INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

IMPROVEMENTS IN HEAT TRANSFER PERFORMANCE OF FLUID BY USING NANOPARTICLES

[1]M.Durai Selvam , [2]K.Kodimurugan, [3]N.Markkandayan, [4]A.Sindhu and [5]J.Ganesan

[1,2,3]UG-Students EEE, Sree Sowdambika College of Engineering, Aruppukottai, Tamilnadu

[4]Assistant Professor/Department of ECE, Sethu Institute of Technology, Kariapatti, Tamilnadu

[5]Associate Professor/EEE, Sree Sowdambika College of Engineering, Aruppukottai, Tamilnadu

Abstract: - Heat transfer is gas or liquid that performs heat transfer. It may used to prevent overheating, for heating or storing thermal energy. Water, synthetic oil and molten salt can be used as a heat transfer fluids. Water is a good heat transfer fluid as it has a high thermal capacity and low viscosity. In this paper the various types of Heat Transfer Fluid (HTF) and desired characteristics of HTF was discussed in simple manner and also this paper gives the basic concepts in Synthesis of nanoparticles, Analyzing nanoparticles and characteristics of nanoparticles. The results shows that heat transfer performance of HTF can be enhanced by adding high thermal conductivity nanoparticles to the base fluid.

Keywords— Nanoparticles, HTF, thermal conductivity, Nano fluid

I. Introduction

The definition of Nano technology was given by National Nanotechnology Initiative in U.S. Nano technology deals with structures having particle size of 1 to 100nm [1-2]. Nanotechnology is the design, fabrication and use of Nano structured systems and the growing, assembling of such systems mechanically, chemically or biologically to form Nano scale systems and devices [9] .

Nano particles were particles that have particle size of 100 nm or less. The properties of many conventional materials change when formed from Nano particles. This was due to the reason that Nano particles have a greater surface area per weight than larger particles. Iron oxide Nano particles were used to improve MRI images of cancer tumors. The Nano particles were coated with a peptide that binds to a cancer tumor. Once the Nano particles were attached to the tumor, the magnetic property of the iron oxide enhances the images from the magnetic resonance imagery scan [9].

A. Applications of Nanotechnology

Nano capacitors based filters

Nano transformer based SMPS

Nano cables

Nano insulators

Nano powders used for welding rods and electrodes

Nano based rectifiers

Nano resistance

Nano engineering materials

Nano sic Arrestors

Nano ZnO Arrestors

Nano technology used in receivers

Nano alloys

Nano capacitor based microphones

Nano electrets

Nano nuclear engineering

Nano thermo electric materials

II. CHARACATERIZATION OF NANOMATERIALS TOOL

Generally numerous chemical analysis methods are used in the field of nanomaterials. Some of the more common chemical analysis methods are Raman spectroscopy, Fourier transform infrared spectroscopy(FTIR), X-ray diffraction(XRD), X-ray photo electron spectroscopy (XPS), Augon electro spectroscopy(AES), Energy dispersive spectroscopy(EDS).

The primary methods for imaging or visualizing nanomaterials the following methods are used they are Scanning Tunneling Microscopy(STM),Transmission Electron Microscopy(TEM), Scanning Electron Microscopy(SEM) and Atomic Force Microscopy(AFM).

A. Scanning Tunneling Microscope (STM)

Is a microscope that enables imaging at the atomic level. The components of an STM include scanning tip, piezoelectric controlled height and X-Y scanner, coarse sample-to-tip control, vibration isolation system, and computer. The resolution of an image is limited by the radius of curvature of the scanning tip of the STM. Additionally, image artifacts can occur if the tip has two tips at the end rather than a single atom; this leads to "double-tip imaging," a situation in which both tips contribute to the tunneling. The following fig. 1. Shows the image of STM machine and fig. 2 shows the STM image of Aluminum oxide.

