Experimental Investigation on Thermal Behavior of Nano Particle Dispersed PCM For Energy Storage Application

Gowtham P[1], Mithun Kumar G[2], Rohith R[3], Mr. R. Bharathiraja[4]
[4]Assistant Professor, Dept of Mechanical Engineering,
[1, 2, 3]Dept of Mechanical Engineering,
[1, 2, 3, 4] Dr. Mahalingam College Of Engineering And Technology, Pollachi, India.

Abstract- *This paper investigates the thermal properties enhancement of paraffin wax, embedded with nanoparticles such Graphene and nano SiO2 additives used for thermal energy storage. The hybrid phase change material were prepared by dispersing Graphene and SiO2 nanoparticle of 0.5 mass%, and 1.0 mass% with paraffin wax. The size of the secondary particles was assessed using Transmission Electron Microscope (TEM), Field Emission Scanning Electron Microscope (FE-SEM) and X-Ray diffraction technique.The thermo physical properties of paraffin wax were examined by Differential Scanning Calorimetry (DSC), Thermo Gravimetric Analysis (TGA). Experimental results show that the dispersion of nanoparticles can decrease the melting temperature and increase the solidification temperature of PCM. • Thermal conductivity studies indicated that hybrid nanoparticles might enhance paraffin's thermal conductivity. Pure paraffin wax has a thermal conductivity of 0.24, but with hybrid PCM, it could reach a value of 0.47719.*

I. INTRODUCTION

Phase change materials (PCMs) acts as a connecting bridge between energy supply and demand for a long time because of their properties.Moreover, PCMs grabbed a lot of attention and can be used effectively after the integration with Energy storage system.Main drawback of PCM is low thermal conductivity which can be enhanced by dispersing nano particles in the PCM.A nanoparticle is a small particle that ranges between 1 to 100 nanometres in size. Nanoparticles are undetectable by the human eye, which exhibit significantly different physical and chemical properties.

The research on energy storage materials concentrates on phase change materials (PCMs) that show an adequate choice. The low thermal conductivity of the majority of PCMs obstructs them from overcoming obstacles associated with quick load changes during the charging and discharging processes. To solve this issue and achieve superior thermal properties, numerous studies have suggested a variety of techniques based on improving the thermal properties of PCMs and designing PCM heat exchangers.

The latent heat thermal energy storage (LHTES) is progressively promising because of its higher thermal energy storage capacity within a small temperature range. The LHTES along with PCMs offer several advantages over widely used sensible thermal energy storage technology (i) Thermal energy can be stored and used as per the application/requirement, (ii) PCMs can store 5 to 14 times more heat per unit volume, (iii) The phase change of PCMs usually happens almost at a constant temperature, and (iv) The availability of the abundant PCMs finds their applications in a broad span of temperatures(-10 °C to 300 °C).

The PCMs are found in numerous forms in the market for several heat storage applications. Commonly, PCMs are categorized into three major categories, such as (i) Organic, (ii) Inorganic, and (iii) Eutectics. The choice of suitable PCM mostly depends on the type of application. Kamal Sharma (2019)studied the thermal performance of graphene reinforced paraffin wax phase change material (GrPW –PCM) for thermal energy storage applications.. The graphene and paraffin wax were strongly interacted with each other, which finally results in less microcracks and strong interfaces.Raja Elarem(2021)studied impact on the thermophysical properties of paraffin wax by the nanoparticles. The latent heat capacity of paraffin decreased with increasing nanoparticle concentration although it could increase in special cases.K.Mylsamy & P.T.Saravanakumar (2019) investigated the influence of low mass% SiO_2 nanoparticles on the thermal properties of the paraffin wax for solar thermal energy storage applications. The Scanning Electron Microscope (SEM) analysis ensured the distribution of nano-SiO_2 particles in paraffin wax and formation homogeneous mixture of nano-SiO_2/ paraffin PCMs. Hussain H. Al-Kayiem(2016) studied with, 20nm copper nanoparticles dispersed into paraffin wax to synthesis Cu-PCM nanocomposites. The analysis shows the thermal degradation temperature shifted to higher temperature when paraffin wax was mixed with Cu nanoparticles due to physical bonding interaction of nano Cu and paraffin wax molecules.Hisham Maher(2020)studied and developed relatively higher thermally conductive PCM composites employing different mass fractions of paraffin wax and two thermally conductive enhancer nanomaterials namely silicon carbide(SiC) and silver (Ag).

