International Journal of Enterprise Computing and Business Systems

ISSN (Online) : 2230-8849

Volume 2 Issue 1 January 2013

International Manuscript ID : ISSN22308849-V2I1M8-012013

SYNTHESIS AND EXPERIMENTAL DETAILS OF THERMOPHYSICAL PROPERTIES OF NANOFLUIDS

Pradeep Prabhakar

Director Principal , L.R.I.E.T., Solan

Dr.Chanpreet Singh
Associate Prof., M.E., UCOE, Punjabi University Patiala

Dr..D. GangaCharayulu
Chemical Engg. Department, Thapar University,Patiala

Abstract

Miniaturization has been a trend in modern science and technology and this trend is rapidly emerging as a new revolution in the form of nanotechnology. As a new and dynamic research frontier, nanofluids are used to enhance thermal conductivity of the base fluids. Nanofluids of metallic solids in pure state(Silver, gold, copper etc.), non metallic solids , metallic liquids (Al, Na at 644K) and carbon nanotubes in particular have been a major focus of various scientists all over the world for their valuable thermophysical properties. This paper presents a brief report on synthesis of silver and gold nanofluids by chemical reduction method and studies of thermophysical properties of the silver nanofluids i.e. thermal conductivity in particular. The synthetic route opted here is advantageous as it is an in situ preparation as well as economic in terms of time and cost. The varied and important potential applications of silver and gold nanofluids are also

highlighted. Nanofluids can serve as excellent heat transfer fluid and can find applications in the fields which are based on heat transfer.

Keywords: Nanofluids, thermal conductivity, base fluid, single step approach.

Introduction

Nanotechnology is the study of manipulating matter on an atomic and molecular scale. Generally nanotechnology deals with structures sized between 1-100nm in at least one dimension.

Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self assembly, developing newer materials controlled at atomic scale.

Nanofluids, a novel outcome of nanotechnology are emerging as a solution to many problems associated with conventional heat transfer fluids. Nanofluids are here referred to as novel because of the novel thermophysical properties possessed by these, especially in terms of thermal conductivity in comparison to conventional heat transfer fluids. Before discussing the heat transfer properties of nanofluids, a quick review of nanofluids is required.

The word ‘nanofluid’ was first conceived by Dr. Choi in 1995[1] in Argonne National Laboratory to describe a fluid consisting of solid nanoparticles with size less than 100 nm suspended in it. This fluid is usually referred to as base fluid. Common base fluids are water , organic liquids(ethylene glycol),oils , lubricants, biofluids etc.

Materials commonly used as nanoparticles include:

- Chemically stable metals (Au, Cu etc.)
- Metal oxides (alumina, CuO)

ISSN (Online) : 2230-8849

Volume 2 Issue 1 January 2013

International Manuscript ID : ISSN22308849-V2I1M8-012013

- Metal carbides (SiC)
- Metal nitrides (AlN, SiN)
- Carbon in various forms e.g. carbon nanotubes

Solids have thermal conductivites which are orders of magnitude larger than those of conventional heat transfer fluids [2] as shown in the table1:

Table1

Material	**Form**	**Thermal conductivity(W/mK)**
Carbon	**Nanotube** **Diamond** **Graphite** **Fullerene film**	**1800-6600** **2300** **110-190** **0.4**
Metallic solids	**Silver** **Copper** **Nickel**	**429** **401** **237**
Non metallic	**Silcone**	**148**
Metallic liquids	**Aluminium** **Sodium at 644K**	**40** **72.3**
Others	**Water** **Ethylene glycol** **Engine oil**	**0.613** **0.253** **0.145**

By suspending nanoparticles in conventional heat transfer fluids, the heat transfer properties of the base fluid can be increased because of enhancement in the thermal conductivity [1-5].

Scattering solid particles (μm or even mm dimension) into liquids to improve the thermal conductivity of base fluids is hardly new [9], it has been well known for 100 years since the times of James Clerk Maxwell's theoretical work (1853).

These mm dimension solids in base fluids cause problems such as :

- Sedimentation
- Clogging flow channels
- Erode pipelines
- Severe pressure drops

Nanofluids provide a promising solution to the above problems. Several good comprehensive reviews have summarized the available studies on nanofluids and their better heat transfer medium in comparison to micro sized fluids because they have larger thermal conductivities as compared to conventional fluids.

Nanofluids of various materials have been prepared successfully[1],[8-10] e.g. carbon nanotubes , metallic oxides, metallic solids, non metallic solids. Among these, nanofluids containing carbon nanotubes have gained enormous interest of the researchers as well as technocrats.

As evident from the given data, among metallic solids, silver has a sufficiently high value of thermal conductivity. So we choose silver which is expected to have good heat transfer properties ideally suitable for thermal engineering applications.

Silver nanofluid comprising of metallic silver dispersed in water are synthesized by a novel single step method which is unique one where preparation of nanofluids and hence the process of drying , storage,

ISSN (Online) : 2230-8849

Volume 2 Issue 1 January 2013

International Manuscript ID : ISSN22308849-V2I1M8-012013

transportation and redispersion of Ag nanoparticles can be avoided and ultimately production cost may be reduced as well. These aspects of this work are explained with the help of subsequent experimental details.

