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Mechanical Reinforcement of EPDM Nanocomposites with Graphene Oxide: A Morphological and Mechanical Investigation.

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Nanocomposites offer distinct advantages over traditional composites due to their exceptional mechanical, thermal, optical, and electrical properties, combined with their low cost and lightweight nature. Graphene-based nanocomposites have garnered significant attention in recent research, while elastomers and rubbers have emerged as versatile materials in advanced fields, including polymer nanocomposites (PCNs). The incorporation of nanoparticles like graphene has the potential to dramatically enhance material properties.

This study investigates EPDM nanocomposites filled with graphite and graphene oxide, prepared using solvent blending without compatibilizing agents. Morphological analysis reveals excellent compatibility between the components. Mechanical characterization of EPDM/graphene oxide nanocomposites demonstrates consistent improvements in properties with increasing graphene oxide concentration.

Keywords: EPDM, Graphene Oxide, Solvent Blending, Morphology, Mechanical Properties.

INTRODUCTION

Recent advances have revealed that the addition of low concentrations of nanofillers to polymers can markedly enhance their mechanical, thermal, barrier, and flammability properties, all while preserving their processability [1][1]. The reinforcing impact of filler is ascribed to various aspects, including polymer matrix characteristics, the nature and type of nanofiller, polymer and filler concentration, particle aspect ratio, particle size, particle orientation, and particle distribution [3]. Clays [3][4], carbon nanotubes [5], graphene [6][7], nano cellulose [8], and halloysite [9], among other nanoparticles, have been utilized to create nanocomposites with various polymers. As a result, PNCs are a novel family of materials with distinct features that outperform typical doped and composite polymer systems. The profound interactions at the interface between nanoparticles and the polymer matrix, coupled with the inherent nanoscale differences, fundamentally set polymer nanocomposites (PNCs) apart from conventional systems.

Graphene oxide (GO) is commonly synthesized via the Hummers method, a straightforward and cost-effective approach. The material remains a focal point of interest among nanomaterials researchers, owing to its exceptional conductivity upon reduction, selectivity following functionalization, and heightened sensitivity.[10] Graphene oxide is made up of a single-layer graphene sheet that is covalently bound to oxygen functional groups on the sheet's basal planes and edges. There are hydroxyl and epoxy groups on the basal planes, and carboxyl, carbonyl, phenol, lactone, and quinone groups can be found on the margins.[11][12][13][14] The polar functional groups on GO make it very hydrophilic and water-soluble, which is useful for processing and chemical derivatization. These oxygen-based functional groups, on the other hand, can degrade the electronic, mechanical, and electrochemical properties of GO by causing significant structural defects, lowering electrical conductivity, and potentially limiting its direct application in electrically active materials and devices. GO, on the other hand, can be functionalized by partially reducing it to rGO using various chemical or thermal treatments[15] to enhance carrier transport[16]. This chemical alteration reduces its resistance by several orders of magnitude[16] and converts the material into a semiconducting graphene-like substance.

EPDM (ethylene propylene diene monomer) is an unsaturated polyolefin rubber with numerous applications. Graphene-based nanocomposites possess excellent mechanical, electrical, thermal, optical, and chemical properties. EPDM-GO composites were made utilizing a solvent blending process with dicumyl peroxide as a curing agent, and the morphology of the composites was investigated using FT-IR, W-XRD, and SEM techniques in this study. EPDM reinforced with GO and virgin EPDM mechanical characteristics were also examined.

EXPERIMENTAL

MATERIALS

EPDM rubber sample pack was obtained from Dupont–Dow. Graphene Oxide was obtained from Sigma-Aldrich. Toluene was supplied by CDH, New Delhi. Double distilled water was used throughout the study.

PREPARATION OF EPDM/GO NANOCOMPOSITES

A variation of graphene oxide (1, 3, 5, 7 and 10 phr) concentrations were added to EPDM rubber (16 g) dissolved in toluene (300 mL) in a three-necked flask (500 mL) and ultrasonicated for excellent dispersion. The contents were mechanically stirred for 5 hours at 60 degrees Celsius, cured by adding dicumyl peroxide (3 phr) just 4-5 minutes before heating was completed, and immediately transferred into glass moulds were thin films of the nanocomposite were obtained, by dipping the mould into the water after extracting the solvent.

