Available online at www.sciencedirect.com
ScienceDirect
Journal of Taibah University for Science 10 (2016) 403–406
Journal of Taibah University for Science
www.elsevier.com/locate/jtusci

Short Communication

Investigation of the dielectric properties of TiO_2 nanofluids

Alagappan Subramaniyan [a], Lakshmi Priya Sukumaran [a], Rajangam Ilangovan [b,*]

[a] Department of Physics, Thiagarajar College of Engineering, Madurai 625015, India
[b] Centre for Nanoscience and Nanotechnology, University of Madras, Chennai 600025, India

Available online 21 July 2015

Abstract

Nanofluids are tailored suspensions of nanoparticles in a selected base fluid. Nanofluids provide advantages including high thermal conductivity, electrical conductivity and optical absorption compared to the base fluid by itself, even for only a small volume fraction of nanoparticles. The choice of the nanoparticles and base fluid is a challenge in order to achieve maximum absorption. In this work, a method is suggested for selecting the best base fluid for TiO_2 nanoparticles to yield the best nanofluid based on the Maxwell-Garnett (MG) effective medium approach.

Keywords: Nanofluid; TiO_2; Water; Ethylene glycol; Propylene glycol; Maxwell-Garnett model

1. Introduction

Maxwell introduced the idea of microcolloidal suspensions approximately 134 years ago [1]. Since then, researchers have investigated and applied microfluid technologies for heat transfer applications. However, drawbacks such as sedimentation, abrasion, and wear resistance have limited the growth of microfluids as an industry. The birth of nanotechnology gave rise to nanosuspensions or nanofluids. The term nanofluid was coined by Stephen Choi in 1995 [2] at Argonne National Laboratory, USA. Nanofluids are suspensions of nano-sized solid particles (1–100 nm) in selected base fluids. Nanofluids can be prepared in two ways: a single-step method [3] or a two-step method [4]. The single-step method is based on the simultaneous synthesis of nanoparticles and nanofluids, and the two-step method involves the synthesis of nanoparticles in the first step followed by their dispersion in a suitable base fluid in the second step. From 1995 to 2008, nanofluids were investigated as a heat transfer fluid, with the best results reported by Eastman and Choi [5]. Nanocopper with ethylene glycol as the base fluid exhibited a 40% increase in its thermal conductivity for a 0.3 vol.% of copper. The increased thermal conductivity of nanofluids can lead to the miniaturization of electronic devices and the ability to provide the required electronic cooling.

From 2009, nanofluids have been experimentally and theoretically investigated for their electrical properties. Investigations have proven their highly conducting properties compared to their base fluids [6–8]. Magnetic nanofluids with a tunable thermal conductivity and viscosity were investigated by Philip [9]. Nanofluid optical properties were investigated by Taylor [10] for efficient direct absorption solar collectors (DASC). The success of nanofluids for DASC depends on the appropriate

* Corresponding author. Tel.: +91 9442043043.
E-mail address: rajangamilangovan@gmail.com (R. Ilangovan).
Peer review under responsibility of Taibah University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jtusci.2015.05.005
1658-3655

Table 1
List of materials investigated in this work.

Nanoparticle	Volume fraction of nanoparticles	Base fluid	Nanofluid
TiO_2	0.1–0.2	Water	TiO_2–water
TiO_2	0.1–0.2	Ethylene glycol (EG)	TiO_2–EG
TiO_2	0.1–0.2	Propylene glycol (PG)	TiO_2–PG

choice of both the base fluid and the nanoparticles. The best nanofluids should also have a high stability. In this work, an attempt is made to identify the best base fluid for a given type of nanoparticle to achieve the best optical properties for efficient DASC using the Maxwell model.

2. Experimental description

The selection of best nanofluid for optical absorption depends on the choice of both the nanoparticles and the base fluid. The combination which gives highest dielectric constant for the nanofluid is selected based on the Maxwell-Garnett (MG) effective medium approach.

The Maxwell-Garnett approximation is used when calculating the dielectric properties of inhomogeneous materials or mixtures of materials. It is applicable when one of the components is dispersed within a second component. Nanofluids are solid nanosuspensions in a liquid matrix. It is assumed that the nanoparticles are spherical or ellipsoidal to satisfy the MG model. Electrostatic interactions exist between the different nanoparticles, which can create charged dipoles and lead to distortions. However, the field created by the distortions is assumed to be uniform [11].

To select the best nanofluid for TiO_2, water, ethylene glycol, and propylene glycol were used as base fluids. These fluids were chosen as a result of their being used often in heat transfer applications. The volume fractions investigated ranges from 0.1 to 0.2, as low volume fractions yield high stability (Tables 1 and 2).

The different combinations of nanofluids and base fluids investigated were grouped into 10 samples. Samples 1–4 include EG and PG as base fluids and were investigated at 10^4 Hz and 10^7 Hz, respectively, and at a constant temperature of 20 °C. Samples 5–10 were water-based nanofluids and were investigated at 10^4 Hz and 10^7 Hz with increasing temperatures.

The best fluid was theoretically calculated using the Maxwell-Garnett effective medium approach in which:

Table 2
List of samples investigated in this work.

Sample	Material	Frequency (Hz)	Temperature (°C)
1	TiO_2 + EG	10^4	20
2	TiO_2 + EG	10^7	20
3	TiO_2 + PG	10^4	20
4	TiO_2 + PG	10^7	20
5	TiO_2 + Water	10^4	0
6	TiO_2 + Water	10^4	20
7	TiO_2 + Water	10^4	100
8	TiO_2 + Water	10^4	200
9	TiO_2 + Water	10^7	100
10	TiO_2 + Water	10^7	200

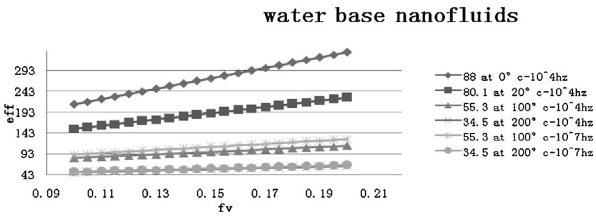

Fig. 1. Graph of the dielectric constants for water based nanofluids at different temperatures and frequencies.

E_{eff} – effective dielectric constant of the nanofluid,
E_f – dielectric constant of the base fluid,
f_v – volume fraction and
E_p – dielectric constant of the particle.

The dielectric constant of materials can change with the temperature and applied frequency. In this investigation, the dielectric constants of the nanofluids are studied at a constant frequency of either 10^4 Hz or 10^7 Hz over a temperature range from 0 to 200 °C. The dielectric constants at different temperatures and frequencies are shown in Fig. 1. The investigations of the dielectric constants for nanofluids in ethylene glycol and propylene glycol were performed at the same frequency (10^4 Hz and 10^7 Hz), but only at 20 °C due to the limited availability of theoretical data.

$$E_{\text{eff}} = E_f[1 + \{(3 f_v[(E_p - E_f)/(E_p - 2E_f)\}]/\{1 - [f_v\{(E_p - 2E_f)/(E_p + 2E_f)\}],$$