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To cite this article: N F Ab Ghani *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **736** 052010

IOP Conf. Series: Materials Science and Engineering **736** (2020) 052010 doi:10.1088/1757-899X/736/5/052010

Mechanical properties of styrene butadiene rubber toughened graphene reinforced polystyrene

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Abstract. In this study, styrene butadiene rubber was used for toughened polystyre/graphene nanoplatelets (PS/GNP) nanocomposites. The objective of this research is to determine the effect of styrene butadiene rubber (SBR) contents on the toughness of PS/GNP nanocomposites. In order to achieve the objectives of the research PS/GNP nanocomposites were prepared with various SBR content styrene butadiene rubber content, while the contents of GNP were fixed at 0.5 wt%. The PS/GNP/SBR nanocomposites were prepared by melt blending technique. Mechanical properties of SBR toughened PS/GNP nanocomposites showed a decrement of toughness and tensile strength with increasing content of SBR. SEM study shows that the rubber dispersed uniformly within the blends with polystyrene nanocomposites. SEM results show that the polystyrene mixed with graphene nanoplatelets (PS/GNP) had the smooth surface compare to samples have toughened with styrene butadiene rubber. The mechanical properties of PS/GNP nanocomposites with contain of 15 wt% of SBR shown the best of toughening effect.

1. Introduction

Polystyrene (PS) plastic could be a naturally transparent thermoplastic that can be obtained both as a typical solid plastic and as a rigid foam material. PS plastic is generally used in a wide range of consumer product applications and is also useful in industrial packaging. [1, 2]. The characteristic of polystyrene is stiff, hard, and very brittle [3]. Since the invention of artificial polymers throughout the first 1900's, compounding of polymers with inorganic filler and fibers was developed as a versatile route resulting in novel compound materials with improved thermal and mechanical properties with engaging cost/performance quantitative relation. Worldwide, there has been a replacement and intense need to tailor the structure and composition of materials with the use of reinforcement filler on the nanometer scale.

Graphene nanoplatelet (GNP) contains attractive polymer matrix nanofiller. Graphene nanoplatelet has a good balance of properties and costs. Graphene nanoplatelets has high modulus, good strength, fine barrier properties and excellent electrical and thermal characteristics [4, 5]. The unique graphene monolayer structure attracted tremendous attention in the development graphene-filled polymer nanocomposites (GNP). Polystyrene modification with additional nanofillers such as graphene nanoplatelets (GNP) results in improved conductivity and strength, but is also usually accompanied by a loss of toughness. In order to solve this issue, several studies have been carried out to develop techniques of toughening polystyrene, such as using rubber particles as an effect modifier [6]. According to Bucknall, polymer toughening techniques were often associated with mechanisms of plastic deformation [7].

The development of rubber toughened PS/GNP nanocomposites was a relatively new material concept. To best of our knowledge, there were no attempt made thus far to enhance toughness of PS/GNP nanocomposite by using rubber. Styrene butadiene rubber (SBR) was used as the toughening agent to overcome the brittleness of polystyrene nanocomposites [8]. The key question is to find the best styrene butadiene rubber content to achieve toughening effect of PS nanocomposites. To investigate this, the tensile properties, flexural properties and impact resistance of polystyrene nanocomposites will compare at difference weight fraction of styrene butadiene rubber content (5, 10, 15, 20 and 25 wt%) while the contents of graphene nanoplatelets were fixed at 0.5 wt% in polystyrene nanocomposite matrix. This study will highlight the mechanical properties and characteristics of styrene butadiene rubber as toughening agent.

2. Experimental

2.1. Materials

GNP used is a commercial grade from Soochow Hengqiu Graphene Technology Co., Ltd. The multilayer GNP was a powder form with 95 wt% purity and had from 6 to 10 layers. Polystyrene used was the commercial grade PS, while Butadiene Rubber (SBR) was donated from Malaysian Rubber Board.

2.2. Preparation of nanocomposites

In the twin-screw extruder, SBR toughened PS/GNP nanocomposites were prepared with barrel temperatures between 220°C and 270°C at an output rate of 100 rpm. SBR toughened PS/GNP nanocomposites were prepared at 0 wt%, 5 wt%, 10 wt%, 15 wt%, 20 wt% and 25 wt% of SBR, while the contents of GNP were fixed at 0.5 wt%. The extruded materials were moulded using Hot and Cold Moulding Press machine at 220°C for 20 min with pressure of 10MPa into standard tensile, flexural and Izod impact specimen.

