

EFFECT OF POLYSTYRENE-MODIFIED NATURAL RUBBER (SNR) ON MECHANICAL PROPERTIES OF WASTE NATURAL RUBBER LATEX/POLYSTYRENE BLEND (WNRL/PS)

Orathai Boondamnoen¹, Azlan Ariffin^{1*}, Azura A. Rashid¹, Masahiro Ohshima², Saowaroj Chuayjuljit³

¹*School of Materials and Mineral Resource Engineering, Engineering Campus, Universiti Sains Malaysia, Nibong Tebal, 14300 Penang, Malaysia*

²*Department of Chemical Engineering Kyoto University Graduate School of Engineering, Kyoto University, Katsura, Saikyo-ku, Kyoto, Japan*

³*Department of Materials Science, Faculty of Science, Chulalongkorn University, Phayathai, Bangkok 10330, Thailand*

*Corresponding author : School of Materials and Mineral Resource Engineering, USM, Penang, Malaysia

e-mail : azlan@eng.usm.my

ABSTRACT

Interests on recycling of rubber products are augmenting due to the serious environmental hazard. Furthermore, recycling give economic advantages cheaper materials could be produced. Waste natural rubber latex which is usually discharged from factories contains good quality hydrocarbon chain with lightly cross linking which is the main focus in this work. The aim of this research is to develop the waste natural rubber latex (WNRL) and polystyrene (PS) blends using polystyrene-modified natural rubber (SNR) as a compatibilizer. These blends were prepared through melt mixing technique using internal mixer at difference amount loading of SNR. Mechanical properties of blends were compared. It was found that the WNRL and PS blends (WNRL/PS) have improved properties at amount loading 5 phr of SNR. The interfacial adhesion was observed on the morphology of tensile fracture surface by using a digital microscope. The mechanical properties were compared with STR L and PS blends as well.

KEYWORDS: waste natural rubber latex, thermoplastic elastomer, polystyrene-modified natural rubber, SNR, compatibilizer.

1. INTRODUCTION

Nowadays, the latex industry has widely evolved to support the world demand such as glove industry, prophylactic industry, latex thread industry, etc. The consumption of natural rubber latex is growth average 4.2% per year [1], the main process of these products is dipping process which results in high amount of rejected latex. Due to high demand of quality products, around 15% of consumption might be waste. These rejects

usually contains high quality of hydrocarbon chains. For the reason as mention, the factories face great challenge in terms of economic and ecological problems.

Initially, to overcome this problem, reclamation is done. However this way is limited by prohibition for open burning due to release of zinc compound into the environment [2]. Recycling is the best option in considering since it takes into consideration of economic and ecological aspects. Waste material has become a topic of interest among researchers nowadays. Previous studies recorded the usage of powder waste latex as filler in epoxidised natural rubber (ENR). It was found that the filler assist the compound in reducing the stickiness of ENR compounding during mixing by observation of the curing time, scorch time and induction time decrease when the filler content increased. In addition, considering the different particle sizes and amount loading of filler, it was found that the smallest particles gave the optimum properties. The properties also increase when filler loading is increased [2]. Another way to reuse the latex product wastes is to blend it with high density polyethylene (HDPE). These latex product wastes were treated before blending. It was found that the latex product wastes from different sources gives similar mechanical properties and processability compared with thermoplastic elastomer base on natural rubber and HDPE. Thus, it can be said that thermoplastic elastomer can be developed from latex product waste and HDPE [3].

Recently, thermoplastic elastomers are the material which attends attention from industry and research. Due to their properties that include elastic and thermoplastic properties, they are able to stretch and return it to close original shape when the stress is removed and melts at high temperature as well. It means that this material can

be recycled which is good for environment. Some research were mentioned early on the usage of waste latex in thermoplastic materials while some research uses waste type rubber [4,5,6,7] or using recycle rubber powder [8]. However, TPE main problem is the interfacial adhesion [6,8,9]. They are improved by using a compatibilizer or third component in binary blends [6,7,9,10]. The main propose for compatibilization are adjusting of interfacial tension, stabilizing of morphology and improving of adhesion between phases [11]. The compatibilization process can be divided into two items, there are non-reactive and reactive compatibilizations [11,12]. The non-reactive process is the addition of third component which is miscible in binary polymer. For example as reported that the extrude deformation of polystyrene and polybutadiene blends reduce with SBR which use as compatibilizer increase. [13]. Another one is reactive process which contain reactive site on polymer chain and able to react with other polymer. For example, the waste rubber tire power and polypropylene blends with additional of maleic anhydride-grafted styrene-ethylene-butylene-styrene in [5,6] or maleic anhydride-grafted polypropylene [7]. Some researchers did treatments or modified one of components prior to blending and it was recorded that the properties were improved after treatment [14,15]

In this research, an attempt was done on producing thermoplastic elastomer base on waste natural rubber latex (WNRL) and polystyrene (PS). The polystyrene-modified natural rubber (SNR) was used as a blend compatibilizer in blending to improve its properties. The objective of this research is observing the effect of SNR on mechanical properties of blends. The blends were carried out at different amount loading of SNR.

