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Impact of Magnesium Oxide incorporation on tensile and hardness properties of Polystyrene/Magnesium Oxide composites

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ABSTRACT

Polystyrene polymer composites containing 0, 5, 10 and 15% by weight of magnesium oxide powder are elaborated using melt-compounding applying a single screw extruder. The effect of magnesium oxide on the properties of polystyrene matrix was investigated using both of XRD, tensile test and Shore D hardness measurements. The morphology of our synthesized Polystyrene/Magnesium oxide (PS/MgO) composites was studied using SEM analysis.

KEY WORDS: polystyrene, composites, magnesium oxide, XRD, tensile test, Shore D hardness, SEM.

1. INTRODUCTION

It is well known that the virgin polymers are distinguished by lower moduli and strength (Kuo, 2011). This is why the scientists are oriented to use inorganic particles as filler to improve their properties. Recently great attention has been focused on metal oxides owing to their excellent properties, to make new polymeric materials exhibiting improved physical and mechanical properties (Harishanand, 2013).

The polystyrene is an important engineering thermoplastic polymer largely used in all the fields of our daily life; in automotive, electric, packaging and building application (Mann, 2007). This huge use is due to its unique properties such as it low cost, transparency, good electrical insulation and processability, rigidity, and low water absorbability (Yan, 2014).

The reinforcement of polystyrene has received great attention by both academy and industry to ensure the mechanical and thermal requirements as well as the good resistance to fire and fatigue. Polystyrene composites including minerals (Hachani, 2015), boron nanotubes (Zhi, 2006), carbon nanotubes (Patole, 2013) and fibers (Zhu, 2010) have excited the interest of researches.

Polystyrene/MetalOxide composites have attracted considerable interest in the field of materials chemistry. Hashim (2012) investigated the electrical conductivity of polystyrene doped calcium oxide composites, it was found that the electrical conductivity of polystyrene increases with increasing of calcium oxide concentrations and temperature. Zan (2004), studied the photocatalytic degradation of PS/TiO_2 composites, it was reported that the presence of TiO_2 nanoparticles in polystyrene films greatly promotes the photocatalysis degradation of the composite. Yan (2014), found that the PS/Fe_3O_4 composites exhibit super paramagnetic behavior at room temperature.

Many techniques used for the preparation of polystyrene composites have been reported including solution blending, micro emulsion and in-situ polymerization, the melt-compounding route still attracts growing interest; this kind of methods is mixing a polymer, in the absence of any solvents, with fillers above the softening point of the polymer matrix using an extruderapplying the shear forces exerted in this device. The melt-compounding method takes advantage of well-established polymer processing technique (Tanahashi, 2010).

Magnesium oxide (MgO) known as magnesia is a beneficial material used in numerous fields as catalysis, ceramics, and refractory as well as paint industry (Gandhi, 2011). The literatures have demonstrated that magnesium oxide can be elaborated by different techniques such as the dehydration of magnesium hydroxide, flame spray pyrolysis, decomposition of various magnesium salts using co-precipitation method, sol-gel techniques and surfactant methods (Kumar, 2013).

In the present work, the PS/MgO composites with various MgO particle loadings were prepared by melt-compounding method applying single screw extruder. The scanning electron microscope (SEM) was used to characterize the dispersion state of MgO and the morphology of the PS/MgO composites. The effect of the MgO on the structure of PS was also investigated by X-ray diffraction (XRD). The effects of the filler particles loading on tensile properties and shore D hardness were also studied and discussed as well.

2. EXPERIMENTAL

Synthesis of PS/MgO composites:

Materials: Commercial polystyrene was used as polymer matrix supplied by Spanish Petrochemical UI. Magnesium oxide powder was obtained from BIOCHEM Chemopharma. To ease the compounding of polystyrene pellets with magnesium oxide powder, the polystyrene pellets were grinded by commercial lab milling.

Samples Preparation: PS/MgO composite films at 0%, 5%, 10% and 15% of magnesium oxide were blended by melting compounding using a laboratory scale single screw extruder (Plasti-Corder PLE 330), the extrusion conditions were a barrel temperature of 180^{0}C and a speed screw equal to 27r.p.m.

Characterization of PS/MgO composites:

X-rays diffraction: The phase identification of the neat polystyrene and magnesium oxide powder, the structure investigation of PS composites films filled with different magnesium oxide loading levels, both were studied using X-rays diffraction technique using Advanced Bruker D8 diffractometer. XRD scans were recorded from 10 to 90°.

Tensile properties: The tensile test for the studied samples was performed using Zwick Roell testing machine according to ASTM D 638. Five specimens were examined from each composite formulation and the five test results were averaged and then reported.

Hardness D shore: The hardness Shore D of the studied samples was carried out using a commercial durometer according to ASTM D 2240. Three measurements were performed for each formulation and the hardness middle value was reported.

