

A Study of Optical Spectroscopy of Neoloy and PVA Polymer Nanocomposites

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Abstract

Novel polymeric alloy, also known as Neoloy, is a polymeric alloy composed of polyolefin and thermoplastic engineering polymer. It was developed specifically for use in high-strength geosynthetics. The first commercial application was in the manufacturer of polymeric strips used to form cellular confinement systems (geocells). Novel polymeric alloy was developed to replace high-density polyethylene (HDPE) in geosynthetics. Although HDPE is widely used due to its low cost, ease of manufacturing and flexibility, its relatively high creep, low tensile strength and sensitivity to elevated temperatures limit its use, for example, in long-term, critical geocell applications. Used in the manufacture of geosynthetics, such as the Neoloy Geocell cellular confinement system, novel polymeric alloy provides geocells with a higher tensile strength and stiffness, and are more durable over dynamic loading and under elevated temperatures than those made from HDPE. The lifespan of novel polymeric alloy geosynthetics, such as geocells, makes them suitable for long-term design in infrastructure, such as highways, railways, container yards and high retaining walls.

Keywords: PVA nanocomposites, Iron oxide, Energy gap, Fluorescence.

1. INTRODUCTION

Novel polymeric alloy is compounded for geosynthetic applications, such as high-modulus geocells or geogrids. In geocell applications strips are co-extruded in multi-layer strips. Outer layers are a blend of polyolefins while the core layer is formed from a high performance polymer. The blend is generally immiscible (an alloy), where the high performance polymer is dispersed in a matrix formed by the polyolefins. Since polymer blends are basically unstable, they undergo stabilization during melt processing, at a Nano-level combined with compatibilized material. The novel polymeric alloy core layer/s is made of a high performance polymer compound with a storage modulus of =1400 MPa at 23 °C, measured by Dynamic Mechanical Analysis (DMA) at a frequency of 1 Hz according to ASTM D4065; or an ultimate tensile strength of at least 30 MPa. The outer layers are usually made of a polyethylene or polypropylene polymer, with a blend or alloy with other polymers, fillers, additives, fibers and elastomers. The high performance alloys of polyamides, polyesters, and polyurethanes are combined with polypropylene, copolymers, block copolymers, blends and/or other combinations.

While most polypropylene homopolymers are too brittle and most polypropylene copolymers are too soft, certain grades of polypropylene polymers are stiff enough for engineering purposes, yet soft enough so that a geosynthetic can be handled for installation. These polymers are modified, via proprietary treatment processes and the addition of additives such as nanoparticles to attain the required physical properties. Unlike low crystalline polymers such as polypropylene, which require a post-extrusion processing such as orientation, cross-linking, and/or thermal annealing, higher crystalline polymers such as novel polymeric Alloy can be extruded as strips and welded in section without post-extrusion treatment. The sheet can be extruded into strips and welded, sown, or bonded together to form geosynthetic products. Such additives (stabilizers for polymers) may be selected from, among others, nucleating agents, fillers, fibers, hindered amine light stabilizers (HALS), antioxidants, UV light absorbers, and carbon black in the form of powders, fibers, or whiskers.

Novel polymeric alloy was developed for a high-modulus geosynthetics, including geocells, geogrids and geomembranes, which require higher strength, stiffness and durability. In a geocell application, the high modulus of Novel Polymeric Alloy means stiff and strong cell walls, which provide a very high elastic response to dynamic

loading even after millions of cycles without permanent plastic deformation. The strength and stiffness of novel polymeric alloy, as measured by tensile strength, long-term resistance to deformation, coefficient of thermal expansion (CTE) and performance at elevated temperatures (storage modulus), provides a performance lifespan previously available in geocell applications. This is a notable development in the geosynthetic /geocell industry, allowing the use of geocells for example, in structural reinforcement for flexible pavements, earth retention walls, and other heavy-duty geosynthetic applications, where long-term durability under heavy loading is critical (Leshchinsky, et al., 2009). At the same time, novel polymeric alloy properties enable the manufacture of lighter geocells which retain suitable engineering strength for moderate loading as typically found in slopes, channels and retaining wall applications. Poly(vinyl alcohol) (PVOH, PVA, or PVAL) is a water-soluble synthetic polymer. It has the idealized formula $[\text{CH}_2\text{CH}(\text{OH})]$. It is used in papermaking, textiles, and a variety of coatings. It is white (colourless) and odorless. It is sometimes supplied as beads or as solutions in water.

2. NEOLOY PVA POLYMER NANOCOMPOSITES

PVA based nanocomposites in recent years have become the subject of research interest for developing PVA materials with improved properties by incorporation of inorganic nanoscale materials. The incorporation of inorganic fillers into organic matrix leads to improved property through reinforcement effect. For instance, PVA-Nano metal oxide composites are especially used as tissue replacement materials and high performance fibers because of their superior mechanical properties. As a member of vinyl polymers, PVA has also been used to produce carbon materials because of its high carbon content. The incorporation of nanometal oxides specially supports to form carbonaceous materials at lower temperatures. The carbonaceous materials of PVA Nano metal oxide nanocomposites are widely utilized for applications such as energy production, catalyst and air purification process.

