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The Impacts of Graphene Oxide as a Nanocomposite Ingredient

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ABSTRACT

The impacts of Graphene Oxide (GO) as a nanocomposite ingredient on polymer morphology and resultant property alterations, including mechanical, barrier, and electrical conductivity, are briefly reviewed in this work. This review primarily focuses on the effects of stress measurements on mechanical enhancement. The mechanical characteristics of nanocomposite materials are primarily influenced by the variable degrees of GO aggregation in various polymer matrices as a result of their weak inter-particle attractive interactions. By examining the surface morphology of these nanocomposites with scanning probe microscopy, such as Atomic Force Microscopy (AFM) and scanning electron microscopy, it is possible to evaluate the near surface dispersion of GO in polymer/GO nanocomposites (SEM) Wide-Angle X-Ray Scattering (WAXD) can be used to study GO dispersion in the bulk by examining the diffraction peaks associated with the undispersed GO fraction in the polymer matrix. We examine how the hydrophilicity of graphene oxide and its hydrogen bonding potential can improve the water flux of these nanocomposite materials in mem- brane applications. The percolative dispersion of GO nanoparticles can also advantageously increase the electrical conductivity of polymer films and bulk polymers, although this often necessitates further chemical processing of the GO nanoparticles to convert them to reduced GO.

KeyWords: ***Graphene Oxide (GO); Atomic Force Microscopy (AFM);) Wide-Angle X-Ray Scattering (WAXD)***

INTRODUCTION

It is commonly recognised that adding well-dispersed fillers and additives to polymers can greatly enhance their mechanical and physical properties [1]. In this context, we investigate the formation of polymer nanocomposites using Graphene Oxide (GO), a recently popular nanomaterial. By subjecting graphite to oxidation agents, which improve the graphite's dispersion in water by imparting oxygenated functionalities to the structure of the graphite and exfoliating the layers, graphene oxide GO is created.

Due to the notable enhancement and improvement of many nanocomposites' mechanical, thermal, and electrical properties, GO has recently become one of the most alluring nano-fillers in polymer nanocomposite technology. These improvements could result in creative solutions for a variety of applications. For instance, GO could be able to overcome the significant problem of biological species fouling polymer membranes in water filtering applications. Due to its ability to modify the smoothness of the membrane surface as well as its hydrophilicity and electrostatic repulsion properties, which can all work against bio-adsorption or even cause bio-degradation, GO can serve as an anti-biofouling agent for nanocomposite membranes [2]. Other nanoparticles in this family of graphitic nanomaterials lend themselves to increasing properties of nanocomposites in general, even if GO is very desirable as a nanofiller material.

In this regard as examples, graphene, graphene oxide and reduced graphene oxide nanosheets and nanotubes can have different interactions with many poly- mers at high loading due to the differences of their surface functional group. For example, reduction of graphene oxide to its ‘‘r-GO’’ form is one of the interesting nanoparticles due to its similar electrical properties to graphene. r-GO is produced by removing (reducing) functional group of GO using chemical or thermal treatments [3]. However, the dispersion of r-GO in polymeric and other materials is a notable challenge, hence it is typically reduced in situ while GO is conveniently dispersed in water and other hydrogen bonding polar solvents. Note also that GO has largely insulating properties. GO improves the performance of hydrogen, H_2 and oxygen, O_2 permeability and also increases the proton conductivity of Polyimides (PI)

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membranes due to the interaction between sulfonic functional group and GO [4]. GO has also been shown to have useful properties as nanosheets for bio-nanotechnology applications such as drug delivery, anti-bacteria, and DNA sensors [5,6] As previously indicated, fouling issues with polymeric membranes in various water treatment applications are most frequently caused by organic natural materials.

This issue is thought to be effectively solved by adding GO to these membranes to change their hydrophilicity [7]. Due to its tolerance to high pH and harsh chemicals, Polysulfone, or PSf, is one of the most widely used polymers for water filtration. The membrane is preserved for a longer lifespan thanks to the superior mechanical and thermal properties of PSf in addition to its improved trans- port barrier, which lowers the lifetime cost of the membrane in applications. To change the surface properties of Polysulfone and make it more hydrophilic, graphene oxide must be dispersed in PSf to create GO/PSf nanocomposite membranes because PSf is naturally hydrophobic [8]. Contrarily, the addition of Carbon Nanotubes (CNTs) to polysulfone can also enhance the mechanical and thermal properties of these materials, but the high cost of CNTs relative to GO restricts their applications [8]. In addition, GO disperses better in organic solvents and polymers than CNTs do, while CNTs exhibit weak dispersion in both [9,10].

Polyethersulfone (PES) is another intriguing polymer that can be employed as a commercial or laboratory ultrafiltration membrane. However, it shares a fouling issue with many polymers due to a lack of hydrophilicity, which negatively affects its water permeability characteristics. However, the addition of GO to the PES matrix enhances the membrane's hydrophilicity, resulting in greater water permeability [11]. A nanofiltration membrane made of Polyvinylidene Fluoride (PVDF) is also employed because of its thermal stability and controllable surface shape (morphology). PVDF has a similar fouling problem to PES polymer, but it can be remedied by adding GO [12].