2. EXPERIMENTAL

2.1 Preparation of WNRL sheet form

The waste natural rubber latex was casted on glass plate and dried in ambient temperature for 3 days after that were removed to hang in ambient temperature for further drying. The WNRL sheet was milled through a two roll mill. After that a mill-sheeted of WNRL was cut in small pieces to use as a blend component

2.2 Mixing, molding and preparation of sample

The blends were prepared based on waste natural rubber latex (WNRL) and polystyrene (PS) with composition 20/80 containing the polystyrene-modified natural rubber (SNR) 5, 10, 15 and 20 phr of total polymer. The blends of WNRL/PS were prepared by melt mixing technique. The mixing was done in a Haake internal mixer (Model Polydrive R600/610) with rotor speed of 60 rpm at 140 °C. PS was melt for 2 min prior to the addition of WNRL and SNR mixing was continued mix up to 10 min. After mixing, the blend was taken out and leaved at ambient temperature prior to compression. The blends were preheated for 6 min and compressed for 4 min at temperature of 140 °C. After that compress

sheets were cooled down under pressure for 3 min at ambient temperature. The samples were cut from the sheet before investigated the mechanical properties.

2.3 Characterization

Tensile test

The sheets were cut as a strip shape with dimensions 115.0x12.2x1.0 mm (LxWxT) referring to Fig. 1. The strip shape was used instead of a dumbbell shape for tensile test due to sample are brittle. Tensile test was done referring to ASTM D 412 test method with a cross head speed 50 mm/min using an Instron universal machine model 3366

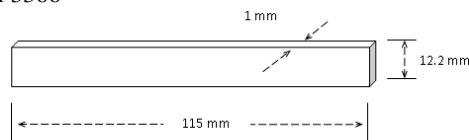


Fig. 1 strip shape

2.4 Morphology studies

The morphological studies of tensile fracture surfaces were carried out using Dino-Lite AM413ZT digital microscope at magnification of 200

3. RESULTS AND DISCUSSION

3.1 Tensile strength

The tensile properties of waste natural rubber latex/polystyrene (WNRL/PS) at composition 20/80 with different loading level of addition of styrene graft natural (SNR) are shown in Fig 2-6. Referring to Fig. 2 the tensile strength of all blends with addition of SNR is higher than the WNRL/PS blend without SNR and STRL/PS blend. An early observation could be made here where the SNR improves the adhesion between phases of rubber and polystyrene. Comparing the amount loading in WNRL/PS blends, the tensile strength first increase with addition of SNR at 5 phr of total polymer, and then decrease after loading level of SNR is excess 5 phr.

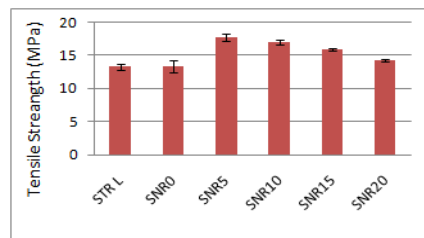


Fig. 2 Tensile strength of WNRL/PS blend with four loading level of SNR

The reason the tensile strength increases is because the SNR behaves as a compatibilizer to adhere interfacial between phases of binary of components [16]. SNR contains polyisoprene and polystyrene segments in the SNR structure as predicted in Fig. 3. The polyisoprene segments in SNR is well dispersed in rubber phase like polystyrene segments is well disperse in polystyrene

phase. This will then improve the adhesion between phases of these polymer components.

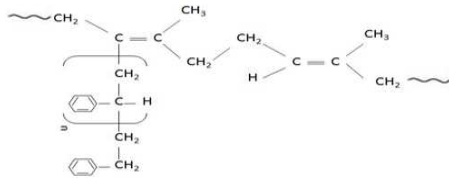


Fig. 3 Predicted SNR structure [16,17]

On the other hand after addition of SNR excess 5 phr, the tensile strength decreases. This could be explained by when a compatibilizer is added in the blends, it will move and form layer at interfacial between of matrix and dispersion phases [9,12,18] as shown in Fig. 4. If the amount of compatibilizer added is in excess, then its layer at interfacial phases will be too thick. This will lead to weak points or flaw at interfacial between phases because the tensile properties of polymer blends are responsive with interface [9]. This is the reason that tensile strength of the blends with contains SNR excess 5 phr become poorer

