Analysis of Latent Heat Energy Storage System of Paraffin with Al_2O_3 Nanoparticle in A Heat Sink

Ms. A Mercy Vasan
Saranathan College of Engineering,
Tiruchirappalli-12, India

K. Balaprasanna
Saranathan College of Engineering,
Tiruchirappalli-12, India

S. Joel Silas
Saranathan College of Engineering,
Tiruchirappalli-12, India

B. Praveen
Saranathan College of Engineering,
Tiruchirappalli-12, India

V. Muralidharan
Saranathan College of Engineering,
Tiruchirappalli-12, India

Dr. S. Suresh
National Institute of Technology,
Tiruchirappalli-15, India

***Abstract*:- This paper discusses on the solution to the limitations of conventional cooling methods for electronic packing, and also explains a method to increase the efficiency of the thermal storage system by using PCM and Nano matrix. The setup is used to take reading for 10W with setpoint temperature as 80°C and at three different compositions 0.5%, 1% and 3% Al_2O_3 with paraffinas phase change material. Differential scanning calorimetry was used to find the thermal energy storage properties of nano-enhanced phase change material. The FTIR results showed no evidence of new chemical bond due to nanoparticle addition. The calculated results showed that there was an increase in thermal conductivity from 0.212 w/mk to 0.216 w/mk by increasing the concentration from 0.5 % to 3% of Nanoparticles.**

Key words: Phase change material (PCM), Nanoparticle (NP), latent heat, latent heat thermal storage(LHTS)

I. INTRODUCTION

Heat transfer during melting and solidification has been of major interest with different applications of thermal energy storage (TES) using phase change materials (PCMs)[1].*Heat* transfer rate depends on the thermal conductivity of the material used [2].To increase the thermal conductivity of the PCM, there have been many methods employed like the addition of nano structured materials, composite materials and nanofillers[3-*9]*.Since most of the electronic and other mechanical device lose their performance as their temperature increase, it is necessary to keep their temperature at a nominal level to increase their performance. It can be done either by active or passive cooling methods. In active systems, a fan is employed to continuously remove heat from the heat sink, but it has some disadvantages like high energy consumption and noise whereas in passive cooling there are no such disadvantages and it is also said that the passive cooling is usually enhanced by employing heat sink[10].Researchers selected different PCM with a suitable melting point for transient electronic cooling applications. Also, heat dissipation from the PCM can be enhanced by adding NP, and these PCM are being used in laptops, telecommunication rooms, cell phones to reduce the surface temperature of the processing unit[11-12] There are different methods of storing energy viz sensible heat, latent heat, thermochemical method. Sensible heat TES stores energy in a liquid or solid medium by increasing its temperature without changing the phase of the storage material. Latent TES use the storage capacity of the PCMs when the material changes its phase which stores and release energy in a small volume compared to sensible storage[13]. The last method is the thermochemical method where reversible chemical reactions are used for thermal storage[14].Hence PCM was taken for thermal energy storage. Amid available PCMs normal paraffin of type C_nH_{2n+2} is regarded as one of the good PCMs for LTES[15-18].Since the thermal conductivity of the PCM is low and also there is low melting and solidification rates, there is a need to enhance the performance of LHTS[19] and liquid leakage problem[20]. In order to enhance the thermal conductivity of the PCM, there are two methods. The first method involves the dispersion of metallic or nano-metallic particles with high thermal conductivity into the PCM.These particles include carbon nano fibers, carbon nano tubes copper or aluminum trioxide powder[21-25]. The other method for improving the thermal conductivity of the PCM is by impregnation of PCM into high thermal conductivity material with a porous structure like Expanded graphite, carbon or metal foam[26].

II EXPERIMENTAL

A. SYNTHESIS AND CHARACTERIZATION OF NANO PARTICLES

Paraffin with melting temperature 58-60°C was obtained from spectrum reagents and chemicals, Cochin. The NP Al_2O_3 -99.5%, 40-50nm was obtained from alfa aesar. The reasons for choosing paraffin includes high latent heat storage application, proper thermal characteristics such as little or no super cooling, varied phase change temperature, good thermal, chemical stability, self-nucleating behavior.

The other properties such as not poisonous, low cost, good heat storage and heat retrieval cycle and some drawbacks include low thermal conductivity and leakage problem [18].The NEPCM was prepared by mixing the paraffin and NP in a ball milling machine.

