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Synthesis of CuO Nanofluids and Analysis of its increased effective thermal conductivity for Flat Plate Heat Pipe

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Abstract: Copper oxide nanopowders were synthesized by chemical reduction method in which sodium hydroxide solution was used as a reducing agent. Copper acetate monohydrate precursor was used for the synthesis of CuOnanopowders. Solid state characterizations of synthesized nanopowders were carried out by X-ray diffraction (XRD) and SEM analysis techniques. Nanofluids of synthesized nanopowders were prepared in water as well as in ethylene glycol. Thermal conductivity measurements of prepared nanofluids were studied in which maximum thermal conductivity enhancement was observed innanofluid. Flat heat pipes are intended to move heat from a high power density location to low power density location. The vapor flow inside flat heat pipes is different than in cylindrical heat pipes and the higher interior surface area creates the need for more structural support. Those results open up our idea to use CuOnanofluids in flat heat pipe as a basic fluid material.
Keywords: Copper Oxide nanoparticles, Nanofluids, Flat plate heat pipe, Thermal conductivity.

Introduction:

Nanofluids are a new class of fluids powered by dissolving nanometer sized materials such as nanoparticles, nanofibers, nanotubes, etc., in base fluid. Nanofluid is used as heat transfer fluid prepared by dispersing nanoparticlein water/ethylene glycol to enhance the thermal conductivity and also heat transfer performance [1]. The thermal conductivities of metal nano fluids like Al, Cu, Ag, Fe, and Mg are higher in nature. Thereby, fluids having solid metallic particles are suggestively improved thermal conductivities which will be useful for conventional heat transfer fluids [5]. Normal fluids have low heat transfer properties compared to most metallic fluids. The improvement of thermal characteristics in heat transfer nanofluid will solve the thermal issue of energy devices [6]. Still researchers are working in synthesis and characterization of nano fluids to find out better thermal property. So nanofluids are suitable to use under flow conditions and the flow of suspension. But these Nano fluids are different from normal heat transfer fluids which have Newtonian characteristics. The rheological properties of nanofluid will ensure the heat transfer property and thermal characteristics [2]. To develop the mechanism of heat transfer enhancement,the fluid-particle and particle-particle interactions within the fluid should have been widely studied. The rheological properties of micro particles under both static and dynamic conditions are completely different from the rheological properties of nanoparticles. The rheological property of nanofluids is studied to understand the mechanism of heat transfer enhancement [7]. In this research, we investigated the optimum thermal conductivity and rheological properties of copper oxide nanofluid dispersed in water/ethylene glycol.

Experimental Procedure:

Synthesis of Copper Oxide Nanopowders:

Copper oxide nanopowders were synthesized by chemical reduction method in which sodium hydroxide (NaOH) was used as a reducing agent. Sodium Hydroxide (NaOH) used as a reducing agent for the synthesis of CuO nanoparticles. The details of synthesis process are given below.

Synthesis of Nanopowder:

0.5M copper nitrate trihydrate was dissolved in 100 ml water and 0.75M sodium hydroxide was also dissolved in 20 ml water by stirring. Sodium hydroxide solution was added drop by drop to copper nitrate solution. The black colour precipitate was obtained after complete reduction of copper nitrate to copper oxide. Precipitate was filtered and washed twice with water and twice with methanol and dried in vacuum. Black colourCuOnanopowder was collected.

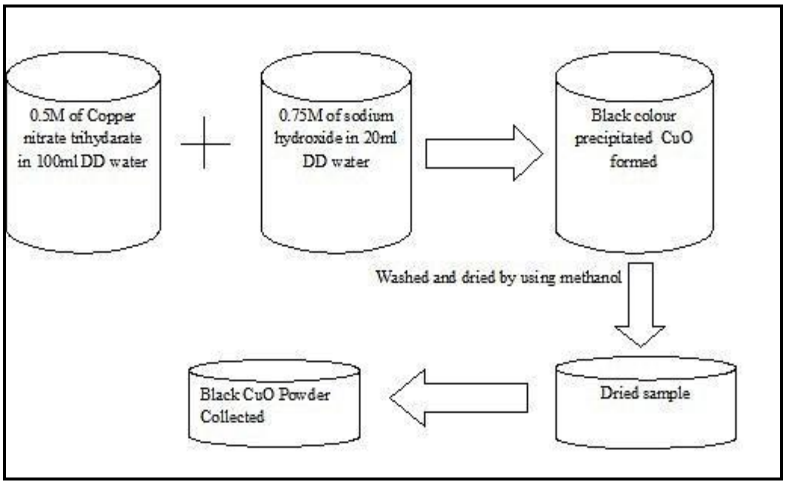


Figure 1. Synthesis Chart of CuO Nanopowder

Preparation of Nano Fluid:

For the preparation ofCuOnanofluids, 50 mg copper oxide nano powder was mixed with 50 mL of ethylene glycol/water base fluid (45:55 volume media) and stirring for 2 h. In the resulting solution 0.1% poly vinyl pyrrolidone (PVP) (50mg) was mixed with continuous stirring for 3 hours. For proper dispersion, the resulting solutions were kept on sonicator for 2 hours.