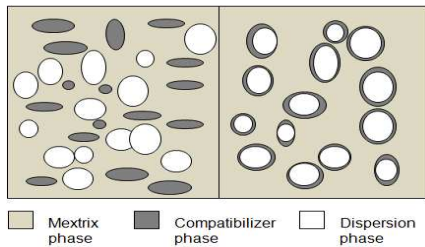


Fig. 4 Schematic representation describing the behavior of matrix and dispersed phases in a polymer blend with addition of compatibilizer [12]

3.2 Elongation at break

Fig. 5 shows elongation (EB) at break of WNRL/PS blends with different loading level of SNR. It can be seen that EB of the blends contain SNR for all four loading levels are higher than EB of the blend without SNR. It can be said that EB of blends are improved by addition of SNR. This is because SNR act as a compatibilizer to adhere the interface between phases of rubber and polystyrene. The WNRL and PS are more compatible and more adhesion surface between rubber and PS phases after addition of SNR. This is observed in the morphologies micrographs as shown in Fig. 7. It was observed that particle size of the blends with SNR is smaller than the blend without SNR. However after addition of SNR excess 5 phr, the trends of EB decreases when amount loading of SNR increase. This is because SNR reduce the stiffness of the blends which resulted in low resistance of elongation [9]. Due to the EB property of SNR is very high (1012%) and tensile strength is very low (1.2 MPa) as reported in early research [16]. SNR is one component in blends then its properties will be

shown in blends as well. It is the nature of polymer blends, the properties of blends depend on the properties and compositions of each polymers [12]

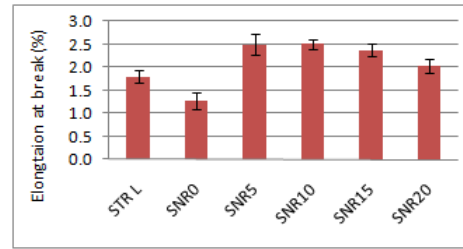


Fig. 5 Elongation at break of WNRL/PS blend with four loading level of SNR

Comparing the EB of WNRL/PS and STRL/PS, the EB of WNRL/PS is lower than EB of STRL/PS. This is because the presence of the cross linking in WNRL phase, it resist to mobility of molecule chain to slip past each other [19]

3.3 Young's modulus

The relationship between Young's modulus and loading level of compatibilizer is shown in Fig. 6. The Young's modulus decrease when the addition of compatibilizer increases. This is because the structure of predicted SNR is a flexible molecule as shown in Fig. 3. The main chain of molecule is the repeating unit of polyisoprene and the side chain is polystyrene (25/75 PS/NR [16]). Lead to the restricting of mobility of chain molecule decreases thus the stiffness of blend decrease after addition of compatibilizer [4,9]

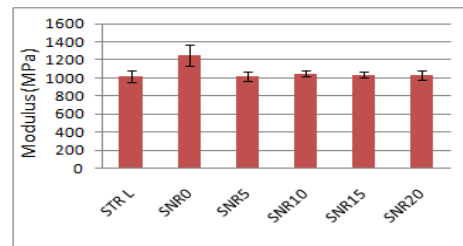


Fig. 6 Young's modulus of WNRL/PS blend with four loading level of SN

3.4 Morphology

Fig. 7 shows the digital micrographs of the tensile fracture surface of 20/80 WNRL/PS blends with different loading level of SNR. Comparing the WNRL/PS blends between with and without SNR, it could be observed that in every WNRL/PS blends with addition of SNR, the dispersion of WNRL phase in PS matrix phase is better than WNRL without SNR. Moreover the reduced particle sizes of WNRL were present in WNRL/PS with SNR blends, it means that the chance of separation between phases is reduced [14]. This can be said that the SNR assist to improve the morphology of WNRL/PS blends. The evident of big in Fig. 7(b) indicate that there is poor adhesion between WNRL and PS phases. It conduct the

stress transfer between phases is poor. As shows that tensile strength of blends was improved after addition of SNR [14]. This is because the addition of an optimal compatibilizer reduces the interfacial tension of the phases [9].

