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2D HEXAGONAL BORON NITRIDE-LOADED EUTECTIC PHASE CHANGE MATERIALS BASED HEAT SINK FOR THERMAL MANAGEMENT

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Abstract: In modern times, compressed and high power-density electronic appliances (100 W/cm^{2}) have drawn significant attention in recent high-end electronic applications. During the application, the chip generates heat energy. It usually operates on baseload and does not produce high heat rates all the time. However, it may dissipate extra heat load for a certain period for various reasons. This additional high heat rate needs to be dissipated efficiently; otherwise, it may lead to malfunctioning. Therefore, a unique and efficient cooling technique based on phase change material is desirable to tackle extra heat load.
2D expanded graphite and h-BN loaded eutectic-based phase change material (WG-EPCM) was developed through the melt-mixing process. The h-BN's quantity (wt. %) was varied to observe its effect on thermo-mechanical and thermal heat storage characteristics. Overall, the addition of h-BN leads to a significant increase in thermal conductivity. Differential scanning calorimetry was deployed to study heat storage capacity and transition temperature. The study on thermal conductivity, heat storage and phase transition temperature of WG-EPCM will be presented in detail.

Keywords: White graphene, Eutectics, Phase change materials, Heat storage, Thermal conductivity.

I. INTRODUCTION

A composite phase change material (PCM) for thermal energy storage could be produced when graphene oxide is mixed with disodium hydrogen phosphate. The results from X-ray diffraction, scanning electron microscopy show an improvement in thermal management i.e thermal energy storage. Due to ever growing population and the need for thermal comfort, energy consumption is increasing in geometric proportions.

Instead of air conditioning systems, phase change materials are increasingly used for indoor thermal comfort. Phase change materials can absorb or release heat according to whether the indoor temperature is too high or too low. Phase change materials are also used as thermal insulating materials. The effect of outdoor temperature over indoor temperature has been drastically reduced because of the use of Phase change materials. There are three categories of phase change materials i.e organic, inorganic and eutectic. Paraffins and fatty acids are organic and they give marginal benefits. Inorganic phase change materials like salt hydrates give outstanding performance. Eutectic phase change materials like palmitic-stearic acids give advanced cooling performance.

Various kinds of cooling systems are adopted for TMS. Currently, PCM-based materials have drawn a considerable market to maintain uniform temperature to traditional cooling methods. To intensify the effective means of storing heat, a PCM composition with appropriate phase transition is essential, as described in **Figure 1**, in which the PCM will absorb and release heat during melting and cooling, respectively. The existing PCM materials may not handle the heat dissipation solely as they possess significantly less thermal conductivity [9, 11, 12, 15, 16, 19, 20].

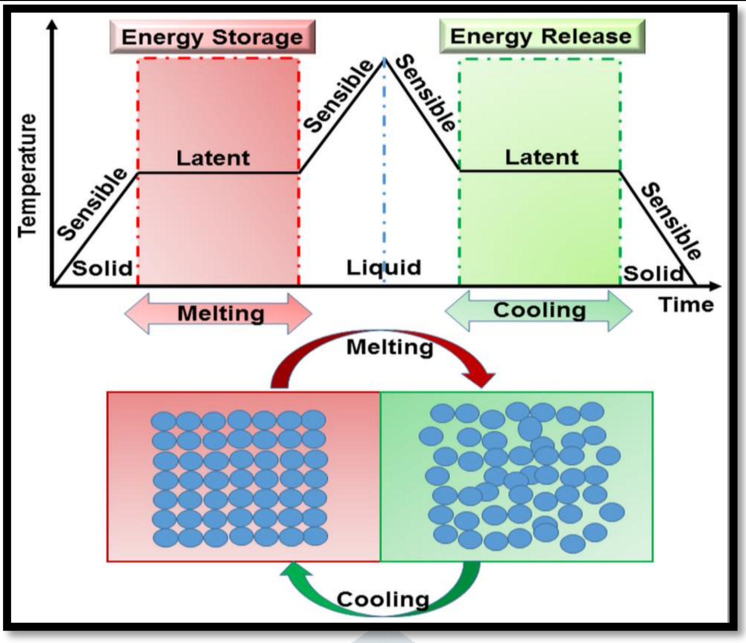

Figure 1 Illustration of underlying principle involved in heat storage/release by PCM

II. TECHNICAL PROCEDURE

The Phase change materials undergo a change in physical phase when a sufficient amount of heat is supplied [21].

