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Effect of gamma irradiation on the mechanical properties of PVC/ZnO polymer nanocomposite

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Polyvinyl Chloride (PVC) based nanocomposite with different weight ratios of Zinc oxide (ZnO) nanoparticles is prepared by using a gel-like technique. The weight-ratio of ZnO nanoparticles, in a range of 2.5–10 wt%, is used to prepare nanocomposites' in the tetrahydrofuran (THF) solvent. The as-prepared samples are exposed to gamma (γ) radiation at different doses in a range of 5–40 kGy. The mechanical properties of irradiated samples are compared to that of unirradiated samples. For unirradiated samples, the elasticity is found to increase with the addition of ZnO nanoparticles. However, the plastic region of the stress-strain curve gets slightly affected on increasing the concentration of ZnO. Additionally, the elastic modulus is noticed to drop exponentially with ZnO concentration. For pure PVC, a slight dependence of stress-strain curves on the gamma irradiation doses has also been detected. Further, the gamma irradiation dose results in a detectable decrease of elastic modulus for pure and low weight-ratio ZnO nanoparticles. However, the irradiation dose does not have any effect on the elastic modulus for the 10 wt %, which is the highest weight ratio used in this study.

1. Introduction

Nanocomposites are such unique materials that, at least, one of the phases displays dimensions in the range of nanometers (Roy, Roy, & Roy, 1986). Progress in nanocomposite materials encompasses development of many industries such as the aerospace industry, manufacturing machine parts with high-performance, and manufacturing medicine. Polymer nanocomposites have been broadly reported for their diverse possible applications such as UV shielding (Cheng, Zeng, & Chen, 2014; Li, Fu, & Mai, 2006; Li et al., 2014; Man et al., 2015; Tu et al., 2010) and radiation dosimeter and protection (Maeyama et al., 2014; Mojica-Sánchez, Vaz, Oliveira, & Santa-Cruz, 2014; Yıldırım & Oral, 2014). A number of recent studies have reported the effects of additives such as nano-scale fillers on the physical properties of polymeric nanocomposites (Ibrahim, Ayesh, & Al Shoaibi, 2009; Imai et al., 2009; Tang, Cheng, & Ma, 2006). Particularly, ZnO nanoparticles have drawn an increasing attention in recent years due to their role in enhancement of physical and chemical properties of PVC nanocomposites films. Some contemporary studies have also investigated systematic changes in the physical parameters of such nanocomposite films in comparison to the pure PVC film; higher glass transition temperature, specific heat and thermal stability are studied in detail (Elashmawi, Hakeem, Marei, & Hanna, 2010). Such changes are typically attributed to strong interactions that take place among ZnO nanoparticles and PVC in the composite (Elashmawi et al., 2010).

One of the main goals of present study is preparation of highly dispersed polymer based nanocomposites comprising of a PVC host and a ZnO filler. Study of the suitability of the gel-like preparation technique is imperative to bring a significant change in mechanical properties of the host. Finally, the elastic modulus is an interesting parameter to study by varying the dosimetric parameter of low dose gamma rays to observe ensuing changes in the mechanical property of nanocomposites.

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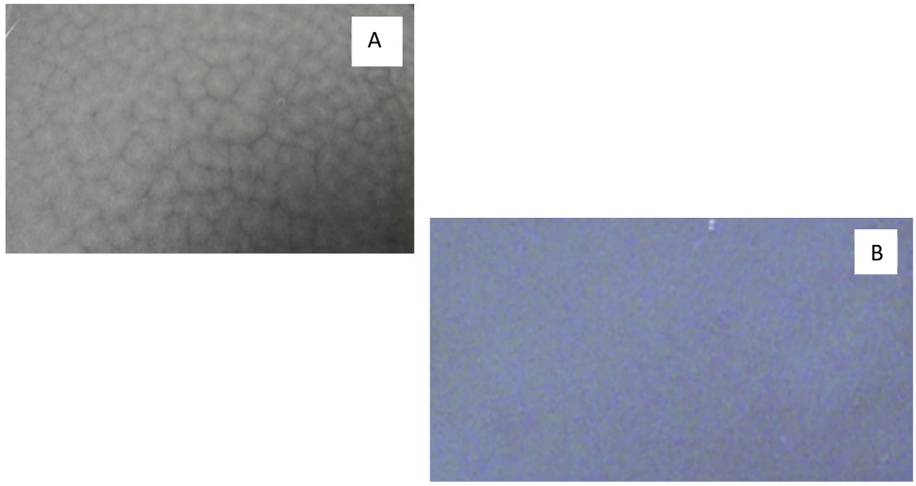

Fig. 1. 5 wt% PVC/ZnO nanocomposite (A) untreated ZnO (B) Treated ZnO.