Scanning electron microscopy (SEM): Magnesium oxide distribution and dispersion in the polystyrene matrix were studied using scanning electron microscopy technique. This study was performed in a JEOL JSM-6335F FEG electron microscope. The surface of both of the polystyrene and its composites films were coated with gold thin layer for better imaging.

3. RESULTS AND DISCUSSION

XRD results: The XRD patterns of polystyrene, magnesium oxide and the polystyrene composites at different magnesium oxide loading levels are shown in figure 1. Regarding to the polystyrene spectrum, It can be seen that it has an amorphous structure distinguished by halo centered at 2θ = 19.68°, this pattern conforms to the reported one (Ding, 2005). The magnesium oxide has a well-defined crystal structure giving peaks at 37.21°, 43.12°, 62.41°, 74.74° and 78.42° with miller indices values (111), (200), (220), (311) and (222) respectively, similar peaks have been reported in the literature (Rao, 2014). Unexpected small peaks detected at 2θ= 18.49°, 38.41° and 59.86° attributed to the presence of small proportion of impurities in the used magnesium oxide. The different composites spectra presented the peaks corresponding to PS matrix as well as that magnesium oxide; indicating that the studied composites combine between the amorphous nature of polystyrene and the crystalline one of magnesium oxide with a significant decrease in amorphous character of polystyrene. Moreover, the intensity of crystalline peaks in these spectra clearly increases with the increasing of magnesium oxide content in each composite formulation.

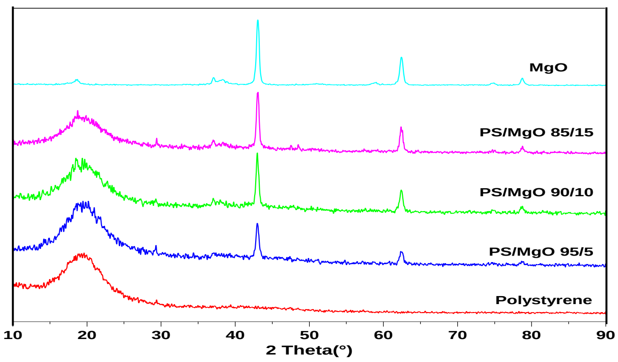


Figure.1.XRD patterns of polystyrene, MgO and polystyrene/MgO composites.

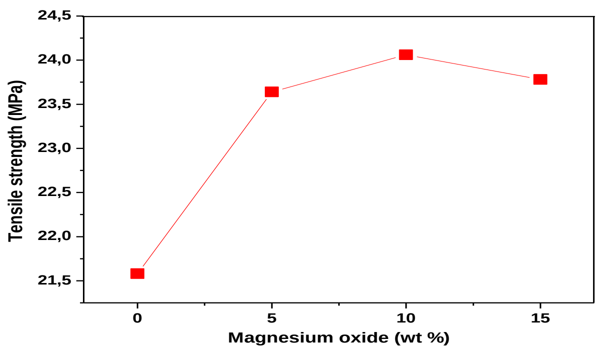
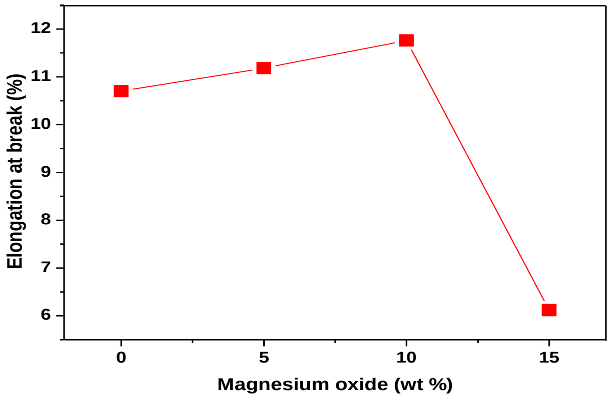


Figure.2.Tensile strength variations of polystyrene/MgO composites as function of magnesium oxide loading.

Tensile test results: The tensile strength corresponding to both of the virgin polystyrene and it composites as function of magnesium oxide loading levels are given in figure 2. The tensile strength was found to increase with the increasing of magnesium oxide until to 10% wt loading. When magnesium oxide content up to 15 wt%, the tensile strength decreased with a higher value than that reported one of the virgin polystyrene. Aggarwal (2011), observed similar trends in the case of polystyrene/wood flour composites. This variation in tensile streng, this strongly related to the different quality of the observed morphology; in the case of 10 wt % loading the good dispersion of the magnesium oxide particles in the polystyrene matrix has a positive effect on the tensile strength. However, in the case of 15 wt % loading the appearance of agglomerates reduces this mechanical parameter, probably due to the weakening of the composite films.

The variation of elongation at break as function of magnesium oxide content is shown in the figure 3. The elongation at break of the studied composites increased when the filler concentration was increased to 10 wt%. Further increase in filler content to 15 wt % reduces dramatically the elongation at break.



