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# Enhanced Thermal Conductivity and Superior Antimicrobial Activity by Cu/Ni Nanofiber Dispersed Fluids with Prolonged Stability

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***Abstract*: The present study reports the synthesis, characterization and antibacterial properties of Cu/Ni nanofluids. The influence of various synthesis parameters on the stability of nano suspensions were studied and optimized. The samples were characterized using UV-Visible spectroscopy and TEM imaging techniques. The TEM images revealed the formation of nanofibers. The optimized composition of the Cu/Ni nanofluid was found to be stable for more than four months with zeta potential value of 40.4mV. The thermal conductivity studies showed 19% enhancement in comparison to the base fluid (water). The antibacterial properties of the nanosuspensions were studied by performing minimum inhibitory concentration tests (MIC) and zone of inhibition analysis.***

***Keywords* : Bimetallic Nanofluids, Cu/Ni nanofibers, Thermal conductivity, Antimicrobial activity.**

## I. INTRODUCTION

Conventional heat transfer fluids used for heating and cooling applications in industries exhibit poor heat transport properties. In order to enhance its thermal properties, [1] initiated the dispersing of metal/metal oxide particles with size in micrometer scale. The larger particle size exhibited demerits such ss poor stability which resulted in surface clogging of micro channels, pipeline damage and surface erosion. To overcome the above limitations, the concept of dispersing nano sized particles in various base fluids was initiated by Choi and Eastman [2]. Nanofluids are suspensions of nanoparticles in base fluids such as water, ethanol, engine oil, ethylene glycol etc. The unique properties of the nanofluids such as high surface area to volume ratio and better stability results in remarkable thermal properties. The nanoparticles include metals, metal/non-metallic oxides, sulfides and carbides and ceramic oxides. The thermo-physical properties of the nanofluids depend mainly on the preparation method. Generally, nanofluids are prepared using two-step and one-step synthesis methods. Though, the two-step method is widely used for the synthesis of nanofluids, its tendency to aggregate due to high surface area results in poor stability. The one step method developed by Eastman *et al*., resolved the above limitation by preventing the agglomeration of nanoparticles [3]. The optimization of synthesis parameters plays a significant role in enhancing the stability of the nanofluids. The dispersion of various metal/metal oxides, especially, copper/copper oxides in base fluids employing surfactants thus enhancing the thermal transport properties are widely studied [4-9]. The combined efficiency of copper and nickel mixed metal nanoparticles prepared using chemical method in enhancing the heat transfer properties are less reported. Thus, this paper mainly focuses on the synthesis of Cu/Ni nanofluids by one-step chemical method with enhanced stability for improving the thermal conductivity and antimicrobial properties.

## II. EXPERIMENTAL

The general procedure for the synthesis of Cu/Ni nanofibers initially involves dissolving a calculated quantity of cupric nitrate trihydrate (98%) in distilled water followed by addition of cetyltrimethyl ammonium bromide (CTAB, 99%) and diethanolamine (98%) under vigorous stirring. To the above mixture, hydrazine hydrate (99%) was added drop-wise whence; the colour changes from blue to brown. After 30 minutes, an aqueous solution of nickel nitrate monohydrate (99%) was added to the above mixture followed by drop-wise addition of ammonia and sonicated for 30 minutes (Leela Sonic, 20kHz, 5mm probe). The contents are made upto 100 mL with distilled water and the sample identification & composition is given in Table-I. The copper/nickel nanofluids were characterized using UV–Visible spectrometer (Perkin Elmer - Lambda 19) and transmission electron microscope (Philips CM 200). The stability of the copper / nickel nanofluids was studied using zeta potential analyzer. The thermal conductivity of nanofluids were measured at 30°C by transient hot-wire method using THW, KD2-Pro Decagon instrument. The efficiency of copper/nickel nanofluids towards the antibacterial activity were investigated against staphylococcus *aureus* and pseudomonas *aeruginosa*.

