Short Communication

Thermal Conductivity of Cu_2O-TiO_2 Composite -Nanofluid Based on Maxwell model

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Abstract
Nanofluids are colloidal suspension of nanoparticles in a base fluid and have superior thermal properties in comparison to their base fluids. Novel properties of nanofluids are yet to be explored to the highest potential. Currently extensive investigation has been done on thermal conductivity of metallic and oxide nanofluids. Composites offer the advantage of tailor made properties and fluids with nano composite can offer tunable thermal conductivities .The present work deals with investigation on thermal conductivity of Cu_2O-TiO_2 nanocomposites with water as base fluid using Maxwell model for different volume fractions of nanophase. The thermal conductivity variation is analyzed with respect to volume fraction of each phase of the nanocomposite.also by varying volume fraction of the individual phase of nanocomposites. The highest thermal conductivity was obtained for the Cu_2O-TiO_2 (1:9) with water as base fluid. The results depend on the shape of Cu_2O-TiO_2, viscosity of nanofluid, interfacial layer thickness and size of nanoparticle due to the constraints in Maxell thermal conductivity equation.
Keywords: *Cu_2O-TiO_2, Composites, Maxwell model, Thermal conductivity.*

1. INTRODUCTION

Composites are tailor made materials to achieve desired range of properties. Naomaterials have a higher surface to volume ratio and hence composites made from nanomaterials (nanocomposites) have better thermal, optical, magnetic, electrical properties compared to their bulk composites. The particle size dependence of nanocomposites [1] has made them more attractive and advantageous. Thus nanocomposites can be tailored by size of nanoparticle and shape of nanoparticle. Nanocomposites are nanomaterials with any one of the phase in 1-100nm range.

Nanofluids are suspension of nanoparticles in a suitable base fluid. The solid nanoparticles are dispersed in a liquid phase. The term Nanofluids was coined by Stephen U. Choi in 1995 at ANL, USA [2]. Many reviews on thermal conductivity of nanofluid signify the enhancement in thermal conductivity of base fluid for a small volume fraction of nanoparticles. Nanofluids have been shown to be useful in manufacturing, automotive, medical and transportation industry in addition to thermal cooling applications [3]. Thermal conductivity of nanofluids is practically measured by hot wire method, Transient method and oscillatory method [4-6]. Several theoretical models like Maxwell, Hamilton crosser, Wasp, Bruggeman, Patel model [7], etc have been applied to metallic, ceramic and CNT nanofluid for the measurement of thermal conductivity and results have been compared between experimental and theoretical values. A review on the existing analytical models is described by Arun S.Majumdar [8]. Efforts have also been laid on reducing errors between experiments and theory based on innovative Maxwell model with emphasis on interfacial particle layer thickness. Composite nanofluids (CNF) is yet to be investigated through Maxwell model and the present work deals with investigation on thermal conductivity of Cu_2O-TiO_2 (CNF) based on Maxwell model for the first time.

2. EXPERIMENTAL

2.1 Thermal conductivity of composite

The thermal conductivity values of Cu_2O, TiO_2, water and engine oil are taken as 4.5, 11.7, 0.613 and 0.141 in W/m-k respectively. These are approximate values of the thermal conductivity of solids and liquids at temperature of 25°C. The series model of nanocomposite is applied for different volume fractions of Cu_2O using the below equation.

$$K_{comp}=K_{Cu20}\, V_{Cu20} + K_{TiO2}\, V_{TiO2}$$

Table 1. *Thermal conductivity of composite*

V_{Cu20}	K_{comp}
0.1	10.98
0.2	10.26
0.3	9.54
0.4	8.82
0.5	8.1
0.6	7.38
0.7	6.66
0.8	5.94
0.9	5.22

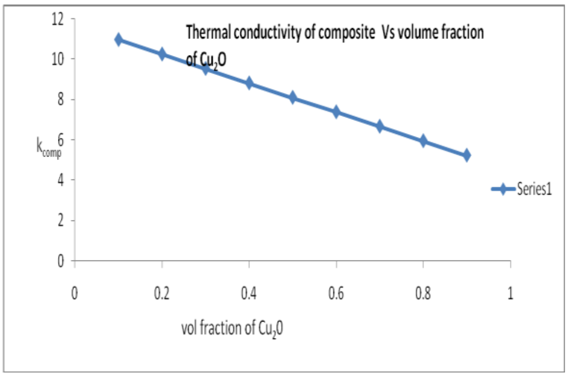

Figure 1. *Variation of thermal conductivity*

The thermal conductivity of Cu_2O-TiO_2 composite nanofluid is investigated for water and ethylene glycol as base fluids with a variable volume fraction of the composite from 0.1-1.Recently we have reported successful preparation and characterization of Cu_2O-TiO_2 nanofluid [9]. The thermal conductivity of TiO_2 is 2.5 times the thermal conductivity of Cu_2O but Cu_2O can absorb more solar energy than TiO_2 over a wavelength range from 350 - 700 nm as reported by Maolin Zhang. The main purpose of the investigation is to exploit the best properties of Cu_2O and TiO_2 combination to get maximum absorption of solar radiation and at the same time increase the thermal conductivity to achieve more efficient direct absorption solar collectors.