Fig.1. image of STM machine

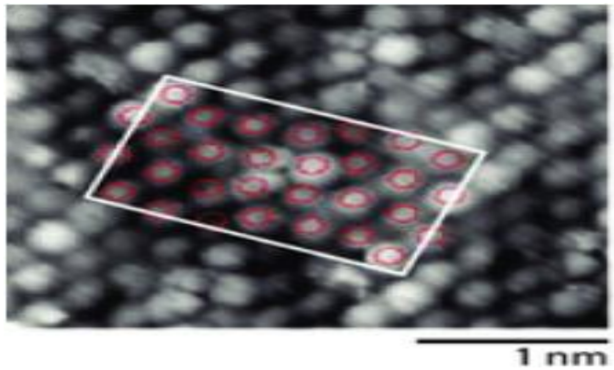

Fig.2. STM image of Aluminum oxide

B. Scanning Electron Microscopy (SEM)

Electron microscope is based on the use of electron waves rather than right wave, to image sample are created by scanning a focused high energy electron beam on the sample. Special detectors record the interaction of the electron beam with sample surface, revealing topological information about the sample. The following fig.3 shows the image of SEM machine and Fig. 4 shows the SEM image of Al_2O_3.

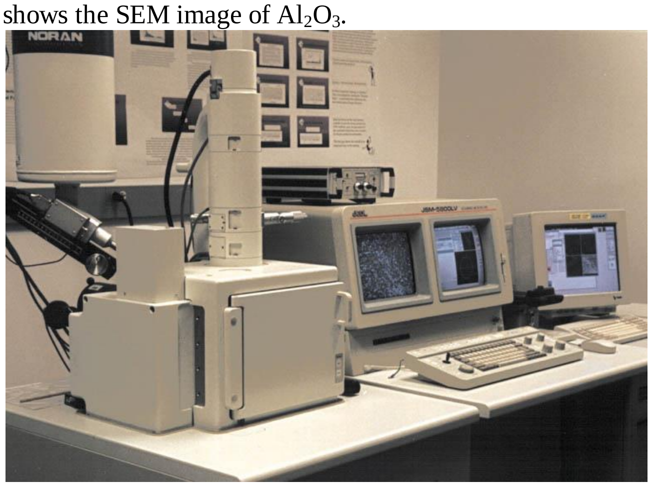

Fig. 3. Image of SEM machine

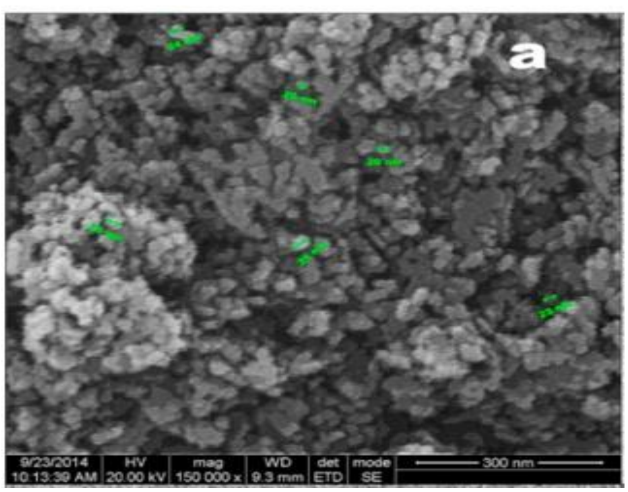

Fig.4. SEM image of Al_2O_3

Advantages of SEM

- Sample topography readily imaged.
- Imaging may be combined with chemical mapping.
- Sample preparation can be very easy.
- Work has instrument used for daily analysis.

Disadvantages of SEM

- Ultra high vacuum required.
- Cannot measure sample height dimensions

C. Transmission Electron Microscopy(TEM)

In a thin samples or small particle size, the electron beam of a microscope can be transmitted through the sample.the high energy beam, small spot size and small excitation volume of the sample allow for very high resolution images. The highest resolution TEM microscopes can image features as small as 1A˚. The following fig.5.shows the image of TEM machine and fig. 6 shows the TEM image of Al_2O_3.

