

Graphite Enhances Conductivity of Polymer Composites

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Abstract-Polymers containing conducting fillers and conducting polymer composites have been extensively studied because of their potential applications in light emitting devices, batteries, electromagnetic shielding, antistatic and corrosion resistant coatings and other functional applications. Graphite is carbonaceous material available commercially at relatively low cost. It attracts attention because of their appreciable mechanical and electrical properties as well as high aspect ratio and low density, which enable the graphite for easy processing. The electrical conductivity of the nano composites increases even with the addition of a small amount of graphite. Again non conductive polymer becomes conductive by the addition of a small amount of expanded graphite.

I. INTRODUCTION

Polymer composites are of scientific and industrial interest because of their enhanced properties arising from the reinforcement of nano fillers [1-4]. A significant advantage of nano additives are the use of a much smaller amount (1-4 wt%) with markedly observed improvement in properties including oxygen permeability, flammability, and conducting properties.

Polymers containing conducting fillers and conducting polymer composites have been extensively studied because of their potential applications in light emitting devices, batteries, electromagnetic shielding, antistatic and corrosion resistant coatings and other functional applications [5-7]. Different conductive fillers such as carbon black and carbon nano tubes have been extensively explored for their composite components [8-9]. These fillers effectively improve conductivity of the composites. The significant improvement in electrical conductivity arising from the increase in the filler content was observed for most composites and it was explained by the percolation transition of the conductive network formation [10].

A variety of carbon nano materials such as carbon nano tubes(CNTs) and graphite have been used for preparing polymer composites[10-14]. The improvement of CNTs reinforced composite has been impeded by difficult dispersion of polymer matrix and their high cost. In comparison to CNTs, graphite attracts attention because of their appreciable mechanical and electrical properties

as well as high aspect ratio and low density, which enable the graphite for easy processing and their potential applications in various high technology aspects, for example sensors, catalysis, super capacitors, electromagnetic shielding, radar evasion, rechargeable batteries, conductive inks, and antistatic textiles [15], thermistors, aerospace as well as in secondary battery and bipolar plates in the polymer electrolyte membrane fuel cell [16].

Graphite is a carbonaceous material available commercially at relatively low cost. Its structure consists of carbon layers in an alternating stacked sequence and bonded by weak van der Waals forces. Expanded graphite(EG) [17] is a layered material as montmorillonite, produced when bulk graphite is exposed to strong oxidizers such as sulphuric acid, nitric acid, or potassium permanganate. Graphene is a sheet of graphite and a two dimensional material which composed of several planar sheets with sp^2 bonded carbon atom. The flat carbon sheets of EG has generated huge activity in many areas of science and technology due to its unprecedented physical and chemical properties. In contrast to pristine graphite, the EG sheets are heavily oxygenated bearing hydroxyl and epoxide functional groups on their basal planes, in addition to carbonyl and carboxyl groups located at the sheet edges. The presence of these functional groups makes EG strongly hydrophilic, which allows graphite oxide to readily swell and disperse in water. The enhanced processability of EG allows it to be incorporated into polymer matrices and the scalability. And low cost of this process make it attractive for industrial applications.

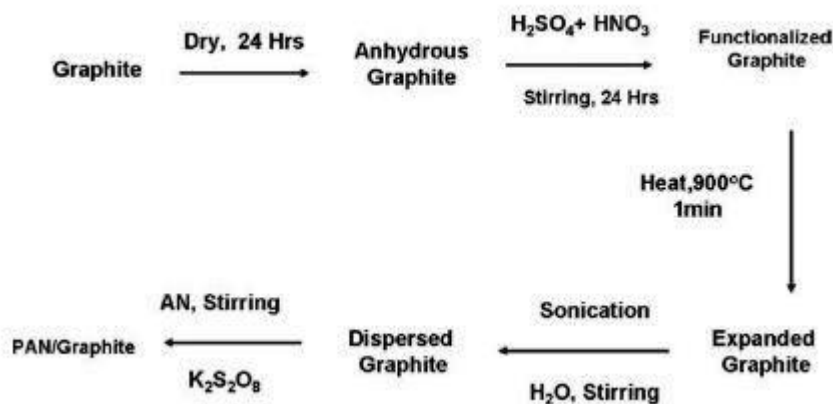
In this paper, we are discussing the role of graphite fillers in the electrical conductivity of EG-reinforced polyacrylonitrile-co-polymethyl methacrylate (PAN-co-PMMA) composites prepared by incorporating EG sheets into a co-polymer matrix and PAN/EG composites (expanded graphite sheets dispersed with PAN matrices by continuous sonication technique).

