Investigation of the structural properties of nitrile rubber matrix nanocomposite polymeric materials reinforced with nanoparticles used in medical applications

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Abstract: With recent growth of polymer science, the polymer matrix nanocomposites are one of the most important polymeric materials that exhibit very good mechanical and thermal properties. Rubber based nanocomposites is one of the mast interesting field in the literatures and material science. In this study, the structural properties of natural rubber in the presence of nano iron oxide reinforcing nanoparticles have been investigated. The dispersion and distribution of iron oxide nano particles within the rubber polymeric matrix have been examined by electronic microscope evaluations. The obtained results showed that the nano particles of iron oxide have been properly distributed in the acrylonitrile butadiene rubber matrix. Moreover, from the result of this study, it is found that less agglomeration formation has occurred in the polymeric matrix by nano particles. This finding reveals that the presence of nano-particles do notprovide a deteriorating effect on the mechanical and physical characteristics of the final nanocomposite.

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1. Introduction

Polymer materials are used as common constructive materials in many health applications i.e. manufacturing medical equipment etc.. Specially, polymers are used as the composite matrix in composite materials. Composite materials are one of the main branches of science that nearly started at about half century ago. In these high performance materials, a combination of some reinforcement parts and matrix part forms a new composite material [1-6].

In the composite materials, combination of the properties of each ingredient caused the good performance of the final composed material. Moreover, for enhancing composite properties, reinforcing fillers can be added to composites. Among the reinforcing fillers, nano materials have been attended in recent years [7-9].

Nano materials are special effects on the composite materials due to their nano size. Nano size of these reinforcing fillers cause more surface area. Effective surface area of filler leads to good interactions with matrix. Therefore nanomaterials are used as the reinforcement in many researches by the previous investigators [10, 11].

Acrylonitrile butadiene rubber (NBR) is one of the most applicant rubbers that could be used in the industrial and laboratory applications. Acrylonitrile butadiene rubber could be used as the main matrix for composites materials. It should be noted that NBR is attended for their good physical and mechanical properties like proper processing conditions, good flexibility and suitable damping properties. Acrylonitrile butadiene rubber and nitrile rubbers could be used as the attended matrixes for composites and nanocomposites applications. In composites applications, NBR was used as binders in the researches in the literatures [12-14]. Moreover, in the literatures acrylonitrile butadiene rubber could also used as main matrix in the nanocomposite materials [15-18].

In most of these works, layered silicate like nano clay had been used for enhancement of nanocomposites properties. In these papers, the influences of the nano filler materials especially nano clay on the mechanical, thermal and morphological properties of nanocomposites have been investigated. These researches showed that the nano materials which used could properly influenced on the mechanical and morphological properties.

Moreover, usage of other nano reinforcements has been used in the acrylonitrile butadiene rubber matrix nanocomposites [19, 20]. In these works, nano fillers like silica and iron oxide have been used in the NBR matrix. But for these fillers, morphological properties especially for nano iron oxide were less attended in the literature.

Hence, in this paper, the influence of nano iron oxide on the morphological properties of acrylonitrile butadiene rubber based nanocomposites has been investigated. Morphological properties of these rubber based nanocomposites could be an attractive subject for laboratorial and industrial applications.

2. Experiments

Materials

The nitrile rubber as main matrix in nanocomposites used in this study was JSR N230SL supplied by Japan Synthetic Rubber with 35% Acrylonitrile content and Mooney viscosity of ML (1 + 4) at 100 °C = 42.

For curing reactions, curing system was used. The curing components are including Sulfur, Zinc Oxide as activator and stearic acid as accelerator agents. The curing system was kindly prepared by local company.

Nano iron oxide was supplied from nanophase Technologies Corporation with mean particle size of 30 nm and specific surface area 38 m2/g. The shape of nano iron oxide particles is spherical and their density and purity is about 5.2 g/cm3 and 99% respectively. The formulation of the compounds is shown in the Table 1 based on one hundred parts of NBR (phr).

Table 1: Formulations of NBR.

NBR	Fe2O3	Sulfur	ZnO	Stearic acid
100	0	5	5	2

Table 2: Formulations of NBR/Fe_2O_3 compound.

NR	Fe2O3	Sulfur	ZnO	Stearic acid
100	5	5	5	2

Sample preparation

For sample preparation, first of all acrylonitrile butadiene rubber must be masticated by two roll mills. Rubbers like acrylonitrile butadiene rubber have more viscose properties which caused difficult conditions for sample compounding.

For decrease the long of chains of polymer in rubber materials, the mastication process should be done. Hence, in rubber compounding, first NBR was masticated by two roll mills. For this operation, NBR was entered in the gap between of two rolls over and aver. This process caused more shear stress on the NBR chains and resulted to decreasing of molecular weight of NBR compounds.

Mastication stage was done for about 5 minutes. After softening of NBR, nano iron oxide powders were added to NBR paste gradually. After incorporation of nano iron oxide to NBR bulk, curing system was added to compound. Before adding of curing system to rubber paste, the components of curing system were mixed accurately.

After finishing of incorporation stage, dispersion stage was started. In dispersion stage the prepared sample was passed through from two roll mill for better dispersion and distribution of nano iron oxide particles in the NBR matrix.

After that, the paste was put in the mold for curing. The cure temperature is 150°C. After curing the compound, post curing reaction was done.

The formulation of compounds is shown in Table 1 based on one hundred parts of NBR. The formulation of the nanocomposite compounds is shown in the Table 2 based on one hundred parts of NBR (phr).

Morphological Test

For characterization of prepared compounds, morphological properties were focused in this paper. Characterization of compounds was done by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). SEM instrument by Leo Co. Germany was used.