Fig.5. Image of TEM machine

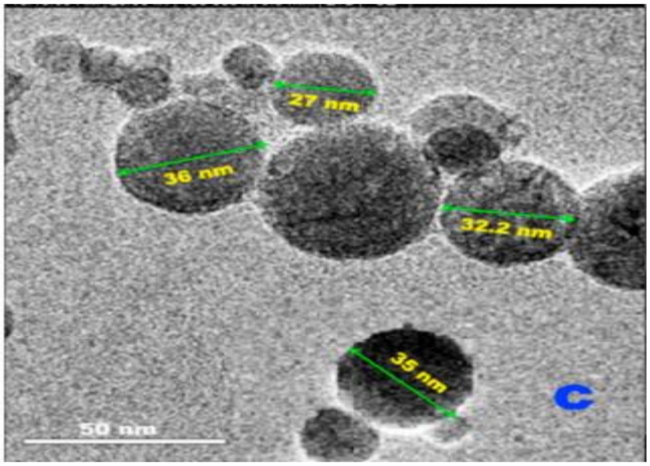

Fig.6. TEM image of Al_2O_3

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Advantages of TEM

High resolution

Imaging may be combined with chemical and x-ray mapping.

Disadvantages of TEM

Ultra high vacuum required.

All structures features projected onto a common plane.

Special sample preparation required.

D. Atomic Force Microscopy (AFM)

High resolution analysis of Nano scale images may also he observed with atomic force microscope. This microscopic technique is based on the use of a very fine probe that is scanned across the surface, registry high changes in the sample.

The following fig. 7 shows the image of AFM machine and fig. 8 shows the AFM image of gold nanoparticles.

Fig. 7 Image of AFM machine AFM image of gold nanoparticles

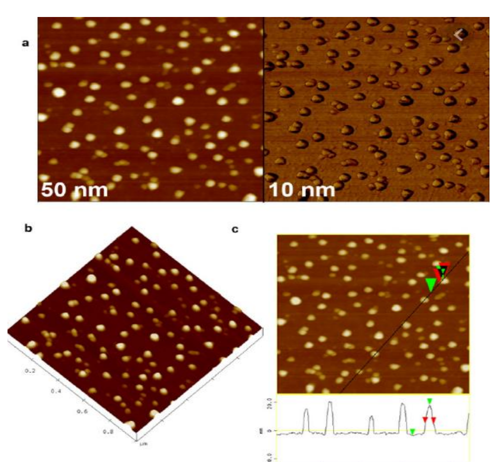

Fig.8.AFM image of gold nanoparticles

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Advantages of AFM

Vacuum conditions not required

3D depth measurement possible

May he conduct under liquid immersion environments Disadvantages of AFM

Low sample height variation required.

No chemical spectroscopy possible.

Image aberrations can occur due to tip radians effect.

III. CHARACTERISTICS OF NANOMATERIALS

It is very diverse.

It is based upon molecular self-assembly.

It is used in fields of science, organic chemistry, molecular biology, semiconductor physics, micro-fabrication medicine, electronics & energy production.

It was used to create many new materials.

It has impact on environment and economics.

It is the engineering of functional systems at the molecular scale.

It is used to make high performance products.

IV. LIMITATION OF NANOTECHNOLOGY

It is used to make high performance products.

Integration of nanostructure and nanomaterials was not easy.

Demonstration of novel tools to study at nanometer was difficult.

New measurement technologies were more challenging than ever.

It requires extremely sensitive instrumentation.

Monitoring and manipulation of the material processing in the atomic level was crucial.

Self-purification of Nano materials makes doping very difficult.

Huge surface energy.

Uniform size distribution was difficult to achieve in Nano materials.

It is not easy to achieve desired size, morphology, Chemical composition and physical properties.

Ostwald ripening and agglomeration would occur.

V. PROPERTIES OF NANO MATERIALS

The properties of many conventional materials change when formed from nanoparticles. This was due to the reason that nanoparticles have a greater surface area per weight than larger particles.

A. Physical properties

Large fraction of surface atoms.

Large surface energy.

Spatial confinement.

Reduced imperfections.

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Lower melting point.

Lower phase transition temperature.

Reduced lattice constants due to a huge fraction of surface atoms.

B. *Mechanical properties*

The enhancement in mechanical strength was simply due to the reduced probability of defects.

Carbon nanotubes were the strongest and stiffest materials. This was due to covalent bonds formed between the individual carbon atoms.

