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Synthesis and Characterization of TiO_2-CNTs Nanocomposite and Investigation of Viscosity and Thermal Conductivity of a New Nanofluid

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Abstract

Nanofluids are kinds of fluids engineered by dispersing nanoparticles in base fluids, a new challenge for thermal sciences provided by nanotechnology. Due to their excellent characteristics, nanofluids find wide applications in enhancing heat transfer. This paper presents synthesis and characterization of TiO_2-CNTs nanocomposites by sonochemical method and investigation of some properties of TiO_2-CNTs nanocomposite suspended in 50:50 (by weight) propylene glycol and water mixture as a new nanofluid.

1. Introduction

The concept of nanofluid is not new as in 1857 Michael Faraday first reported the study on the synthesis and colours of colloidal gold, but it was possible to put it into practice only after the tremendous development of nanotechnologies during the last decade [1]. Nanofluids are composites consisting of nanoparticles with sizes varying generally from 1 to 100 nm dispersed in heat transfer liquids such as water, ethylene glycol, propylene glycol and so on [2]. Nature is full of nanofluids, like blood, a complex biological nanofluid where different nanoparticles (at molecular level) accomplish different functions, and functional components actively respond to their local environment. According to the types of liquids (organic and inorganic) and kinds of nanoparticles, one can get different types of nanofluids like process extraction nanofluids, environmental (pollution-controlling nanofluids), bio, and pharmaceutical nanofluids. Some properties such as: Stability, Small concentration, Newtonian behavior and abnormal enhancement of thermal conductivity, provided necessary force to begin research in nanofluids, with the expectation that these fluids will play an important role in developing the next generation of cooling technology. Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chillers, heat exchanger, nuclear reactor coolant, in grinding, machining, in spacetechnology, defence and ships, and in boiler flue gas temperature reduction.[3,4].The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. The first materials tried for nanofluids were oxide particles, primarily because they were easy to produce and chemically stable in solution[5]. Thereafter, carbon nanotubes were used to produce nanofluids and greater enhancement of thermal conductivity observed for CNTs nanofluids compared with oxide nanofluids[6,7]. In this study We have reported the preparation of a new nanofluid including of nanocomposites instead of nanoparticles dispersed in 50:50 (by weight) propylene glycol and water mixture, for the first time.

2 Experimental

2.1 Materials and characterization

All chemicals were of reagent grade and used as received. XRD patterns were recorded by a Rigaku D-max C III, X-ray diffractometer using Ni-filtered Cu Kα radiation. Elemental analysis was obtained by Carlo ERBA Model EA 1108 analyzer. Scanning electron microscopy (SEM) images were obtained on Philips XL-30ESEM equipped with an energy dispersive X-ray spectroscopy. Fourier transform infrared (FT-IR) spectra were recorded on Shimadzu Varian 4300 spectrophotometer in KBr pellets.

2.2. Synthesis of CNT/TiO_2 nanocomposites

CNT/TiO_2 nanocomposites were produced from CNTs and tetraethyl orto-titanate precursor, by the surfactant wrapping sonochemical technique [4]. This simple technique, utilizing sodium dodecyl sulfate (SDS) as the CNT surface functionalizing agent provides a well-defined, uniform, continuous, mesoporous TiO_2 (anatase) layer over the CNTs [8]. The fabrication of CNTs–TiO_2 nanocomposites was carried out as follows: firstly, certain amount of raw multiwall CNTs (0.1 g) was dispersed into acetone solution of Tetraethylorthotitanat by ultrasonication; SDS (0.04 g) was further added as a shape controller. Then, hydrolysis was initiated by adding some deionized water in to the mixture; CNTs–TiO_2 nanocomposites could be obtained by filtering and drying the aforesaid mixture in a vacuum oven at 77 °C for at least 20 h; Finally, CNTs–TiO_2nanocompositespowder was heated at a heating rate 1 °C/min to at temperature of 400°C, in an oven under ambient condition, maintaining at this temperature for 30 min.

2.3. Synthesis of nanofluid

In our experiments, we used TiO_2-CNTs nanocomposites were dispersed in a 50:50 (in weight) propylene glycol and water mixture for the nanofluid mixture was then stirred and agitated thoroughly for 30 min. with an ultrasonic agitator similar to the preparation of nanofluids by He et al. [9].

3. Results and discussion

3.1. Characterization of nanocomposite

FT-IR spectra were recorded and are shown in Fig. 1.In Fig. 1a, which is dedicated to carbon nanotubes, there are no functional groups. As shown in Fig. 1b,the absorption around 1630 cm^{-1} is assigned to the bending vibration of adsorbed water molecules. The absorption from 3000 to 3600 cm^{-1} is due to the stretching vibration of the hydrogen-bonded OH groups of the adsorbed water. The broad band below 950 cm^{-1} in the FT–IR spectra of all the TiO_2 samples belongs to the characteristic vibrations of the inorganic Ti–O–Ti network[10].