III. METHODOLOGY

3.1 Nano composite Preparation

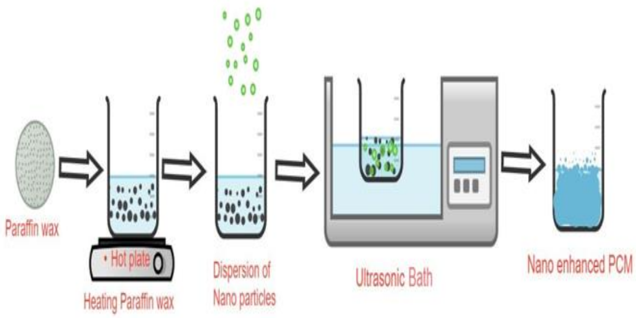


Fig 1 Nano composite preparation

A 10g of paraffin wax is taken in a beaker. The paraffin wax is melted using the hot plate at 58℃ or above. Then the nanoparticle i.e. graphene+SiO_2 is taken as 0.5% and added it to the melted paraffin wax in the beaker. Now it will be partially mixed and the nanoparticles getssedimented at bottom of the beaker. So, it is placed in the ultrasonic bath for about 45 minutes to one hour which is used to mix the nanoparticles with the Paraffin wax completely. The temperature should be maintained above 58℃ in the ultrasonic bath. The beaker is taken out from the ultrasonic stirrer and kept at atmospheric temperature to change the phase of the material from liquid to solid. Similarly different percentage of nanoparticles like 1%, 1.5%, 2% is added and the sample Nano enhanced PCM is prepared for the below tests.

