Exp. Theo. NANOTECHNOLOGY 2 (2018) 165-172 https://doi.org/10.56053/2.3.165

Preparation and investigation on thermal properties of copper oxide nanofluid for solar energy absorption

A. Subramaniyan [1], *G. Kanagaraj* [2,*], *Kalyan Surya Jagan* [3,*]

[1]Department of Physics, Thiagarajar College of Engineering, Madurai - 625015, Tamil Nadu, India.
[2]Department of Mechatonics Engineering, Thiagarajar College of Engineering, Madurai-625015,Tamil Nadu, India.
[3]Department of Mechanical Engineering, Thiagarajar College of Engineering, Madurai-625015, Tamil Nadu, India.
*) Email: ks.jagan@gmail.com

Received 12 April 2018, *Accepted* 30 Aug. 2018, *Accepted* 15 Sep. 2018

Nanofluids are colloids of nanoparticles in a selected base fluid. The primary application of nanofluid is to increase the heat transfer extent of liquid coolants like water, ethylene glycol, oil etc. In the present work, Copper Oxide (CuO) nanoparticle is prepared by sol-gel technique from $CuSO_4.5H_2O$ as a precursor material. CuO nanofluids are prepared by two-step method. In the first step, sol-gel synthesis technique is utilized and the second step involves dispersion by ultrasonication. To examine the crystallite size, shape, composition and surface area of prepared CuO nano particles are characterized by XRD, SEM, FTIR, and BET. Further, the heat absorption capacity is also investigated for the prepared CuO-water nanofluid with the varying weight fraction of 0.1, 0.2 and 0.3 in open sunlight. The maximum solar thermal absorption is reported for 0.3wt% CuO-water nanofluid.

Keywords: CuO, nanofluid, weight fraction, solar energy.

1. INTRODUCTION

It is an ever-increasing demand for nonrenewable energy has forced several researchers to investigate alternative sources of energy like solar energy. It is widely accepted that various parts of the globe receive solar energy to different extents and proper absorption, storage, recovery and efficient usage mechanisms of solar energy are the need of the hour. Nowadays nanotechnology has influenced engineering and medical fields by the great extent. The idea of nanofluids [1] has opened a gateway in nanofluid-based direct absorption solar collectors (DASC) [2]. In many industrial applications, fluids are generally used as a cooling medium and the enhancement of the heat transfer behavior of these fluids is of great importance in many applications. Nanofluids were also called as next generation heat transfer fluids [3-5] but the impact of research on nanofluids has shifted from heat transfer to electrical conductivity accelerators [6], smart fluids [7] and efficient optical absorbers [8]. The solar absorption characteristics are reported with carbon black nanofluids [9]. An investigation of solar heating technologies [10], their associated economic benefits and solar cookers [11] have also been driven with nanofluids. The absorption of TiO_2 nanofluids was reported by [12] theoretically to recommend TiO_2 for DASC.

Copper oxide nanoparticles are an interesting class of material having multifunctional properties with promising applications in the areas of catalysts, batteries, magnetic storage media, solar energy, and superconductors [13]. CuO nanofluid is a suitable for solar absorption because it is synthesized easily and can reduce the raw material cost in comparison to carbon nanopowders along with less toxicity. CuO are semiconductor oxides with a bang gap of 2.1 eV [14] and thus may favor good solar absorption for nanofluids based DASC. Literature reveals that investigations are yet to be performed with CuO nanofluids. The main aim of this study is to synthesize copper oxide nanoparticles, which were then applied to prepare CuO–water nanofluid, using sol-gel technique and dispersion by ultrasonication and to examine the solar absorption characteristics against carbon black for the suitability of energy absorption ability.