CHARACTERIZATION

The Fourier transform infrared (FT-IR) spectra were captured using a Nicolet Nexus-670 spectrophotometer in the 400-4,500 cm-1 range. X-ray diffraction patterns were acquired using Cu Ka radiation using an X-Pert Pro diffractometer. Tensile testing was carried out using an INSTRON 3365, UK, following ASTM-D3039 standards, with a cross-head speed of 100 mm min-1. The gold-coated surfaces were inspected under a scanning electron microscope (CARL-ZEISS, Model EVO-50).

RESULTS AND DISCUSSION

MORPHOLOGICAL STUDIES

FT-IR, SEM, and TEM analyses were used in the morphological research. The IR spectra of pure EPDM are shown in Figure 1. The peak at 2925 cm-1 is due to C-H stretching, whereas the peak at 1630 cm-1 is due to C=C stretching, and the signals 1460 and 720 cm-1 are due to CH2 bending. The CH3 bending could be responsible for the absorption at 1375 cm-1.

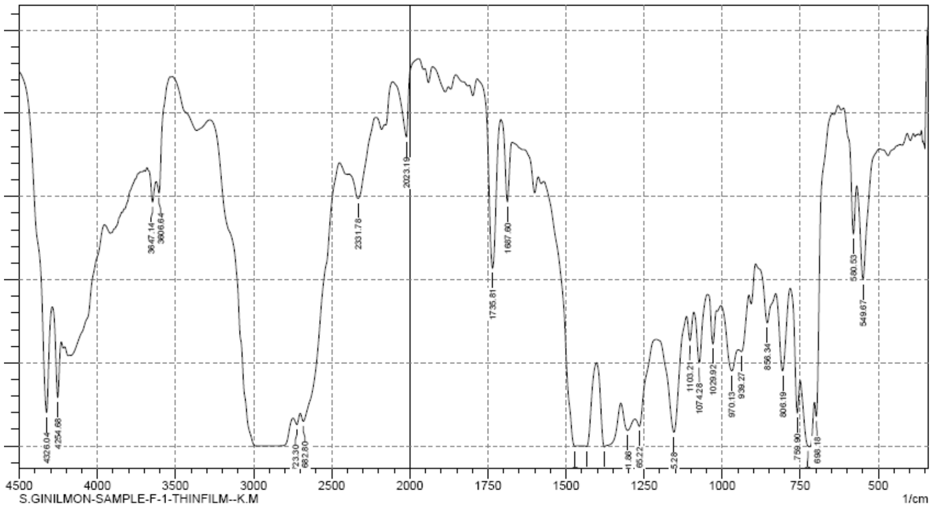

Figure 1 – FT-IR spectra of pure EPDM

The IR spectra of EPDM-GO nanocomposites are depicted in Figure 2. The signals 2925, 2580, 1630, 1460, 720, and 1375 cm-1 are associated with EPDM, whereas the absorption at 1657 cm-1 is associated with carboxyl group stretching, and the signals found between 1000 and 1250 cm-1 are associated with C-O-C stretching and the vibrational mode of the C-O group. Absorptions between 3300 and 3675 cm-1 correlate to O-H stretching. The signals 1657, 1000-1250, and 3300-3675 cm-1 confirm the presence of Graphene Oxide in pure EPDM.