XRD pattern of CNTs, TiO_2 and TiO_2-CNTs nanocomposites is shown in Fig. 2. The two features peaks of CNTs at 2θ position of 26.0° and 43.4°, can be identified in Fig. 2a. From XRD pattern of TiO_2 (Fig. 2b), it can be observed, the anatase constitutes the major crystal form in the pure TiO_2 (JCPDS card no: 04-0477) sample. Fig.2c presents the XRD results of the TiO_2-CNTs nanocomposites that were prepared by the sol–gel process. The XRD patterns show that only anatase phase TiO_2 can be identified in the nanocomposite; the rutile phase of TiO_2 was not observed. These results imply that the TiO_2nanocrystalline structure was retained with CNTs in theTiO_2 matrix. Furthermore, peaks at 2θ position of 26.0° and 43.4°, which are the characteristics of carbon nanotubes, were not observed in the XRD patterns of nanocomposites. The interpretation of this phenomenon was that the main peak of the CNTs at 26.0° might overlap with the main peak of anatase TiO_2 crystallites at 25.4° since these two peaks are very close. Moreover, the TiO_2 crystallinity is much higher than that of the CNTs, which could cause the TiO_2 to shield the MWCNTs peaks [11]. It is therefore quite difficult to identify CNT characteristic peaks in XRD patterns of the nanocomposite.

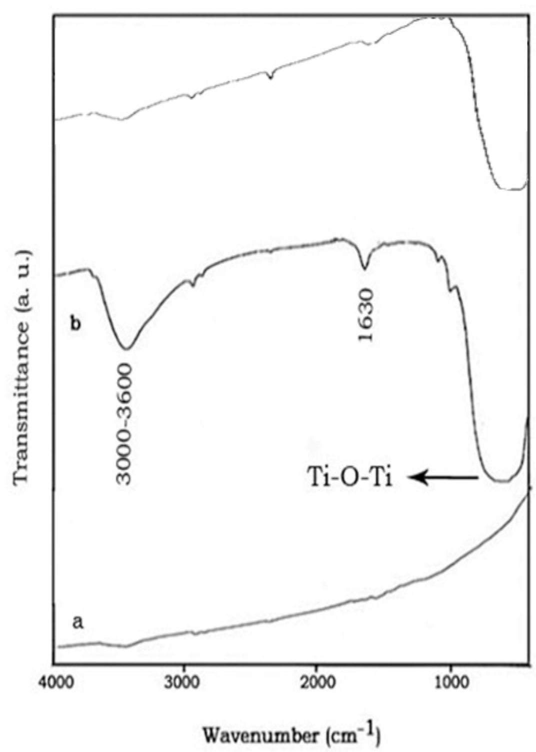

Fig. 1. FT-IR spectra of a) carbon nanotubes b) TiO_2 and c) TiO_2-CNTs nanocomposites.

The morphologies of CNTs-TiO_2 composites were revealed by SEM investigation and the typical SEM images are showed in Fig. 3

3.2. Investigation of thermal conductivity of TiO_2-CNTs nanofluids

Nusselt number is a parameter that the heat transfer characteristic of a flowing fluid can be specified by it, which takes into account the Prandtl number including thermal conductivity. Thus, a first evaluation of the heat transfer potential of a nanofluid is to measure its thermal conductivity. The thermal conductivity of nanofluids is much improved when compared with usual fluids.

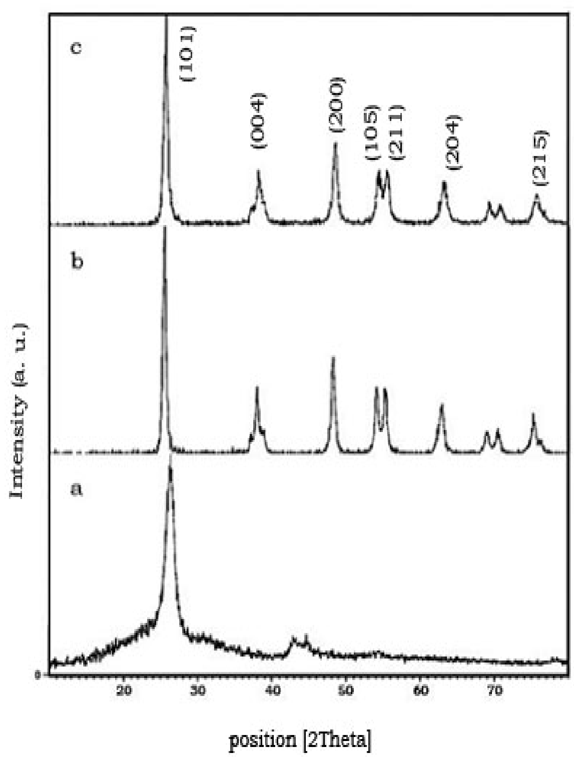

Fig. 2. XRD pattern of a) CNTs, b) TiO_2 and c) TiO_2-CNTs nanocomposites.