II. ROLE OF EXPANDED GRAPHITE IN PAN AND PAN-CO-PMMA COMPOSITES

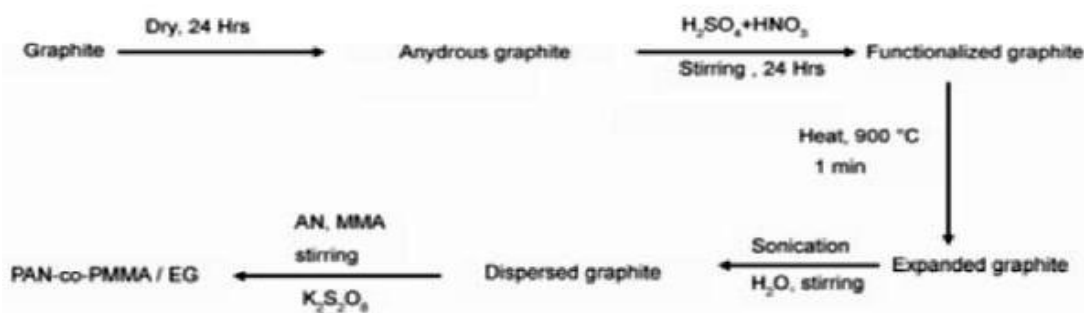
2.1 Synthesis

Synthesis of PAN/EG and PAN-co-PMMA/EG composites have been discussed [18, 19]. Following are

the basic synthesis process followed at the time of synthesis.



Synthesis 1. Synthesis process for PAN/EG composites



Synthesis2: Synthesis process for PAN-co-PMMA/EG composites

2.2 Characterization analysis

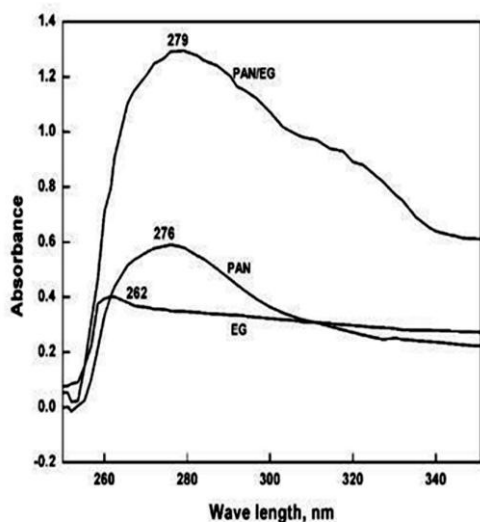


Fig1.UV-Vis spectra of(a) EG (b)PAN and (C)PAN/ Expanded graphite

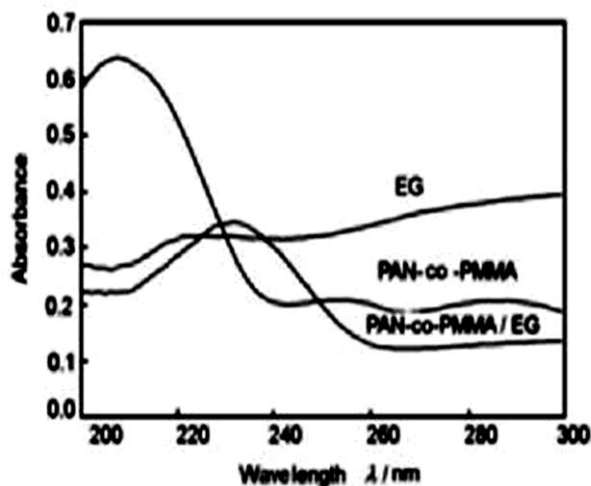


Fig2. UV-Vis spectra of (a) EG (b) PAN and (c)PAN-co-PMMA/Expanded graphite

The UV-visible spectra of the samples are used to provide the evidence of chemical interaction between PAN and expanded graphite, PAN-co-PMMA and expanded graphite. The major absorption peak of