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## III. RESULTS AND DISCUSSION

During the synthesis of Cu/Ni nanofibers, the influence of various parameters was studied and optimized using characterization techniques.

***a) Influence of volume of hydrazine hydrate*** – The effect of amount of hydrazine hydrate on the stability of nanofluids were studied by preparing the samples consisting of 0.05g of Cu/Ni (Cu/Ni-NF-500) and 0.1g of CTAB respectively. The volume of hydrazine hydrate was varied between 0.5mL – 3.0mL. The stability of the nanofluids was evaluated using zeta potential analyzer and the values are detailed in the Table-I. It can be noted that change in quantity of hydrazine hydrate did not influence the zeta potential values.

**Table-I: Effect of various parameter on the stability of Cu/Ni Nanofluids**

| S.N. | Sample ID | Cu (g/100 mL) | NiO (g/100 mL) | Vol. of hydrazine hydrate (mL) | Quantity of CTAB (g/100mL) | Zeta Potential (mV) |
|---|---|---|---|---|---|---|
| A | Cu/Ni-NF-500 | 0.025 | 0.025 | 0.5 | 0.1 | 29.8 |
| | | | | 1.0 | 0.1 | 29.6 |
| | | | | 2.0 | 0.1 | 29.6 |
| | | | | 3.0 | 0.1 | 29.6 |
| | | | | 0.5 | 0.05 | 40.4 |
| B | Cu/Ni-NF-1000 | 0.05 | 0.05 | 0.5 | 0.05 | 29.8 |
| | | | | 0.5 | 0.1 | 29.8 |
| | | | | 1.5 | 0.1 | 29.8 |
| C | Cu/Ni-NF-1500 | 0.075 | 0.075 | 0.5 | 0.05 | 30.2 |

***b) Influence of CTAB concentration:*** Based on the above studies the concentration of the hydrazine hydrate was optimized as 0.5mL. The effect of the amount of surface modifier was studied by preparing nanofluids Cu/Ni-NF-500 with 0.5mL of hydrazine hydrate. The amount of CTAB was varied between 0.05g - 0.1g respectively. The sample with 0.05g CTAB exhibited good stability and zeta potential values were found to be the highest. It can be concluded that increase in the surfactant content decreases the zeta potential (Table-I)

***c) Influence of Cu/Ni content:*** This study involved preparing samples comprising of 0.5mL of hydrazine hydrate and 0.05g of CTAB (optimized based on the above studies) and the precursor quantity (Cu/Ni content) was varied between 0.05g – 0.1g. The stability of the samples was found to decrease with increase in the amount of Cu/Ni content from 0.05g to 0.1g. The zeta potential values clearly indicate a decrease in stability, which may be attributed to the increase in the particle size due to agglomeration. Generally, nanofluids with the zeta potential value less than -30 mV or more than +30 mV have good stability due to strong repulsion forces between the nanoparticles, Therefore, the composition of nanofluid that showed the zeta potential value of 40.4 mV was optimized.

**UV-Visible spectral analysis:** The absorption characteristics of the optimized composition of copper/nickel nanofluids (Cu/Ni-NF-500) were studied using the UV-visible spectrometer (Fig. 1). The absorption band at 576 nm revealed the formation of metallic copper nano particles [6] and the absorption band at 409 nm confirms the formation of nickel oxide nano particle [10]. On increasing the concentration of Cu and Ni, the particle size of Cu increases, inferred by shift in the absorption towards longer wave length, while the same did not influence much on particle size of NiO.