The thermal conductivity of TiO_2-CNTs nanofluids was measured using H471 apparatus. Measurements were taken for all samples of nanofluid at different temperature. From Fig. 4, the thermal conductivity of the nanofluid samples first increases intensely with temperature and after 28 C it increases on-linearly with temperature slightly.

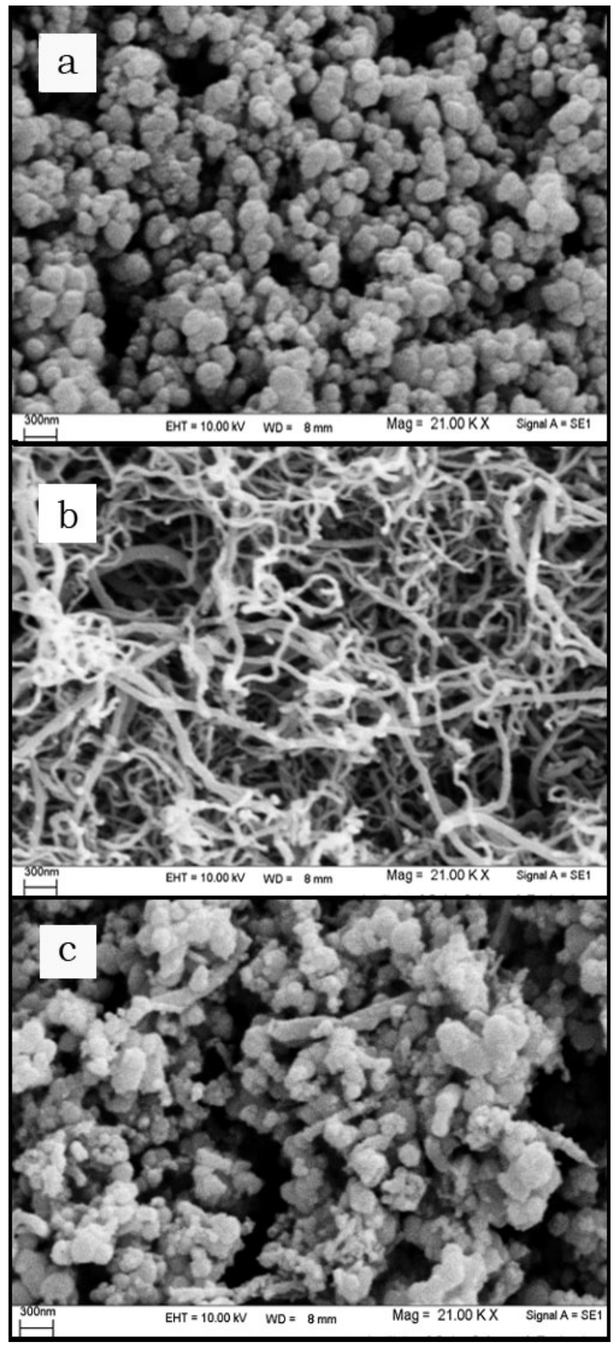

Fig. 3. SEM images of a) TiO_2, b) CNTs and c) TiO_2-CNTs nanocomposite.

The thermal conductivity increases with increasing temperature, as well as in all studies of this relationship have been rising. But nanotubes, and titanium oxide nanocomposites increased markedly in the case of nonlinear nanotubes and nanocomposites can be pointed to the important role of interactions that lead to behavior change in nanofluids it is linear to nonlinear behavior.

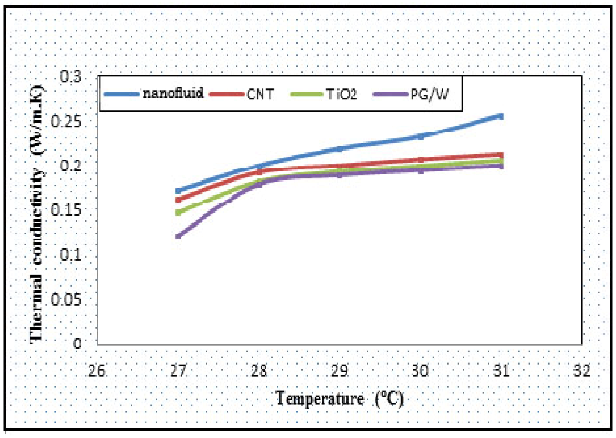

Fig. 4. Enhancement in the thermal conductivity of samples with temperature.

