diamond. Furthermore, CNTs can resist the thermal decomposition up to 2,800°C in vacuum and can be bent at a large angle without damage.

The unique structure and properties of CNTs have seen a wide range of potential applications in advanced technologies. New applications for these amazing nanotubes are being reported daily in electronics, chemistry, optics and biology. In this regard, their potential applications include the usage in flat panel displays, rechargeable batteries, memory chips, structural reinforcements, biomedical applications, supercapacitors and hydrogen storage. The total market value of the applied products of CNTs is estimated to be more than US$ 350 billion per year.



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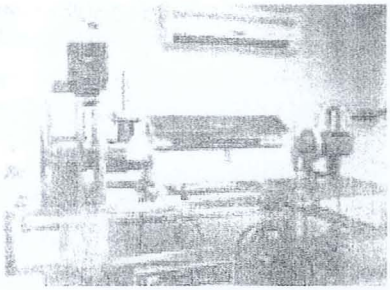

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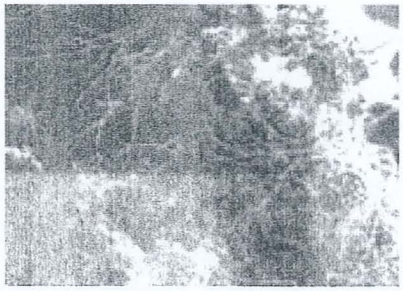

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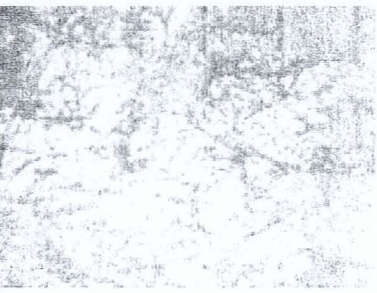

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01 Batch type CNT production rigs
02 A rotary horizontal reactor installed in USM-MTDC funded laboratory
03 SEM image of CNTs
04 A low magnification TEM image shows dense as-produced CNTs
05 A high resolution TEM image shows the high graphitisation of the CNT wall structures

entral to the research strategy in USM is the idea that dvancements in nanoscience and nanotechnology should be iven by innovations and applications. New materials synthesised rational approaches are regarded as the key for success. t to be useful, these nanomaterials must be assembled and ocessed into complex and functional architectural elements that n be further assembled into applications and devices. As such, gnificant effort has been placed in developing a technology to oduce CNTs on a large scale and to work on the development CNT applied products. The group focuses on developing ultra-ecise growth control at different length scales, morphology, size d structure because these will define and enable control over e physical and chemical properties of CNTs.

ne of the group's core technologies is methane catalytic vapour position (CVD), an approach that the group has developed since 01. It was found that the addition of a small and controlled nount of catalyst/support to the synthetic ambient dramatically creases the growth yield of CNTs. The finding represents a major eakthrough in the CNT field, simultaneously addressing many itical problems, such as scalability, purity and cost that have gued the use of CNTs for real applications and opens up new portunities ranging from biology to nanodevice and optical plications. Currently, the Carbon Nanotube Research Group is working on various projects that take advantage of controlled growth to develop exciting new research and application frontiers, as well as projects that pursue the ultimate syntheses that will grow CNTs with completely defined structures.

The technology of methane CVD involves a low cost process that utilises a specially designed catalyst as an enhancement agent to decompose methane gas, the primary composition of natural gas, into CNTs and hydrogen. The technology can be easily scaled up to produce CNTs in a bulk quantity. It is important to note that only a specifically designed catalyst is efficient in enhancing the formation of CNTs in this process. The carbon atoms, decomposed from methane gas, will deposit on the active site of a specially designed catalyst and self-assemble to form tubular carbon nanostructure, which are the CNTs.

CH^4	Heat	C	$2H^2$
	⟶		+
Methane	Catalyst	CNTs	Hydrogen

The advantages of this process are listed as follows:

- provides a single-step process solution
- utilises cheaper and abundant methane gas as feedstock
- operates at atmospheric condition, which is more cost effective

- controllable/selective growth of CNTs
- produces hydrogen as a by-product, which in itself is of high value and is environmentally friendly
- can be operated by a single operator
- the technology is scalable to any production size
- low cost of production

In the intensely competitive CNT synthesis race, faster and more powerful technologies in addition to intellectual capital are imperative to maintain leadership. As the synthesis is central to the whole effort of the group, the group has developed several generations of controlled methane CVD systems that can grow samples and implement any sophisticated synthesis process. A dedicated research laboratory has been installed with four CVD systems designed for various purposes. With a full-automatic furnace, one can run 12 CVDs a day at a maximum, during which time one can focus on other aspects of research. Recently, the group also designed and fabricated a rotary production system that enables the production of CNTs continuously via methane CVD at a capacity of 1,000 kg/year. These advanced systems have been developed to significantly accelerate research while simultaneously enabling highly reproducible and precisely-controlled growth.

