Assisted Alignment of Carbon Nanotubes

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ABSTRACT

Extensive research has been focused on the processing of carbon nanotubes polymeric composites. The ability to impose a preferred alignment of carbon nanotubes in a composite will increase the effectiveness of utilizing nanotubes in composite applications. The alignment of nanotubes will maximize the interfacial bonding across the nanotube matrix interface. Nanomagnetic particles made of magnetite are used to impose preferred orientation on carbon nanotube in a composite matrix. The nanomagnetic particles are attached by surface adsorption to the carbon nanotubes surface. The external applied magnetic field is utilized to attract the nanomagnetic particles toward the higher field. The carbon nanotubes are stretched along the field line because of the nanoparticles movement toward the higher field. Industrial applications of carbon nanotube composites become more feasible with this technology.

Keywords Nanotubes, Alignment, Nanomagnetics

1. INTRODUCTION

Carbon nanotubes have unique physical properties with a very high length to diameter ratios which has made its use as one of the strongest fiber known. Different techniques were introduced to produce uniform polymer nanotubes composites [1-4].

Various methods of alignment of nanotubes have been reported, such as carbon arc discharge [5], clipping of epoxy resins [6], rubbing of films [7], Chemical vapor deposition [8-10] and mechanical stretching of nanotubes in polymer matrix [11]. Magnetic orientation based on difference in magnetic susceptibility between the carbon nanotubes and the polymer has also been reported [12-13]. However, the magnetic susceptibility of both the polymer and the carbon nanotubes is very weak (in the order of 10^{-6}) [14], and require high magnetic fields (~15-25 tesla) to induce the orientation. The technique becomes very expensive for industrial applications.

In this study, magnetic nanoparticles are used to induce preferred orientation of magnetic nanotubes in a polymer composite. The magnetic nanoparticles are attached to the carbon nanotube surface. Because of the Van der Waals forces on the carbon nanotubes, they will have a strong physical adsorption capacity. The strong Van der Waals force exerted by the surface of the nanotubes can attach almost its weight equivalent of iron oxide onto its surface. Because of its graphene sheet structure, the large surface area is responsible for this kind of attachment. The physical attachment of nanomagnetic particles with the carbon nanotubes caused much better alignment of the nanotubes in a weak magnetic field. Nanotubes with attached magnetic particles are observed using ESEM, STEM and AFM. The alignment in the presence of the magnetic fields has been confirmed by STEM, ESEM and by Raman laser microscopy

2. IRON OXIDE AND SWNT COMPOSITE

Iron oxide is prepared by the conventional coprecipitation procedure. The precipitate was sonicated. 0.10 mg of SWNT (from Carbon Nanotechnologies Inc. Texas) was dispersed in methanol by ultrasonication. The black precipitate of iron oxide (magnetite) in alkaline medium was added to it and the mixture was thoroughly stirred. SWNT-magnetite composite was formed almost immediately. The whole mass was being attracted by 0.5 T magnets.

SWNT-Magnetite Polymer Composite

SWNT-magnetite was mixed with commercially available epoxy resin (PR 2032) and further crosslinked with a hardener (PH 3660) at room temperature. The crosslinked SWNT magnetic composite were formed by keeping the above mixture at room temperature. 12 ml of this resin mixture and 1ml of SWNT magnetite dispersion was mixed thoroughly and put in a 4 ml standard plastic cuvette with a lid. The resin and SWNT mixture was allowed to set for 24 hours. After 24 hrs, a solid block of the resin was formed and was released by breaking the plastic cuvette. To align the SWNT-iron oxide composite, another cuvette with above composition of resin and SWNT was placed in between two 0.5tesla (square shaped) permanent magnets (Fig 1). 100nm and 50nm films were cut from these blocks by microtoming.

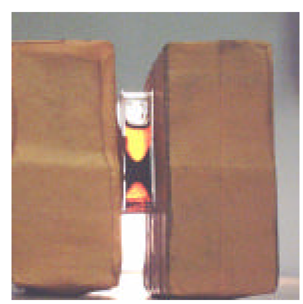

Fig 1 Exp Setup

Fig 2 shows the STEM micrograph for iron oxide coupled with SWNT aligned in epoxy with the help of the external magnetic field. The STEM was done in 100nm thick microtomed samples obtained from the epoxy SWNT composite block. The rope-like bundles of nanotubes containing a cluster of iron oxide nanoparticles attached sporadically on the tubes were observed. ESEM micrograph (fig 3) obtained with 100 m thick film shows the presence of unaligned SWNT and aligned SWNT in magnetic field at different magnifications very clearly. Care was taken to avoid while cutting the samples. It has been reported that the tubes in a polymer resin composite can be aligned by preferential cutting process [6]. Alignment of carbon nantubes was confirmed by use of near-infrared Raman spectra.

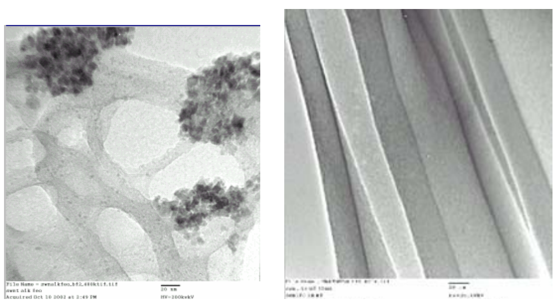

Fig 2 a&b Magnetic particle adsorbed to nanotube and aligned nanotubes

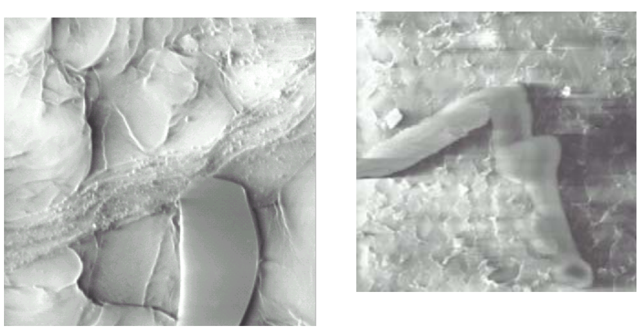

Fig 3 a&b unaligned nanotubes

3. CONCLUSION

SWNT were aligned by assistance of magnetic particles. The magnetic nanoparticles adsorb to the carbon nanotubes surface. An external weak applied field can be used to induce preferred alignment of magnetic nanotubes in the polymer composite. The alignment of nanotubes in the polymer was confirmed by Raman spectra. Utilization of magnetic nanoparticles to induce alignment of nanotubes in composites is relatively inexpensive and may facilitate industrial applications of carbon nanotube reinforced composites.

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