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# UNIVERSITI SAINS MALAYSIA

First Semester Examination  
Academic Session 2009/2010

November 2009

## **EBB 323/3 - Semiconductor Fabrication Technology** **[Teknologi Fabrikasi Semikonduktor]**

Duration : 3 hours  
[Masa : 3 jam]

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Please ensure that this examination paper contains TEN printed pages before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

This paper contains SEVEN questions.

*[Kertas soalan ini mengandungi TUJUH soalan.]*

**Instruction:** Answer **FIVE** questions. If candidate answers more than five questions only the first five questions answered in the answer script would be examined.

**[Arahan:** Jawab **LIMA** soalan. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]

The answers to all questions must start on a new page.

*[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]*

You may answer a question either in Bahasa Malaysia or in English.

*[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

In the event of any discrepancies, the English version shall be used.

*[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]*

1. [a] The type of doping and crystal orientation in a silicon wafer with a diameter of 150 mm or less can be identified by a flat mark. Sketch a standard flat for p-type (111) and n-type (100) wafers.

*Jenis dopan dan penghalaan hablur wafer silikon dengan garispusat 150 mm atau kurang dapat dikenalpasti dengan tanda rata. Lakar tanda rata piawai bagi wafer silikon jenis-p (111) dan jenis-n (100).*

(20 marks/markah)

- [b] How is the doping type and crystal orientation of silicon wafer determined if there is no flat mark?

*Bagaimana menentukan jenis dopan dan penghalaan hablur wafer silikon jika ianya tidak mempunyai tanda rata?*

(20 marks/markah)

- [c] The growth of GaAs on silicon wafer is able to provide a large wafer for IC fabrication. If you want to extend this process to InP, HgCdTe, or other compound systems, what would you need to find out to determine whether or not it would be possible?

*Pertumbuhan GaAs di atas wafer silikon dapat menyediakan banyak wafer bagi fabrikasi IC. Jika anda ingin memperluaskan proses ini kepada InP, HgCdTe, atau sistem sebatian lainnya, apa yang perlu anda cari untuk menentukan adakah memungkinkan atau tidak?*

(40 marks/markah)

- [d] What are the advantages and disadvantages of using  $\text{AsH}_3$  gas to grow GaAs by MOCVD.

*Apakah kelebihan dan kekurangan menggunakan gas  $\text{AsH}_3$  dalam penyediaan GaAs menggunakan MOCVD.*

(20 marks/markah)

2. [a] Describe and explain briefly three (3) main problems in a doping process using thermal diffusion.

*Tentukan dan jelaskan secara ringkas tiga (3) masalah utama yang dihadapi dalam proses pendopan menggunakan peresapan terma.*

(20 marks/markah)

- [b] Why is the ion implantation process better than diffusion for doping process?

*Mengapa proses implan ion lebih baik daripada proses resapan di dalam proses pendopan?*

(20 marks/markah)

- [c] Suppose we have a p-type silicon wafer, how could we change a selected surface area to n-type silicon?

*Seandainya kita mempunyai wafer silikon jenis-p. Bagaimana cara mengubah kawasan permukaan terpilih menjadi silikon jenis-n?*

(30 marks/markah)

- [d] As the gate length of a metal oxide semiconductor field effect transistor (MOSFET) is scale down to sub-micron level, the junction depth of source and drain must also be reduced. What is your opinion whether ion implantation can be used to form the shallow junction?

*Oleh kerana panjang get bagi transistor kesan medan logam oksida semikonduktor (MOSFET) dikurangkan ke paras sub-mikron, maka kedalaman simpang bagi sumber dan saluran juga harus dikurangkan. Berikan pendapat anda adakah implantasi ion dapat digunakan untuk menghasilkan simpang cetek?*

(30 marks/markah)

3. [a] A proximity aligner is used to expose  $1\ \mu\text{m}$  apertures. The gap between apertures and mask is  $25\ \mu\text{m}$ . The separation between the mask and g-line source is  $0.5\ \text{m}$ . Is the Fresnel criterion satisfied in this set-up?