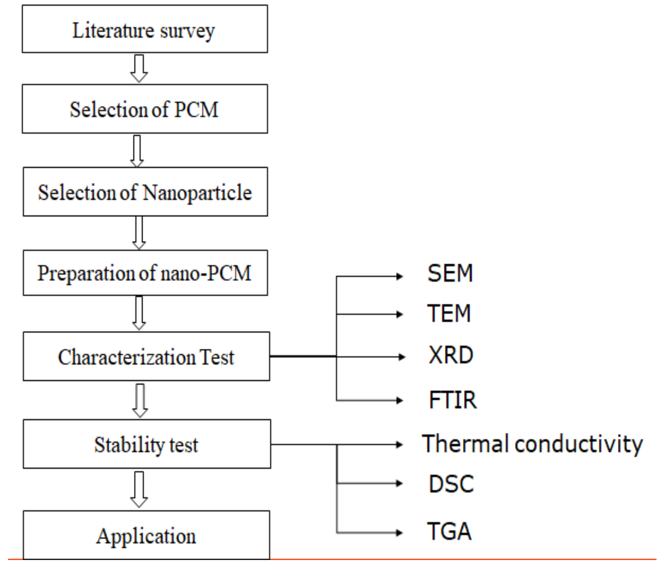


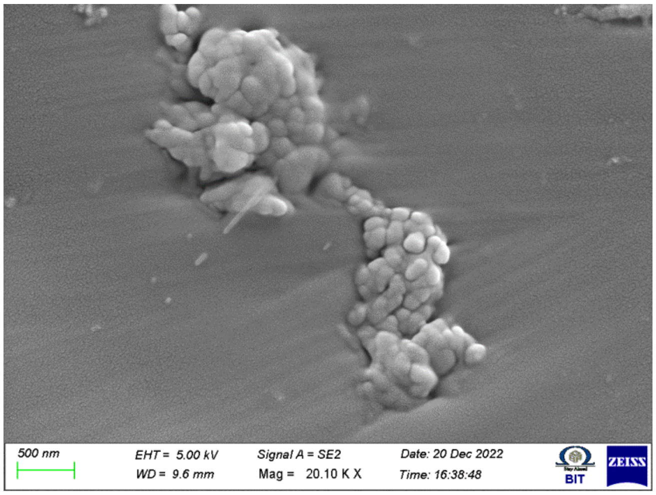
Fig 2 Work flow Flowcahrt

Ultrasonic Bath Nano PCM inside Ultrasonic Bath

IV. CHARACTERIZATION STUDY

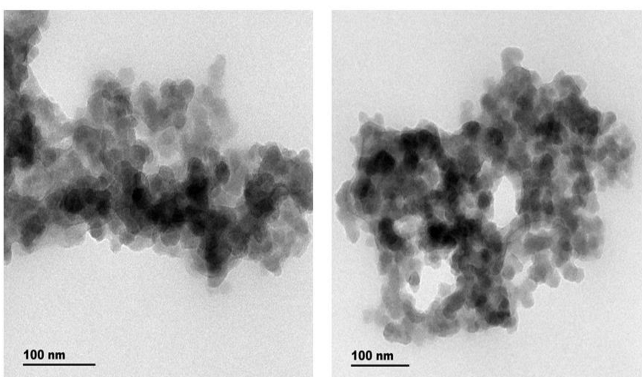
4.1 SEM Images

The SEM also has much higher resolution, so closely spaced specimens can be magnified at much higher levels. Because the SEM uses electromagnets rather than lenses, the researcher has much more control in the degree of magnification. From the SEM result, we infer the surface of the material in a magnified 3D structure which helps to identify the impurities on the surface of the material and the proper dispersion of the graphene nanoparticle throughout the Phase change material i.e. Paraffin wax.The below image shows the SEM result of Graphene dispersed Paraffin wax material which is magnified at 500nm.



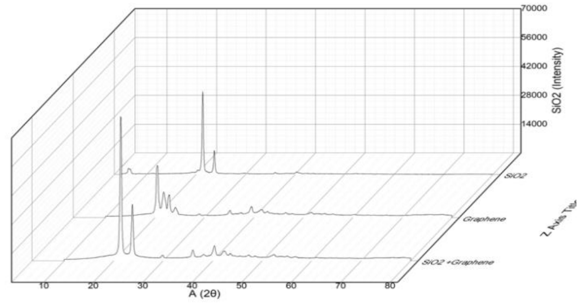
4.2 TEM Images

TEMs produce the most magnified images in 2D.As a result, TEM can reveal various sample properties such as morphology, crystallization, stress, and even magnetic domains. The below image shows the graphene is dispersed evenly throughout the phase change material. It is displayed in a 2D structure with magnification of 100 nm.Also below result offers information on the internal composition of the prepared nanoparticles dispersed paraffin wax..



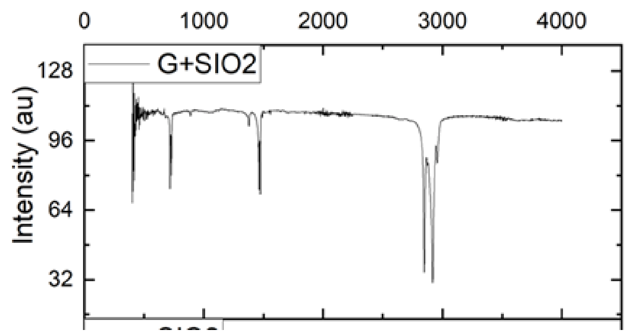
4.3 XRD

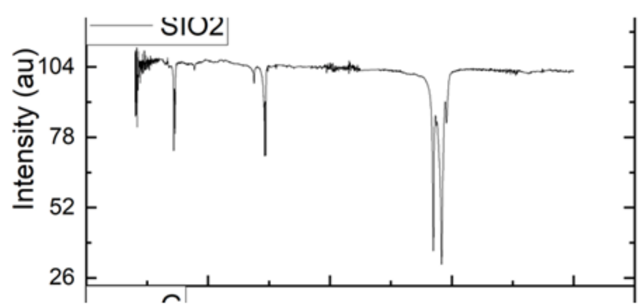
X-Ray diffraction analysis (XRD)provides detailed information about the crystallographic structure, chemical composition, and physical properties of a material. The below graph shows the XRD result of graphene dispersed paraffin wax. In the graph, the intensity of SiO_2, Graphene and prepared nano PCM sample .We can infer the intensity of the material increases when the graphene nanoparticles is added to the Paraffin wax.