2.3. Characterization of nanocomposites

2.3.1. Scanning Electron Microscopy (SEM) Analysis. Scanning Electron Microscopy (SEM) using Hitachi TM3030 Plus investigated the structure of flexural fracture surface of the PLA/GNP/SBR nanocomposites.

2.3.2. Mechanical test. A universal testing machine (AG-Xplus Series, Shimadzu, Japan) was used to determine tensile and flexural strength of PLA/GNP/SBR nanocomposites. Tensile and flexural samples were prepared respectively in accordance with ASTM D638 and ASTM D790. In determining the final value, the average of five specimens of tensile and flexural considered.

3. Result and Discussion

3.1. Scanning electron microscopy (SEM) analysis

Scanning electron microscopy (SEM) images were taken from fracture surfaces of different weight fraction specimens (Figure 1b, c and d) to characterize the effectiveness of the SBR dispersion. Figure 1a contains a representative image of polystyrene nanocomposite. A fairly even distribution is achieved throughout the entire body of the specimen, especially visible for this investigation in the area of interest. In Figure 1a, the fracture surface for polystyrene nanocomposite (PS/GNP) was more smooth compare to others. This morphology shows smooth surface because it’s brittle. This is because polystyrene nanocomposite was very brittle and it was easier to fracture as indicated from morphology analysis. The dominant mechanism for polystyrene deformation is craze formation, and various craze formation that leads to toughness enhancement [7].

Figure 1b, 1c and 1d are the image of surface fracture for PS/SBR and PS/GNP with 5wt% and 10wt% of SBR. From that picture we can see that the increase of surface roughness of the composites with increase content of rubber in the polymer. Besides, in Figure 1b and 1c have uniform the distribution of styrene butadiene rubber in this polymer compare to Figure 1d. The composition of PS/GNP with 5 wt% of SBR was more uniform (Figure 1c) than PS/SBR without graphene nanoplatelets as a filler (Figure 1b) because the graphene also contributed to make it uniform distribution in polystyrene. This indicates that the optimum loading of the styrene butadiene rubber in that polymer was achieved, hence the coalescence effect was not happened.

The presence of void in Figure 1b and 1c is due to the absence of rubber particle [9]. Rubber particle was detached during the impact test which also make the shape of void become a bit elongated. The reason is that the bond between the rubber and the matrix is weak and the rubber particle is pulled away from the matrix forming a hole. From that the tensile strength also will decreased when added more rubber contents in the polymer matrix. Wu indicates that rubber toughening requires a minimum adhesion [10].