As shown in **Figure 2**, during duty periods when heat is applied on the base of the heat sink, the temperature of the heat sink's surface increases until it reaches the melting temperature of the PCM. At this point, the PCM starts melting and absorbs the heat, called the latent heat of fusion, until it is completely melted. Then, the temperature increases again to reach approximately the steady state temperature that would have been reached when using a heat sink without PCM. During passive periods the stored energy will be emitted and the PCM will re-solidify.

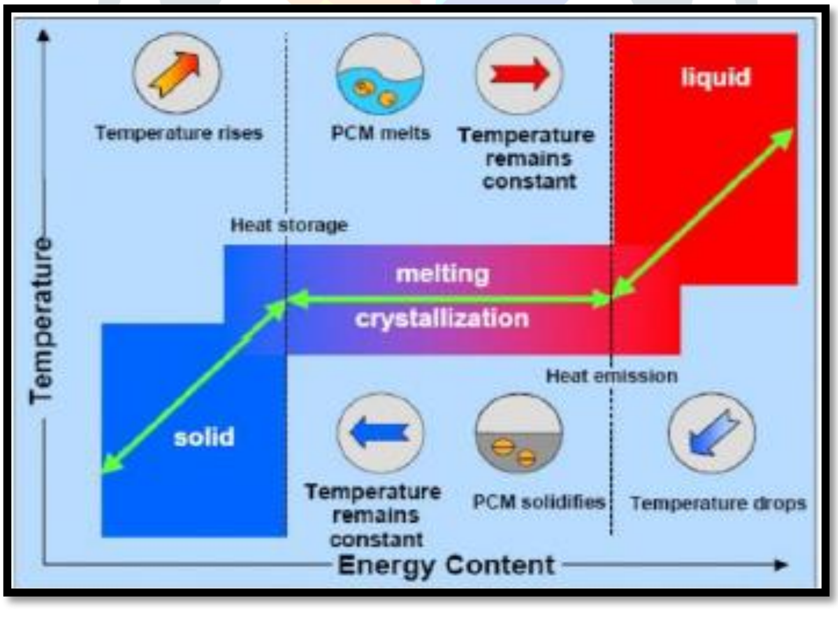

Figure 2 State of PCM with respect to Temperature.

The volume of PCM to be used depends upon the amount of energy to be absorbed during the power-on period. The factor which determines the PCM volume is the number of thermal cycles the system will experience in its useful lifetime. Resolidification of the PCM has more issues than the melting of PCM. When PCM is used at the chip level, Paraffins and hydrated salts are best suited. For high heat dissipation, heat sinks made of channels are used. For air cooled microchannels, design is made considering the laminar flow which results in lower pressure drops. Phase change materials can be incorporated to traditional heat sinks such as the standard pin-fin and longitudinal plate fins.

III. EXPERIMENTAL WORK AND MATERIALS

An experimental study was done on the heat sink for cooling of electronic appliances, with and without PCM addition of nanocomposite and nanoaaditive. The 2D expanded graphite and hexagonal boron nitride (h-BN) loaded eutectic-based phase change material (WG-EPCM) was developed through the melt-mixing process. The h-BN's quantity (wt. %) was varied to observe its effect on thermo-mechanical and thermal heat storage characteristics.