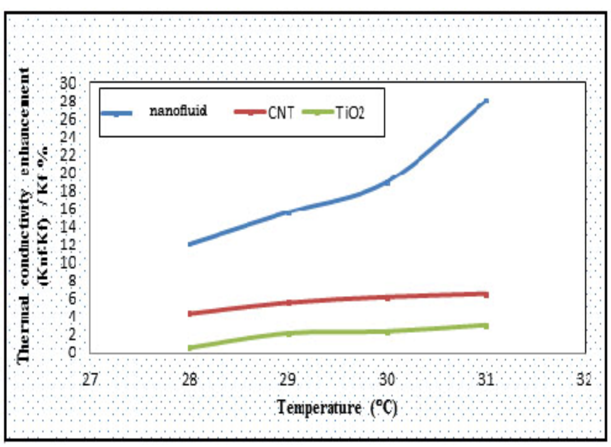

Fig. 5. Comparison of thermal conductivity of different samples

3.3. Investigation of viscosity of TiO_2-CNTs nanofluids

Determining the viscosity of the nanofluid is essential to establishing adequate pumping power as well as the convective heat transfer coefficient, as the Prandtl and Reynolds numbers (functions of viscosity) will be influenced. Experimental data for the effective viscosity of aqueous nanofluids is limited to certain nanoparticles, such as Al_2O_3[12–15], CuO[14,16], TiO_2[12] and MWCNT [17].

Viscosity generally increases with increasing temperature due to Brownian motion components, and decreases the change in fluid viscosity with temperature is more severe. The increase in viscosity due to the addition of nanoparticles to the base fluid temperature dependency of nanofluid increases within creasing concentration. Mechanism of change of viscosity with temperature isn't very different from the base fluid that such behaviors also visible in the published studies

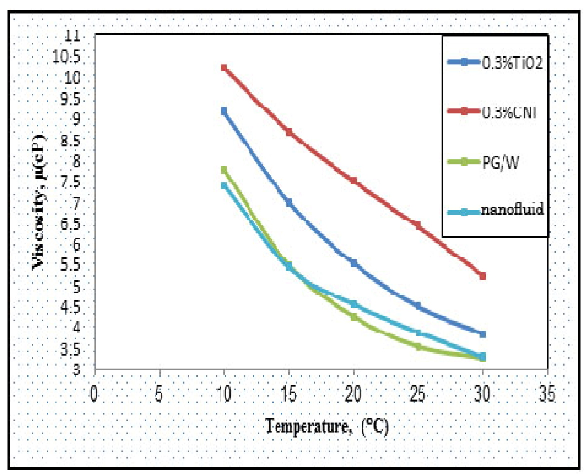

Fig. 6. Experimental values of viscosity for same concentrations of samples respect to temperature

4. Conclusion

TiO_2-CNTsnanocomposites have been successfully prepared by a simple sonochemical method. Also nanofluids of these nanocomposites have been synthesised by dispersion of them in 50:50 propylene and water mixture. FT-IR, XRD and SEM and techniques have been used for characterization of nanocopmosites. The thermal conductivity and viscosity of this new nanofluid has been investigated.

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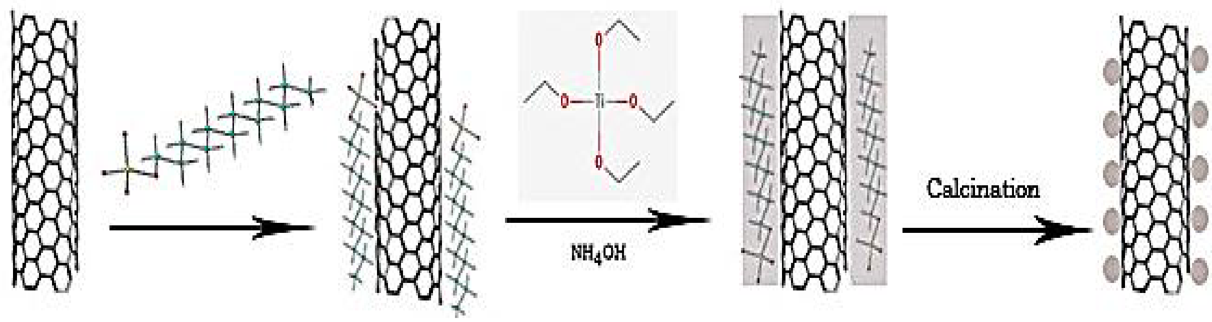

Fig. 7. Schematic for synthesis of nanocomposite.

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