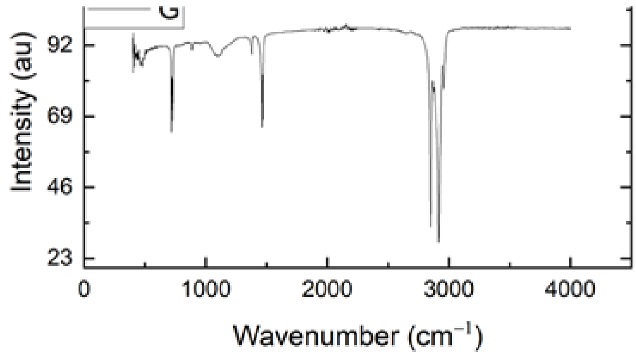


4.4 FTIR

FTIR is useful in identifying and characterizing unknown materials, detecting contaminants in a material, finding additives, and identifying decomposition and oxidation. The result showed that a lot of numbers of peaks were detected, informing the complex structure material. The y-axis—or vertical axis—represents the amount of infrared light transmitted or absorbed by the sample material being analyzed. The residues are shown as waves in the below graph for each material.



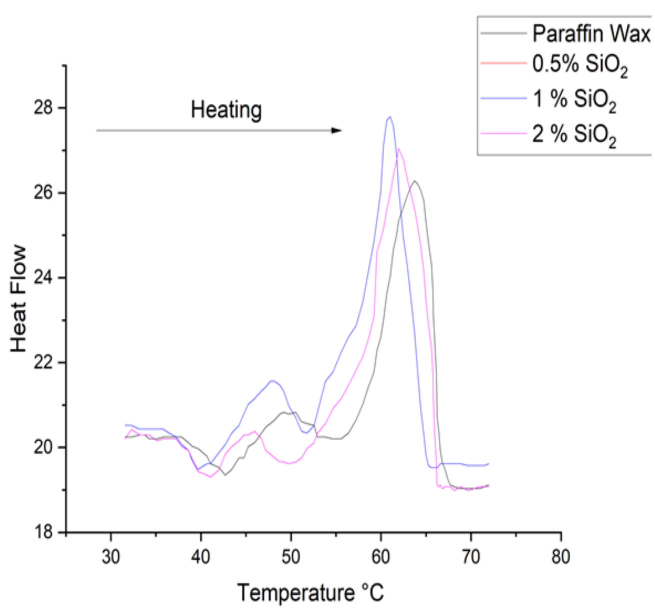




V. RESULTS AND DISCUSSION

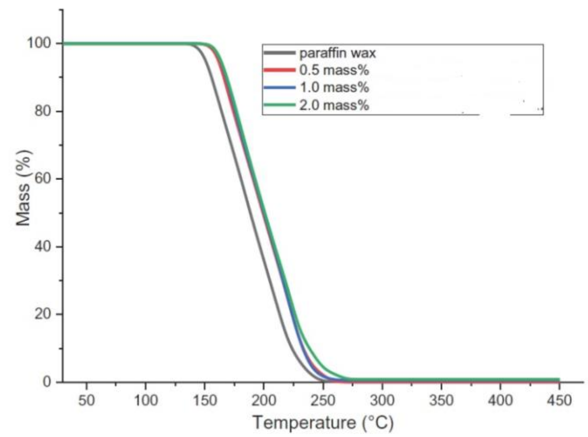
5.1 DSC

DSC is used to measure the rate of heat flow and compares differences between the heat flow rate.The biggest advantage of DSC is the ease and speed with which it can be used to see transitions in materials. From the below DSC result we can infer notice the change of heat flow at different temperatures. In the graph, the rate of heat flow is higher at around 62°C temperature while testing sample which contains 1% of SiO_2. Also we can find the differences of heat flow at different composition and temperatures.