2. EXPERIMENTAL DETAILS

CuO nanoparticles can be prepared by various top-down routes like microwave synthesis, electro deposition, and sol-gel techniques. Among the available techniques, sol-gel technique offers several advantages specifically like low cost, composition control and easy preparatory methods. The different precursors of copper oxide include copper acetate, copper sulphide, copper chloride and copper nitride. In the present study, copper nanoparticles were prepared by a sol gel process in which chemical reduction was used. 5 gm of copper sulphate pentahydrate ($CuSO_4.5H_20$) was dissolved in 50 ml deionized water and sodium hydroxide was added to maintain a Ph level of 10.5. Poly ethylene glycol was added during stirring for every half an hour and the solution was simultaneously stirred for about four hours to obtain a dark black liquid. The solution was dried at 150°C for 2 hrs and further heated at 50-60°C for about one hour. Finally, the powders were hand milled and washed with water and ethanol mixture to get CuO nanopowders. 0.1,0.2 & 0.3 g of CuO were dispersed in 20 ml of water with a sonicator for 10 mins to obtain CuO nanofluids of three weight fractions (0.1,0.2 &0.3).

The CuO nanoparticles are investigated for their structure by X-ray Difraction technique, morphology by SEM, composition and bonding by FTIR and surface area by BET. The nanofluids were observed by visual sedimentation method and no trace of sedimentation is observed for 24 hours after which 0.3 wt% shows some sedimentation. The solar absorption of nanofluids and water was investigated by observing the rise in temperature for 75 mins. Temperature profile is noted simultaneously for water (base fluid), 0.1,0.2 and 0.3 wt% nanofluid for an interval of 300 seconds.

3. RESULTS AND DISCUSSION

In order to examine the crystallite size, shape, composition and surface area of prepared CuO nano particles, they are characterized by XRD, SEM, FTIR, and BET. The XRD pattern of prepared CuO nanoparticles is in Figure 1 indicate good crystallinity of the copper oxide nanoparticles, no characteristics peaks of any other phase of CuO were observed in accordance with JCPDS data card 80-1916. The diffraction are obtained for diffraction angles values of 35,38,43,48,50 and 74.The results are also in accordance with JCPDS Data as reported earlier for CuO [15]. Using Debye Scherrer formula and a wavelength of 1.54A for X-rays, the average crystallite size was found to be in the range of 50-100 nm.