TABLE 1: MATERIAL PROPERTIES

Material	Thermal Conductivity (w/mk)	Density (Kg/m^3)	Specific Heat (J/Kg K)	Latent heat of fusion(KJ/Kg)	Melting point °C	Mean Diameter(nm)
Paraffin	0.212	880	2.8	173.6	56-58	--
Al_2O_3	30	3890	880	--	2072	50

B. HEAT SINK DESIGN AND FABRICATION

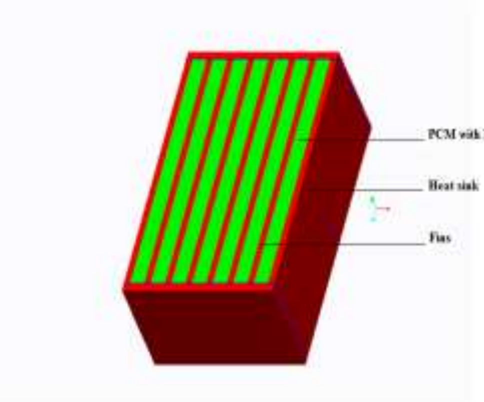

Fig: 1 Heat sink

The heat sink was fabricated by casting and then milling.The material used was aluminum. An aluminum block of 135*120*40 was cast out using casting process. The cuboidal block was first face milled to remove the defects due to casting. The rectangular block was reduced to 95*60*40 mm after milling of the block. Using an end mill cutter of 5mm dia and 30mm shear length seven grooves of depth 25mm were milled at an equal spacing to a length of 95mm. These grooves are used to make fins in the heat sink as the finned heat sink is used to improve thermal contact with the environment[20].Fins are very good in providing thermal penetration as they are used in direct heat transfer pathways into PCM during solidification[14]

C. EXPERIMENTAL SETUP AND TEST PROCEDURE

The heat storage characteristics of paraffin and Al_2O_3/paraffin NEPCMs in LTES system were studied by taking different weight percentage of Al_2O_3 nano particle of 0.5%,1%,3%.The experimental setup includes an LXI data logger, thermocouples 3 NOS, the heat sink is insulated acrylic on all sides except top and bottom, a heater pad, laptop and an autotransformer to set the power required for taking reading. The heat at 10W is supplied by the auto transformer to the heat sink and the required temperature reading was taken for the following material viz, No PCM, PCM, NEPCM were the nano particle was Al2O3.The is supplied at 10W by the autotransformer to the heater pad and from the pad heat was given to the heatsink and there are three thermocouples at the bottom of the heat sink and it takes reading after 10 s time interval until it reaches SPT.The temperature reading is given to the data logger (KEYSIGHT 34972A LXI Data Acquistion/Switch Unit) and it feeds the laptop with the temperature reading from which the datas are retrieved and analysed.

D. RESULTS AND DISCUSSION

These are the thermophysical properties which are to be found for the NEPCM where the conversion of the mass to volume fraction is given by the equation (1)where ϕ_{vol} is the volumetric fraction, ϕ_{wt} mass fraction, density of the PCM, $\rho_{alumina}$ density of the alumina(NP).

$$\phi_{vol} = \frac{\phi_{\omega t}\ x\ \rho_{PCM}}{(1-\phi_{wt})\ x\ \rho_{alumina} + \phi wt\ x\ \rho_{PCM}} \quad (1)$$

The thermal conductivity of the NEPCM is found by using the Maxwell model where K_{PCM} is the thermal conductivity of the PCM, $K_{alumina}$ thermal conductivity of alumina(NP)

$$K = K_{PCM}\ x\ \left[\frac{K_{alumina}+2\ x\ K_{PCM} - 2\ x\ \phi_{VOL}(K_{PCM}-K_{alumina})}{K_{alumina}+2\ x\ K_{PCM} + \phi_{VOL}(K_{PCM}-K_{alumina})}\right] \quad (2)$$

The latent of fusion of the NEPCM is found by using the equation where L_{PCM} is the latent heat of fusion of the PCM, ϕ_{wt} is the mass fraction.

$$L = (1- \phi_{wt})\ x\ L_{PCM} \quad (3)$$

The density of the NEPCM is found by using the following equation where is the density of NEPCM, is the density of alumina(NP)

$$\rho = (1-\phi_{vol})\ x\ \rho_{PCM} + \phi_{vol}\ x\ \rho_{alumina} \quad (4)$$

The specific heat of the NEPCM was found by using the following equation where $C_{p_{PCM}}$ is the specific heat of the PCM, ϕ_{vol} is the volume fraction, $C_{p_{alumina}}$ is the specific heat of the alumina (NP)

$$C_p = (1-\phi_{vol})\ x\ C_{p_{PCM}} + \phi_{vol}\ x\ C_{p_{alumina}} \quad (5)$$

TABLE 2: MATERIAL PROPERTIES

S. No	**Material**	**Thermal Conductivity(W/Mk)**	**Enthalphy (Kj/Kg)**	**Density (Kg/M^3)**	**Specific Heat(J/Kgk)**
1	Paraffin	0.212	173.6	880	2800
2	Paraffin + 0.5 Np	0.21270	172.73	883.31	2797.88
3	Paraffin+1 % Np	0.2130	171.86	888.13	2794.82
4	Paraffin+ 3% Np	0.2163	168.39	900.77	2786.75