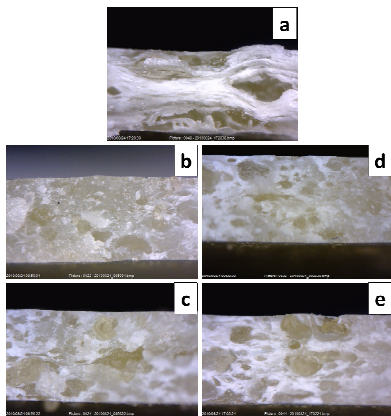


Fig. 7 Digital micrographs of tensile fracture surfaces of 20/80 WNRL/PS with different loading of SNR (200X) (a) 0 phr (b) 5 phr (c) 10 phr (d) 15 phr (e) 20 phr

4. CONCLUSIONS

The SNR is effective in improving the tensile strength, elongation at break and morphology but decreases the Young's modulus of waste natural rubber/polystyrene blends. The optimum amount of SNR loading is at 5 phr. The interfacial adhesion between the WNRL phase and the PS phase is improved. The dispersion of WNRL phase in the PS phase is better that can be proved by digital micrographs.

ACKNOWLEDGEMENT

The authors thank the AUN/SEED Net Project under the Grant no. 304/6050170 for financial support and also gratefully acknowledge to Universiti Sains Malaysia for facility support.

REFERENCES

- [1] Rajan V.V., Dierkes W.K., Joseph R. and Noordermeer J.W.M. (2006) Science and technology of rubber reclamation with special attention to NR-based waste latex products. *Progress in polymer science* 31, p.811-834.
- [2] Mathew G., Singh R.P., Nair N.R. and Sabu T. (2001) Recycling of natural rubber latex waste and its interaction in epoxidised natural rubber. *Polymer* 42, p.2137-2165.
- [3] Rajalekshmi S. and Rani J. (2002) Studies on the Rheology and the Mechanical Properties of Thermoplastic Elastomer from Latex Product Waste and High Density Polyethylene. *Journal of Elastomers and Plastics* 34, p.313-322.
- [4] Awang M. and Ismail H. (2008) Preparation and characterization of polypropylene/waste tyre dust blends with addition of DCO and HVA-2

- (PP/WTD_{P-HVA2}). *Polymer Testing* 27, p. 321-329.
- [5] Shu L. Z., Zhen X. X., Zhen X. Z. and Jin K. K. (2009) Characterization of the properties of thermoplastic elastomers containing waste rubber powder. *Waste Management* 29, 1480-1485.
- [6] Zhen X. X., Zhen X. Z., Kashik P., Jong U. B., Sung H. L. and Jin K. K. (2010) Study of microcellular injection-molded polypropylene/waste ground rubber tire powder blend. *Materials and Design* 31, p. 589-593.
- [7] Zhen X. X., Shu L., Z. Sung H. L., Dong J. K., Dae-Suk B. and Jin K. K. (2008) Microcellular foams of thermoplastic vulcanizates (TPVs) based on waste ground rubber tire powder. *Materials Letters* 62, p 4396-4399.
- [9] Ismail H., Galpaya D. and Ahmad Z. (2009) The compatibilizing effect of epoxy resin (EP) on polypropylene (PP)/recycled acrylonitrile butadiene rubber (NBRr) blends. *Polymer Testing* 28, p. 363-370.
- [10] Skulrat P., Charoen N., Azizon K. and Suda K. (2008). Influences of blend compatibilizers on dynamic, mechanical and morphological properties of dynamically cured maleated natural rubber and high-density polyethylene blends. *Polymer Testing* 27, p. 566-580.
- [11] Leszek A. U. (2002). Compatibilization of polymer blends. *The Canadian Journal of Chemical Engineering* 80, p. 1008-1016.
- [12] Lloyd M. R. (2007) *Polymer Blends*. Germany. p. 9-51, 70-75, 200-202
- [13] Susan J., Zachariah O. and Sabu T. (2002). Melt elasticity and extrudate characteristics of polystyrene/polybutadiene blends. *Materials Letters* 53, 268-276.
- [14] Awang M., Ismail H. and Hazizan M.A. (2007) Processing and properties of polypropylene-latex modified waste tyre dust blends (PP/WTD_{ML}). *Polymer Testing* 27, p. 93-97.
- [15] Siriwan R., Sombat T. and Taweechai A. (2009). Chlorination and characterization of natural rubber and its adhesion to nitrile rubber. *European Polymer Journal* 45, p. 2017-2022.
- [16] Ong S. K. (2004) Blends of polypropylene with natural rubber and with polystyrene-modified natural rubber. p. 89-90
- [17].Nanthaporn P., Yoshimasa Y. and Seiichi K. (2008) Mechanism of graft copolymerization of styrene onto deproteinized natural rubber. *Colloid Polymer Sci* 286, p. 411-416.
- [18] Monsy M. and Sabu T. (2003) Compatibilisation of heterogeneous acrylonitrile-butadiene rubber/polystyrene blends by the addition of styrene-acrylonitrile copolymer: effect on morphology and mechanical properties. *Polymer* 44, p. 1295-1307.
- [19] Robert O. E. (2000) *Polymer Science and Technology*. America. P.79-80,360-363