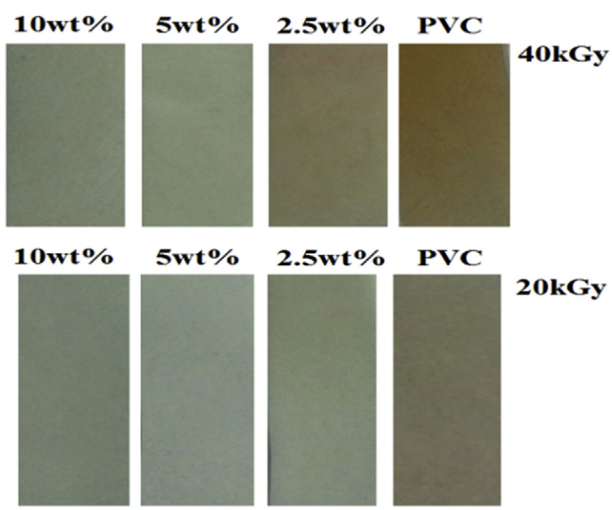

Fig. 2. Photographic pictures for pure and nanocomposite samples after 20 KGy and 40 KGy gamma rays irradiation.

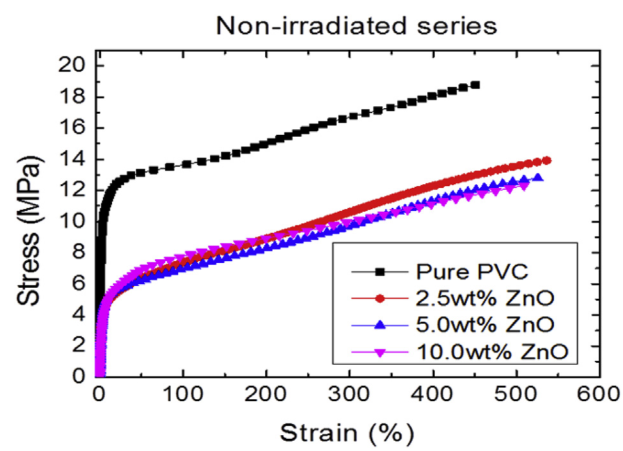

Fig. 3. Stress-strain curves for PVC/ZnO non-irradiated nanocomposite.

2. Experimental details

2.1. Preparation of ZnO/PVC nanocomposite

In order to prepare ZnO/PVC nanocomposites films, a polymer solution is prepared mixing 4 ml of THF solvent with 1 g of PVC, which is procured from Saudi Basic Industries Corporation (SABIC), Riyadh, Saudi Arabia. Once the PVC is completely dissolved, wet ZnO nanoparticles (Sigma Aldrich – particle size <100 nm), hydrated with water, are added systematically and a mixed phase is prepared at ZnO weight percentages of 0% (control), 2.5%, 5%, and 10% wt%. The PVC/ZnO mixture is left to stirr for 1 h and then placed in an ultrasonic stirrer (Sonicator) for 15 min to ensure a good dispersion of nanoparticles through the host polymer. Further, the mixture is poured onto a 12 mm circular glass Petri dish and is allowed to dry overnight. Fig. 1 shows a comparison between two samples (5 wt% ZnO) with and without treatment. The formation of aggregation is clear for sample A while a good dispersion is shown for sample B.

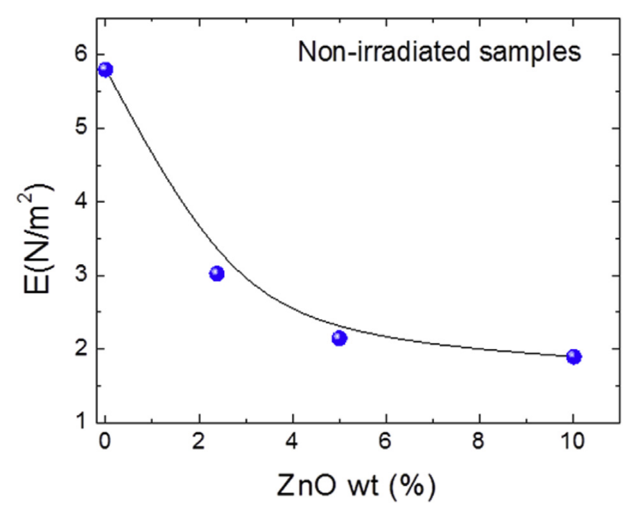

Fig. 4. The dependence of elastic modulus on ZnO weight ratios (for non-irradiated series).

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