Mass production is a key factor in establishing a CNT industry. For CNTs to become a widely used industrial material, the cost must be reduced to the level of classic carbons, such as activated carbon or carbon fibres. This translates to a 100-fold to 1000-fold reduction in production cost in the future. The Carbon Nanotube Research Group has already solved this problem by using methane as the carbon source. The group is committed to, and actively engaged in, developing new approaches for the mass production of economical, pure and high quality CNTs based on controlled growth.

CNT applications

The simple and cost effective process to produce CNTs at a large scale developed by the Carbon Nanotube Research Group has significantly reduced the price of CNTs. Consequently, it is expected to encourage the development of CNT applications that can be tagged at a more competitive price in the market. The technology developed by the group has been filed for patent and quoted in Frost & Sullivan's 2007 market survey report.

"Abdul Rahman Mohamed and his research group at the School of Chemical Engineering, Engineering Campus, Universiti Sains Malaysia, have synthesized CNTs and carbon nanofibers over supported-NiO catalysts by catalytic decomposition of methane at 550 degree C and 700 degree C. The researches characterized the catalytic activity by the conversion levels of methane and the amount of carbon accumulated on the catalysts. The researches then found the selectivity of CNTs and carbon nanofiber formation using transmission electron microscopy (TEM)." - Frost & Sullivan: Carbon Nanotubes - Road to Commercialization.

The wide range of potential commercial applications of CNTs promises great commercial value for the invention by the Carbon Nanotube Research Group. Industry enthusiasts believe that CNTs will radically improve the performance of tiny sensors, electronic and optical devices, catalysts, batteries, fuel cells, solar cells and drug delivery vehicles. Owing to the huge applications of CNTs, the global market for nanotubes in 2002 has recorded approximately US$ 12 million. The global demand for CNTs is estimated at US$ 40 billion in 2020. The versatility of CNTs scales up their demand, pegging them at the current market price range from US$ 100 to US$ 2000 per gramme, depending on their purity and types. CNTs have an amazingly wide range of applications and these applications boost the electronic, chemical, mechanical, material, pharmaceutical and medical industries, with the revolutionary changes arising in these areas. Therefore, CNTs promise mankind a higher standard of living, better quality of life and healthier and fitter lifestyles. In addition, hydrogen is produced as a side product of the methane CVD technology and hydrogen has been recognised as a future source of energy and is widely needed in the chemical and petrochemical industries.

The way forward

For the past 10 years that the Carbon Nanotube Research Group has been researching on CNT synthesis, it has filed patents in multiple countries on the process and catalyst to produce CNTs. Marching forward, the group is now intent to commercialise the innovative production technology and market CNT products. To that end, a new company will be established as a subsidiary under Sanggar SAINS Sdn. Bhd. The company has the following visions:

- establishing its own production with wholesale/retail distributions
- contract manufacturing of high-value CNTs
- licensing technology to a current CNT manufacturer
- partnership/joint venture with a methane-producing company for large-scale production of CNTs
- partnership/joint ventures with companies interested in specific application areas

anoSeal Plus - root canal sealer treatment using nnotechnology

SM researchers at the School of Dental Sciences have invented anoSeal Plus, the world's first endodontic or root canal sealer eatment using nanotechnology. NanoSeal Plus can greatly crease the success rates of root canal treatments and allow tients to keep their teeth. It is yet another example of how SM has successfully transformed a research discovery into an novation that ensures the sustainability of the quality of life and e that can compete in the global market. From the economic int of view, the innovation is expected to generate new industries d consolidate existing industries in Malaysia. Additionally, anoSeal Plus will reduce the dependence of Malaysian dentists imported dental materials.

e three-year effort by the Nanoseal Plus research team resulted a nanohybrid endodontic material suitable for root canal eatments. The sealer, developed using a simple and inexpensive chnique, has a structure similar to the tooth. In root canal eatments, the pathologic pulp is removed from the root canal stem. The canal is then cleaned, disinfected and obturated th root canal filling materials to prevent re-infection. The root nal filling materials are divided into the core material (gutta rcha points) and root canal sealers. The functions of the alers are to cement the core materials into the canal and to fill e discrepancies between the canal wall and core materials. A perly sealed canal will prevent bacteria from the mouth getting to the canal and infecting the tissue at the root of the tooth. The sealers also act as a lubricant to enhance the positioning of the core filling materials. Finally, the tooth will be restored to maintain its shape and function. Root canal treatments preserves teeth so that they continue to function and thus, the extraction of the affected teeth can be avoided.