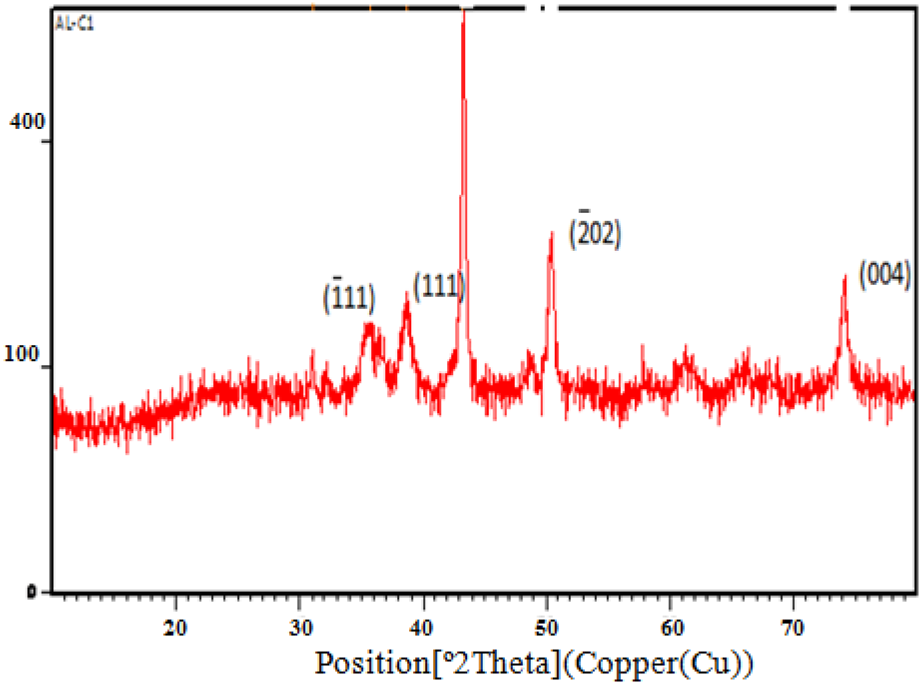

Figure 1 XRD spectrum of prepared CuO nanopowders**.**

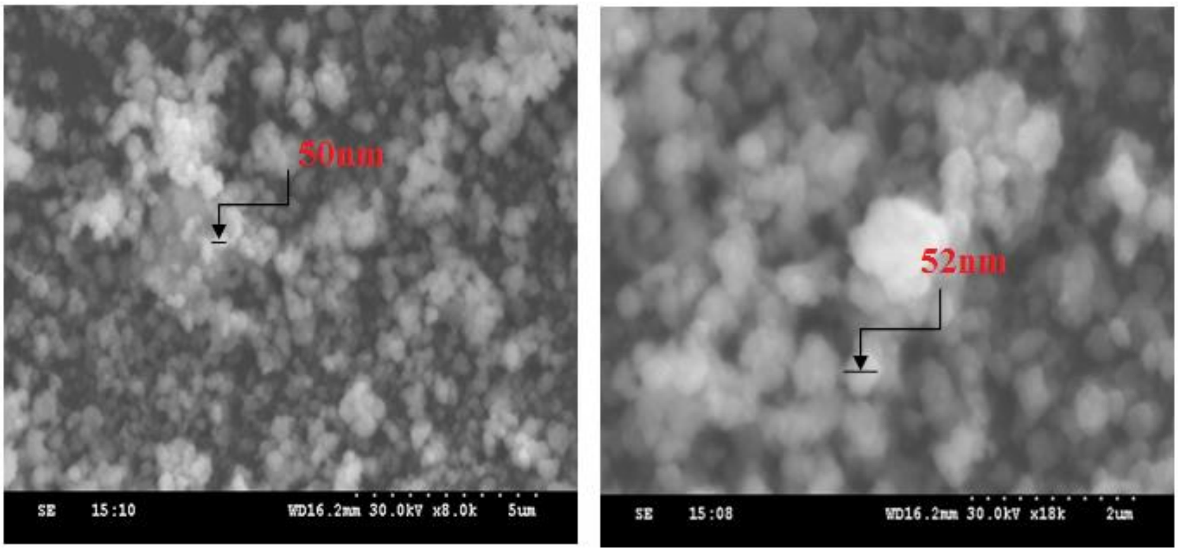

Figure 2 SEM images of prepared CuO nanoparticles.

Figure 2 shows the scanning electron microscope (SEM) image of as prepared CuO nanoparticles.The image reveals agglomerates of CuO. This may be due to an improper solvent selected and impact of temperature. The morphology is nearly spherical and the particle diameter can vary from 50 nm to 100nm. It is of concern that spherical nanoparticles can help in radial heat transfer of absorbed solar energy within the nanofluid and increase the solar absorption capacity. Brunauer–Emmett–Teller tests on CuO recorded a surface area of 9.590 m^2/g which corresponds to 100nm for a density of 6.3g/cc. The results of Brunau–Emmet–Teller (BET) analysis is presented in Table 1. The mean surface area was determined as 9.590 m^2/g.

Table 1 BET results of prepared CuO nano particle

Compound	CuO
Surface area (S) m^2/g	9.590
Density (d) gm/cm^3	6.3
Diameter from BET	99nm

Figure 3 shows the recorded FTIR spectrum of a CuO nanoparticle. The broad absorption bands between 3000 and 3700 cm-1 due to OH - and C– 0 groups within the materials. The three infrared absorption peaks reveal the vibration modes of CuO in the range of 500 to700cm-1[16]. Another major peaks is observed at 516.94 cm-1 which should be a stretching of CuO. 20 ml of prepared CuO nanofluid with weight fraction (0.1,0.2 0.3), base fluid are enclosed in identical glass containers of 1 cm diameter. They are simultaneously exposed to sunlight.

