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Natural Rubber/Styrene Butadiene Rubber/Recycled Nitrile Glove (NR/SBR/rNBRg) Ternary Blend: Tensile Properties & Morphology

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ABSTRACT

Recycling waste rubber products by utilising them in rubber blends had provided the simplest and most cost-effective ways in solving several environmental issues regarding the abundance of scrap rubbers. Discarded nitrile gloves, in which the defects and rejects from the nitrile gloves production were used in this study. Ternary blends of natural rubber/styrene butadiene rubber/recycled nitrile glove (NR/SBR/rNBRg) were prepared. The effects of blend ratio (50/50/00, 50/40/10, 50/30/20, 50/20/30, 50/10/40, 50/00/50, 40/50/10, 30/50/20, 20/50/30, 10/50/40 and 00/50/50 (phr/phr/phr)) on tensile properties and morphology of NR/SBR/rNBRg ternary blends were studied. The result indicates that the NR/SBR/rNBRg ternary blends exhibited a decrease in tensile properties as the rNBRg content increased. However, the optimum tensile properties of the blends exhibited at 50/30/20 blend ratio. The resilience and crosslink density of the blends decreased with addition of rNBRg while the hardness increased when more rNBRg content added. However, significant drop in hardness can be observed at 40 phr of rNBRg content, due to the random dispersion of rNBRg on the surface of the test pieces. Scanning electron microscopy (SEM) analysis indicated that, poor attachment of rNBRg particles into the blends as rNBRg content increased.

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INTRODUCTION

Waste rubber does not degrade rapidly and had caused environmental pollution. Waste rubber usually comes from the scrap rubber products that do not meet processing requirements and product specifications, either defects or rejects from manufacturing process [7]. To reduce the pollution caused by discarded waste rubber, recycling is the best solution available. Addition to reducing the environmental pollution, recycling of waste rubbers helps in conservation of energy; by reducing the dependence on petroleum for energy sources and providing industrial raw material; regenerative rubber and powdered rubber are raw materials of the rubber industry [3].

Natural rubber (NR) and its blend compounds have been extensively studied because of their superior performance in many applications. NR has a high percent of cis-1,4 structures, which mean it has higher tensile strength than synthetic rubbers for its crystallizing by orientation. NR can be blended with synthetic rubbers to improve its mechanical properties [4]. Styrene butadiene rubber (SBR) is a general purpose synthetic rubber that can have high filler loading capacity; good flex resistance, crack initiation resistance and abrasion resistance, which make it useful for several engineering and industrial applications [11]. NR is usually blended with SBR for tire applications, which requires good mechanical properties and good abrasion resistance of both rubber gums.

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Acrylonitrile butadiene rubber (NBR) is a synthetic rubber of copolymerised acrylonitrile and butadiene and has good fuel resistance and low gas permeability, which attributes depends on the acrylonitrile content. It is widely used in industry for sealant applications due to its moderate cost, excellent resistance to oils, fuels and greases, and good processability [15] [1]. Nitrile glove is one of the products made from NBR and widely being used in medical and healthcare sectors.

[9] reported that SBR is incompatible with NBR while [7] studied the comparison between NR/SBR blend and NR/NBR blend in fatigue and mechanical properties, to the extent of blend homogeneity, depends on the mixing method, solubility parameters and nature of blend constituent rubbers. The effects of blend ratio and different crosslinking systems on curing, morphology and mechanical properties of SBR/NBR blends have been studied by [5]. The study on the compatibility by detecting the crosslink density of NR/SBR blend and NR/NBR blend was carried out by [2]. [12] studied the effect of virgin NBR (vNBR) and recycled NBR (rNBR) incorporation on the curing characteristics and mechanical properties of SBR/vNBR and SBR/rNBR blends. To the best of our knowledge, no recent research has focused on utilising recycled NBR obtained from nitrile glove in ternary blend with NR and SBR. In this study, a fixed nitrile glove sheet size was incorporated in NR/SBR/rNBRg ternary blends. The effect of blend ratio on the tensile properties and morphology were studied.

MATERIALS AND METHODS

Materials:

The materials used in this study and their descriptions are shown in Table 1. The size of the nitrile glove sheets was cut approximately about 20 – 30 cm^2 from the recycled glove.

