New Nano Solid Based on Carbon Nanomaterials-Nanoparticle through Aqueous Solutions

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ABSTRACT

A better understanding of the bonding and aggregation processes occurring between carbon nanomaterials and metal oxide particles in aqueous solutions is important in developing novel nanosolids for applications in sensor development, highly conductive paint nanotube alignment, polymer composites, Li-ion batteries, and many other areas. The current investigation reviews these processes and describes the aggregation processes occurring between carbon nanomaterials and metal oxide particles (metals) in various aqueous solutions. The results indicate that the charge attraction between the particles results in a strong, homogeneous bonding that occurs within the aqueous solution and, for the first time, demonstrates and describes the aggregation process of these nanoparticles. The relative importance of the many parameters that impact the aggregation process are identified and discussed, and guidelines for controlling the aggregation process are presented. This is a simple and cost-effective process to manufacture the novel nano solid based on carbon nanomaterial and metal oxide. In addition, the process is easy to be large scale and optimized. The methodology could lead to many significant applications and commercialization.

Keywords: Aggregation technique; Nanofluids; Charge attraction; Nano Solid; CNT's; Nanoparticles.

1 INTRODUCTION

The alignment of magnetic metal oxide nanoparticles in aqueous solutions is relatively easy; however, the alignment of carbon nanomaterials such as CNT's, CNFs, and graphene is more complicated, as they do not typically possess magnetic properties. An interesting solution for this problem was first introduced by Hong et al. [1], in which SWNTs alignment in water was achieved by attaching Fe₂O₃ NPs to the SWNTs by using sodium dodecylbenzene sulfonate (SDBS) as binder then applying a magnetic field. In this work and related references [2, 3], it was observed that the aggregation process could be accomplished in an aqueous medium in the presence of SDBS surfactants. The presence of SDBS is crucial to help obtain good dispersion for the CNTs and promote the attraction of the nanoparticles through the electrostatic interaction between the sulfonic head of the surfactant that has a negative

charge, sue to the dissociation process in water and the partially positive nanoparticles [4]. However, the previous studies focus only on fluids. As a result, all components (carbon nanomaterials, surfactants, and metal oxides) were in the aqueous state. In most circumstances, surfactants are needed but not helpful to the enhancement of the physical properties of the mixture. As a result, there is a need to develop a new method to fabricate uniformly aggregated solids containing carbon nanomaterials and metal oxides for composites, battery electrodes, etc.

In the subsequent investigation, a new concept for fabricating novel solids based on carbon nanomaterials and metal oxides through aqueous solutions is developed, and their use in several important applications is proposed and discussed. This work aims to gain a comprehensive grasp of the bonding and aggregation processes that occur between CNMs and metal oxide nanoparticles.

2 INVESTIGATIVE APPROACH

The manufacturing process is shown in fig. 1, and the experimental procedure followed to prepare the magnetic sensitive NPs is the same one reported in reference [4]. Briefly, SDBS was mixed with cnts and dispersed in deionized water using ultrasonication. Then the nanoparticles were added into the mixture and dispersed again. After that, vacuum filtration was used to separate the fabricated aggregated solids. Finally, a vacuum oven was used to dry the aggregated solids. The solution was filtered and dried in a vacuum oven. The same procedure was followed for the fabrication of Fe_2O_3 -CNT's using CNT's in the place of graphene.



Figure 1 Synthesis scheme for the aggregated Nanoparticles-CNTs

3 CONCEPT DETAIL DISCUSSION

Several different types of nanoparticles were used to coat the carbon nanomaterials through the aggregation process. For example, Fe₂O₃ nanoparticles were aggregated on the surface of CNT's as shown in Fig. 1. Hong et al. [5] used the aggregated nanoparticles-CNTs in a fluid to improve the TC. However, this approach is not applicable in non-aqueous solutions, such as epoxy, because SDBS is soluble only in aqueous solutions. Therefore, Younes et al. fabricated the aggregated nanoparticles-CNT's in a water solution first, then dried the aggregated nanoparticles-CNT's in a vacuum oven overnight and finally dispersed them using the ultra-high tip sonicator in an epoxy solution [6]. Figure 2A shows an SEM image for the CNT's that were used in the aggregation process. As shown, the CNT's are agglomerated and interconnected with each other. To better observe the CNT's, a TEM image has been acquired, as depicted in Fig. 2b. The TEM image indicates that the CNT's are MWNTs as the diameter of the tubes is larger than 20 nm. The TEM image (Fig. 2c) suggests that Fe₂O₃ NPs have an average particle size between 25-50 nm. Furthermore, the Fe2O3 crystals are shown in the figure with a hexagonal structure, (Fig. 2c inset) shows the lattice fringes and the space is around 0.37 nm. In addition, the crystallinity of the Fe2O3 NPs is further confirmed by the diffraction pattern acquired from TEM analysis as depicted in Fig. 2d.