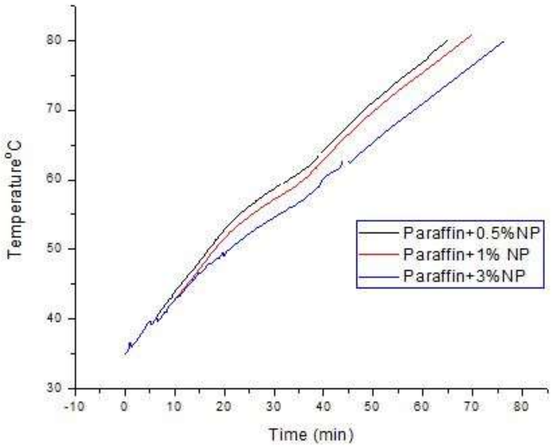

Fig :2 Graph Depicting the time Vs temperature of Heatsink with PCM and PCM added NP to reach SPT

The fig:3 depicts the time vs temperature of PCM among various proportions of alumina nano particle present in the mixture where there the temperature of the heat sink is less when the heat sink is filled with PCM+ 3% NP when compared to other proportions such as 0.5% ,1% and the thermal conductivity of the NEPCM increases when the paraffin is added with 3% NP which is in TABLE 2.

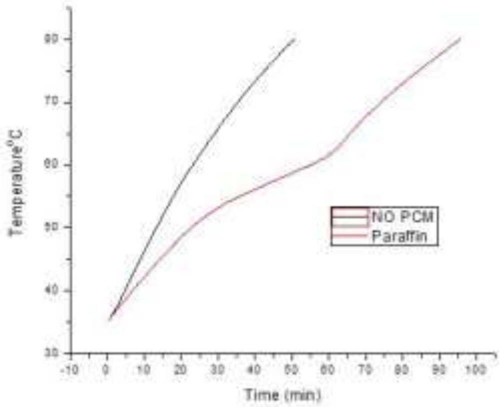

Fig: 3 Graph Depicting the time Vs temperature of Heatsink with PCM and NO PCM to reach SPT.

The fig: 3 clearly tells that PCM significantly traps the heat initially as sensible heat and then as latent heat, which allows it to absorb more heat content than the case where there is no PCM is present in the system, for the same time the temperature is less for heat sink with PCM we can say that there is more heat transfer from the setup to the environment.

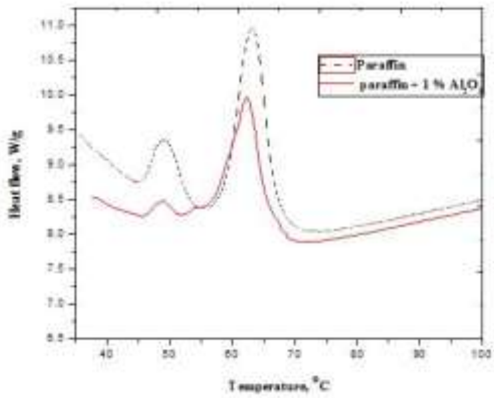

Fig:4 DSC curve for paraffin and paraffin +1% NP

From fig.4 it can be seen that for both paraffin and paraffin + Al_2O_3 1% the transition starts at 55.05 ºC and the transition ends at 72ºC . Area under the peak tells the latent heat of the PCM and NEPCM from the graph we can see that the area is small for the NEPCM and its latent heat is less compared to PCM.

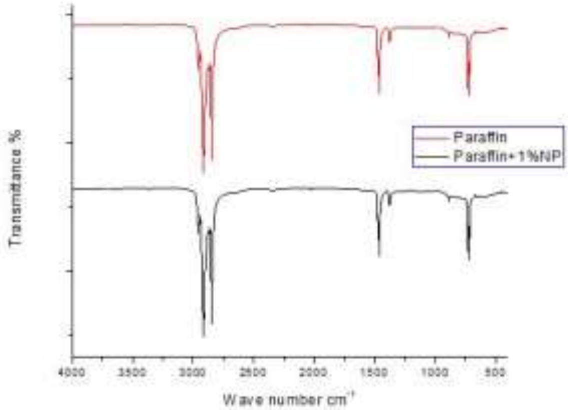

Fig:5 FTIR of paraffin and paraffin +1% NP

The fig:5 shows the Fourier transform infrared spectroscopy (FTIR) of paraffin and since both the plots are similar we can tell that there is no NP added. For the wave number around 2970 cm^{-1} both the plots are similar and this shows the paraffin is pure and no NP is added and we can infer that there is no new bond formed and chemically stable after the addition of NP.

III CONCLUSION

From this experiment we came to know that the time taken to reach the SPT for PCM was 96min and the time taken to reach the SPT for NEPCM for 0.5%,1%,3% increases from 65min to 76min and with this result we can tell that the NEPCM with 3% has the ability to store more heat compared to 0.5%. At a particular instant, the temperature of the heat sink is low for the Heat sink filled with 3% of NEPCM. From this it can be said that the heat sink operates at lesser temperature for same time and as a result there is an increase in performance of the heat sink,the DSC results also shows that the latent heat is less for

NEPCM and more for paraffin.The thermal conductivity of PCM increases on the addition of NP and there was more heat transfer when there is addition of NP.

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