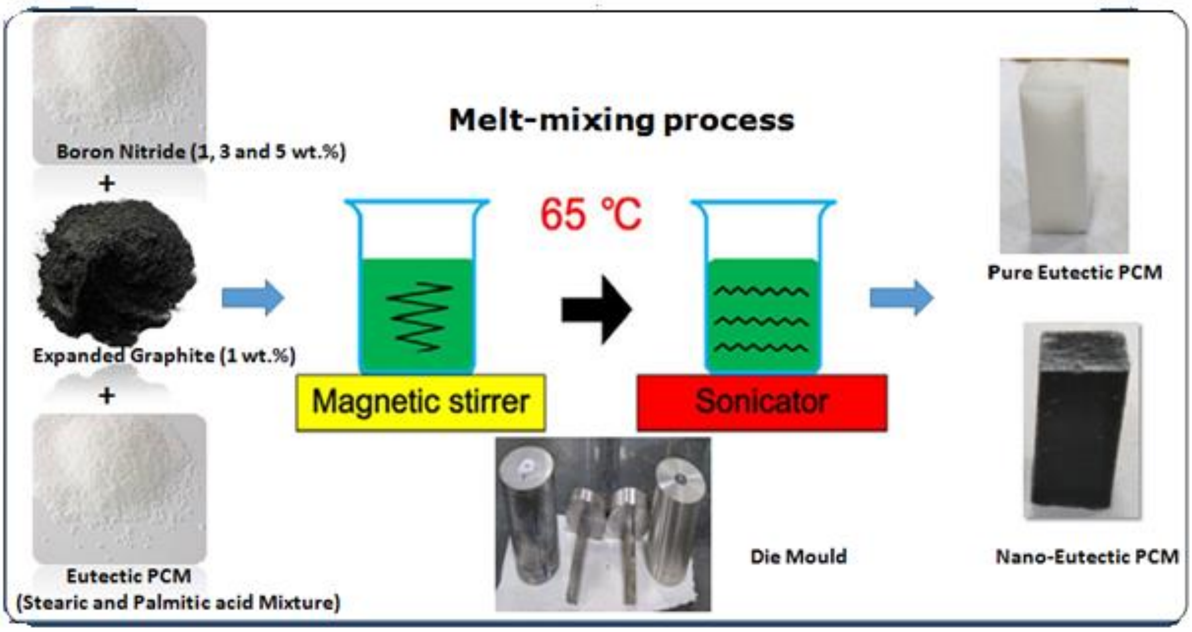

Figure 3 Schematic diagram for prepare of eutectic PCM composites

It is also observed that the thermal conductivity in the direction perpendicular to the graphene planes also does not have much variation in eutectics. Even the randomly oriented graphene flakes produce substantial increase in the thermal conductivity of the composite. The composites have only weak temperature dependence which is suitable for all Phase change material applications. In electronics and telecom equipment cooling is essential to its proper operation. Traditionally, the heat rejection has been carried out by conduction and convection techniques. Phase change materials can absorb peak energy loads during the power-on operation and then reject it at another time. They undergo phase change which enables small volumes of material to absorb large amounts of energy. Particularly, transient applications are best suited for phase change materials.

When white graphene loaded Phase change material is used, it further increases the performance. Phase change materials are selected in the temperature range at which they change phase and for the latent heat associated with the phase change. It takes advantage of thermal inertia and phase change effects combined. In order to enhance cooling, Phase change materials can be embedded into the heat exchanger structure. The two fluids at different temperatures are separated by the Phase change material.

The resulting eutectic PCM is poured into molds and allowed to solidify under controlled humidity conditions. Many graphene solutions could be obtained and they have different average thicknesses and lateral dimensions. The composites are molded into disks and they show changes in colour from white to black. The reduction in the number of hydrocarbon chains in the composites shows that reaction occurs between the alkane chains of the paraffin in the graphene hybrid PCM composite. Additions of nanoparticles to PCM are used for temperature regulation between liquid and solid states. The thermal transport mechanism occurs through both nanoparticles and the host medium. The arrangement of the graphene flakes creates a network in the PCM allowing for thermal percolation.

IV. RESULTS AND DISCUSSION

As shown in **Figure 4**, the 2D expanded graphite (1wt. %) and hexagonal BN loaded eutectic-based phase change materials (WG-EPCM) was developed through the melt-mixing process. The h-BN's quantity (1wt. %, 3wt. %, and 5wt. %) was varied to observe its effect leads to a significant increase in thermal conductivity at 5wt. % is 355 %.