Figure 2 (a) SEM image shows many CNT's entangled together (b) High-resolution TEM images showing CNT's. (c) Low magnification TEM image of x-Fe₂O₃ nanoparticles (d) Diffraction pattern obtained from TEM analysis and it shows the crystalline properties of the x-Fe₂O₃ particles.

3.1 Applications

The novel carbon nanomaterials-nanoparticle solids fabricated in aqueous solutions have many applications.

3.1.1. Lubricants and Nanogrease

Nanogrease is another important application for the aggregated nanoparticles-CNTs. Several publications have appeared in recent years discussing the fabrication of nanogreases using aggregated nanoparticles-CNTs with high thermal and electrical conductivity properties [7]. A study by Younes et al. concluded that SWNTs form a strong 3D net structure because of the strong Van der Waals forces, and it is the main reason behind the creation of stable SWNTs nano grease, as shown in Fig. 3. In addition, this study demonstrated that the attachment of the iron oxide at the outer face of the CNT's prevents the formation of the 3D network structure. Furthermore, the results indicate that the TC for SWNTs grease at 10 wt% has not to change regardless of the strength of the magnetic field or its application duration time, which is because of the strong Van der Waals forces between the SWNTs, which hinder the moving and resist the magnetic field [8].



Figure 3 Camera picture for SWNTs grease

3.1.2. Nanofluids

The idea of using the aggregation process in nanofluids to increase the TC of CNTs or graphene nanofluids was also investigated. The aggregation of magnetic nanoparticles on the surface of CNT's or Graphene makes them sensitive to the magnetic field. Then by applying a magnetic field, the aggregated nanoparticles-CNT align with the magnetic field (see fig 4). This alignment improves the TC [9]. However, in the solution form, the aggregates may fall apart because of the presence of water.



Figure 4 SEM image of 0.017 wt% SWNT, 0.017 wt% Fe₂O₃ and 0.17 wt% SDBS with magnetic field. (A) Scale bar 100 μ m, and (B) scale bar 10 μ m

4.1.1. High Thermal Performance Materials

Liu et al. [10] have used the same aggregation approach to fabricate magnetic sensitive SWNTs epoxy nanocomposite. Tip-sonicator and SDBS surfactant were used to ensure good dispersion of the SWNTs in an aqueous solution. After 10 minutes of the dispersion process, Fe_2O_3 was added, and the solution was dispersed for 10 more minutes. Finally, the solution was vacuum filtrated and dried in an oven at 80 °C overnight. The dried SWNTs- Fe_2O_3 has then dispersed again in an epoxy solution to fabricate the composite. Subjecting the composite to a magnetic field during the curing procedure was found to effectively align the SWNTs- Fe_2O_3 , which led to an enhancement in the mechanical and the TC of the composite, as is depicted in fig 5



Figure 5 Comparison of the tensile strength epoxy nanocomposites. (B) TC for different wt% of SWNTs nanocomposites.

5 CONCLUSION

It has been demonstrated that carbon nanomaterials such as CNTs, graphene, and CNFs and nanoparticles such as fe203 and sio2 could be aggregated homogeneously in the nanoscale in fluids and form nano solids. These solids have shown interesting physical values that may be applicable in several applications. The detailed characterization indicates that the charge attraction between the particles results in a strong, homogeneous bonding process within the aqueous solution and demonstrates and describes the nanoscale aggregation process. The relative importance of the many parameters that impact that aggregation process is identified and discussed. Guidelines for controlling this process are presented and discussed, along with methodologies whereby the manufacturing process can be optimized to improve the manufacturing processes most commonly utilized. This method not only can be used for CNTs but also can be extended to non-carbon nanomaterials. The

nanoparticles also could be comprised of elemental metals, metalloids, metal alloys, metal sulfides, metal selenium, and/or a combination thereof. In addition, this method is simple, cost-effective, and easy to be applied in large scale applications. The results and concepts presented have the potential for significant commercial value.

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