expanded graphite in DMSO solution (see fig. 1,2) at 262 nm is originated from the surface of the expanded graphite. The UV-visible spectrum of PAN in DMSO solution shows the characteristics absorption at 276 nm [20]. The UV-visible absorption peak of PAN/EG composite in DMSO is observed at 279 nm. The curve of PAN-co-PMMA exhibits absorption at 210 nm, whereas PAN-co-PMMA/EG exhibits an absorption at

238 nm. The red shift observed in the nanocomposites may be caused due to the interaction of expanded graphite sheets with the cyanide group of polyacrylonitrile [21,22] in PAN/EG composite and by the electronic conjugation within the carbon framework ,i.e. the graphene sheets with the cyanide group of polyacrylonitrile in PAN-co-PMMA/EG composites [23-24].

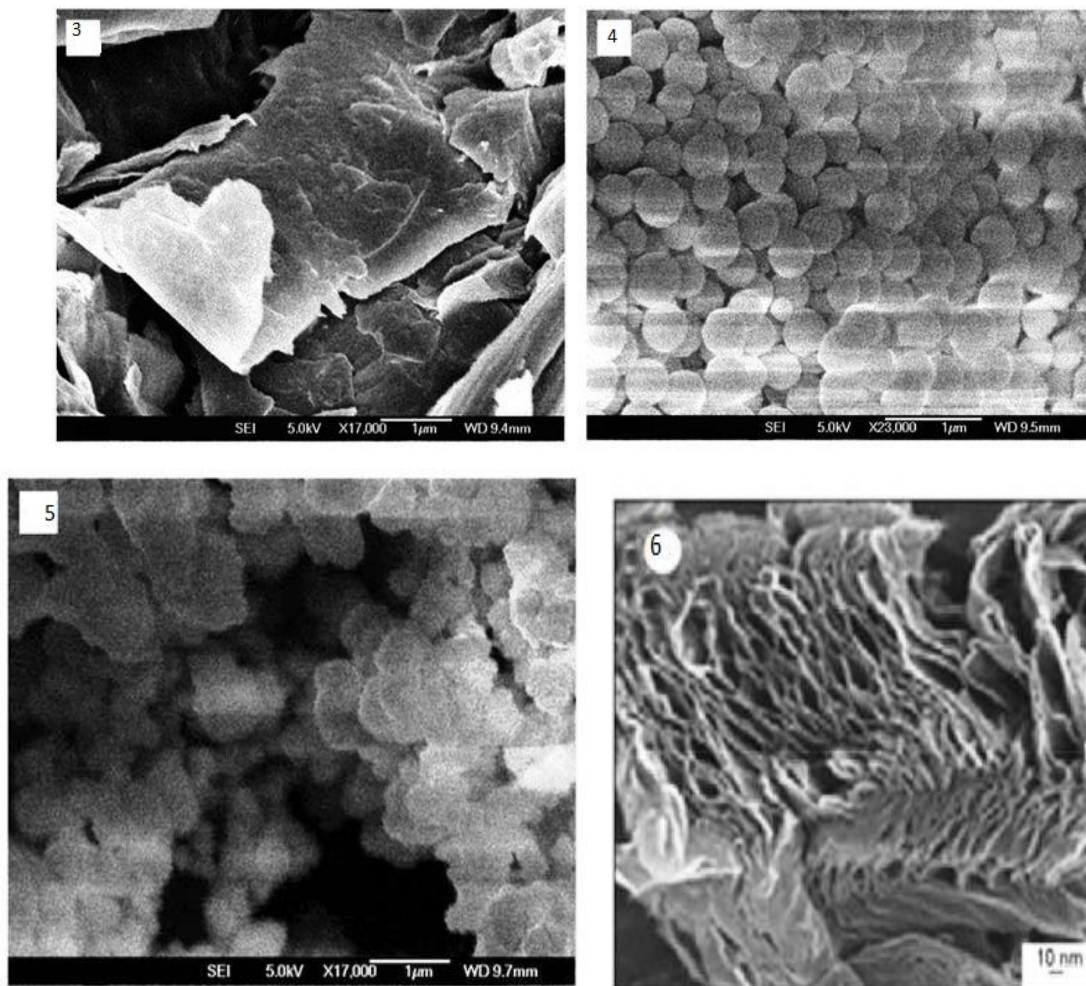


Fig3, 4, 5, 6: SEM images of (3) Expanded graphite (4) Virgin PAN (5) PAN/EG (6) PAN-co-PMMA/EG composite at 4% EG concentration

The morphology of any composite is essential to understand the shape and the quality of dispersion of fillers in the matrix which in turn governs different physiochemical properties. Fig.3 showed the SEM image of sonicated expanded graphite and fig. 4,5 for virgin PAN , PAN/EG nanocomposites. The morphological response is sensitive to the inter connectivity of the expanded graphite, which is directly related to electrical conductivity. It is revealed that the EG completely distorted into sheets with a thickness of 30-80 nm as graphite nanosheets. Single sheets with a