Table 1: Characteristics of the materials

Materials	Description	Source
Natural rubber	Standard Malaysia Rubber L (SMR L)	Malayan Testing Laboratory Sdn. Bhd.
Styrene butadiene rubber	Synthetic Rubber SBR-1502	Kumho Petrochemical
Recycled nitrile glove (rNBRg)	Size : 20– 30 cm^2	Topglove (M) Sdn. Bhd.
N-cyclohexyl-2-benzothiazyl sulfenamide (CBS), zinc oxide, stearic acid, sulphur, antioxidant and processing oil	Compounding materials	ADV System Technology

Compounding:

The compounding recipe of NR/SBR/rNBRg ternary blends are shown in Table 2. The mixing procedure was carried out using two roll mills according to ASTM D 3184-89 at room temperature.

Table 2: Compounding recipe of NR/SBR/rNBRg ternary blends

Materials	Recipes (phr)
NR/SBR/rNBRg	50/50/0, 50/40/10, 50/30/20, 50/20/30, 50/10/40, 50/0/50, 40/50/10, 30/50/20. 20/50/30, 10/50/40, 0/50/50
ZnO	5
Stearic Acid	2
CBS	1.5
Antioxidant	1.5
Processing Oil	5
Sulfur	2.5

Curing Characteristics:

Curing characteristics of NR/SBR/rNBRg ternary blends were studied using a Hung Ta Moving Die Rheometer according to ASTM D 2240-93. Samples of about 4.0 g of each blend were used to test at 160^{o}C. The blends then were compression moulded at 160 ^{o}C according to respective cure time (t_{c90}) obtained from rheometer.

Measurement of Tensile Properties:

Dumbbell shaped samples were cut from the moulded sheets. Tensile test were performed at a cross-head speed of 500 mm/min using an Instron 3366 Universal Testing Machine according to ASTM D 412-93. The tensile strength, modulus at 100% elongation (M_{100}) and elongation at break (E_B) were investigated. The hardness measurements of the samples were performed according to ASTM D 1415-88 using Shore A type manual durometer. The resilience was studied using a Wallace Dunlop tripsometer according to ASTM D 1054-91. The rebound resilience was calculated according to the following equation:

$$Resilience\ (\%) = \frac{1 - cos\theta_2}{1 - cos\theta_1} \times 100 \quad (1)$$

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where θ_1 is the initial angle (45^o) and θ_2 is the maximum rebound angle.

Scanning Electron Microscopy (SEM) analysis:

Tensile fracture surface of respective ternary blends was analysed with JEOL JSM-6460LA. The objective was to obtain the images that related to the quality of the bonding between NR, SBR and rNBRG and to detect the presence of micro-defects if any.

RESULTS AND DISCUSSIONS

Tensile Properties:

Table 3 tabulated the tensile strength, modulus at 100% elongation (M_{100}), elongation at break (E_B), resilience and hardness of NR/SBR/rNBRg ternary blends, respectively. Generally, the addition of rNBRg content into the ternary blend had decreased the tensile properties. The decrement in tensile properties of NR/SBR/rNBRg blends was due to the compatibility of NR, SBR and rNBRg. The difference in the molar concentrations of double bonds in each elastomer resulted in differences in the polarity, number of allylic carbon sites for sulphur vulcanization and reactivity of the crosslink sites [13,8]. According to [2], NR/SBR blends are more compatible compared to NR/NBR blends. Thus, in this study, the increasing of rNBRg weight ratio decreased the compatibility of the blends and reduced the tensile properties.

Comparing all of the blends, it is clearly shown that at the same blend ratio, the blends with weight ratio of NR superior to SBR exhibited better tensile properties, since NR is crystalline when stretched while SBR is amorphous [2]. However, for the blends of the NR weight ratio superior to SBR, the tensile properties increased up to 20 phr of rNBRg content. It is believed that when rNBRg content was less than 20 phr in the blends, uniform dispersion of rNBRg content in the blends, which allowed the rNBRg particles embedded into the NR/SBR matrix, are responsible for better tensile properties of NR/SBR/rNBRg blends, as illustrated by SEM micrographs of the blend.

Resilience is the ratio of energy released by the recovery from deformation to that required to produce the deformation [10]. The resilience of the ternary blends decreased upon addition of rNBRg into NR/SBR matrix. The molecular mobility of the rubber chain decreased, thus increased the stiffness of the rubber vulcanizates. The addition of rNBRg content also resulted in more rigid rubber vulcanizates and increased the hardness of the rubber blends (Vinod, Varghese, Alex, & Kuriakose, 2001). However, the hardness of the blends decreased significantly at 40 phr of rNBRg. This might be due to the random dispersion of rNBRg particles on the surface of the hardness test samples.