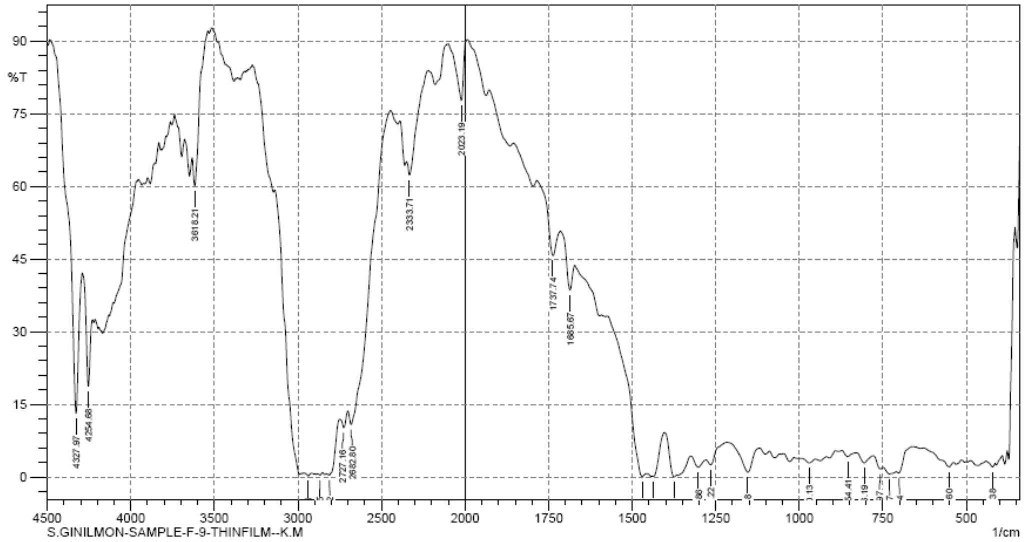

Figure 2 – FT-IR Spectra of EPDM-GO nanocomposites

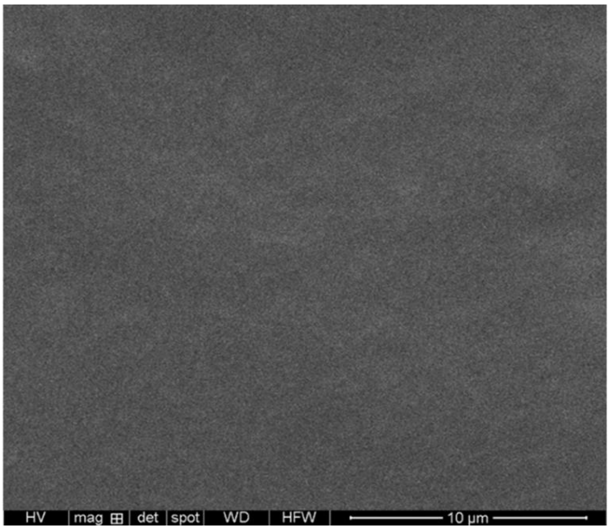

Figure 3(a) – SEM image of pure EPDM

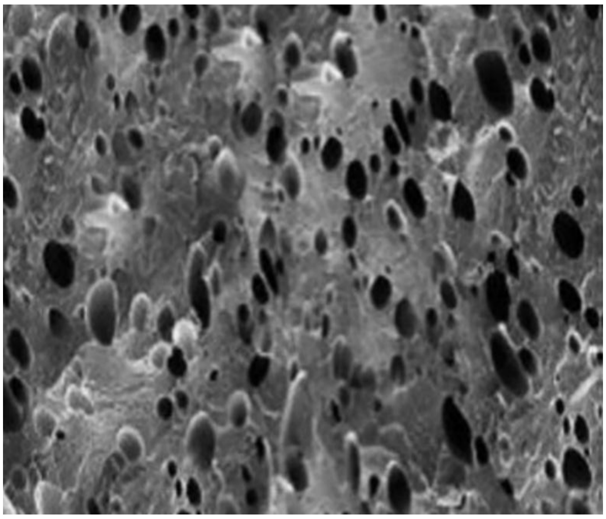

Figure 3(b) – SEM image of EPDM incorporated with 10phr graphene oxide

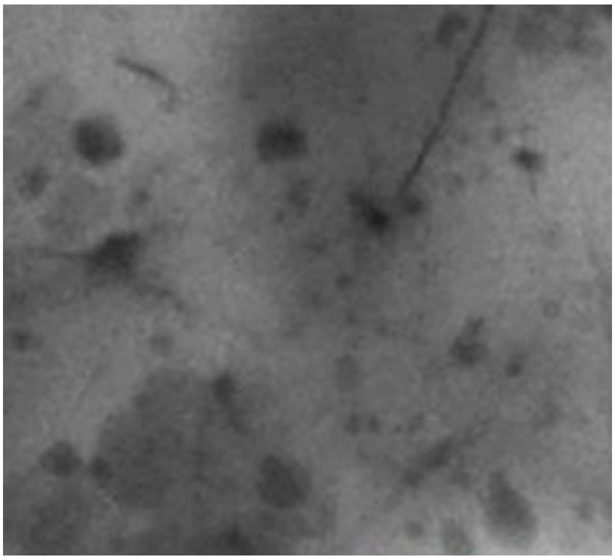

Figure 4(a) – TEM image of EPDM incorporated with 10phr graphene oxide (100 nm)