thickness of about 70 nm are found, indicating that the EG is composed of graphene nanosheets. HRSEM image (Fig.6) taken of the composite revealed that the graphene nanosheets are well dispersed in the copolymer matrix.

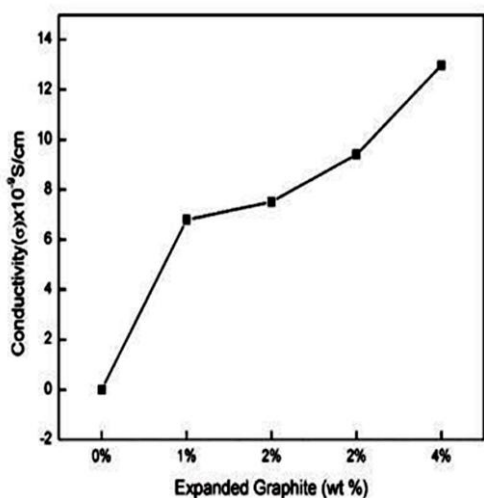


Fig7.Electrical conductivity of PAN/EG

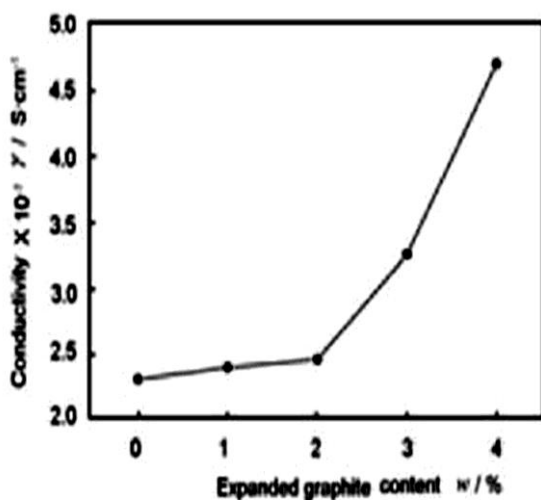


Fig8.Electrical conductivity of PAN-co-PMMA/EG

Electrical properties of composites generally depend upon the particle size, rate of dispersion and structure of conducting fillers along with the properties of host polymers. The addition of conductive fillers to an insulating polymer can result electrically conductive composite, if the particle concentration exceeds the percolation threshold. This is the particle volume fraction required for the formation of a three dimensional conductive network of the fillers within the polymer matrix. The Polymer/EG composites exhibits a very low percolation threshold for electrical conductivity because of large aspect ratio and the nanoscale dimension of expanded graphite. Fig.7 shows the variation of the electrical conductivity of PAN/EG composites as a function of EG content. The electrical conductivity of PAN-co-PMMA/EG nanocomposites is enhanced, due to a better dispersion of EG in the polymer matrix (Fig.8). The addition of EG with PAN improves its conductivity significantly with a sharp transition from an electrical insulator to an electrical