Experimental Apparatus:

The transienthot-wire (THW) method wasusedto measure fluid's thermal conductivity. ATHW system uses a platinum wire suspended symmetrically inside a fluid which place dinsidea verticalcy lindrical container. Nagasaka and Nagashima's method, in which the wire is coated with athinelectricalin sulation layer, wasusedinth eresear chexperimenttoe liminate error and measurement of electrically conducting fluids[8]. Generally, the Transient hot wire technique works under the principle of measuring thetemperature/time response of the wire toanelectrical pulse. The wire isusedas heater element and also asthermo meter, therby thermal conductivity, *k*iscal culated from aderivation of Fourier'sLaw where *q* is the applied electric power and T_1 andT_2 are the temperatures at times t_1 andt_2. The temperature coefficient of the wire's resistance reveals the temperature rise of the wire. Therefore the temperature rise of the wire can be determined by the change in its electrical resistance with respect to time. Regulation experiments were performed for CuO inside water/ethylene glycol in the temperature range of 250-300 K and at atmospheric pressure.

$$k = \frac{q}{4\pi(T_2 - T_1)} \ln \frac{t_2}{t_1} \qquad (1)$$

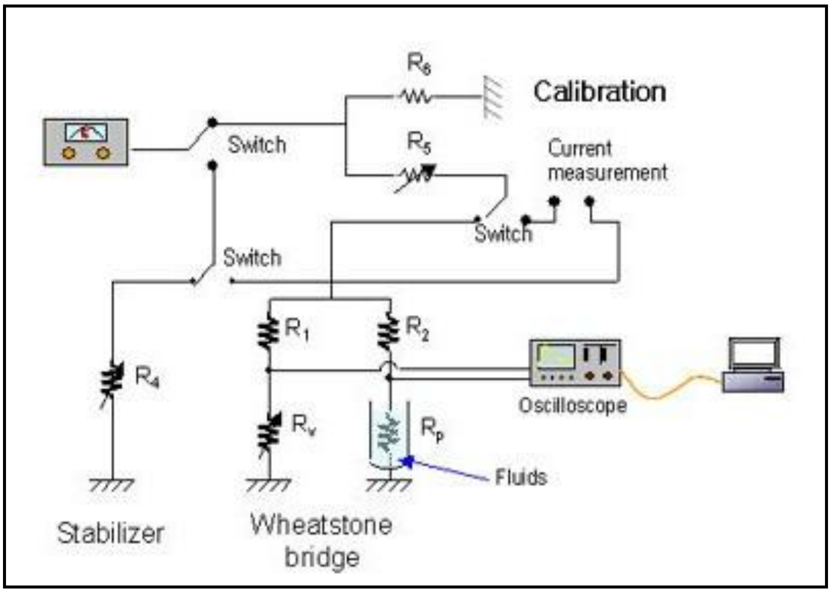


Figure2. The schematic Diagram of hot-wire method

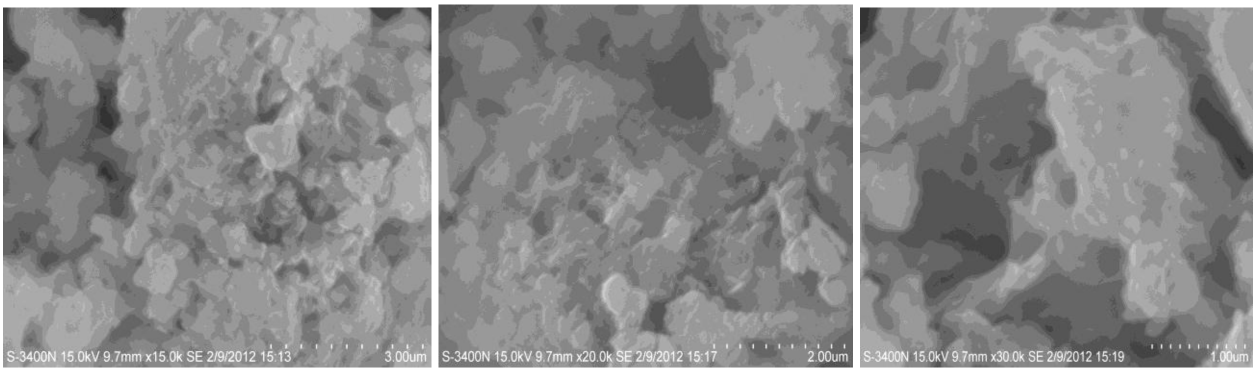
Thermal Conductivity:

Thermal conductivity of base fluids was recorded first before recording the thermal conductivity of CuOnanofluids at 25°C. The values of thermal conductivity of water base fluid and ethylene glycol/ water base fluids were 0.6108W mK^{-1} and 0.4943 W mK^{-1} respectively. The thermal conductivity of Nanofluid dispersed in water medium and nanofluid dispersed in water/ethyleneglycol (45:55) was 0.8303 W mK^{-1} and 0.7823 W mK^{-1} which showed 36% and 42% enhancements of thermal conductivities respectively over their base fluid. The thermal conductivity enhancements in nanofluids dispersed in water was relatively low, and it may be due to some agglomeration or precursor's effects or nature of base fluids [3]. The thermal conductivity enhancement value (%) of Ethylene Glycol/water medium was greater than the water medium. In overall, it was also clear that all nanofluids were showing more thermal conductivity enhancement over their base fluids (Table).

Table 1. Thermal Conductivity of Nano Fluids

Sample	**Thermal conductivity (W/mK)**	**Thermal diffusivity (mm^2/s)**	**Specific heat (MJ/m3K)**	**Enhancement in Thermal Conductivity (%)**
H2O	0.6108	0.1540	3.135	-
CuO with water base	0.8303	0.6426	1.292	36
45:55 Ethylene Glycol: Water	0.4943	0.1765	0.3595	-
CuO with 45:55 Ethylene glycol: Water	0.7823	0.5744	1.368	58

SEM Analysis:



3 (A) 3 (B) 3 (C)

Figure 3 (A), (B), (C): SEM Images of CuOnano particles

SEM image of the samples A, B & C are given in figure 3. Morphology of CuO nanoparticle image seems to be porous and the spherical shaped uneven ball sizes were aggregated when it was exposed to increase in temperature.

XRD Analysis:

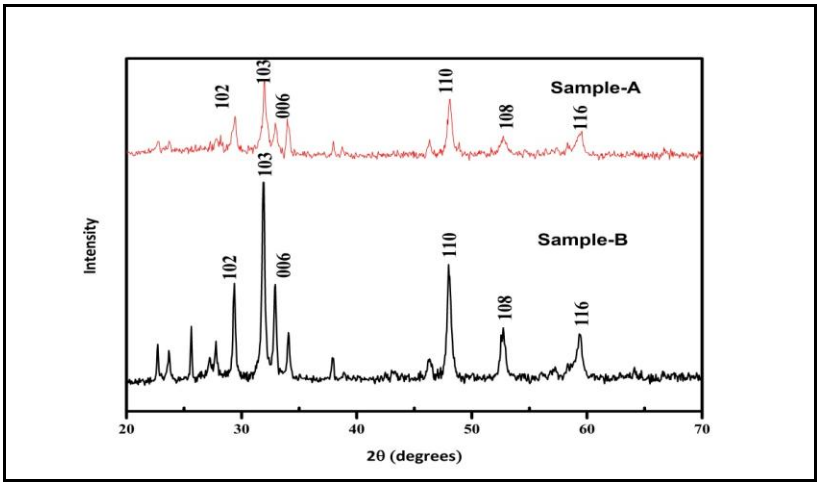


Fig 4: XRD pattern of CuO nanoparticle

Crystalline nature of the prepared CuO nanoparticles were identified from their corresponding powder XRD patterns (Fig 4). All the diffractions were well matched with monoclinic phase of CuO (standard JCPDS File No: 048-1548). Diffraction peaks with 2Θ 35.9°, 37.75°, 40.81°, 50.97°, 63.95° and 68.75° respectively were indexed to (102), (103), (006), (110), (108) and (116) planes. Average crystallite size of the nanoparticles was calculated using Scherer equation. From the results, it is found that the crystallite size increases with calcination/annealed temperature as evidenced from the past results.

Conclusion:

X-ray diffraction and SEM analysis have confirmed the formation of CuOnanopowder. The particle size of the different nanopowders was calculated by Scherer equation and obtained below 50 nanometers. And by Hot wire apparatus, we found an enhancement of 58% in thermal conductivity with CuOnanofluid (water/ethylene glycol). Thereby prepared CuO Nano fluids are optimum to use in the Porous wicked flat plate heat pipe as a main working fluid.

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