The nano hybrid material is biocompatible, improves apical healing and produces hermetic apical seals. The material contains nanofillers that are more reactive and give better adaption of sealers to the tooth structures compared to other sealers in the market. Their similarity to the structure of dentine and/or enamel prevents leakage after treatment. The silica nano particle fillers are produced using the sol-gel process (10nm in size). These particles strengthen the physical properties of nano hybrid sealers and also fill the space between nano HA particles to prevent matrix from producing voids in the sealers.

The way forward

NanoSeal Plus is now being patented under the guidance of the Innovation Office, USM. The third draft of the patent has been submitted and waiting for the next patent status. Prodental Sdn. Bhd. in Kuala Lumpur has agreed to produce and sell NanoSeal Plus to the domestic and export market; once the patent is received. The research team is currently working on the next product, a root canal sealer that can be injected into the root canal without the use of the gutta percha. The sealer uses resin and can be set chemically inside the canal.

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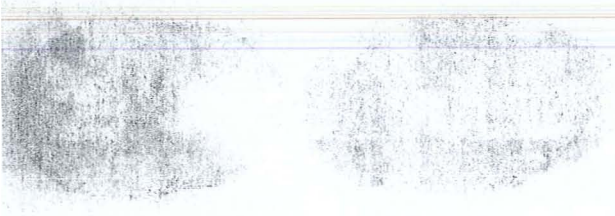

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06 Nano hybrid particles were synthesised at USM's School of Dental Sciences by the wet chemical method using calcium hydroxide $Ca(OH)^2$ and phosphoric acid (H^3PO^4) as Ca and P precursors, respectively

07 Subcutaneous area of mice on first week of evaluation at 400x of magnification, showed increases of lymphocytes and decreases of inflammatory cells

08 Subcutaneous area of mice on second week of evaluation at 400x of magnification. No inflammatory cells detected

09 The TEM micrograph of nano structured HA. The HA nano crystals were found to be rod-like with the size of 40 to 60 nm (left). The nano silica particles, 10 nm in size (right)

10 Root specimens showing dye penetration (left) filled with a commonly used sealer [AH 26] and no dye penetration (right) filled with NanoSeal Plus

NanoBiotechnology for Biomedical Applications

NanoBiotechnology Research and Innovation (NanoBRI), a multidisciplinary research team at USM's Institute for Research in Molecular Medicine (INFORMM), is formed subsequent to the signing of the Sub-License Agreement for Advancement of Nanotechnology between Universiti Sains Malaysia (USM) and BiotechCorp on 25 July 2008. Malaysian Biotechnology Corporation (BiotechCorp) has acquired an exclusive, global license from Nanobiotix S.A. Paris France for the manufacture of nanoparticles and development of related applications such as Drug Delivery Systems and Diagnostics for non-oncology applications.

Three principal researchers from multidisciplinary backgrounds; Dr. Khairunisak Abdul Razak (School of Materials and Mineral Resources Engineering), Associate Professor Azlan Abdul Aziz and Associate Professor Shaharum Shamsuddin have taken up residence at Nanobiotix from September 2008-August 2009 to undergo a technology transfer training. In consideration for the training, USM is to develop a minimum of two new applications or products of substantial commercial value per year for a period of 4 years. Progress on products development is monitored by the Steering Committee composed of representatives from USM, BiotechCorp and Nanobiotix.