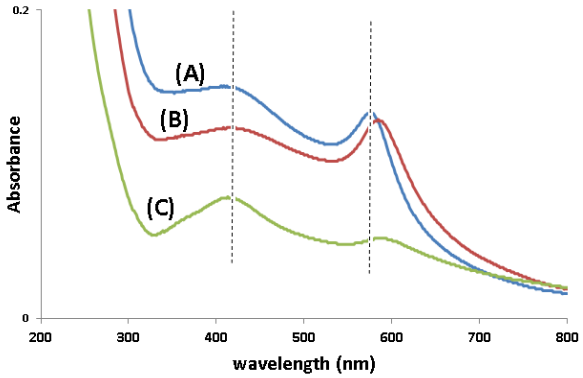


**Fig. 1. UV-Vis spectrum of Cu/Ni Nanofluids (A) Cu/Ni-NF-500 (B) Cu/Ni-NF-1000 (C) Cu/Ni-NF-1500**

**Transmission Electron Microscopy**: The morphology showed the formation of nanofibers with diameter of the 8 nm to 25 nm (Fig. 2).

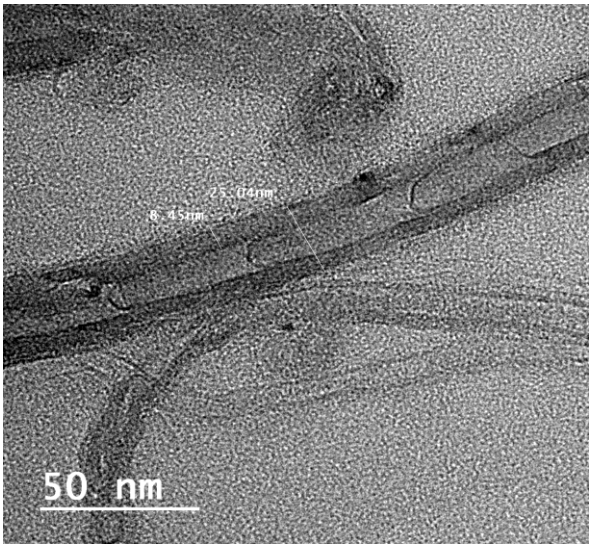


**Fig. 2. TEM Image of Cu/Ni-NF-500 nanofluid**

**Thermal conductivity studies:** The thermal conductivity of nanofluids was studied by using KD2 pro table top thermal property analyzer. From the results, it is observed that increase in hydrazine content did not influence the thermal conductivity, but, decrease in the volume of surfactant increases the thermal conductivity (Table-II).

**Antimicrobial Activity Studies:** Antimicrobial reduction measurements were carried out by determining the minimal inhibitory concentration (MIC). The typical procedure involves preparing five test tubes, each containing 1 ml of nutrient broth. To the first test tube 1 ml of the nanofluid suspension was added and shaken well.

Then, 1 mL suspension from the first test tube was transferred into the second test tube and accordingly similar procedure was repeated thrice i.e., up to fifth test tube and all the test tubes were inoculated with loop-full of inoculum of pure culture of the selected test organisms and incubated at 37°C for 24 h. After the incubation period, the test tubes were examined for the turbidity indicating the microbial growth (Table-III).

**Table-II: Thermal conductivity of Cu/Ni nanofluids**

| Sample ID | Vol. of hydrazine hydrate (mL) | Amount of CTAB (g) | Thermal conductivity (W/(m.K) |
|---|---|---|---|
| Cu/Ni-NF-500 | 0.5 | 0.1 | 0.627 |
| | 1.0 | 0.1 | 0.631 |
| | 2.0 | 0.1 | 0.639 |
| | 3.0 | 0.1 | 0.62 |
| Cu/Ni-NF-500 | 0.5 | 0.05 | 0.69 |
| | | 0.1 | 0.627 |
| Cu/Ni-NF-1000 | 0.5 | 0.05 | 0.75 |
| | 0.5 | 0.1 | 0.73 |
| | 1.5 | 0.1 | 0.63 |

**Table-III: Minimum inhibitory concentration analysis**

| Sample | Test organism | Cu/Ni content X $10^{-4}$ g/mL | | | | Control (Nalidixic Acid) |
|---|---|---|---|---|---|---|
| | | *2.5* | *1.25* | *0.625* | *0.312* | |
| Cu/Ni-NF-500 | *S. aureus* | NG | NG | NG | NG | NG |
| | *P. aeruginosa* | NG | NG | NG | G | NG |