Multi walled CNT have a tensile strength of 63GPA. Individual CNT have strength up to 100GPA.

CNT has a low density of 1.3 to 1.4 g/cm3. Specific strength - 48,000 kNmKg-1

CNT undergo bucking when placed under compressive, torsion or bending stress due to it hollow structure and high aspect ratio.

C. *Magnetic Properties*

Magnetic properties of Nano materials were different from that of bulk materials. Ferromagnetism of bulk materials disappears and transfers to super Para magnetism in Nano meter scale due to the huge surface energy. Iron oxide nanoparticles were used to improve MRI images of cancer tumors. The Nano particles were coated with a peptide that binds to a cancer tumor. Once the Nano particles were attached to the tumor, the magnetic property of the iron oxide enhances the images from the magnetic resonance imaginary scan. Thermal Properties Self purification was an intrinsic thermodynamic property of Nano material Heat treatment increases the diffusion of impurities, intrinsic structural defects and dislocation. Increased perfection would have appreciable impact on the chemical and physical properties.

D. *Chemical Properties*

Chemical stability was improved.

Chemical properties were size dependent.

Chemical properties of Nano materials were changed by adjusting the size, shape and extent of agglomeration.

E. *Optical Properties*

Optical properties of Nano material can be significantly different from bulk crystals. The optical absorption peak of a semiconductor nanoparticle shifts to a short wavelength due to an increased band gap. The optical absorption peak of metals was shifted by hundreds of nm. The color of metallic nanoparticle may change with their sizes due to surface Plasmon resonance.

F. *Electrical properties*

The dielectric strength of the insulating materials were improved by adding Nano fillers of SiO_2, TiO_2, ZrO_2, ZnO and so an. The insulation resistance of the enamel was increased by adding Nano fillers of SiO_2, TiO2, ZrO_2, ZnO and so an. Dielectric loss, temperature rise was increased in the enamel by the addition of ZnO, Sic, ZrO_2, TiO_2, and SiO_2 nano fillers. The value of constant and capacitance was improved by the addition of Nano fillers polyamide enamel used as the coating of the winding of the electrical machines. The efficiency, thermal withstanding capacity of the electrical machines was improved by the addition of Nano fillers to the enamel used for the coating of the windings of it. Electrical conductivity of nanomaterials could be improved due to the better ordering in micro structure.

VI. PHYSICAL PROPERTIES OF NANO FLUIDS

A. *Nano fluids*

Is a dilute liquid suspension of particles with a dimension smaller than 100nm. Nano fluid consists of solid nanoparticles dispersed in a heat transfer fluid. The Nano fluid concepts was first materialized by Choi at National Laboratory in USA. Now Nano fluid gives excellent heat transfer improvement over conventional fluids.

B. *Thermal conductivity*

The following factors affecting the thermal conductivity of the Nano fluids. They are volume fraction, size, shape, aspect ratio, temperature, effect of clustering and thermal conductivity of base, nanoparticles. By suspending the nanoparticles in heat transfer fluid the heat transfer performance can be improved. The suspended nanoparticles increase the surface area and the heat capacity of the fluid.

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C. Viscosity

The following factors affecting the viscosity of Nano fluids they are temperature, particle size, particle size distribution, shear rate, surfactant and volume concentrations. Viscosity is a significant parameter in designing Nano fluids for flow and heat transfer applications. The quantities measured in rheological investications are forces, deflections, velocities and viscosities.

D. Density

The following factors affecting the density of Nano fluids they are volume concentration, density of base fluids and density of nanoparticles. Density is calculated according to Pak and Cho's equation. For typical Nano fluids with nanoparticles at less than 1% volume fraction, a change of less than 5% in the fluid is expected.

E. Surface Tension

The following factors affecting the surface tension of Nano fluids they are nanoparticle concentration, size and surfactant. Surface tension increases with particle concentration and particle size, due to van der Waals force between particles at the liquid or gas interface increases surface free energy and thus increases the surface tension.

VII. TYPES OF NANO MATERIALS USED

The following nanomaterials are used in Nano fluids to improve the heat transfer of fluids.

