CuO Nanoparticle Enhanced Paraffin for Latent Heat Storage Applications

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ABSTRACT:
Present work focuses on the chemical synthesis of copper oxide nanoparticle which is further doped in phase changing material (paraffin) in different doping concentrations. Thereafter the thermo physical property of nano-enhanced phase-changing material is investigated through XRD, FTIR, DSC, EDAX XRD and TEM results show that the grain sizes of CuO NPs are in the range of 5 to 17 nm. Chemical composition and surface morphology are shown by EDAX and FESEM. DSC analysis shows that maximum augmentation in latent heat of fusion and the melting temperature of NEPCM occurs for 2% of doping concentration nonmaterial which further decreases dramatically over 2% of concentration.

Keywords: Energy storage, Phase change material, Nanoparticle, NEPCM,

1. INTRODUCTION
To meet popular demand for energy in each developing sector, an abundance of renewable energy is required. As Solar energy is the cheapest and emission-free clean energy source available most of the year, but due to its uncertainty in availability and cost-effective storage, its wide application is curtailed. Therefore an effective energy storage technique is much needed to store the surplus energy for futuristic needs. Thermal energy storage system (TESS) having advantages such as good energy storage capacity, high performance, cost-efficiency, fast charging/discharge rates and hazardless design is one of the most prominent techniques of energy storage [1]. Therefore a variety of different TESS systems are developed to increase the energy utilisation rate[2]. out of the various techniques available latent heat thermal energy storage system (LHTES) is one of the most prominent techniques of energy storage [3]. Due to its numerous advantages such as compactness and high energy storage, the latent heat thermal energy storage (LHTES) technology with Phase Change Materials (PCMs) has drawn the attention of many researchers in recent times[4]. PCMs have a unique property called a variation in phase temperature. which releases and absorbs heat energy at a constant temperature [5] Figure 1 illustrates the method of melting and freezing of a PCM. Fig 2. demonstrate the various energy storage techniques. Among the various PCM. Organic PCMs are widely used. Paraffin, fatty acids, alcohol and glycol are some examples of organic PCMs.[6] The key disadvantage of organic PCM is having lower thermal conductivity (0.24 W/mK), which reduces charging and discharging rate during phase change[7]. Which further curtails the heat storage and removal rate during the charging and discharging processes. To resolve the issue of paraffin's low thermal conductivity, the high thermal conductivity metallic, non-metallic particles are distributed into paraffin [8]. Having high volume-to-surface ratio in PCMs[9]. The current research focuses on the addition of CuO(Copper oxide) nanoparticle in paraffin wax to enhance the thermal performance of NEPCM [9]
2. LITERATURE REVIEW:

The field of nanofluid-based thermal energy storage has emerged as a growing area of technology for the storage of thermal energy in recent years. Nanoparticles play a role in providing higher thermal conductivity, accelerating the process of loading and unloading cycles during melting and freezing. The nanoparticles form clusters and networks during repeated refrigeration/heating cycles leading to a theoretically improved thermal conductivity. Choi in 1995 first proposed nanofluids and studied the various thermo physical property such as density and viscosity thermal conductivity. PCM. Examined latent heat storage technology for solar water heaters. Has designed thermal energy storage system with two solar water heaters and paraffin as storage material. Reviewed for thermal energy storage systems on nanoparticle-based fatty acid and paraffin. The thermal conductivity is shown to be improved by nanoparticle dispersion in PCMs in some way otherwise more nanoparticles dispersion may have a negative effect as dynamic viscosity increases. The experimental examination is required to optimise nanoparticles in PCM for maximum thermal conductivity and minimum decreased heat storage ability observed that adding silicon nanoparticles would improve \( \text{KNO}_3 \) thermal storage characteristics. He said that with the addition of silicon nanoparticles, phase and the latent heat of potassium nitrate can be greatly changed. Experimentally studied...
the thermal physical properties of paraffin (octadecane) by incorporating Al₂O₃ nanoparticles. An increase in dynamic viscosity and thermal conductivity was observed with Al₂O₃ nanoparticles [19]. Prepared paraffin/expanded graphite's-based composite phase change material using domestic microwaves and their thermal energy storage properties [20]. Prepared shape stabilised PCMs using thermal energy storage application fatty acids eutectics/extended graphite composites. [21] Proposed The most critical considerations in the selection of any particular PCM.

In the current work, CuO NPs is prepared with the wet Chemical technique and subsequently dispersed with varying mass fraction into organic PCM (Paraffin) to prepare nano Enhanced Phase Changing material (NEPCM). Further their thermal properties such as Peak melting temperature and latent heat of fusion were studied using XRD, EDAX, TEM, FTIR and DSC techniques.

3. EXPERIMENTATION:-

3.1. CuO nanoparticles and NPCMs preparation
500 ml of 0.2 M copper chloride (CuCl₂.2H₂O) solution and 2 ml glacial acetic acid (CH₃COOH) is mixed in a conical flax. The blue solution obtained is heated under the continuous magnetic agitation. The above solution was then added 30ml 8.0M sodium hydroxide (NaOH) solution. With the creation of a black suspension, the colour of the solution turns black immediately. The mixture was cooled at room temperature and centrifuged after 2 hours of stirring and boiling of the solution. The wet CuO precipitation was rinsed with sterile water twice to extract the pollution ions. CuO nanopowder was produced with dried precipitate. Further different mass %s of CuO are distributed in paraffin to produce NEPCMs, The entire preparation process of NEPCMs at different weight % of NPs is carried out in the ultrasonic bath for 2 hours.

following chemical reactions takes place during the synthesis of CuO

\[ 4NaOH + Cu_2 \rightarrow 4Na + 2Cu(OH)_2 \]
\[ 2Cu(OH)_2 \rightarrow 2H_2O+2CuO \]

3.2. Materials
Paraffin(CH₃COOH), Cupric acetic acid(CuCl₂.2H₂O) and Sodium Hydroxide (NaOH) were purchased, labelled and are used without further purification.