The temperature of each fluid is recorded in a time interval of 5 minutes for 75 mins to obtain the temperature profile. Maximum solar absorption is observed for 0.3 wt% nanofluid and the absorption capacity increases by 15% from 5 mins to 75 mins. Thus solar absorption can be tuned with the weight of nanoparticles in the base fluid and also by the time of exposure. In addition to this, the area exposed may also influence the absorption characteristics. Figure 4 shows the solar absorbtion characteristics of water and prepared CuOnanoparticles with weight fraction (0.1,0.2,0.3). The solar absorption observed for 0.3wt% CuO nano fluid is higher.

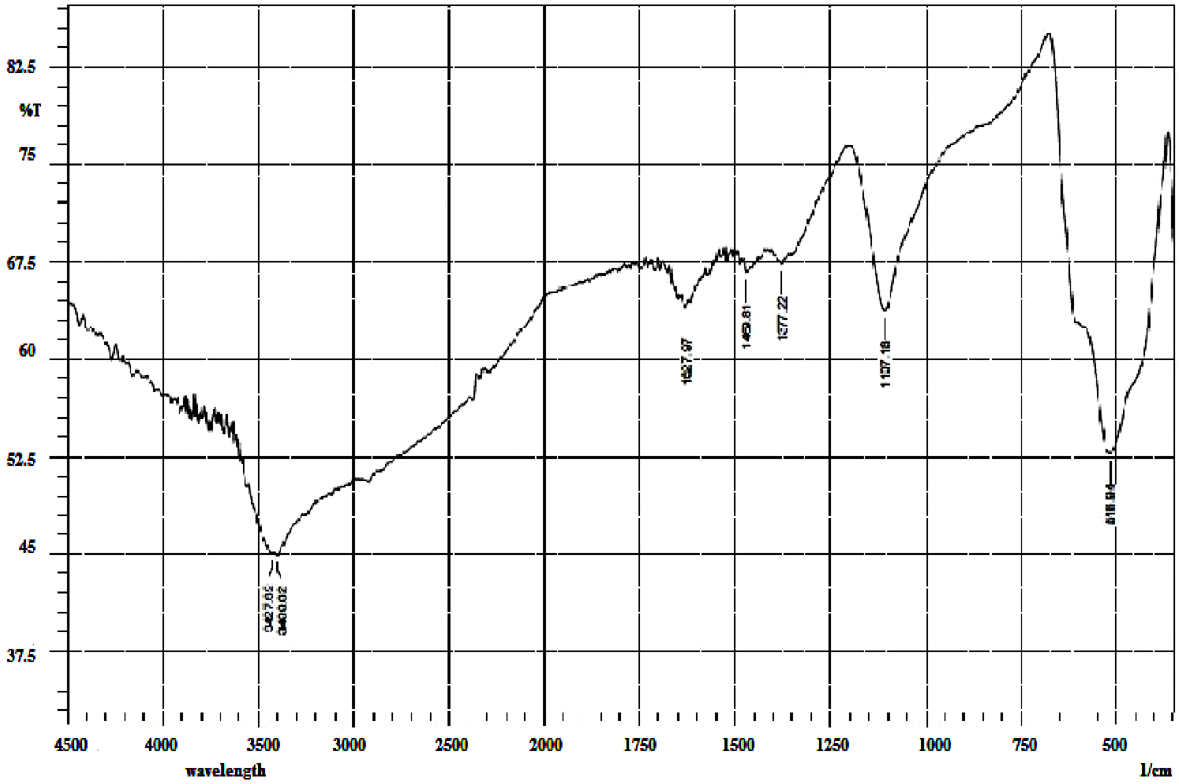

Figure.3 FTIR image of CuO particles

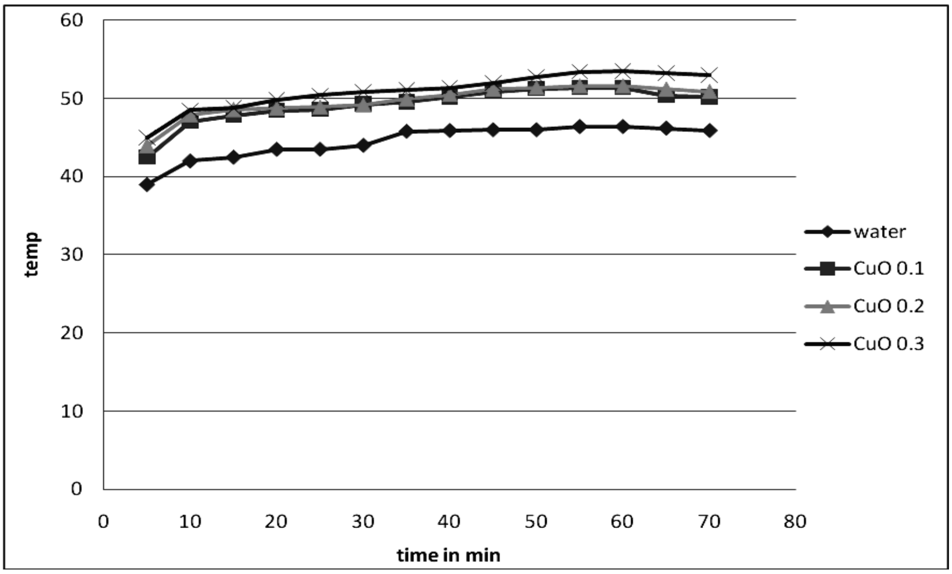

Figure 4 Solar absorption profile for CuO nanofluid and water

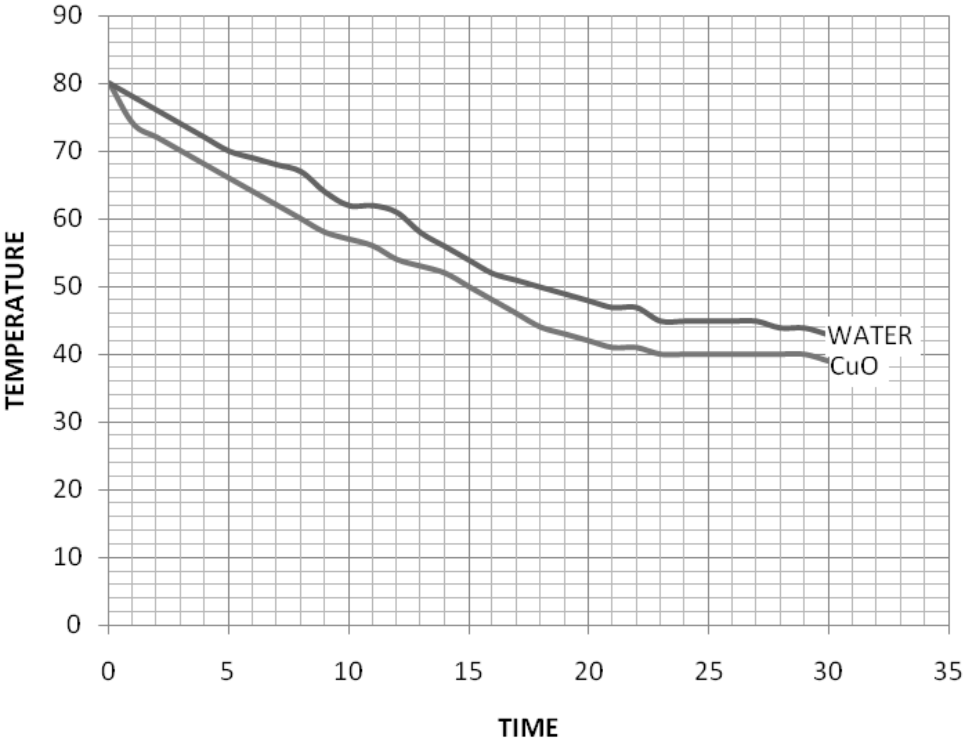

Figure 5 Cooling curve for CuO nanofluid and water

The nanoparticle size and shape along with surfactants may also play a crucial role in deciding the solar absorption. Nanofluids have been proved as better thermal conductivity materials than their base fluids. In the present work they also offer the added advantage of absorbing heat better than the base fluid. This aspect can be exploited for nanofluid based DASC. A cooling curve of water and 0.3 wt% CuO also confirm the rate of heat transfer of nanofluids. Figure 5 reveals that cooling curve of CuO-water nanofluid lies below the cooling curve of water. The presence of nanoparticles in water aid for the extra radiation process in a short time. From the Figure 4 the radiation of 0.3 wt% CuO nanofluid is higher than the water base fluid. This is attributed due to high surface area of nanoparticles [17].