A. *Ceramic nanomaterials*

The following ceramic materials Aluminum oxide (Al2O3) , Copper(II) oxide (CuO) , Silicon carbide (SiC), ferric oxide (Fe2O3) and Etc., are used as nanomaterials.

B. *Metallic nanomaterials*

The following metals Silver (Ag), Gold(Au), Copper (Cu), Iron (Fe), Nickel (Ni) and Etc., are used as nanomaterials.

C. *Alloy nanomaterials*

The following alloys Silver-copper (Ag-Cu) alloy, Silver-Aluminum (Ag-Al) alloy Aluminum-Copper(Al-Cu) alloy are used as nanomaterials.

D. *Carbon based nanomaterials*

The following carbon based CNT, Diamond, Graphene, Graphite and Etc., are used as nanomaterials.

The following Table I shows the thermal conductivity of different materials

TABLE I. THERMAL CONDUCTIVITY OF DIFFERENT MATERIAL

Material Type	**Material name**	**Thermal conductivity(W/mK)**
Metallic solids	Aluminum (Al)	237
	Copper (Cu)	401
	Iron (Fe)	80.40
Non Metallic Solids	Alumina (Al_2O_3)	40
	CNT	3000
	Copper oxide (CuO)	76.50
Liquids	Ethylene Glycol	0.20
	Engine Oil	0.14
	Water	0.61

VIII. SPECIFIC FUTURES OF NANO FLUIDS

Increased thermal conductivity

Increased viscosity

Micro channel cooling without clogging

Reduction in erosion

Energy saving

Possible spectrum of applications

IX. POTENTIAL MECHANISM OF ENHANCEMENTS IN THERMAL PROPERTIES OF NANO FLUIDS

A. Motion of nanoparticles

Collision between the nanoparticles leads to energy exchange among the nanoparticles. Even without collisions, the Brownian motion of particles might enhance thermal conductivity. The following Fig. 1 shows the nanoparticles motion in Nano fluids.

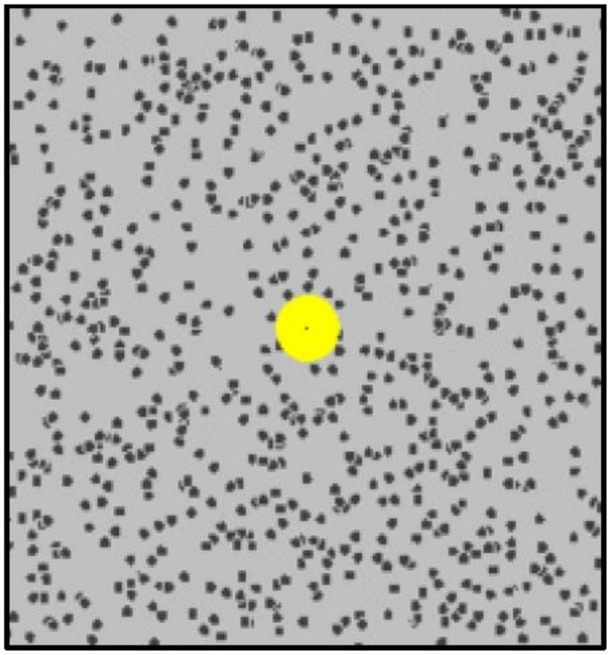

Fig. 1. Nanoparticles motion in Nano fluids

B. Liquid layering at liquid/Particle interface

Liquid molecules are known to form ordered layered structures at solid surfaces. These interfacial layers have different thermophysical properties from bulk liquid and solid particles. Ordered structure of the nanolayer gives higher thermal conductivity than the bulk liquid. The following Fig. 2 show the structure of Nanolayer in Nano fluids.