Table 3: Tensile and physical properties of NR/SBR/rNBRg ternary blends

Blends	TS	M_{100}	E_B	Resilience	Hardness
50/50/00	2.7884	0.8916	376.32	82.8355	44.8667
50/40/10	6.2470	0.9307	648.66	75.9605	44.6333
50/30/20	7.1404	1.0768	719.32	71.7656	44.9667
50/20/30	3.8954	1.0572	608.66	68.9879	45.2667
50/10/40	1.3344	1.0440	230.34	58.2570	43.4000
50/00/50	1.0876	1.0078	122.98	57.9255	43.8333
40/50/10	5.2884	0.9683	614.68	74.4681	44.5667
30/50/20	2.9378	0.9522	549.70	66.4942	45.6667
20/50/30	1.5364	0.9222	540.66	58.3689	45.9667
10/50/40	0.8632	0.8230	141.32	52.4060	43.5667
00/50/50	1.0410	0.9609	156.66	50.3106	45.3333

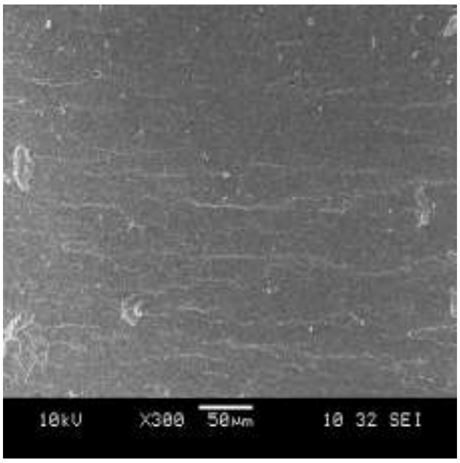
TS : Tensile Strength (MPa)
M_{100} : Modulus at 100% Elongation (MPa)
E_B : Elongation at Break (%)
Resilience : Resilience (%)
Hardness : Hardness (Shore A)

Morphology:

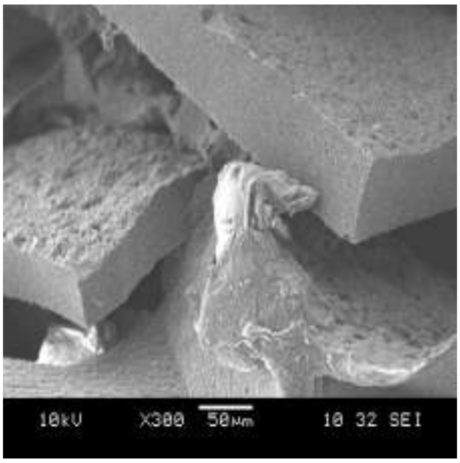
Figures 1(a, b and c) show the comparison of SEM tensile fracture surfaces of NR/SBR/rNBRg ternary blends at 50/50/00, 50/00/500 and 00/50/50 blend ratio, respectively. The micrographs of the failure surfaces of NR/SBR/rNBRg blends in Figure 1(b and c) show the detachment of rNBRg particles from the NR and SBR matrix, respectively while Figure 1(a) of NR/SBR/rNBRg (50/50/00) shows some matrix tearing lines. Comparison can be drawn from Figure 1(b) and 1(c), where the rNBRg particles are well-bonded with NR matrix compared to SBR matrix.

Figures 2(a) and 2(b) show the SEM tensile fracture surfaces of the ternary blends at 50/30/20 and 30/50/20 blend ratio, respectively. At the same recycled content, Figure 2(a) illustrated that the rNBRg particles still embedded to the virgin rubbers matrix upon fractured, while Figure 2(b) show the rNBRg particles detached from the virgin rubber matrix. Incorporation of 20 phr of rNBRg into the blend with weight ratio of NR superior to SBR obtained higher tensile strength compared to the blend with weight ratio of SBR superior to NR.