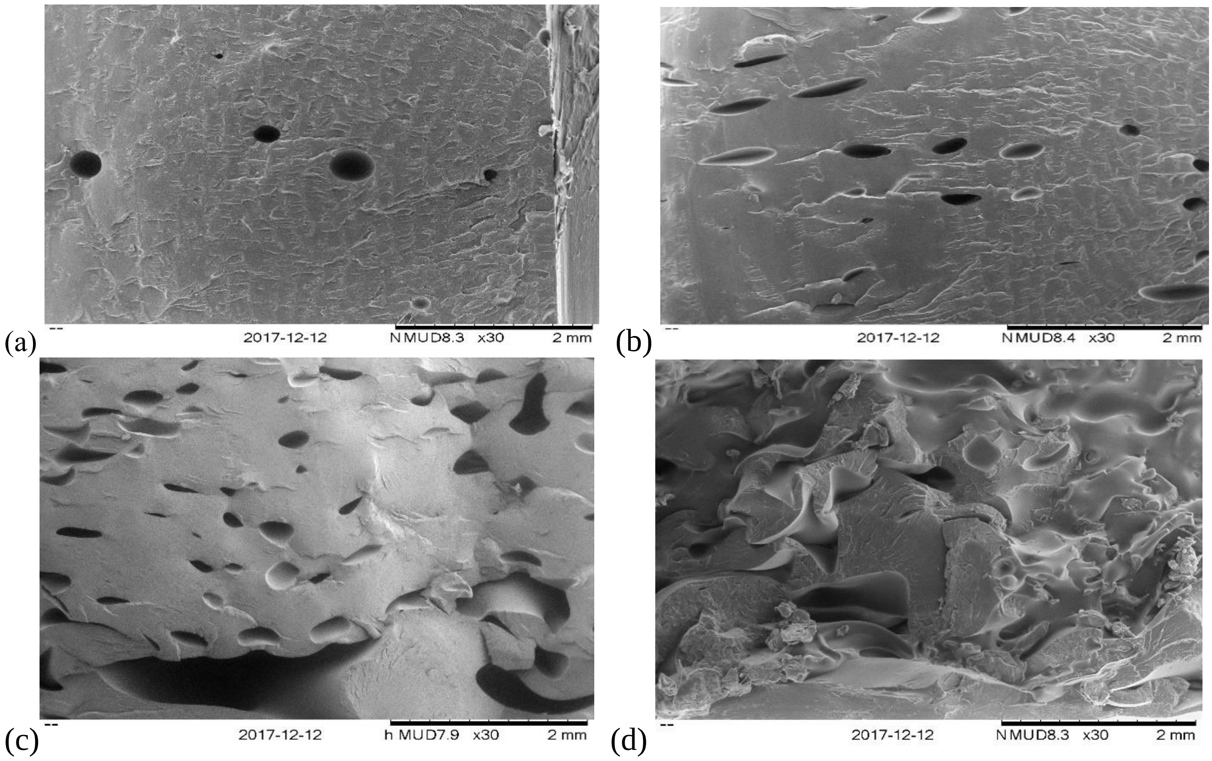

Figure 1. (a) Morphology Structure of PS/GNP (b) Morphology Structure of PS/SBR (c) Morphology Structure of PS/GNP with 5wt% SBR (d) Morphology Structure of PS/GNP with 20wt% SBR.

3.2. Mechanical test

From Figure 2, the tensile strength trend was decrease from 13.9 MPa to 9.6 MPa, while the tensile also decreased from 21.87 MPa to 14.0 MPa when increasing the composition of SBR. It is clearly seen that incorporating various SBR particles composition strongly affected PS/GNP's mechanical behaviour. The trend of tensile strength was decreased because of soft and rubbery behaviour of SBR and poor bond between polymer and rubber was not strong.

From Figure 3, the toughness for PS to PS/SBR was increased in elongation but it was decreased when GNP were present in the system. However, PS/GNP/SBR15wt% exhibit the highest toughness among all PS/GNP/SBR formulations. This is due to well distribution of SBR particles that uniformly distributed in the system as observed from morphology analysis

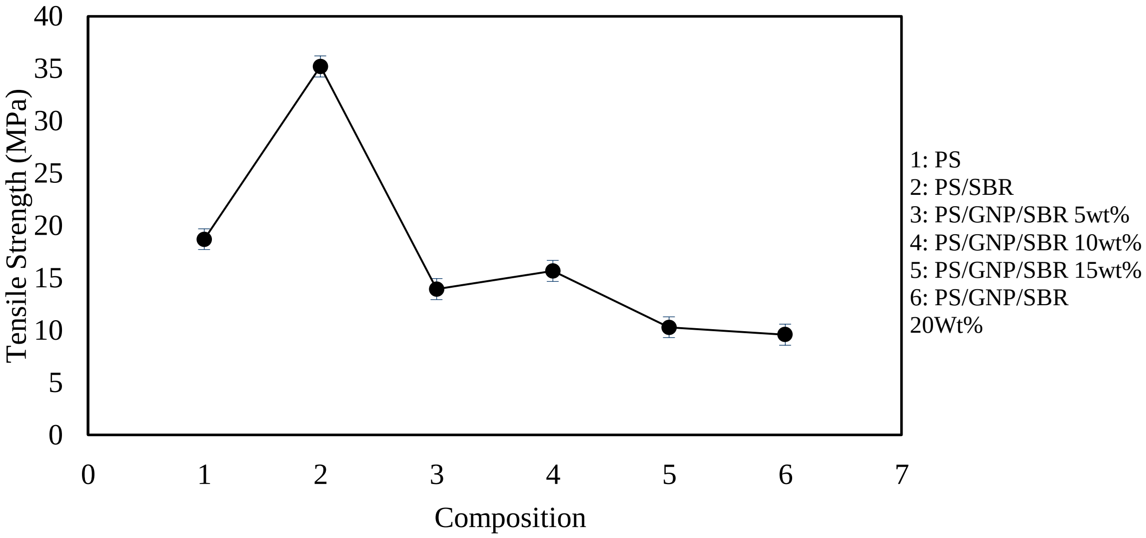

Figure 2. Tensile strength of SBR toughened PS/GNP nanocomposites at various contents of SBR.