2.2 Maxwells model for Cu_2O-TiO_2 composite nanofluid.

Among the existing models for thermal conductivity of nanofluid, Maxwell model is the primary and simplest model. The model assumes spherical nanoparticles suspended in a continuous liquid matrix. Although the model does not include nanoparticle size and interfacial layer thickness of nanoparicle in nanofluid, it is the fundamental model explored by all investigators. The results of Maxwell model are in acceptable range as inferred from the overview on nanofluids by Manna [10]. Maxwell model estimates the thermal conductivity of nanofluid based on the equation

$$K_{eff}= \frac{K_p+2K_b+2(K_p-K_b)\,\Phi}{K_p+2K_b-(K_p-K_b)\,\Phi} \times K_b$$

K_{eff} - Effective thermal conductivity of nanofluid
K_b- Thermal conductivity of base fluid (Water,Ethylene glycol(EG))
K_p- Thermal conductivity of nanoparticles, nanocomposites of Cu_2O-TiO_2
Φ- Volume Fraction.

To understand the effect of composite nanofluid the individual nanofluids are first investigated with Maxwell model. TiO_2 nanofluids have shown to be efficient in heat pipes [11] and Cu_2O nanofluids are efficient solar nanofluids [12] Composite nanofluid is investigated with volume fraction (0.1, 0.5, 0.9) of Cu_2O. This ensures the range of tunable properties obtained with the nanocomposite, the minimum and maximum effect of adding Cu_2O in a TiO_2 matrix.

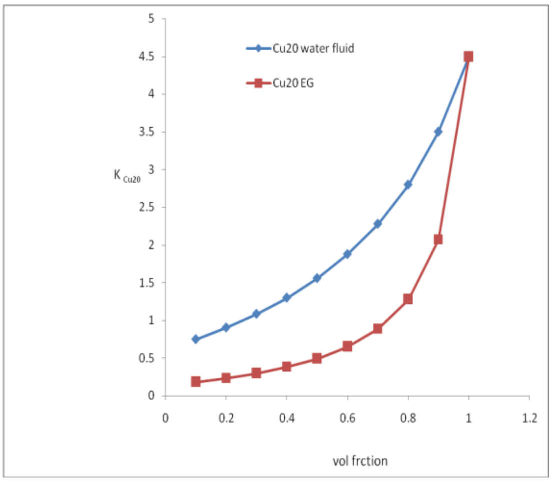

Figure 2. *Thermal conductivity of Cu_2O nanofluids*

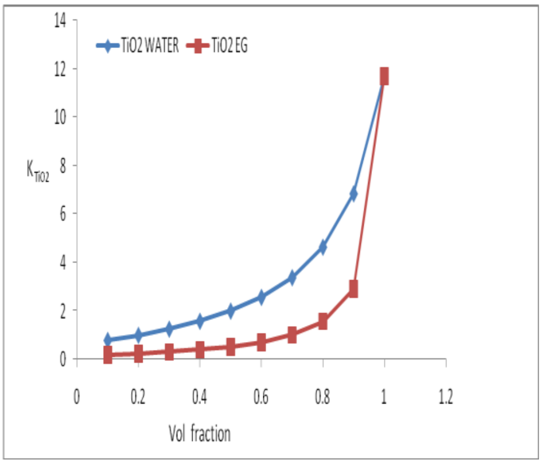

Figure 3. *Thermal conductivity of TiO_2 nanofluids*

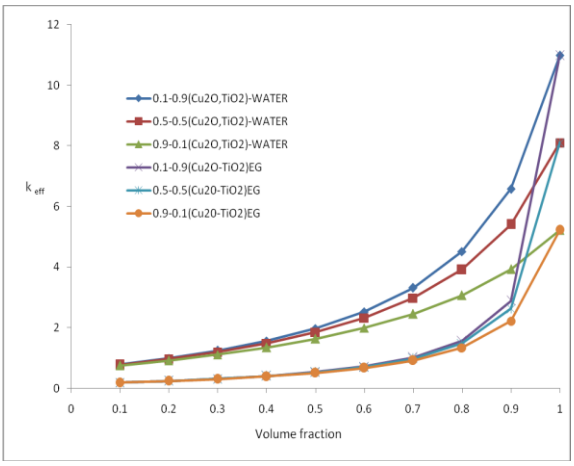

Figure 4. *Thermal conductivity of Cu_2O TiO_2 nanofluids with volume fraction of composites.*

3. RESULTS AND DISCUSSION

Cu_2O and TiO_2 water nanofluids show high thermal conductivity in comparison to their ethylene glycol naofluids. Thermal conductivity of TiO_2 nanofluids are higher than Cu_2O nanofluids irrespective of the base fluid which make them suitable for heat transfer applications. With increase in volume fraction the thermal conductivity of Cu_2O nanofluids are higher in comparison to TiO_2 nanofluids.

The composite nanofluid (0.1,0.5,0.9) have almost the same thermal conductivity till 0.4 volume fraction of the composite solid phase for water base fluids and 0.7 for ethylene glycol base fluids. The percentage increase in thermal conductivity increases from 0.5 -1.But devices which depend on nanofluid technology usually employ low volume fractions of solid phase to ensure stability, prevent agglomeration, clogging abrasion and wear resistance. It is interesting to note that the composite nanofluid offers same results for low volume fractions with respect to thermal conductivities irrespective of the volume fraction of Cu_2O in the composite. Based on above results we suggest volume farction of 0.4 solid phase and Cu_2O-TiO_2 (1:1) ratio to give the highest possible results such as good thermal conductivity and better optical absorption in direct absorption solar collectors.

4. CONCLUSION

The Maxwell model in combination with the composite series model has been investigated for the first time with a Cu_2O-TiO_2 nanofluid. A Composite of Cu_2O-TiO_2 in the ratio of 1:9 shows the highest value of thermal conductivity for all volume fractions for both the base fluids. Since optical absorption of Cu_2O is higher than TiO_2, (1:1) composite with volume fraction of 0.4 for water base fluids may show good absorption and good heat transfer characteristics essential for DASC.

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