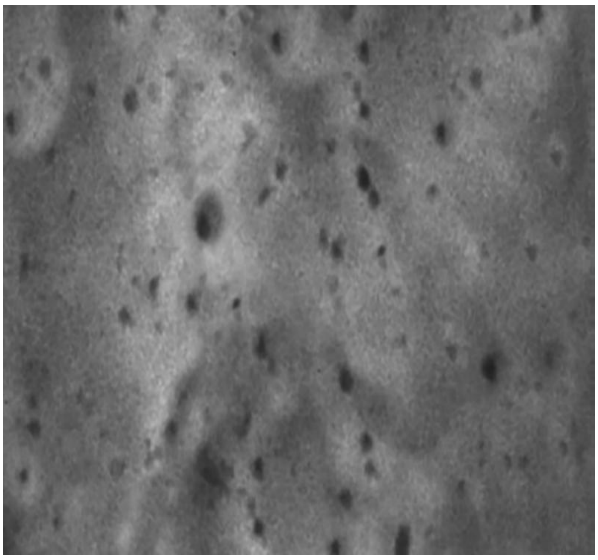

Figure 4(b) – TEM image of EPDM incorporated with 10phr graphene oxide (200 nm)

Figures 3 and 4 show SEM and TEM pictures that clearly show the uniform distribution of Graphene Oxide particles in the matrix.

MECHANICAL PROPERTIES

Mechanical testing was performed on EPDM/GO matrices with varying filler percentages, and (Fig. 5) shows a 170% increase in the tensile strength of EPDM-GO nanocomposites, and (Fig. 6) shows a 180% increase in the tensile modulus of EPDM-GO nanocomposites as compared to pure EPDM.

Figure 7 depicts the influence of filler material on break elongation. When compared to clean EPDM, the elongation at break of EPDM-GO films increases by up to 46%.

As a well known phenomenon, addition of graphene oxide has enhanced the mechanical properties in a huge level. This can be attributed to the performance level of the filler added which has very good tensility.