NG – No Growth of microorganisms; G – Growth of microorganisms observed

Further the microbial growth in the test tubes was confirmed by streaking the loop-full of inoculum from the test tube in the nutrient agar plates and incubated at 37°C for 24h (Fig. 3). The minimum inhibitory concentration for S. *aureus* and P. *aeruginosa* were found to be 0.0000625g/ml and 0.000125g/ml respectively and the results are compared with nalidixic acid (control).

***Zone of inhibition analysis*:** This analysis was carried using the well diffusion method and the 5mm diameter wells were made in the muler hinton agar plates by gel puncture device. 20 µL Cu/Ni-NF-500 suspension was added in each well. The reference selected was nalidixic acid and 20µL of nalidixic acid antibiotic solution was introduced in one of the wells. The plates were incubated at 37°C for 24h without inversion. After the completion of incubation period, the diameter of zone of inhibition was measured. Thus, 20 µL of Cu/Ni Nanofluid suspension consisting of 0.00001g of Cu and Ni exhibited antibacterial activity (Fig. 4).

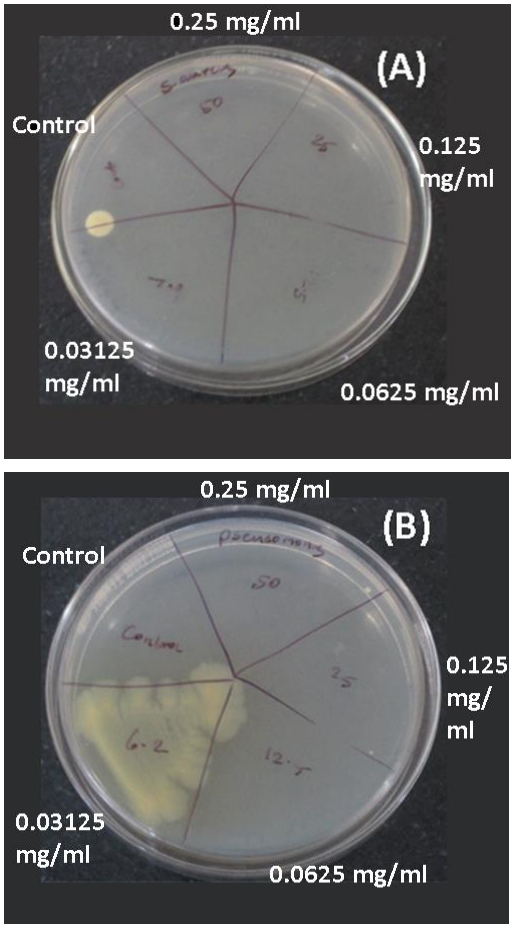


**Fig. 3. Antibacterial analysis of Cu/Ni-BF-500 at various dilutions against (A) S. aureus and (B) P. aeruginosa**

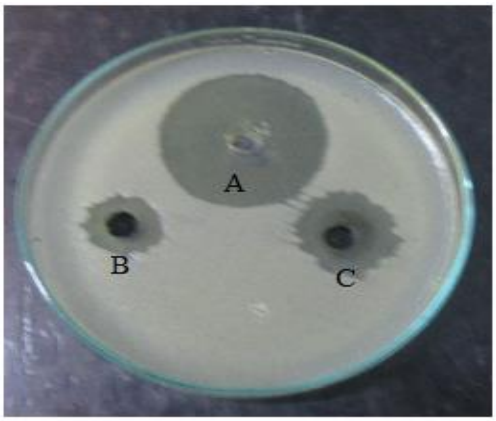


**Fig. 4. Zone of inhibition analysis against S. aureus (A) Nalidixic acid (positive control); (B) Cu/Ni-NF-500 (main); (C) – Cu/Ni-NF-500 (duplicate)**

## IV. CONCLUSION

The synthesis of copper/nickel oxide nanofibers was carried out by reducing cupric nitrate and nickel nitrate with hydrazine hydrate in an aqueous CTAB solution at room temperature. TEM image showed formation nanofibers in the range 8 nm to 25 nm. The UV-visible spectrum showed an absorption band at 576 nm revealing the formation of metallic copper nanofibers and an absorption band at 409 nm revealed the formation of nickel oxide nanofibers.