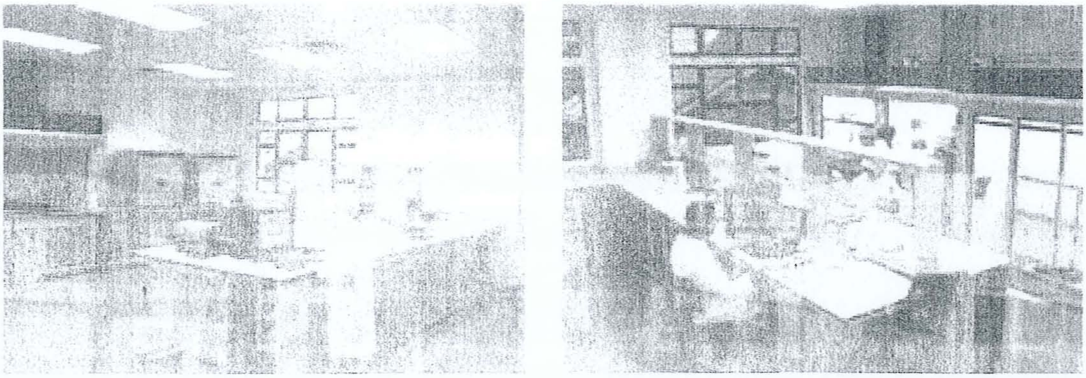
At NanoBRI, dedicated laboratories have been developed equipped with state-of-the-art facilities with funding from USM. The facilities include a nanomaterials synthesis laboratory, a nanomaterials characterisation laboratory, cell culture facilities, a dark room equipped with inverted fluorescence microscope facilities and a biological laboratory. NanoBRI focuses on the design and synthesis of multifunctional inorganic nanoparticles for the various molecular medicine and other biotechnology applications.

The research thrusts

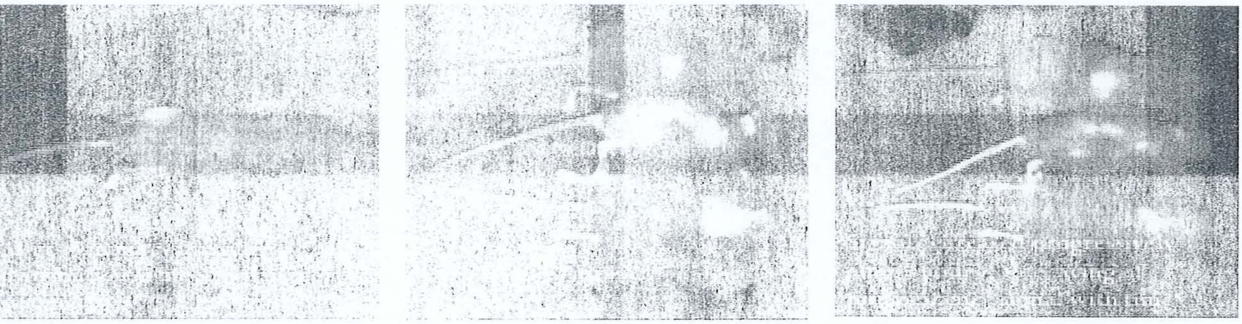
In essence, the research thrusts at NanoBRI are in the design and development of nanoparticles, nanocolloids, reagents design, drugs and molecules carrier design and development, cellular imaging and diagnostic platforms. To date, NanoBRI has the ability to produce at least four types of nanoparticles: NanoSilica, NanoMagnetic, NanoGold and Liposomes with potential applications in biomedical, agriculture and energy production.

Table 1: Potential applications of designed nanoparticles.

Nanoparticles	Potential applications
NanoSilica	• Drug delivery system (DDS) • Molecules carrier
NanoMag	• Therapy - DDS, hyperthermia, radio therapy combined with MRI etc. • Diagnosis - MRI, sensing, cell sorting, bioseparation, enzyme immobilisation, immunoassays, transfection, purification.
NanoGold	• Immunosensors, X-ray contrast agent, DNA-AuNPs assemblies and sensors, AuNP enhanced immunosensing, AuNP sugar sensors, AuNPs bioconjugates (peptides, lipids, enzymes, drugs and viruses) and AuNP biosynthesis.
Liposomes	• [illegible] biomedical field - DDS, protection against enzymatic degradation of drugs, drug targeting, gene transfer. • Food and nonfood applications - e.g., nutrient encapsulation & delivery, functional components encapsulation (proteins and enzymes, flavours, antimicrobials).



11 Laboratories at NanoBRI



12 ... in vivo of DDS with varying time

noBRI researchers have already ... based on the transfer of technology.

Use in TB

The first project is on a drug delivery system (DDS) for the treatment of tuberculosis based on silica nanocarriers. A conventional DDS for tuberculosis (TB) has major drawbacks including limited solubility, poor distribution, degradation in biological medium, lack of selectivity, unfavourable pharmacokinetics and accidental damage on healthy tissue.