A numerous luxury items have been brought by today's society but with them series of problems like air pollution and emission of toxic gases have also been introduced to our society. The necessity to constantly monitor and control such gases sprouted the need for gas sensors. Therefore, we require gas sensors that can detect these gases continuously and effectively to avoid most of the problems. The increasing demand is for better gas sensors with higher sensitivity and greater selectivity. So intense efforts are being made to find more suitable materials with the required surface and bulk properties for the use as gas sensors. Gas sensors have thus found wide applications in industrial production, environmental monitoring and protection etc. A variety of materials have been used for gas sensing which includes electronic ceramics, oxide semiconductors, solid electrolytes and conducting polymers. Recently, there has been a considerable increase in the demand for humidity control in various fields such as air conditioning systems, electronic devices, food, sugar industries, tyre industries and drying processes for ceramics. Thus the physical properties of nanometal oxides doped PVA are interesting due to their varied applications. Thus combining of properties of the organic PVA and inorganic nanometal oxides will help in the generation of the new class of materials with improved properties and that can overcome the drawbacks coming from the individual counterparts as well as will also improve the physical and chemical properties of materials.

3. EXPERIMENTAL STUDY

The synthesis of PVA/iron oxide polymer nanocomposites completed according to the procedure of solution casting. 1.0 g of polyvinyl alcohol powder dissolved in 100ml hot water (90 °C), and then 0.0, 0.5, 2.0 and 5.0 wt% of iron nitrate

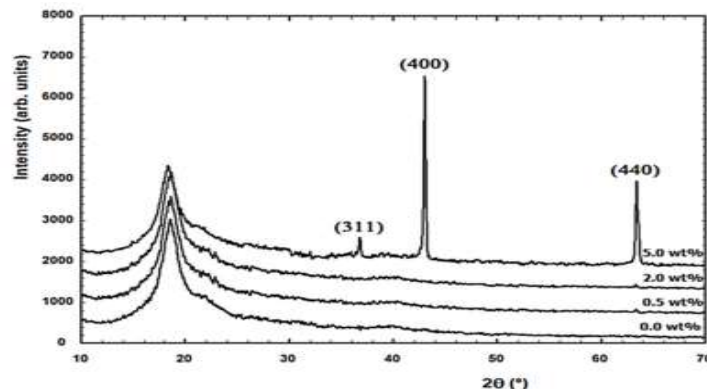


Fig. 1 – XRD scans of PVA/iron oxide polymer nanocomposites

($\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$) added to the solution with continuous stirring for 60min. The resulted homogeneous solution poured into plastic plates and dried in electrical oven at 90°C overnight. Samples were analyzed for XRD measurements via a Bruker AXS D8 Advance diffractometer (Germany) with CuK radiation ($\lambda = 0.15406\text{nm}$). SEM monographs were recorded via (FE-SEM electron microscope, Quanta FEG 250, Holland). Optical absorption data were collected using Jasco spectrophotometer (model V-570).

4. RESULTS AND DISCUSSION

As shown in Fig. 1, the XRD data for PVA/iron oxide polymer nanocomposites exhibits diffraction lines correlated with $\text{-Fe}_2\text{O}_3$ nanoparticles in comparing with (JCPDS#4- 755) with cubic crystal structure and the broad peak at 2θ value of 18.6° is due to the semi-crystalline nature of PVA. The average crystallite size estimated via Scherer equation; $D = 0.9/\cos(\theta)$ is 42.40nm . PVA contains large number of hydroxyl ($-\text{OH}$) groups that can act as chelating sites for the metal cations in a specific pattern. Heating the Fe ion-polymer complex leads to formation of PVA/iron oxide polymer nanocomposites. From the graph above, we can see that the polymer nanocomposites samples containing low concentrations of iron oxide display amorphous patterns with small diffraction lines due to the lower concentration of Fe_2O_3 in PVA matrix. From this data, we can see the interaction between $\text{-Fe}_2\text{O}_3$ nanoparticles and PVA polymer matrix. Fig. 2 provides the results obtained from the preliminary analysis of scanning electron microscopy. From the data in Fig. 2, it is apparent that $\text{-Fe}_2\text{O}_3$ nanoparticles are dispersed inside the PVA polymer matrix. These results are in agreement with those obtained by XRD analysis. The results of the optical absorption measurements for PVA/iron oxide nanocomposites are presented in Fig. 3. In Fig. 3 there is a clear trend of increasing the absorbance with increasing the concentration of $\text{-Fe}_2\text{O}_3$ nanoparticles which is in agreement with the optical absorption data reported in [1,4,6]. From the chart, an absorption peak around 400nm was seen that correlated with $\text{-Fe}_2\text{O}_3$ nanoparticles. Interestingly, there were also a red shift of the optical absorption edge with the ratio of iron oxide.