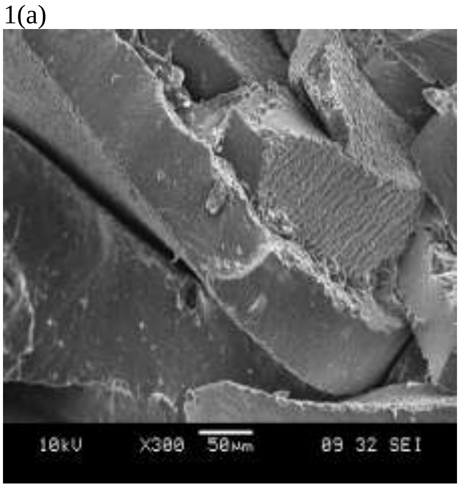
Figure 3 shows the SEM tensile fracture surfaces of the blend at 10/50/40 blend ratio. It is clearly seen the detachment of rNBRg particles from the virgin rubbers, particularly SBR. The empty space can be seen on the surface illustrated the rNBRg particles were easily detached from the rubbers matrix.



1(a)

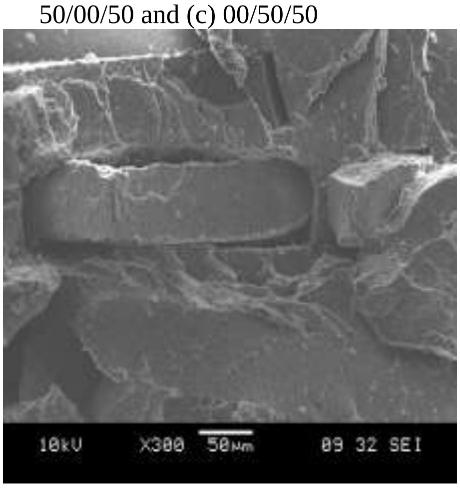


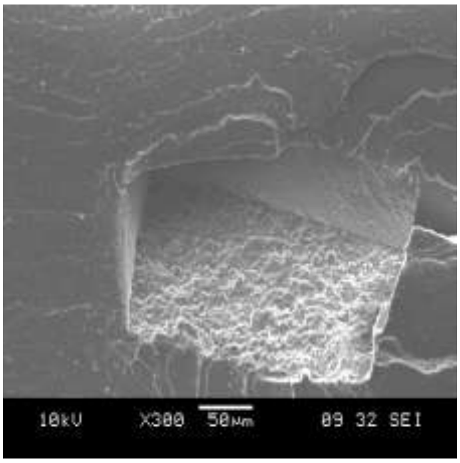
1(b)



1(c)

Fig. 1: Scanning electron micrograph of tensile fracture surfaces of NR/SBR/rNBRg blends, (a) 50/50/00, (b) 50/00/50 and (c) 00/50/50





2(a) 2(b)

Fig. 2: Scanning electron micrograph of tensile fracture surfaces of NR/SBR/rNBRg blends, (a) 50/30/20 and (b) 30/50/20

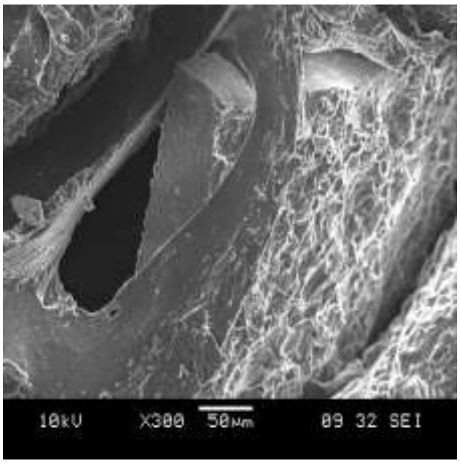


Fig. 3: Scanning electron micrograph of tensile fracture surfaces of NR/SBR/rNBRg blends at 10/50/40

Conclusion:

The tensile properties of NR/SBR/rNBRg ternary blends decreased with increasing of rNBRg content. Generally, NR/SBR/rNBRg blend with NR content superior to SBR gives better properties at similar rNBRg content. It is due to the compatibility between NR, SBR and rNBRg, which NR and rNBRg have higher compatibility compared to SBR and rNBRg. The optimum tensile properties obtained at 50/30/20 blend ratio, due to the uniform dispersion of rNBRg into NR/SBR matrix which allowed the recycled rubber to embedded into the matrix well. The resilience of the blends reduced with increasing rNBRg content, while hardness of the blends increased. The scanning electron micrograph shown that poor interaction between the rNBRg and the rubber matrix at high recycled content.