3.3. Characterizations
The XRD analysis of CuO NPs was performed in the scan range of 20-80° by Expert Pro, 40 kV, 30 mA, the mean particle size is determined using the formulation of Scherrer

\[ t = \frac{0.9\lambda}{\beta \cos \theta} \]

Were \( \beta \) is the angle of diffraction. Composition Study is conducted for the CuO NP using EDAX. Field Emission Scanning Electron Microscope (FE-SEM) with a working voltage of 0-30 kV analyses the surface morphology & microstructure of CuO NPs and confirms the insertion of CuO in paraffin. FT-IR with KBr pellet from 4,000 to 400 cm⁻¹ scan the FESEM sample and confirms chemical inactiveness. The DSC analysis measured the peak melting temperature and the latent fusion heat of pure paraffin and CuO doped paraffin, in a pure nitrogen atmosphere of about 2 °F/min and 5 mg of each sample was put in a sealed aluminium cup.
4. RESULTS AND DISCUSSION:-

4.1. Energy Dispersive X-rays study CuO NP
The weight % of EDAX measured copper and oxide was 52.89% and 47.11%. In the EDAX spectrum, no other impurity traces were detected. The EDAX results therefore verified that pure almost stoichiometric CuO NPs have been formed.

![CuO NP's EDAX spectrum](image)

4.2. Calculation of nanoparticles CuO particle size and lattice parameters
Figure 2 illustrates CuO nanoparticles with XRD spectrum which shows the monoclinic pattern, having system parameters $a=4.81 \text{ Å}$, $b=3.47 \text{ Å}$ and $c=5.33 \text{ Å}$ as compared with regular performance. Using the Scherrer relationship, size of CuO nanoparticle was found to be 6 nm-18nm. The results of XRD are well in line with standard values. The lines of peak expansion show that the particle's size is within the nanometer range and no impurity peaks are seen in XRD data. Primary particles are combined in chain-like clusters with a narrow size distribution. Owing to the presence of short clusters, the greater the particle size.
4.3. CuO NPs and NPCMs morphology

TEM figure gives the surface morphology of CuO NPs. The average CuO particle size was between 5 and 18 nm. Paraffin and NEPCM surface topography imaging were performed using FE-SEM confirming the homogeneous distribution of the CuO NP in paraffin.

![CuO NPs and NPCMs morphology](image)

Figure 5: CuO NPs (a) FE-SEM pictures of pure paraffin (b) cuo paraffin (c)&(d) TEM images

4.4. FTIR analysis of PCM and NPCM

FTIR spectrum of the paraffin and NPCM at 2% mass fraction are shown in Figure 4(a) and 4(b) indicate no extra peaks after the insertion of nanomaterials in the base PCM is reported which confirms the chemical inactivity and stability of the NEPCM.

![FTIR spectrum](image)

Fig 6(a) FTIR OF PCM
4.5. Thermal Properties of PCM and NPCMs

DSC analysis is conducted to observe the melting behaviour of NEPCM composite for different mass percentage. The endotherm thermogram shows maximum augmentation in melting temperature and latent heat of fusion for 2% of the mass fraction. Moreover, further increase in mass fraction shows decrease in the peak melting temperature. Peak melting temperature of the CuO NP composite containing 1.0, 2.0, and 3.0 wt.% was 0.46, 2.14, and 0.68 K more than that of pure paraffin and peak melting temperature of 4.0 and 5.0 wt.% of the CuO NPs were 0.3 and 0.79 K less than base paraffin. Table 1. Shows the thermal variations at various doping % it indicates that Peak melting temp and enthalpy is maximum at 2% of doping.
Fig 8. Variation of Latent Heat of Fusion and Phase Change Temp with mass Fraction

| NANO DOPING (%) | ONSET TEMP (°C) | PEAK MELTING TEMP (°C) | ENTHALPY (KJ/KG) |
|-----------------|----------------|------------------------|------------------|
| 0               | 57.24          | 72.94                  | 221.21           |
| 1               | 62.93          | 73.40                  | 274.07           |
| 2               | 58.13          | 75.08                  | 289.24           |
| 3               | 69.68          | 74.62                  | 103.89           |
| 4               | 57.35          | 73.24                  | 94.28            |
| 5               | 58.17          | 72.15                  | 73.84            |

5. CONCLUSION:
In the present work, CuO nanoparticles were prepared and characterised and inserted finally in paraffin to generate NPCMs. The melting behaviour of NEPCM is analysed using DSC measurement shows the following findings:

a) Melting behaviour is unchanged
b) 38% Enhancement in enthalpy is observed
c) Peak melting temperature is increased
d) Thermal conductivity of NPCMs is increased
e) Peak melting is observed at a concentration of 2%

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