5.2 Thermogravimetric Analysis (TGA)

A technique in which the mass of the sample is monitored against time or temperature while the temperature of the sample, in a specified atmosphere, is programmed.The data obtained in TGA is useful in determining purity and composition of materials, drying and ignition temperatures of materials and knowing the stability temperatures of compounds. The below image shows the graph result of TGA. In this result we can infer the decrease in mass while increase in temperature. The mass reduces at the temperature of 175℃ and becomes zero at 250℃. Also the graph represents the mass of the material with different compositions.



5.3 Thermal Conductivity

The table shows the thermal conductivity of nano enhanced PCM prepared at different compositions. From the table we can infer the gradual increase in thermal conductivity when the nanoparticles were added. Thermal conductivity will be maximum at addition of 1% of graphene and 1% of SiO_2 with paraffin wax.

Samples	Thermal Conductivity
Paraffin wax	0.2400
HYB1 (99.5 PFW + 0.5 SiO_2)	0.2605
HYB 2 (99.5 PFW + 0.5 Graphene)	0.38924
HYB 3 (99 PFW + 0.5 Graphene + 0.5 SiO_2)	0.41221
HYB 4 (98 PFW + 1 Graphene + 1 SiO_2)	0.47719

VI. CONCLUSION

- The size of the nano particles is ensured using Transmission Electron Microscope (TEM).
- Increasing the wt. % of Graphene and SiO2 will reduce the melting point of paraffin wax from 64.70°C to 62.52°C.
- The thermal conductivity of pure paraffin wax was 0.24 and it could be increased from 0.24 to 0.477 for hybrid PCMs

REFERENCES

[1] I.M. Mahbubul, E.B. Elcioglu, R. Saidur, M.A. Amalina, Optimization of ultrasonication period for better dispersion and stability of TiO2–water nanofluid, Ultrason. Sonochem 37 (2017)

[2] H. Behi, M. Ghanbarpour, M. Behi, Investigation of PCM-assisted heat pipe for electronic cooling, Appl. Therm. Eng. 127 (2017)

[3] S.M. Shalaby, H.F. Abosheiash, S.T. Assar, A.E. Kabeel, Improvment of thermal properties of paraffin wax as latent heat storage material with direct solar desalination systems by using aluminum oxide nanoparticles, (2018) 28–30.

[4] K.Y. Leong, M.R. Abdul Rahman, B.A. Gurunathan, Nano-enhanced phase change materials: A review of thermo-physical properties, applications and challenges, J. Energy Storage. 21 (2019) 18–31.

[5] M.S. Yousef, H. Hassan, S. Kodama, H. Sekiguchi, An experimental study on the performance of single slope solar still integrated with a PCM-based pin-finned heat sink, Energy Procedia 156 (2019) 100–104

[6] K.A. Rocky, M.A. Islam, A. Pal, S. Ghosh, K. Thu, Nasruddin, B.B. Saha, Experimental investigation of the specific heat capacity of parent materials and composite adsorbents for adsorption heat pumps, Appl. Therm. Eng. 164 (2020).

[7] M. Palacio, A. Rincón, M. Carmona, Experimental comparative analysis of a flat plate solar collector with and without PCM, Sol. Energy. 206 (2020) 708–721.

[8] S. Laraib Tariq, H. Muhammad Ali, M. AmmarAkram, M. MansoorJanjua, M. Ahmadlouydarab. Nanoparticles enhanced phase change materials (NePCMs)-A recent review, Applied Thermal Engineering,176, 2020.

[9] S.M. Shalaby, H.F. Abosheiash, S.T. Assar, A.E. Kabeel, Improvment of thermal properties of paraffin wax as latent heat storage material with direct solar desalination systems by using aluminum oxide nanoparticles, (2018) 28–30.

[10] S. Motahar, N. Nikkam, A.A. Alemrajabi, R. Khodabandeh, M.S. Toprak, M. Muhammed, Experimental investigation on thermal and rheological properties of noctadecane with dispersed TiO2 nanoparticles, Int. Commun. Heat Mass Transf. 59 (2014) 68–74