The increase in the quantity of surfactant and Cu/Ni content, decreases the thermal conductivity and the stability, as confirmed by zeta potential analysis. The optimized nanofluid (Cu/Ni-NF-500) showed a thermal conductivity of 0.69 W/mK (19% enhancement) with the zeta potential measuring about 40.4 mV. The Cu/Ni-NF-500 nanofluid exhibited antimicrobial activity against S. *aureus* and *P. aeruginosa* .

## REFERENCES


1. J. C.Maxwell, "A treatise on electricity and magnetism", Dover Publications, 1873.
2. J.A. Eastman; U.S. Choi; S. Li.; L.J. Thompson; S. Lee, "Enhanced thermal conductivity through the development of nanofluids". *In Proceedings of the Materials Research Society Symposium*; Materials Research Society: Pittsburgh, PA, USA. 457, 1997, pp. 3–11.
3. J.A. Eastman, U.S. Choi, S. Li, W. Yu. and L.J. Thompson, "Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles", *App. Phy. Lett.*, vol.78, 2001, pp. 718–720. https://aip.scitation.org/doi/10.1063/1.1341218
4. C.H. Lo, T.T Tsung, and L.C. Chen, "Shape-controlled synthesis of Cu-based nanofluid using submerged arc nanoparticle synthesis system (SANSS)", *J. Crys. Growth*., vol. 277, 2005, pp. 636–642. DOI: 10.1016/j.jcrysgro.2005.01.067
5. Lo, C. H.. Tsung, T. T Chen, L. C, Su, C. H. and Lin, H. M., "Fabrication of copper oxide nanofluid using submerged arc nanoparticle synthesis system (SANSS)", *J. Nanopart. Res*. vol. 7(2-3), 2005, pp. 313–320. DOI: 10.1007/s11051-004-7770-x
6. H.T. Zhu, Y.S. Lin.and. Y.S. Yin, "A novel one-step chemical method for preparation of copper nanofluids", *J. Coll. Interf. Sci*., vol. 277(1), 2004, pp. 100–103. DOI:10.1016/j.jcis.2004.04.026
7. H. Bonnemann, S.S. Botha, B. Bladergroen, and V.M. Linkov, "Monodisperse copper- and silver-nanocolloids suitable for heat-conductive fluids", *Appl. Organomet. Chem*., vol. 19(6), 2005, pp. 768–773. https://doi.org/10.1002/aoc.889
8. A.K. Singh and V.S. Raykar, "Microwave synthesis of silver nanofluids with polyvinylpyrrolidone (PVP) and their transport properties", *Coll. Poly. Sci*., vol. 286, 2008, pp. 1667–1673. DOI 10.1007/s00396-008-1932-9
9. W. Yu, H. Xie, X. Wang and X. Wang, "Highly efficient method for preparing homogeneous and stable colloids containing graphene oxide", *Nanosic. Res. Lett.*, vol. 6, 2011, p. 47. DOI: 10.1007/s11671-010-9779-7.
10. Jaydeep Adhikary, Prateeti Chakraborty, Balaram Das, Arnab Datta, Sandeep Kumar Dash, Somenath Roy, Jeng-Wei Chen and Tanmay Chattopadhyay, "Preparation and characterization of ferromagnetic nickel oxide nanoparticles from three different precursors: application in drug delivery", RSC Adv., vol. 5, 2015, p.35917. DOI: 10.1039/C5RA00642B


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