Pictures of SEM analyzer were captured in 10 kV voltages. Moreover, for more assay in morphological properties, transmission electron microscopy (TEM) was also used.

TEM images were captured by The Philips CM200 (field emission gum) transmission electron microscope (TEM) operating at up to 200 kV, a very versatile microscope. For preparing of samples for TEM analysis, microtoming of samples was carried out by ultra microtome reichert OmU3 Austria.

3. Results and discussion

In figure 1, SEM image from nano iron oxide particles have been brought. It could be see in this picture that nano iron oxide particles showed different particle sizes. It may be due to tendency of nano particles for coupling together.

However, this image was taken from nano iron powders as received. It seems that if nano powders of iron oxide disperse in solvent and properly disperse, the SEM image of these powders will show good dispersions. But in this picture, as seen the nano powders pour on the glassy holder without any solvents. Hence, particle agglomeration have been took place. But in the rubber based compounds, agglomerations of nano particles do not take place necessarily.

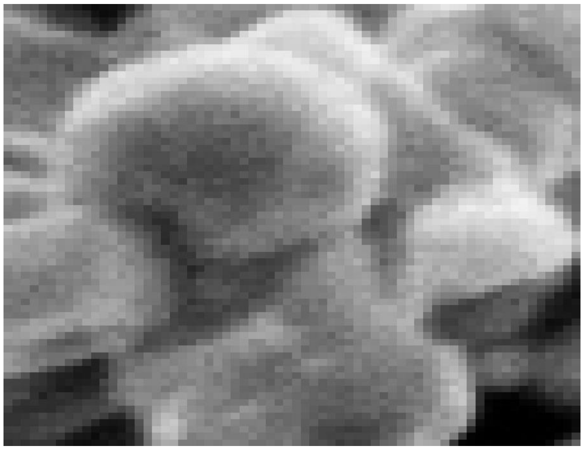

Fig.1. SEM image from nano iron oxide particles.

In figure 2, SEM image from NBR/Fe2O3 compound that inclusive of 5phr nano iron oxide is shown. As it could be seen in this SEM figure, nano particles of iron oxide properly have been distributed in the acrylonitrile butadiene rubber matrix material sample.

This good dispersion of nano particles of nano iron oxide shows that melt mixing and two roll milling method could prepared nanocomposites of NBR/Fe2O3 samples successfully.

Although figure 1 showed that nano particles of iron oxide formed some agglomerations, but in figure 2 we could see the good dispersion of nano iron oxide and resulted of good route in mixing. Moreover of proper dispersion of nano iron oxide, we also could see good distribution of nano iron oxide in acrylonitrile butadiene rubber matrix.

In addition of shear stress of two roll mill on the compounds, the time of this operation could enhance dispersion and distribution of nano iron oxide in the acrylonitrile butadiene rubber based nanocomposite samples.

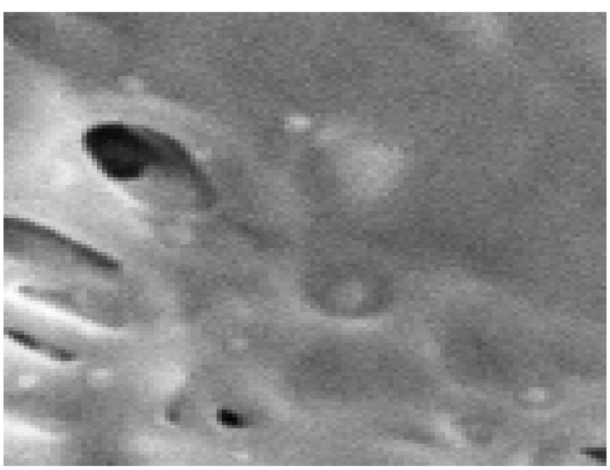

Fig. 2. SEM image from surface of NBR/Fe_2O_3.

For better observation and investigation of the morphological properties of the NBR/Fe2O3 nanocomposites, transmission electron microscopy or TEM images was also used.

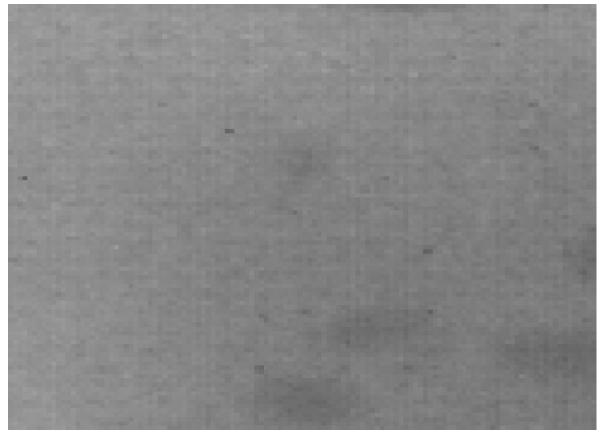

Fig.3. TEM image of NBR/Fe_2O_3.

4. Conclusions

In this paper melt mixing method based on two roll mills was used for preparing the compounds. By two roll mills methods nanocomposites of acrylonitrile butadiene rubber and nano iron oxide has properly prepared. For investigation on the dispersion and distribution of nano particles of iron oxide, SEM and TEM pictures were used. The results of SEM observations showed that the nano iron oxide particles successfully distributed in the rubber matrix. Moreover dispersion of nano iron oxide in the NBR compounds seemed to be proper and little agglomeration of particles have been shown in images. Beside the SEM image, TEM pictures also emphasized the good dispersion and distribution of nano particles of nano iron oxide in NBR binder. TEM image showed that 2 or 3 particles of nano iron oxide get together and there was not much formations of nano particle agglomerations.

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