Experimental details:

Preparation of silver nanofluid:

The reagents used in our experiments were of analytical grade purity and were used without any further purification. The beakers used in this procedure were cleaned by distilled water.
Silver nitrate is taken as the precursor which is reduced by the sodium citrate as follows [9]:

$4Ag^+ + C_6H_5O_7Na_3 + 2H_2O \rightarrow 4Ag^0 + C_6H_5O_7H_3 + 3Na^+ +$
$+ H^+ + O_2\uparrow$

50ml of an aq. solution of sodium citrate was taken in an
iodine flask and placed on a magnetic stirrer bath maintained at 60-70°C. A magnetic bead was put into the solution and the solution was heated as well as stirred for about 5 minutes. To this solution, about 20 ml of an aq. solution of silver nitrate was added slowly while constant stirring till a light pale yellow colour appears which marks the beginning of reduction process. Slowly the solution turns light violet in colour, which shows the formation of colloidal silver. This was transferred to a well washed 125 ml reagent bottle and labeled as sample 1.

In the subsequent experiments, the preparation of silver nanofluids was standardized by standardizing the solutions of silver nitrate as well as sodium citrate.

Sample 2 was prepared by reducing 0.05% silver nitrate with 0.05% sodium citrate solution.

International Journal of Enterprise Computing and Business Systems

ISSN (Online) : 2230-8849

Volume 2 Issue 1 January 2013

International Manuscript ID : ISSN22308849-V2I1M8-012013

Similarly, gold nanofluids have also been prepared by chemical reduction of chloroauric acid with sodium citrate and sodium borohydride.

A remarkable change in the colours of silver colloids was also noted from pale yellow to pinkish violet and finally to grey. This is supposed to be because of increase in the agglomerization of silver nanoparticles[10]. But the enhancement in thermal conductivity shown by all of the above prepared three samples was still better than the corresponding results shown by alumina based nanofluids which practically don't show appreciable thermal conductivities at such lower concentrations of nanoparticles in the base fluid[8]. Moreover, the synthetic route for the Ag Au nanofluids is still simpler and economic in terms of time and cost.

Stabilization of silver nanofluids:

The cause of stabilization of nanofluids is supposed to be the capping as well as stabilizing tendency of citrate ions whose negative ends not only cap the silver nanoparticles formed but also stabilize the nanofluid[10].

This synthetic route is also avoiding the use of additional stabilizer. These additional stabilizers are usually surfactants or the polymers[11]. Studies have shown that surfactants lower the thermal conductivity of nanofluids[13].

Enhancement in the thermal conductivity:

International Journal of Enterprise Computing and Business Systems

ISSN (Online) : 2230-8849

Volume 2 Issue 1 January 2013

International Manuscript ID : ISSN22308849-V2I1M8-012013

Thermal conductivity, k, is the property of a material's ability to conduct heat. It appears primarily in Fourier's Law for heat conduction. Thermal conductivity is measured in watts per kelvin-meter ($W \cdot K^{-1} \cdot m^{-1}$, i.e. W/ (K· m) i.e .the rate of energy loss (in watts, W) through a piece of material[10].

It is an established fact that it is a surface phenomenon and surface area increases with decrease in size and increase in number of particles. [9,10]

This is one of the most important reason which explains the enhancement in the thermal conductivity of nanofluids[8-10], [13].

Thermal conductivity measurement of above prepared samples was done at Thapar University, Patiala using KD2 Pro.

Record of data:

Sample 1

Sr.No. /Direction	**Temperature 1(°C)**	**Temperature2(°C)**	**Thermal conductivity(W/mK)**	**Error (%)**	**%age enhancement**
1 (Upward)	**28.78**	**28.55**	**0.851**	**0.0305**	**33.84**
2(Upward)	**28.55**	**28.51**	**0.847**	**0.0315**	**17.80**
3(Upward)	**28.30**	**28.26**	**0.864**	**0.0317**	**35.77**
4(Upward)	**28.09**	**28.00**	**0.780**	**0.0274**	**22.77**
5(Upward)	**27.88**	**27.85**	**0.784**	**0.0274**	**23.42**

6 (Downward)	**27.22**	**27.21**	**0.748**	**0.0188**	**18.95**
7(Downwar d)	**27.12**	**27.07**	**0.715**	**0.0192**	**13.56**
8(Downwar d)	**27.00**	**26.99**	**0.713**	**0.0196**	**13.11**
9(Downwar d)	**26.90**	**26.89**	**0.700**	**0.0185**	**11.17**
10(Downw ard)	**26.80**	**26.79**	**0.747**	**0.0249**	**17.80**

Average enhancement in thermal conductivity=22.34%

The data is clearly demonstrating the enhancement in the thermal conductivity by silver nanofluids and also a clear dependence of thermal conductivity on the temperature i.e. thermal conductivity decreases with decrease in temperature.

The data which is following is another proof of the above findings. Also it gives an indication of dependence of nanoparticles' size and morphology on the concentration of the precursor (silver nitrate in this case).