REFERENCES

[1] Degrange, J.M., M. Thomine, Ph. Kapsa, J.M. Pelletier, L. Chazeau, G. Vigier, L. Guerbé, 2005. Influence of viscoelasticity on the tribological behaviour of carbon black filled nitrile rubber (NBR) for lip seal application. *Wear*, 259(1–6): 684-692. doi: http://dx.doi.org/10.1016/j.wear.2005.02.110.

[2] El-Sabbagh, S.H., & A.A. Yehia, 2007. Detection of Crosslink Density by Different Methods for Natural Rubber Blended with SBR and NBR. Egyptian Journal of Solids, 30(2): 157-173.

[3] Fang, Yi, Zhan, Maosheng, & Wang, Ying, 2001. The status of recycling of waste rubber. Materials & Design, 22(2): 123-128. doi: http://dx.doi.org/10.1016/S0261-3069(00)00052-2

[4] Findik, F., R. Yilmaz, & T. Köksal, 2004. Investigation of mechanical and physical properties of several industrial rubbers. Materials & Design, 25(4): 269-276. doi: http://dx.doi.org/10.1016/j.matdes.2003.11.003

[5] Habeeb Rahiman, K., G. Unnikrishnan, A. Sujith, & C.K. Radhakrishnan, 2005. Cure characteristics and mechanical properties of styrene–butadiene rubber/acrylonitrile butadiene rubber. Materials Letters, 59(6): 633-639. doi: http://dx.doi.org/10.1016/j.matlet.2004.10.050

[6] Ismail, H., R. Nordin, & A.M. Noor, 2002. Cure characteristics, tensile properties and swelling behaviour of recycled rubber powder-filled natural rubber compounds. Polymer Testing, 21(5): 565-569. doi: http://dx.doi.org/10.1016/S0142-9418(01)00125-8

[7] Ismail, M.N., S.H. El-Sabbagh, & A.A. Yehia, 1999. Fatigue and Mechanical Properties of NR/SBR and NR/NBR Blend Vulcanizates. Journal of Elastomers and Plastics, 31(3): 255-270. doi: 10.1177/009524439903100306

[8] Mangaraj, Duryodhan, 2002. Elastomer blends. Rubber chemistry and technology, 75(3): 365-427.

[9] Mansour, Ashraf, A., El-Sabagh, Salwa, & Yehia, A. Abbas, 1994. Dielectric Investigation of SBR-NBR and CR-NBR Blends. Journal of Elastomers and Plastics, 26(4): 367-378. doi: 10.1177/009524439402600406

[10] Morton, Maurice, 1987. *Rubber technology*: Van Nostrand Reinhold Company.

[11] Noriman, N.Z., H. Ismail, & A.A. Rashid, 2010. Natural Weathering Test of Styrene Butadiene Rubber and Recycled Acrylonitrile Butadiene Rubber (SBR/NBRr) Blends. Polymer-Plastics Technology and Engineering, 49(7): 731-741. doi: 10.1080/03602551003664552

[12] Noriman, N.Z., H. Ismail, & Rashid, Azura, 2008. Curing Characteristics and Mechanical and Morphological Properties of Styrene Butadiene Rubber/Virgin Acrylonitrile-Butadiene Rubber (SBR/vNBR) and Styrene Butadiene Rubber/Recycled Acrylonitrile-Butadiene Rubber (SBR/rNBR) Blends. Polymer-Plastics Technology and Engineering, 47(10): 1016-1023. doi: 10.1080/03602550802355206

[13] Tinker, Andrew J, & P. Jones, Kevin, 1998. *Blends of Natural Rubber: Novel Techniques for Blending With Specialty Polymers*: Springer.

[14] Vinod, V.S., Varghese, Siby, Alex, Rosamma, & Kuriakose, Baby, 2001. Effect of aluminum powder on filled natural rubber composites. Rubber chemistry and technology, 74(2): 236-248.

[15] Yasin, Tariq, Ahmed, Shamshad, Yoshii, Fumio, & Makuuchi, Keizo, 2003. Effect of acrylonitrile content on physical properties of electron beam irradiated acrylonitrile–butadiene rubber. Reactive and Functional Polymers, 57(2–3): 113-118. doi: http://dx.doi.org/10.1016/j.reactfunctpolym.2003.08.004.