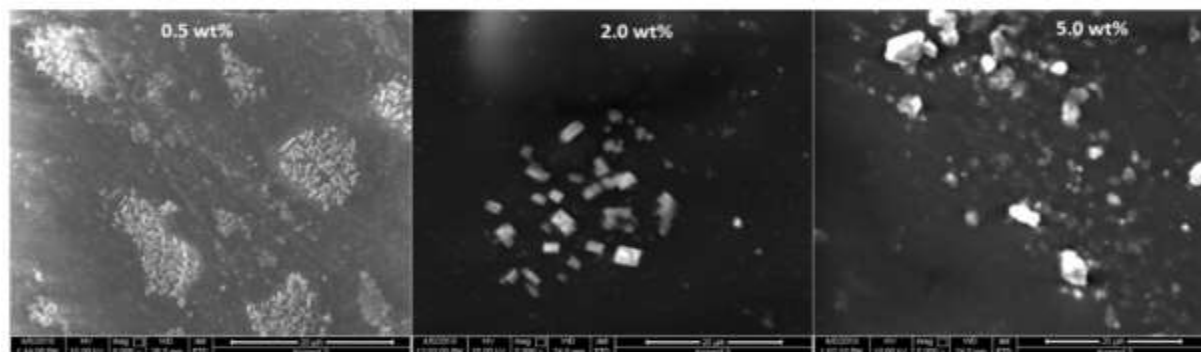


Fig. 2 – SEM monographs of PVA/iron oxide polymer nanocomposites.

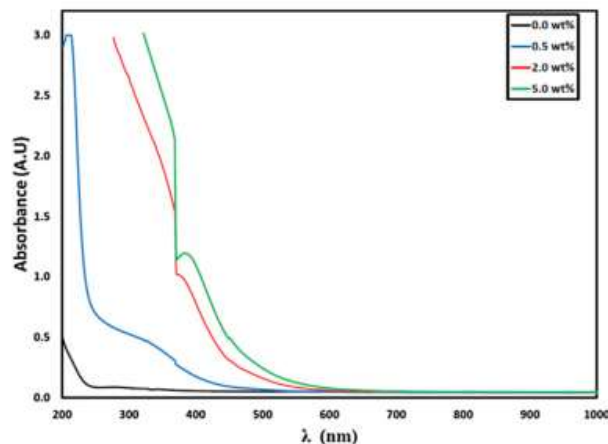


Fig. 3 – Optical absorption scans for the PVA/iron oxide nanocomposites

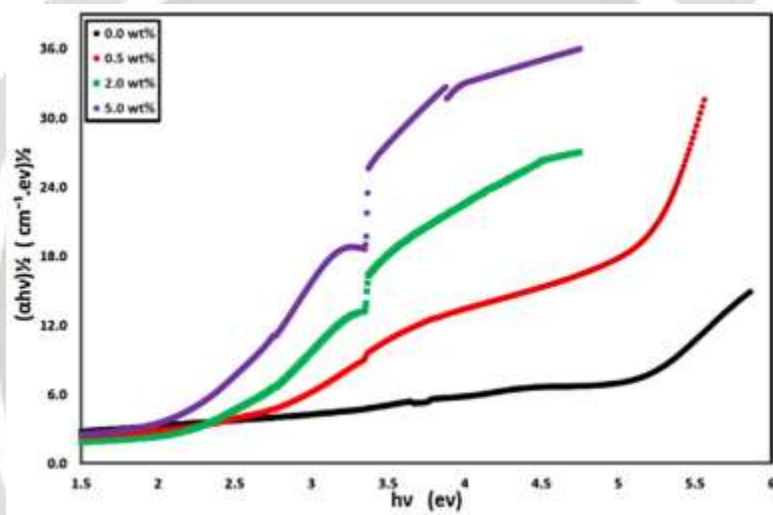


Fig. 4 – Plots of $(\alpha h\nu)^{0.5}$ versus photon energy (h) for the PVA/iron oxide nanocomposites

5. CONCLUSION

Polymer nanocomposites of PVA/iron oxide has been prepared and characterized via XRD, SEM and optical spectroscopy analysis. XRD patterns confirmed the formation of -Fe₂O₃ nanoparticles with cubic crystal structure. SEM images displayed the morphology of both -Fe₂O₃ and polymer nanocomposites. Direct and Indirect energy gaps of the PVA/iron oxide films decreased with the content of iron oxide. The refractive index of the prepared films enhanced with the concentration of iron oxide. The predominant electronic transitions were direct allowed as deduced from Tauc's equation and optical dielectric loss function. Finally, fluorescence spectra of the polymer nanocomposites showed three emission peaks located at 421, 451 and 469nm that suggests the application of these samples for optoelectronic devices.

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