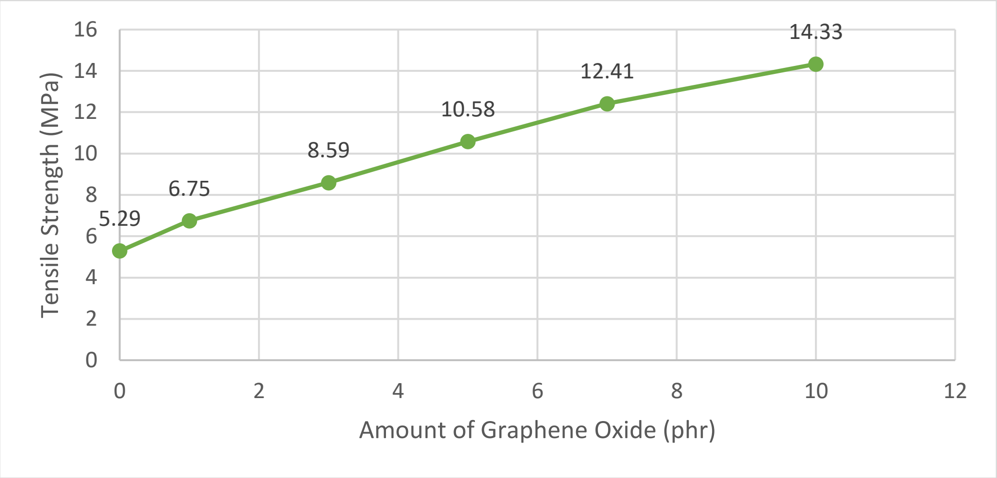

Figure 5 – Tensile Strength of EPDM-GO nanocomposites

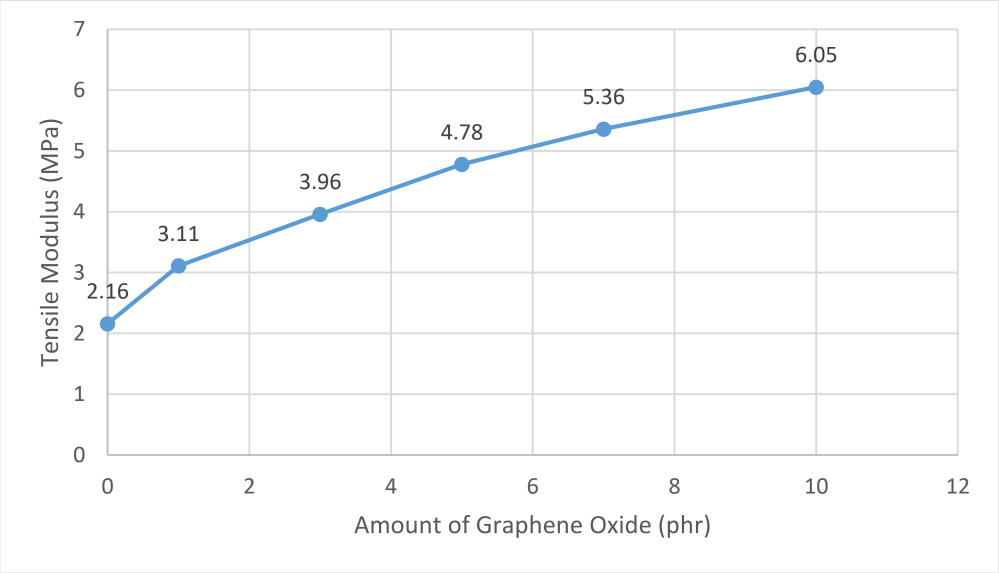

Figure 6 – Tensile Modulus of EPDM-GO nanocomposites

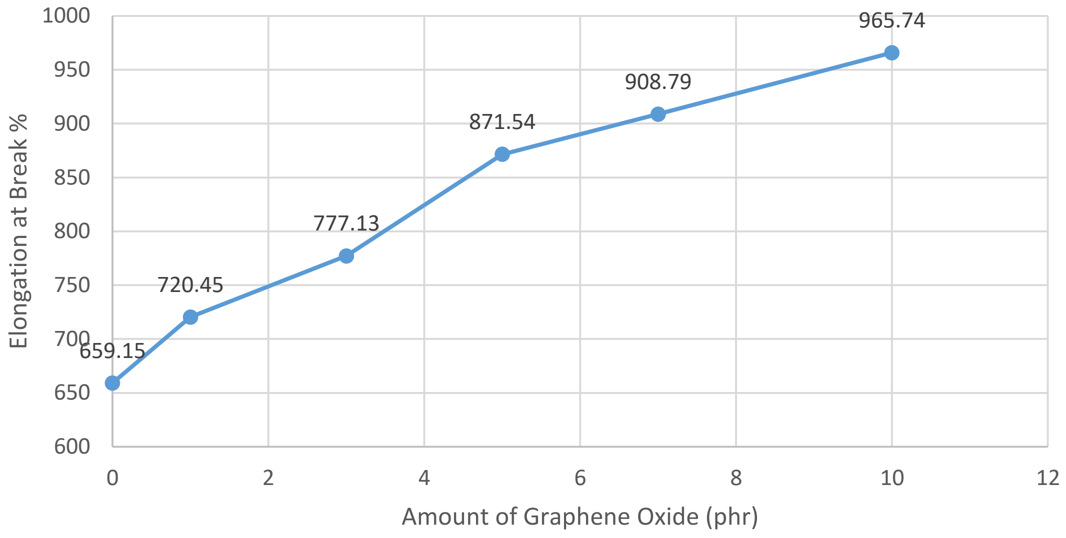

Figure 7 – Elongation at break of EPDM-GO nanocomposites

Conclusion

In conclusion, morphological analysis reveals a uniform distribution of graphene oxide particles within the EPDM/GO composites. Compared to the neat resin, these composites exhibit enhanced mechanical properties, which can be attributed to the homogeneous dispersion of graphene particles throughout the polymer matrix. The developed material holds promise for various applications, including the manufacture of conducting films and lightweight electrical appliances. Furthermore, the incorporation of graphene oxide into the EPDM matrix is expected to expand its scope and potential uses, leveraging the broad applicability of graphene oxide.

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