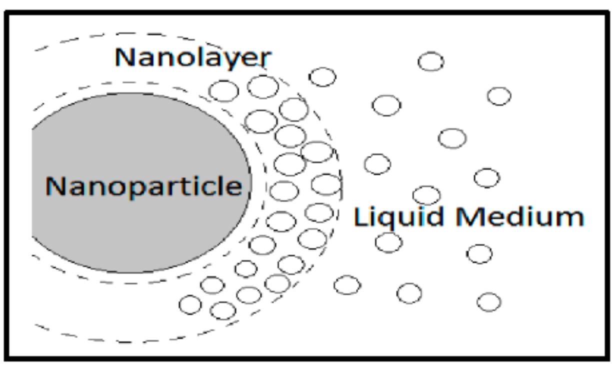

Fig.2. structure of Nano layer in Nano fluids

C. Nature of heat transport in nanopartciles

Macroscopic theories assume that heat is transported by diffusion. In crystalline solids, heat is carried by phonons that is, by the propogation of lattice vibrations. When the size of the nanoparticles in a Nano fluids becomes less than the phonon mean free path, moves ballistically without any scattering. The following fig.3 shows the Heat transport in Nano fluids.

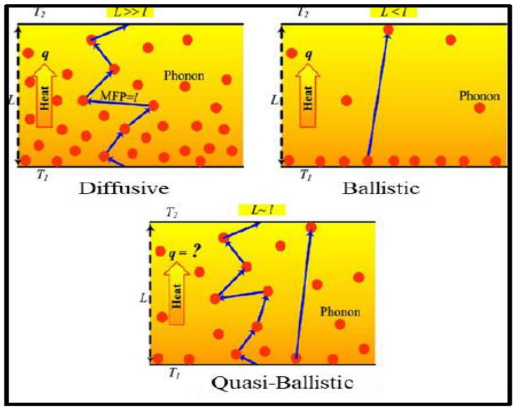

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Fig. 3. Heat transport in Nano fluids

D. Effect of nanoparticles clustering

If particles cluster into percolating networks, they create path for high thermal conductivity. It is advisable to have nanoparticle clustering to an extent. Clustering leads to settling small particles out of the liquid and creating large regions of particle free liquid with high thermal resistance. fig.4 shows the effect of nanoparticles clustering.

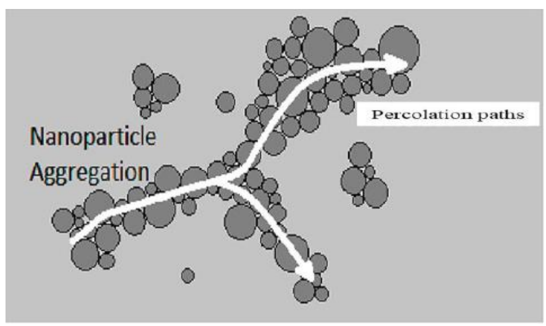

Fig. 4. Effect of nanoparticles clustering

E. Coupled transport phenomena

In a Nano fluids system, there are two or more transport processes that occur simultaneously they are heat conduction, mass transport and chemical reactions.

1) Limitaion

Complexity

Has not been well appreciated yet in nanofliud community

reaction cannot be reversed. They contain only a fixed amount of the reacting compounds and can be discharged only once. Used when long period of storage are required. Lower discharge rate than secondary batteries. Used in smoke detectors, flashlights, remote controls etc., The following fig.1 shows the image of Primary batteries and fig. 2. shows the Schematic diagram of Primary Battery.

X. STABILITY OF THE NANO FLUIDS CAN BE IMPROVED BY FOLLOWING THREE METHODS

A. Controlling the surface charge of the nanoparticles by controlling the pH

By using high surface charge density, strong repulsive forces can stabilize a well dispersed suspension.

B. *Using ultrasonic vibration*

Ultrasonic bath, processor and homogenizer are authoritative tools for breaking down the agglomerations.

C. *Modifying the surface by addition of surfactants*

Surfactant can modify the particles suspending medium interface and prevent aggregation over long period. The properties of the solutions and particles used are mainly considered during selection of suitable surfactants and dispersants. At high temperature the bonding between nanoparticles and surfactants will be damaged is main disadvantage in this process.

XI. Advantages of HTF

Nanoparticles added HTF enhances the heat transfer rate of the base fluids

Reduces the Pumping power

Adjustable properties, including thermal conductivity and surface wet ability

By varying particle concentration to suit different applications

Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization

XII. Applications of HTF

Electronics cooling

Nuclear system cooling

Industrial cooling

Medical applications

HTF in thermal systems

Cooling in microchips

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