*Penjajar kehampiran digunakan untuk dedahan  $1\ \mu\text{m}$  bukaan. Jurang antara dedahan dan topeng adalah  $25\ \mu\text{m}$ . Pemisahan antara topeng dan sumber g-line adalah  $0.5\ \text{m}$ . Adakah susunan ini sesuai dengan ukuran Fresnel?*

(30 marks/markah)

- [b] Discuss why the contrast of a photoresist is decreased at short wavelengths (high photon energies).

*Bincangkan mengapa ketajaman rintang mungkin berkurangan pada panjang gelombang yang pendek (tenaga foton tinggi).*

(20 marks/markah)

- [c] Why is optical lithography not suitable to produce nanoscale patterns?

*Mengapa litografi optik tidak sesuai untuk menghasilkan corak berskala nano?*

(20 marks/markah)

- [d] How to control the patterned size using AFM lithography?

*Bagaimana cara mengawal saiz corak menggunakan litografi AFM?*

(30 marks/markah)

4. [a] A solution consisting of four parts of 70%  $\text{HNO}_3$ , four parts of 49% HF, and two parts of  $\text{HC}_2\text{H}_3\text{O}_2$  is used to etch silicon. If the solution is held at room temperature, what etch rate would be expected? Refer to Figure 1 of the etch rate for silicon in HF and  $\text{HNO}_3$ .

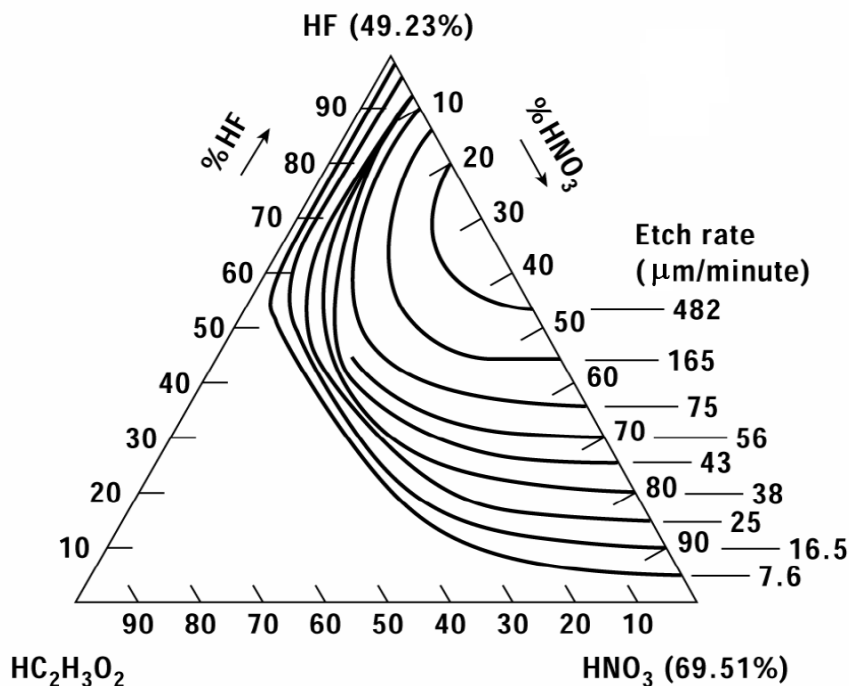
*Larutan terdiri daripada empat bahagian 70%  $\text{HNO}_3$ , empat bahagian 49% HF, dan dua bahagian  $\text{HC}_2\text{H}_3\text{O}_2$  digunakan untuk memutar silikon. Jika larutan disimpan dalam suhu bilik, apakah kadar punaran yang anda jangkakan? Rujuk pada gambarajah bagi kadar punaran silikon dalam HF dan  $\text{HNO}_3$ .*

(20 marks/markah)

- [b] Describe the differences between high pressure plasmas and reactive ion etch systems and explain when these systems are used.

*Jelaskan perbezaan antara sistem punaran plasma bertekanan tinggi dan sistem punaran ion reaktif dan jelaskan bila proses itu digunakan.*

(30 marks/markah)



**Figure 1 - Schematic diagram of the etch rate for silicon in HF and  $\text{HNO}_3$**

**Rajah 1 - Gambarajah kadar punaran silikon dalam HF dan  $\text{HNO}_3$**

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- [c] Briefly explain the differences between wire-bonding and flip-chip technology in electronic packaging.