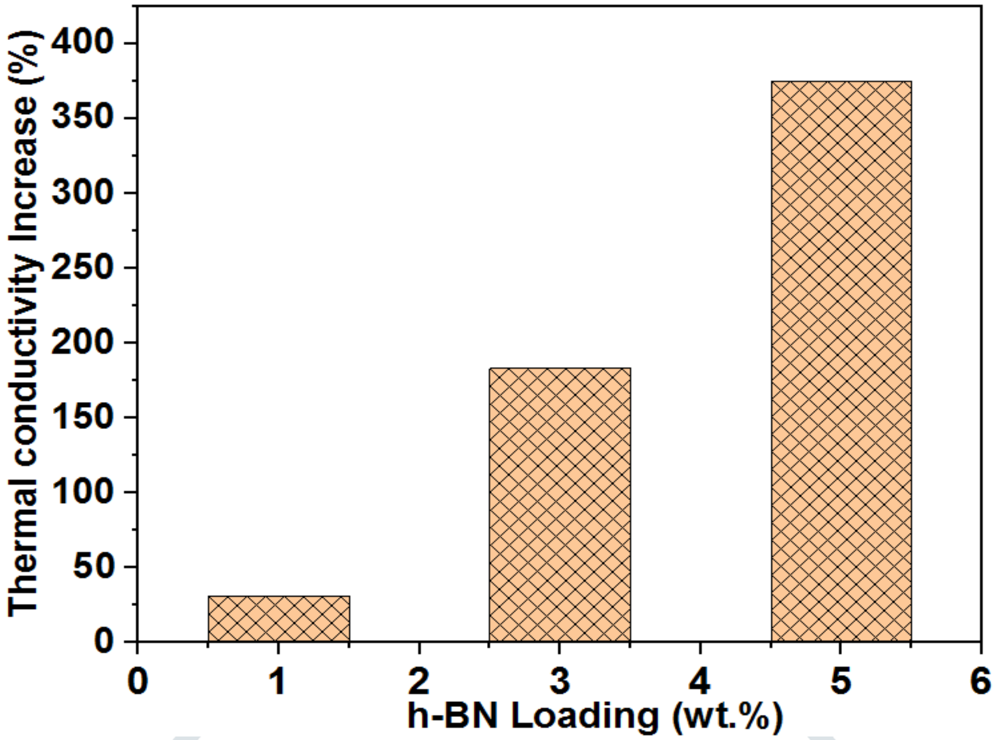

Figure 4 Influence of h-BN loading on thermal conductivity

As shown in **Figure 5,** the addition of h-BN (5wt. %) resulted in lower phase transition, which resulted in more dimensional changes (%) with nano eutectic PCM and less dimensional changes (%) without nano eutectic PCM.