Adaption of nanotechnology in a DDS has advantages of improving delivery of poorly water-soluble drugs, allowing targeted delivery of drugs in a cell or tissue in a specific manner, permitting transcytosis of drugs across tight epithelial and endothelial barriers, enhancing delivery of large macromolecule drugs to intracellular sites of action, co-delivery of two or more drugs or therapeutic modality for combination therapy, allowing visualisation of sites of drug delivery by combining therapeutic agents with imaging modalities and improved real time read on the in vivo efficacy of a therapeutic agent.

NanoBRI has the capability to tune the size of a silica DDS by changing synthesis parameters from 15 nm to 150 nm. Physical and chemical analysis shows that nanocarriers in the range of 40-80 nm are promising for a DDS for TB. The DDS for TB developed has been tested for cytotoxicity in vitro and in vivo shows acceptable cytotoxicity. Preliminary toxicity and biodistribution in vivo of two sizes of drugs have been studied using SWISS nude mice using 50 nm and 80 nm nanocarriers. Toxicity in vivo shows no sign of toxicity on SWISS mice after 11 days treatment for both DDS particle size.

All mice started gaining weight after 7 days, which is similar to the control mice injected with glucose. The biodistribution study shows that smaller size (50 nm) nanoparticles had longer circulation time in blood compared to the larger ones (80 nm) by up to 1 hour. However, after 5 hours both samples showed a similar distribution pattern. Necropsy after 5 hours showed that the DDS for TB was observed in organs e.g., liver, suprarenal glands, ovaries and lungs.

Production of gold antibodies

The second project approved by the Steering Committee is on the production of gold colloidal conjugated antibodies for diagnostic applications (reagents). This research will develop the know-how process to produce gold nanoparticles of various sizes and shapes as well as conjugation with antibodies for diagnostic applications. The know-how process will facilitate innovation in diagnostic devices with enhanced sensitivity at a reduced

13 Different size of gold nanoparticles and gold nanorods

cost that will encourage more research and innovation in diagnostic applications.

This research will assist the nation's capacity building on human resource with new expertise in gold conjugated antibodies which in turn contributes to the development of nanobiotechnology in Malaysia. The new scientific understanding in this project will also contribute to the current knowledge that will benefit Malaysia as one of the main players in the nanobiotechnology field in the Asian region.

It is known that when the size of gold nanoparticles decreases, surface area reactivity increases hence the ability to scatter light increased as well as enhanced the sensitivity in diagnostic applications. Gold nanorods have received attention due to their unique optical properties and facile synthesis. When the aspect ratio of gold nanorods increases, the extinction peak increases and a split between the two plasmon bands (transverse and longitudinal surface plasmon) becomes more obvious.

Hence, nanorods can be tuned to the desired wavelength states by controlling the aspect ratio. The long-axis of gold nanorod conjugated antibodies provides higher sensitivity than nanosphere conjugated antibodies in diagnostic application. The long-axis of gold nanorod will enhance the absorption and scattering of light.

To date NanoBRI has the capability to produce various size gold nanoparticles and gold nanorods. The next step is on optimising the conjugation process of gold nanoparticles and gold nanorods with antibodies such as IgG, IgM and IgA to produce reagents for diagnostic application. The produced reagents will then be tested in available diagnostic kits at INFORMM.

Moving forward, NanoBRI will train interested researchers to use the acquired nanotechnology platform as well as provide contract research in the related area to sub-licensee approved by BiotechCorp. In research and innovation, NanoBRI will work towards enhancing properties of the DDS for tuberculosis as well as reagents for diagnostic application. In the next 3 years, NanoBRI is expected to develop six more nanotechnology-based products of substantial commercial value for biomedical applications.

Facilities	Applications
Nanomaterials synthesis facilities	Synthesis of designed nanomaterials e.g. silica nanocarriers, ferrofluids, magnetic nanoparticle and liposomes.
UV-Vis spectrophotometer	Determine solution absorption/transmission, compound concentration, conjugation quality.
Zeta sizer	Analysis of hydrodynamic size, zeta potential and molecular weight of particles in solution.
Florescence spectroscopy	Determine reactive single oxygen, quenching properties of materials, optical properties.
Florescence microscope	Cellular penetration/uptake.
Microplate spectrophotometer	Analysis of nanoscale level optical density.
Cell culture facilities	Cell culture services, preparation of numerous culture media and a source of culture supplies and sterile reagents), cell propagation services, establishing primary cultures from human and animal tissue samples, cell transformation services, screening services for detecting contamination in cultured cells and sterile workstations for researchers.