*Terang secara ringkas perbezaan di antara teknologi “wire-bonding” dan “flip-chip” di dalam pembungkusan elektronik.*

(30 marks/markah)

- [d] Lead-free solder system is used as flip-chip interconnects. Give an example of lead-free solder and explain its potential problems?

*Sistem solder bebas plumbum telah digunakan dalam penyambungan “flip-chip”. Berikan satu contoh solder tersebut dan terangkan masalah-masalah yang mungkin dihadapinya.*

(20 marks/markah)

5. [a] What is Moore's Law?

*Apa itu Hukum Moore?*

(20 marks/markah)

- [b] Briefly discuss three main components in cleanroom technology.

*Bincang secara ringkas tiga komponen dalam teknologi bilik bersih.*

(30 marks/markah)

- [c] There are four types of particle removal mechanisms in a high efficiency particle air (HEPA) filter. Discuss their differences in terms of removal efficiency.

*Ada empat jenis mekanisma untuk menyekat partikel dalam filter penyekat partikel berkecekapan tinggi (HEPA). Bincangkan perbezaan antara mereka dari segi kecekapan untuk menyekat partikel.*

(30 marks/markah)

[d] What are the criteria for selecting a vacuum pump?

*Apa ciri-ciri untuk memilih sebuah pum vakum?*

(20 marks/markah)

6. [a] During thermal oxidation of Si,  $\text{SiO}_2$  is formed. Briefly explain the possible defects that appear in the bulk oxide and the Si- $\text{SiO}_2$ .

*Semasa pengoksidaan terma pada Si,  $\text{SiO}_2$  akan terbentuk. Secara ringkas terangkan cacat-cacat yang mungkin terbentuk di dalam oksida pukal dan di antaramuka Si- $\text{SiO}_2$ .*

(20 marks/markah)

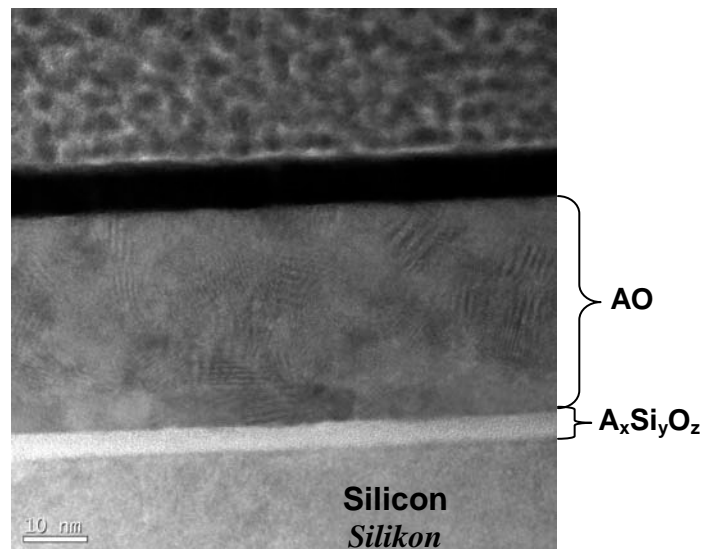
[b] Where does high- and low-dielectric constant materials being employed in an Ultra-Large-Scale Integrated Circuit (ULSI)? Give an example of each dielectric constant materials and propose a deposition method of those materials.

*Di manakah bahan berpermalar dielektrik tinggi dan rendah digunakan dalam "Ultra-Large-Scale Integrated Circuit" (ULSI)? Berikan satu contoh untuk setiap bahan dielektrik tersebut dan cadangkan teknik untuk mengendapkan bahan tersebut.*

(30 marks/markah)

- [c] A Si-based metal-oxide-semiconductor (MOS) capacitor is having a thin dielectric (AO) and an electrode area of  $0.004 \text{ cm}^2$ . Cross-section image (Figure 2) of the oxide-semiconductor has been obtained from a high-resolution transmission electron microscope. An ultra-thin layer of  $A_xSi_yO_z$  has been observed in between AO and Si. High-frequency capacitance-voltage (C-V) measurement has been performed on the capacitor and the result is shown in Figure 3. Permittivity in vacuum,  $\epsilon_0$ , is  $8.854 \times 10^{-14} \text{ F/cm}$ .