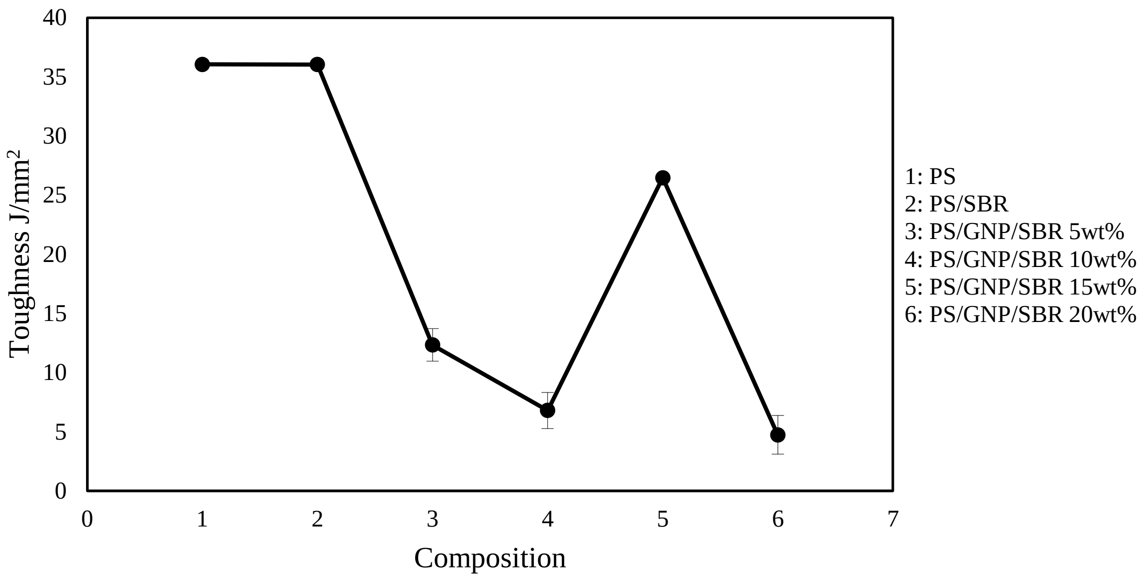

Figure 3. Impact resistance of SBR toughened PS/GNP nanocomposites at various contents of SBR.

4. Conclusion
Styrene butadiene rubber reinforced polystyrene nanocomposites have been prepared by melt blending. In this study, styrene butadiene rubber was used as toughening agent for PLA/GNP

nanocomposites. The mechanical properties of PS/GNP nanocomposites was examined at different SBR contain. The incorporation of SBR had decreased the toughness and tensile strength of PS/GNP nanocomposites due to the presence soft and rubbery behaviour of SBR and poor bond between polymer and rubber. In general, it can conclude that PS/GNP/SBR15wt% shown better toughness compared to other formulations.

Acknowledgement
This study was supported by Universiti Malaysia Pahang, and Minister of Higher Education through financial support using research project grant (grant no. RDU170321).

References

[1] Nair P P, George K and Jayakrishnan N 2015 *Studies on mechanical behavior high impact polystyrene/vinyl clay nanocomposites: Comparison betweenin situpolymerization and melt mixing. Polymer Composites* **38** 68–76.
[2] Xue Y, Shen M, Lu F, Han Y, Zeng S, Chen S, … Wang Z 2017 *Effects of heterionic montmorillonites on flame resistances of polystyrene nanocomposites and the flame retardant mechanism. Journal of Composite Materials* **52** 1295–1303.
[3] Scheirs J 2003 *Modern Styrenic Polymers: Polystyrenes and Styrenic Copolymers*. John Wiley & Sons.
[4] Zhu J, Chen M, He Q, Shao L, Wei S and Guo Z 2013 *An overview of the engineered graphene nanostructures and nanocomposites. RSC Advances 3* 22790.
[5] Li B and Zhong W-H 2011 *Review on polymer/graphite nanoplatelet nanocomposites. Journal of Materials Science* **46** 5595–5614.
[6] Ramsteiner F, Mckee G, Heckmann W, Oepen S and Geprägs M 2000 *Rubber toughening of syndiotactic polystyrene and poly/(styrene/diphenylethylene). Polymer* **41** 6635–6645.
[7] Bucknall C B 1997 *Rubber toughening. The Physics of Glassy Polymers* 363–412.
[8] Veilleux J and Rodrigue D 2016 *Properties of Recycled PS/SBR Blends: Effect of SBR Pretreatment. Progress in Rubber Plastics and Recycling Technology* **32** 111–128.
[9] Luna C B B, Siqueira D D, Araújo E M, Morais D D D S and Bezerra E B 2018 *Toughening of polystyrene using styrene-butadiene rubber (SBRr) waste from the shoe industry. REM - International Engineering Journal* **71** 253–260.
[10] Wu S 1985 *Phase structure and adhesion in polymer blends: A criterion for rubber toughening. Polymer* **26** 1855–1863.