Sample 2:

Sr.No /Direction	**Temperature1**	**Temperature2**	**Thermal conductivity(W/mK)**	**error**	**%age enhancement**
1 Upward	**27.35**	**27.33**	**1.104**	**0.04**	**73.57**
2Upward	**27.28**	**27.28**	**0.909**	**0.034**	**42.74**

ISSN (Online) : 2230-8849

Volume 2 Issue 1 January 2013

International Manuscript ID : ISSN22308849-V2I1M8-012013

3Upward	**27.18**	**27.16**	**0.870**	**0.0321**	**36.69**
4Upward	**27.08**	**27.06**	**0.822**	**0.0289**	**29.05**
5Upward	**26.98**	**26.96**	**0.818**	**0.030**	**28.55**
6 Downward	**26.54**	**26.54**	**0.652**	**0.0114**	**4.10**
7Downward	**26.47**	**26.47**	**0.683**	**0.0176**	**8.54**
8Downward	**26.43**	**26.43**	**0.690**	**0.0163**	**9.90**
9Downward	**26.40**	**26.40**	**0.685**	**0.0161**	**9.12**
10Downward	**26.38**	**26.38**	**0.676**	**0.0150**	**7.80**

Average enhancement in thermal conductivity=25%

The data is again clearly demonstrating the enhancement in the thermal conductivity by silver nanofluids and also a clear dependence of thermal conductivity on the temperature i.e. thermal conductivity decreases with decrease in temperature.

The data is another proof of the above findings. Also it indicates dependence of nanoparticles' size and morphology on the concentration of the precursor (silver nitrate in this case). Thermal conductivity measurement of gold nanofluids are also under experimntation and we hope to get positive results.

Discussion:

The results clearly indicate the enhancement in thermal conductivity of water (basefluid) by silver nanoparticles.

Moreover, it indicates that there is a clear relation between Concentration of silver nitrate reduced and the corresponding enhancement in thermal conductivity of the base fluid (water in this case).

This can be exploited in an elaborated way to see the effect of silver nitrate concentration on the particle size and dispersion of nanoparticles in the basefluid.

The synthetic route opted is more convenient as it is simple in approach. The enhanced thermal conductivity of the silver nanofluids can be exploited in many applications based on [6,7]:

- Heat transfer
- Surfactant and coating
- Extraction
- Pollution cleaning
- Bio and pharmaceutics (drug delivery, functional and tissue cell interaction).

Conclusion:

The single step method used for preparing Ag nanofluids is advantageous over other conventional methods as it is:

- An in situ preparation
- Economical in terms of time and cost

The non agglomerated and stably suspended Ag and Au nanofluids are obtained with a superior thermal conductivity which may be used as an effective tool in many processes based on heat transfer fuels, coolants etc) in place of conventional fluids that are in current use.

Acknowledgement:

We are highly grateful to Chemical Engineering Department, Thapar University, Patiala for providing facility to carry out thermal conductivity measurements there. We would also like to acknowledge the guidance offered by Mr. Gajender, who trained us how to use the Thermal conductivity meter.

ISSN (Online) : 2230-8849

Volume 2 Issue 1 January 2013

International Manuscript ID : ISSN22308849-V2I1M8-012013

References:

[1] Choi SUS. Developments and applications of non-newtonian flows.In: Siginer DD, Wang HP, Eds. American Society of Mechanical Engineering, New York 1995; 231(66): 99.

[2]Cheng L, Recent Patents on Engineering 2009, Vol. 3, No. 1

[3] Peterson GP, Li CH. Adv Heat Transfer 2006; 39: 275.

[4] Wang XQ, Majumdar AS. Int J Therm Sci 2007; 46: 1.

[5] Das SK, Choi SUS, Patel H. Heat Transfer Eng 2006; 27(10): 3.

[6] Cheng L, Bandarra FEP, Thome JR. J Nanosci Nanotech 2008

[7]Cheng L, Mewes D. Int J Multiphase Flow 2006; 32: 183.

[8]Gills C. Roy, Cong Tam Nguyen, D. Doucet, S. Suiro, Thierry Mare, temperature dependent Thermal Conductivity

Evaluation of alumina based Nanofluids, 10.615/IHTC13.p8.150

[9]Xie S Y, Ma Z J, Wang C F, Lin S C, Jiang Z Y, Huang R B and Zheng L S 2004 J. Solid State Chem. 1773743.

[10] (2011) Google [Online]. Available: http://www.google.com

[11] X. C. Jiang,, C. Y. Chen,W. M. Chen, and A. B. Yu, Role of Citric Acid in the Formation of Silver Nanoplates through

a Synergistic Reduction Approach,American Chemical Society,2009

[12] (2011)Nanotechnology: Wikipedia (The free encyclopaedia) [Online].Available: htt://www.google.com

[13]Subella Senara Botha, “Synthesis and Characterization of nanofluids for Cooling purposes”, Masters thesis, South African Institute for Advanced Materials Chemistry, University of the Western Cape, South Africa October 2007.