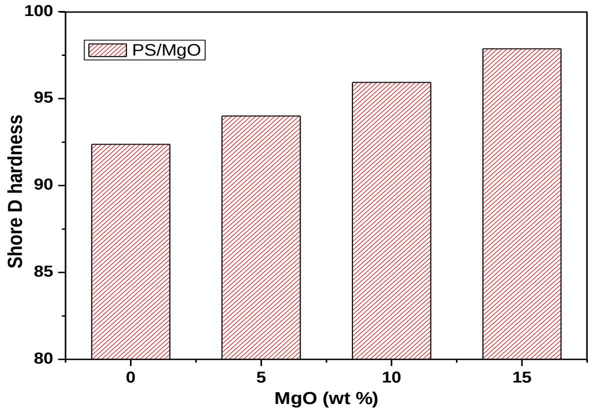
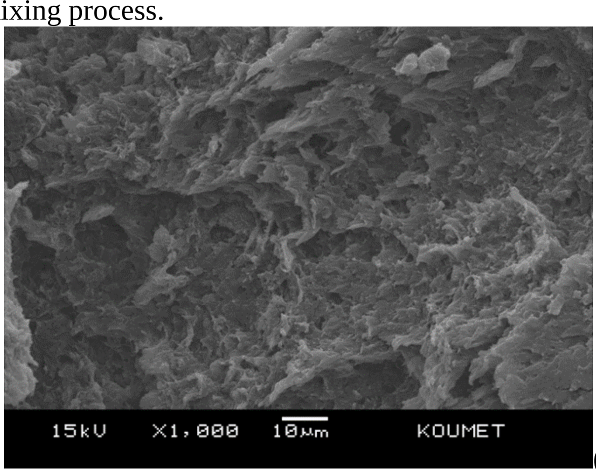


Figure.3.Elongation at break variations of the neat polystyrene and the composites as function of magnesium oxide content.

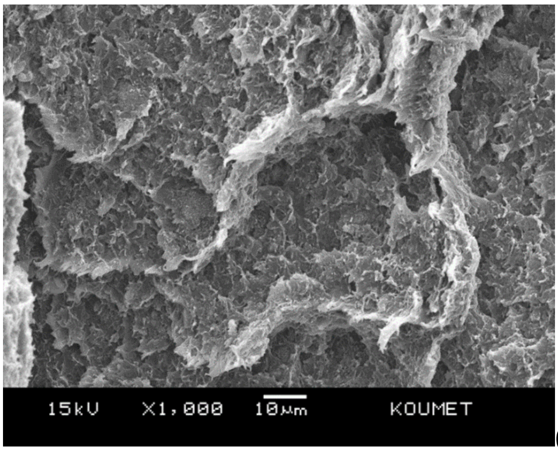
Figure.4.Shore D hardness of the neat polystyrene and the polystyrene composites as function of magnesium oxide loading.

Shore D hardness: The variations of Shore D hardness averaged values for each formulation of the PS/MgO composites are shown in fig 4. It is observed that Shore D hardness values increase with the increasing in magnesium oxide content. The incorporation of the magnesium oxide particles having a high stiffness (McColm, 2013) in the polystyrene matrix leads to a high indentation resistance during the hardness measurement. Tasdemir (2006) has reported similar trend for polystyrene composite Shore hardness after iron powder incorporation.

SEM results: The filler dispersion and distribution state into the polymer matrix strongly affects the resulting properties of the polymer composites, including mechanical strength, electrical conductivity, dielectric constant, heat transfer and optical properties. Uniform filler particle dispersion and distribution is required for maximum properties enhancement of the polymer matrix (Mittal, 2012). SEM analysis is the direct method to estimate the filler dispersion and distribution quality in the polymer matrix. Figure 5 (A and B) shows the SEM images of polystyrene composites filled by 10 and 15 wt% of magnesium oxide, respectively. It can be seen that the magnesium oxide particles are well dispersed and distributed in the PS matrix for the composite having 10 wt% of magnesium oxide. However, in the case of 15 wt% magnesium oxide loading, it is difficult to disperse the filler particles in the PS matrix. Magnesium oxide aggregates can be observed which confirms the problem of dispersion at this loading level during the melt-mixing process.



(A)



(B)

Fig.5.SEM micrograph of the polystyrene composites: (A) polystyrene reinforced by 10% MgO, (B) Polystyrene reinforced by 15%MgO.

4. CONCLUSION

PS/MgO composites were prepared in a single screw extruder with particle content varying from 0 to 15% by weight. The influence of magnesium oxide on the structural, mechanical and hardness as well as morphological properties was studied. The XRD results revealed that the PS/MgO composites presented simultaneously the amorphous nature of polystyrene and crystalline structure of talc leading to significant increase in Shore D hardness. The tensile test clearly demonstrates that the mechanical properties of PS composites were enhanced after magnesium oxide insertion; the formulation filled by 10wt%exhibits the best mechanical properties. The good morphology of the studied samples is the main factor witch conduct to better mechanical properties for the PS/MgO system. All of the results indicate that magnesium oxide is a promising reinforcing agent for PS matrix.

5. ACKNOWLEDGEMENTS

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