4. CONCLUSIONS

Copper Oxide nano-particles were prepared by chemical reduction from copper sulphate with water as base fluids and PEG as a reducing agent. CuO nanofluids with varying wt% (0.1, 0.2, 0.3) were prepared by two step methods via ultrasonication at 42KHz. The prepared CuO nanofluids were tested for their solar absorption for 75 minutes and maximum absorption was observed for 0.3wt%. The radiation of 0.3 wt% CuO nanofluid is higher than the water base fluid. This is attributed due to high surface area of nanoparticles [17]. From the experimental results shows that water cools at lesser time compared with CuO nanofluid which shows that the CuO nanofluid stores more heat than water and this property may useful for direct absorption solar collectors. The structure and morphology of CuO nanoparticles samples were characterized using XRD, SEM, FTIR, and BET. The results reported in this study taken only under stationary conditions. Fruitful results may expect when conducting the experiments under dynamic conditions for greater heat transfer rate due to transport phenomena of spherical shaped nanoparticles particles and rotating fluid. The validation for micoparticles has been studied by S.Torri [18] and coworkers. Based on obtained results we recommend CuO nanofluids as a material for renewable and clean energy. It can also help in control of global warming [19].

References

[1] S. U. S. Choi, ED-Vol 231/MD 66 (1995) 99

[2] E. H. Rhoderick, *Metal semiconductor contacts*, Oxford University Press Oxford (1978)

[3] J. A. Eastman, S.U.S. Choi, S. Li, L.J. Thompson, Applied Physics Letters 78 (2013) 718

[4] Xiang-Qi-Wang,Arun S Mujumdar, International Journal of Thermal Sciences 46 (2007) 1

[5] Paisarn Naphon, Pichai Assadamongkol, Teerapong Borirak,International Communications in Heat and Mass Transfer 35 (2008) 1316

[6] Suvankar Ganguly, Sudipta Sikdar, Somnath Basu. Powder Technology 196 (2009) 326

[7] P. D. Shima, J. Philip, J. Raj, Appl. Phys. Lett. 95 (1995) 133112

[8] Z. Said, R. Saidur, N. A. Rahim, International Communication in Heat and Mass Transfer 59 (2014) 46

[9] Rumen Kirilov, Christian Girginov, Petko Stefchev, Advances in Natural Science: Theory and applications 2 (2013) 31

[10] T. P. Otanicar, Golden Environ Sci Technol. 43 (2009) 6082

[11] M. Esen , Sol. Energy 76 (2004) 751

[12] A. L. Subramaniyan, Sukumaran Lakshmi Priya, M Kottaisamy, R Ilangovan, Journal of Energy in Southern Africa 25 (2014) 123

[13] C. L. Carnes, K. J. Klabunde, J. Mol. Catal. A: Chem 194 (2003) 27

[14] Qingwei Zhu, Yihe Zhang, Jiajun Wang, Fengshan Zhou, Paul K. Chu, J. Mater. Sci. Technol. 4 (2014) 289

[15] B. Akbari, M. Pirhadi Tavandashti, M. Zandrahimi, Iranian Journal of Materials Science & Engineering 8 (2011) 48

[16] Anita Sagadevan Ethiraj, Dae Joon Kang, Nanoscale Research Letters 7 (2012) 70

[17] Uda Hashim, Elley Nadia, Sahir Salleh, Int. J. Nanoelect and Materials 2 (2009) 119

[18] S. Torri, S. Tanaka, Y. Watanabe, Int. J. Nanoelect and Materials 3 (2010) 71

[19] M. Bououdina, Int.J.Nanoelect and Materials 3 (2010) 155