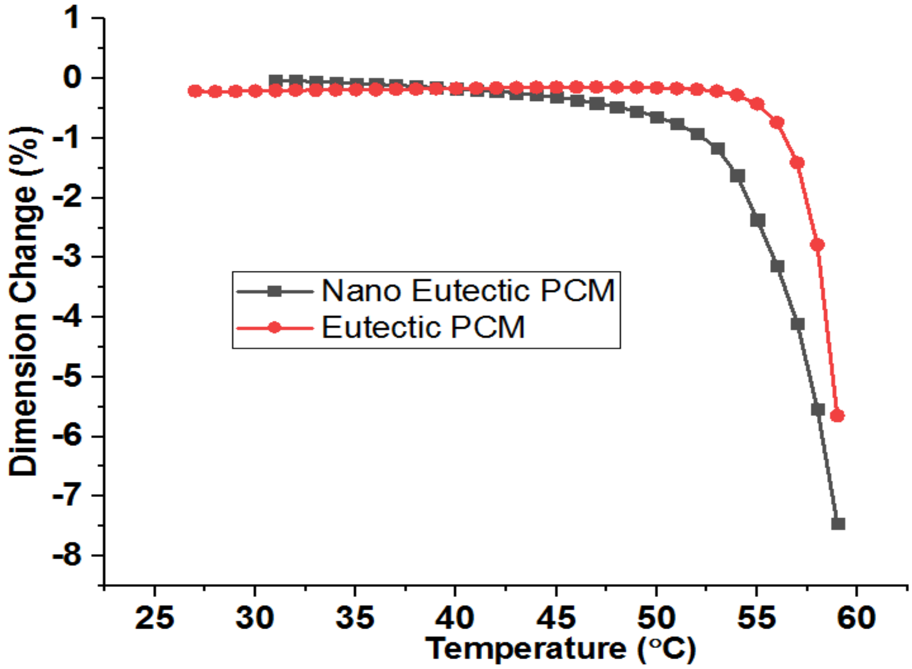

Figure 5 Influence of h-BN loading on dimensional change

The phase transition temperature, heat energy storage, and melting behaviour of EPCM were comprehensively studied by applying the DSC technique. The melting behaviour of EPCM under heating and cooling is illustrated in **Figure 6**. Heat flow curves precisely locate the phase transition temperature, such as onset temp., peak temp., and end temp. of the phase transition temperature, as shown in **table 1**. **Table 1** indicated that the measured phase transition peak temperature of EPCM with and without nano composites were around 59.8, 59.1, 58.3 and 57.1 ºC, respectively and heat energy storage were around -229.7, -226.2, -221.8, -217.4 j/g. It demonstrated that the lowering in phase transition peak temperature was noticed with the increase in the addition of h-BN loading. Increase in the quantity of nanoadditives resulted in a slight decrease in onset temp., peak temp., and end temp and also increase in heat energy storage.

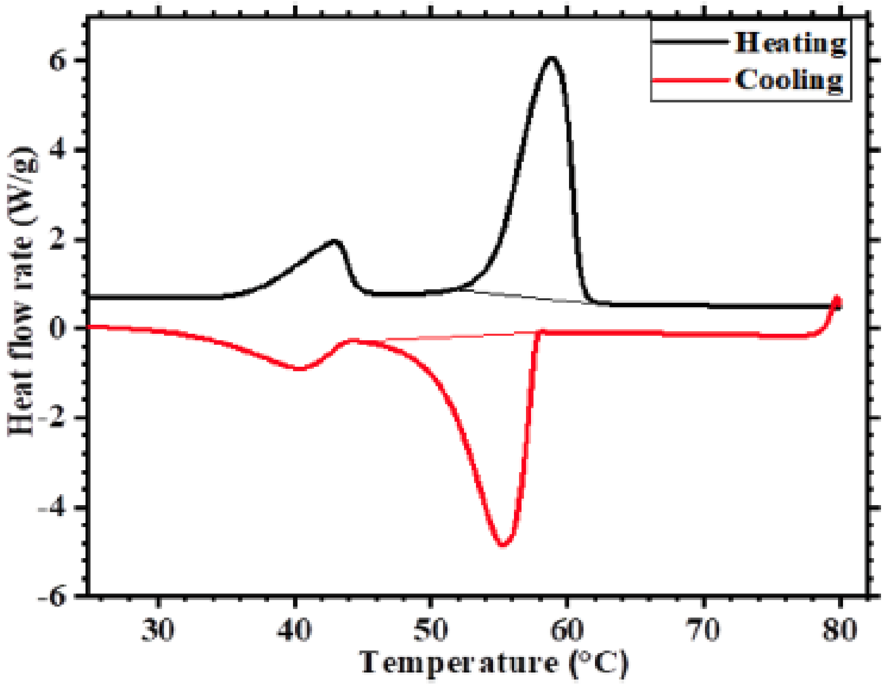

Figure 6 Influence of h-BN loading by differential scanning calorimetry (DSC) signals

Table 1 Comparison of expanded graphite and h-BN on thermal storage of eutectic PCM

S.No	Material	Onset Temp.(°C)	Peak Temp. (°C)	End Temp.(°C)	Energy Stored (j/g)
1	PCM	55.1	59.8	61.9	-229.7
2	PCM-1 WG	54.9	59.1	61.1	-226.2
3	PCM-3 WG	53.9	58.3	60.7	-221.8
4	PCM-5 WG	51.2	57.1	59.5	-217.4

V. CONCLUSION

In summary, the eutectic PCM composite materials with suitable phase transition were developed through melt mixing process. The Eutectic PCM loaded with expanded graphite (1wt. %) and h-BN (1wt. %, 3wt. %, and 5wt. %) was developed. The addition of white graphene WG (5wt. %) leads to increase in thermal conductivity by four fold. The addition of 2D WG (5wt. %) resulted in lower phase transition, which resulted in more dimensional changes (%) with nano eutectic PCM. The addition of nanoadditive lead to decrease in latent heat by 4% as it will not participate in phase transition.

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