conductor. The conductivity vs. EG wt% is plotted at constant frequency. It is found that the conductivity of nanocomposites increased from 2.3 to 4.8×10^{-7} S/cm when the EG percentage increased from 1 to 4 wt%. The increase in conductivity from 1 to 4 wt% shows the percolation threshold which exceeds critical value and increases its electrical conductivity [25]. It is found that impedance decreased with the increase in EG content. The enhancement of electrical properties is due to the dispersion of EG with PAN matrix. The electrical conductivity of nanocomposites gradually increases with an increase in graphite loading. This low percolation concentration also reveals a good dispersion of EG in the PAN-co-PMMA matrix.

Fig9.Electrical impedance of PAN/EG

Fig10.Electrical impedance of PAN-co-PMMA/E

From Fig. and fig 10.the impedance of the PAN/EG and PAN-co-PMMA /EG nanocomposites are found to be reduced with an increase in the EG loading from 1 to 4 mass%, which is attributed to an increase in the conductivity of the nanocomposites.

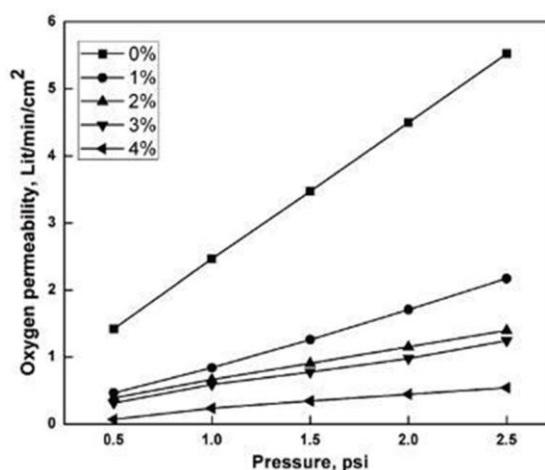


Fig11.Oxygen permeability of PAN/EG

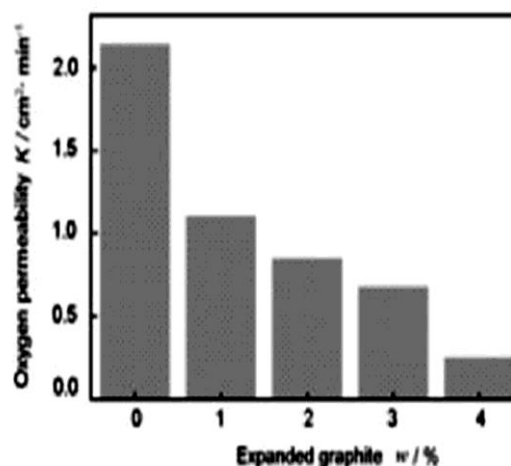


Fig12.Oxygen permeability of PAN-co-PMMA/E

The oxygen permeability of virgin PAN and PAN/EG nanocomposites and of virgin PAN-co-PMMA, PAN-co-PMMA/EG nanocomposites are depicted in fig.11 and 12. The oxygen flow rate through all the nanocomposites are observed to be less as compared with the virgin PAN-co-PMMA up to 1.72×10^4 Pa and virgin PAN up to 2.5 psi. The graph is plotted between permeability vs. EG (wt%) at constant pressure of 1.5 psi and found that the permeability of PAN/EG and PAN-co-PMMA/EG nanocomposites are substantially reduced when EG content increased from 1 to 4%. The permeability of PAN/EG nanocomposites substantially reduces to 13 times and of PAN-co-PMMA/EG nanocomposites reduces by 8 times with increase in EG content. This is because of the fact that the graphite nanoparticles act as a physical obstacle retarding the movement of the gas.

III. CONCLUSION

The oxygen permeability decreases substantially with the increase of EG loading. This result concludes that a non conductive polymer becomes conductive by the addition of a small amount of expanded graphite. Graphite is a good filler which enhances the electrical conductivity of polymer and co-polymer composites.

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