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Tuan Haji Fadillah Yusof
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MOSTI on Human Capital Development for Science & Technology

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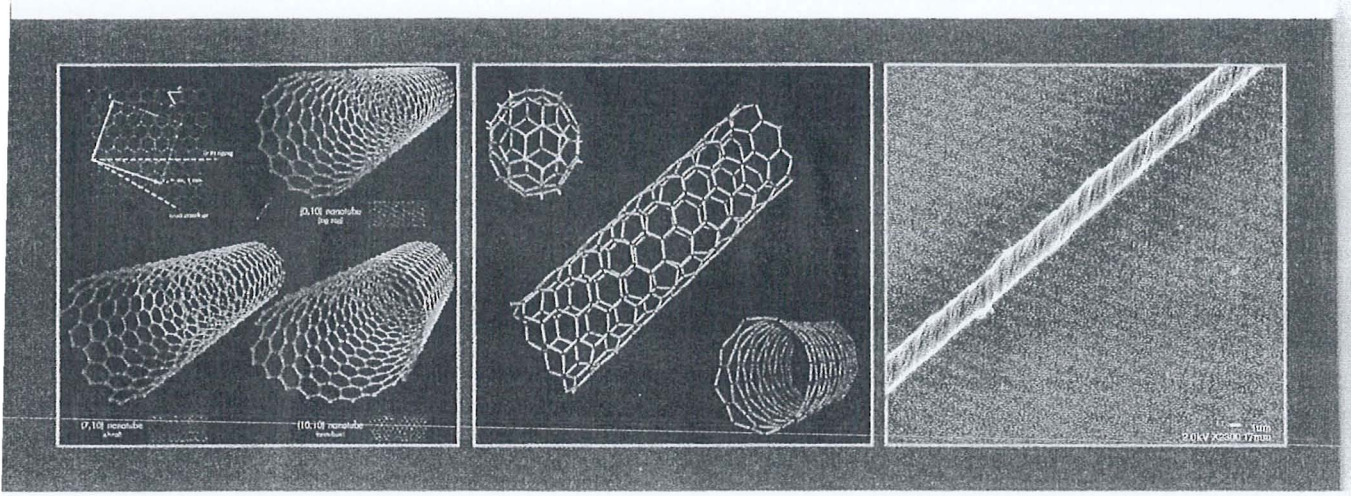
USM's Carbon Nanotubes



With research on nanotechnology fast gaining popularity in today's world, a team of Universiti Sains Malaysia scientists have recently come up with a new cost-effective method of producing carbon nanotubes for the world market. USM's subsidiary, Usains Holdings Sdn Bhd is at the helm to market the carbon nanotubes for the regional market.

Carbon nanotubes, essentially the building blocks in the production of nanotechnology devices can be found in a variety of electronic devices, cellular phones, including semiconductors, batteries, medical equipment, energy storage devices as well as high-tech mechanical applications. It also can be used for hydrogen storage in fuel cell cars to enhance the conductivity of semiconductor elements in electronic products.

Prof Abdul Rahman Mohamed of the School of Chemical Engineering together with his team has discovered an alternative one-step method of producing carbon nanotubes via chemical vapour deposition (CVD) using methane, an essential raw material needed in producing carbon nanotubes. He has been engaged in the research and development project since 2000.

Currently, the conventional production of nanotubes requires a two-step CVD process with benzene as the hydrocarbon ingredient, which is not only an expensive process, but also environmentally unfriendly.

Abdul Rahman said that to date, it could now produce multi-walled nanotubes (MWNT). USM's nanotube products are of high quality and could be made according to customer specifications, adding that further research was ongoing to produce single wall nanotubes (SWNT). There are actually several million nanotubes in one gram, sizes ranging from one to 50 nanometres.

"Besides that, the natural gas industry in Malaysia stands to benefit from nanotube research as methane is needed to produce our nanotubes," he said.

Currently, nanotubes are commercially available produced by European and USA based companies, and are sold at high prices. In some cases sold at over US$300 per gram depending on size.

In comparison, USM's alternative method of producing carbon nanotubes is however, much less expensive compared to existing methods where its production cost is less that US$10 as compared to the current US$100 to US$140 for each gram of MWNT.

"However, the importance of this research is to further understand the formation of nanotubes, so we can produce custom made nanotubes at a lower cost," he said.