In the chemical industry, classic separation methods like distillation are typically used to separate aromatic from aliphatic compounds. Polymer membranes, such Poly Vinyl Alcohol (PVA), have the potential to simplify and reduce the cost of various separation processes. Despite this, PVA's semicrystalline causes it to interact poorly with aromatics. Due to the introduction of the oxygen functional group, adding GO can improve the properties of polymer membrane separation [13]. Furthermore, due to their numerous qualities, including their mechanical, thermal, and chemical capabilities, Nafion or Sulfonated Aromatic Poly(Ether Ether Ketone)S SPEEKs are widely employed for Direct Methanol Fuel Cells, or DMFCs [14]. The high permeability of methanol between the anode and cathode results in low fuel cell efficiency, which is a serious issue for this class of polymers. This system is also shown to have a solution by adding GO nanoparticles, as the GO enhances and modifies the permeability of methanol.

The properties of the membrane are greatly influenced by the graphene oxide's dispersion in the polymer matrix. The casting solvent used to dissolve the polymer is another factor in proper dispersion. In diverse solvents, looked at the stability of graphite oxide dispersion. They used an ultrasonication bath to prepare graphite oxide in water, N,N-dimethylformamide, N-methyl-2-pyrrolidone, tetrahydrofuran, ethylene glycol, and ethanol with a concentration of 0.5 mg mL1. The solutions were then aged for several weeks to allow for characterization. The graphite oxide has excellent dispersion and long-term stability in water, which results in the maximum absorption intensity, followed by DMF and NMP, the UV-vis absorption spectroscopy results. However, in comparison to Carbon Nanotubes CNTs, GO has reduced temporal (time) stability in ethanol because GO is a 2D nanoparticle as opposed to CNTs, which are 1D. In addition, GO has more hydrogen bonds than CNTs, which causes it to aggregate more quickly and to a greater extent with time in the solvent.

For many years, many GO structural models have been researched. According to the various models of Lerf-Klinowski, Nakajima-Matsuo, Hofmann, Ruess, and Scholz-Boehm it shows the structural specifics of GO. But among all of these models, Lerf-Klinowski is the one that many scientists consider to be the most suitable. In essence, graphene oxide in this scenario is just graphene (separate layers of graphite) with some functional groups placed on the surface layers. These functional groups include Hydroxyl (OH) and Carboxylic Acid (COOH) groups attached to aromatic groups at points where epoxide groups and double bonds connect them to one another.

Synthesis of Graphene Oxide (GO)

Preparing graphene oxide in the laboratory can be done by the modified Hummers method. There are three main steps of graphene oxide synthesis by Hummers method as shown. The first step is oxidation of graphite powder to attach functional groups. In this step, graphite powder is added to a mixture of Potassium persulfate $K_2S_2O_8$, phosphorus pentoxide P_2O_5, and sulfuric acid H_2SO_4.

The solution is kept at 80°C for approximately 4.5 h on a hot plate, and then the mixture is cooled to room temperature and diluted by adding deionized DI water and kept overnight in the hood. The mixture is cleaned off residual acid by a filtration process of the solution using a 0.2 μm nylon filter using DI water, monitored each time using a pH meter. After these steps the solution is kept overnight for drying at room temperature to obtain the pre-oxidized graphite product. After drying, the product is treated by the Hummer’s method for controlled oxidation. The graphite powder is added to 120 ml sulfuric acid, H_2SO_4 gradually under an ice bath to reach 0°C with continuous stirring. After reaching 0°C, 15 g of potassium permanganate is added very slowly with stirring, and the temperature was kept below 20°C. The mixture is then heated at 35°C for a fixed amount of time while stirring constantly, and then diluted by adding 250 ml of DI water very slowly under the ice bath. The reason for adding DI water to sulfuric acid slowly is to avoid a significant rise in temperature. After addition of DI water, the solution is stirred for 2 h with the addition of an extra 0.7 L of DI water. 20 ml of hydrogen peroxide is added slowly with continuous stirring for several minutes and then filtered. The mixture is then washed with about 1 L of 1:10 $HCl:H_2O$ (aqueous solution) to remove all metallic ions and then washed by 1 L of DI water to remove the acids. The last step is purification of the product via dialysis for 2 weeks to remove the remaining metal species and acids to get a dispersion of Graphene Oxide (GO).

Conclusion and perspectives

We have briefly reviewed studies of Graphene Oxide (GO) as a nanocomposite element and its impact on mechanical, morphological, barrier, and electric properties in this review article. Due to their high dispersion and generally positive interactions with a variety of polymer matrices, GO has a significant impact on the mechanical characteristics of polymer membranes. After a certain amount of loading, over which it adversely affects modulus, strength, and surface wettability, higher GO dispersion is difficult to achieve. The morphology of polymer/GO nanocomposite films is demonstrated in this review using data from several investigations, with interpretations relating to the evaluated attributes. The review demonstrates how the GO nanoparticles influence the polymer membranes' pore structure, surface roughness, and surface wettability, all of which are related to the membrane permeability characteristics that are manifested in their gas or liquid separation processes. Due to the inherent conductivity of these nanoparticles, the electric conductivity of GO filled polymers also improved following the addition of decreased GO to various polymer matrices.

Future applications of graphene oxide, such as the transport of water and gas molecules over laminar graphene oxide membranes, will make the material even more appealing This will mostly depend on adequate GO dispersion at a big manufacturing scale, not just in the lab. The price of creating GO also restricts its use, so it is important to look into ways to create a lot of it cheaply. While dispersion is a major problem, the stability of GO functional groups that enable dispersion is crucial for their use in polymer composites like water filtration membranes, where chlorine stability is vital for water filtration. The key obstacle to be overcome for many novel applications of this promising class of nanomaterial is increased dispersion at high loading of GO.

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