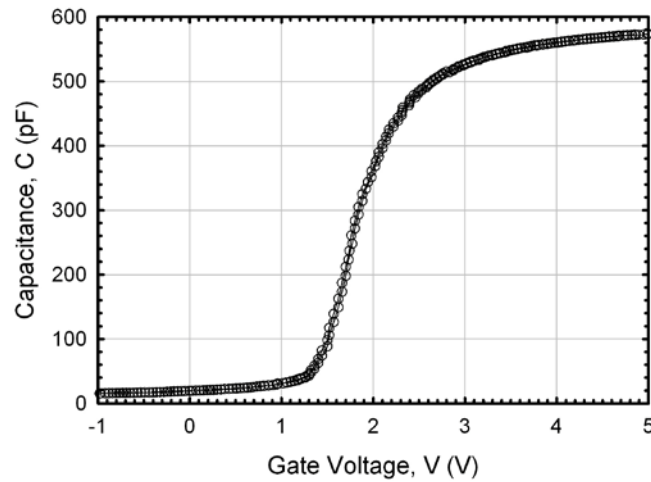
*Suatu kapasitor logam-oksida-semikonduktor (MOS) berasaskan Si mempunyai dielektrik nipis (AO) dan elektrod berkeluasan  $0.004 \text{ cm}^2$ . Imej keratan rentas (Rajah 2) oksida-semikonduktor telah diperolehi daripada transmisi elektron mikroskop resolusi tinggi. Satu lapisan ultra nipis  $A_xSi_yO_z$  telah diperhatikan di antara AO dan Si. Pengukuran kapasitan-voltan (C-V) berfrekuensi tinggi telah ditunjukkan di Rajah 3. Permittiviti di vakum,  $\epsilon_0$ , ialah  $8.854 \times 10^{-14} \text{ F/cm}$ .*



**Figure 2 - Cross-sectional view of high-resolution transmission electron microscope image of dielectric and semiconductor.**

*Rajah 2 - Imej keratan rentas yang diperolehi daripada mikroskop transmisi electron beresolusi tinggi.*





**Figure 3 - High-frequency capacitance-voltage plot of the MOS capacitor.**

*Rajah 3 - Plot kapasitan-voltan berfrekuensi tinggi yang diperolehi daripada MOS kapasitor.*

- (i) Based on the information provided, calculate the **effective dielectric constant** of the dielectric ( $AO + A_xSi_yO_z$ ).

*Berdasarkan maklumat yang diberikan, kira pemalar dielektrik efektif  $AO + A_xSi_yO_z$ .*

(30 marks/markah)

- (ii) Based on the effective dielectric constant result, justify whether AO is a high-dielectric constant material or not.

*Berdasarkan keputusan pemalar dielektrik efektif, tentukan sama ada AO ialah suatu bahan berpermalar dielektrik tinggi.*

(10 marks/markah)

- (iii) Calculate the equivalent oxide thickness (EOT) of the dielectric with respect to  $SiO_2$ .

*Kirakan ketebalan oksida setara dengan  $SiO_2$ .*

(10 marks/markah)

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7. [a] What are the differences between interconnects made from Al and Cu?

*Apakah perbezaan di antara penyambungan diperbuat daripada Al dan Cu?*

(30 marks/markah)

- [b] The most serious reliability problem in interconnect metallization is electromigration (EM).

*Masalah keboleharapan untuk penyambungan logam ialah elektromigrasi (EM).*

- (i) Explain the mechanism of EM.

*Terangkan mekanisma pembentukan EM.*

(20 marks/markah)

- (ii) Describe ways to reduce EM.

*Huraikan kaedah penyekatan EM berlaku.*

(20 marks/markah)

- [c] Explain the mechanism of thin film deposition by sputtering technique. Why is sputtering typically performed between 1 mTorr and 100 mTorr?

*Terangkan mekanisma pengendapan filem nipis dengan menggunakan teknik pemercitan. Mengapa pemercitan perlu dilakukan dalam julat di antara 1 mTorr dan 100 mTorr?*

(30 marks/markah)