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Enhancement of Heat Rejection Rate in Heat Sink Using Phase Change Materials

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ABSTRACT

The decreasing size and combatively low cost of electronics leads to high heat generation from the operating devices. The performance and reliability of these devices are affected by the temperatures. In that situation the thermal management of electronics devices to keep junction temperature within control has become very critical. Some of the Integrated Circuits (IC) such as Central Processing Unit (CPU), hard disk drive, chipset graphics card etc. is very sensitive to temperature. Overheated IC leads to permanent failure or temporary malfunctions. So heat generated by electronic devises must be dissipated for better performance and reliability. Heat sinks are mainly used for the heat dissipation in the IC circuits. But the incident of IC failure due to overheating represent the need for more improvement in the heat sinks. The performance of heat sink can be enhanced by using Phase Change materials (PCM). Phase change materials uses latent heat of fusion for storing and releasing heat by changing the phase from solid to liquid and vice-versa. This paper presents an optimal heat sink for efficient cooling of electronic devices. Differential Scanning Calorimetric (DSC) is used for material testing. The result shows that heat sink with PCM is able to keep IC 15 to 45% cooler than the available heat sink.

INTRODUCTION

The ever decreasing compactness in size and high resolutions of Electronic Devices (ED) leads to increase in the heat generation. High heat production in the ED decreases its performance and in some cases even blast and blows up putting human safety to danger. Thermal management is required to overcome this problem. Heat sink is considered as one of the important part in electronic devices. It dissipates the generated heat in the IC likes CPU, hard disk drive and chipset graphics card. The temperature limit of these heat sinks is minimum due to their small size and light weight. This low temperature limit fails to work at extreme conditions leading to damages in electronic devices. Lots of research has been taken up after the first heat sink work offered by the Tockerman and Pease in 1981 in improving the temperature limit of heat sink. The work is done by studding the various aspects of heat sink like basic materials, types of fins, spacing between fins, liquid cooling through micro channels and size of fins (Junaidi, M.A.R., Culham, J.R., 2007). Some of the study includes the forced convection heat transfer in heat sinks (Peles, Y., 2005) and also like the cooling of heat sink by using PCM (Leland, J., G. Recktenwald, 2003; Himran, S., 1994) yet it needs more effort to make this viable for use in electronics devices. The application of PCM will help it to increase the temperature limits. Since PCM have the ability to store and release the heat energy at almost constant temperature. The storing and releasing of heat energy by changing the phase from solid to liquid and vice-versa. It uses latent heat of fusion for storing and releasing the heat energy (Shankar, N., 2012). The PCM used in for the application in heat sink is paraffin wax.

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The DSC is used for the testing of phase change materials. The experiment is done on the home computer 'Core i3' Central Processing Unit and the result obtained by the experiment shows that after using phase change materials in the heat sink the temperature limit has increased by 15 ^{0}C.

II. Heat Sink:

Heat sinks are used in the electronics devices for thermal management. The fins of heat sink increases the surface area which helps heat to dissipate easily in the devices. Different types of heat sink are available in the market and classification of heat sink is based on various criteria. The classifications of heat sink are shown in Figure 1. In case an external fan is used to blow the air to flow over the fins, than it is called force convection which is shown in Figure 2. In case no any external fan is used for the air flow over the fins then it is called natural convection heat sink which is shown in Figure 3. Force Convection heat sinks are generally used for the home desktop.

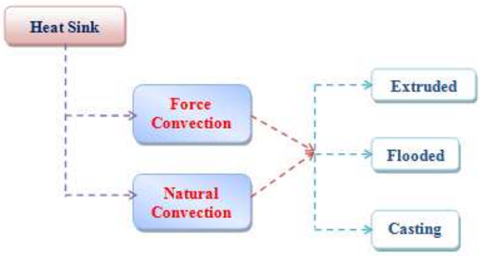

Fig. 1: Classification of Heat Sink.

Heat sinks are further classified as extruded, flooded and casting heat sinks. Extruded heat sinks are generally made up of aluminum or copper by extruding. The fin of heat sink may be rectangular or cylindrical but generally it is rectangular which is shown in Figure 3. Flooded heat sinks are used when higher power dissipation is required. The fin thickness to fin pitch ratio of flooded heat sink is low as 1:3 (Bruno, F., 2004) which is shown in Figure 4. The casting heat sink are used for the pin fin heat sinks due to pin fin these heat sink provide higher performance.

Fig. 2: Force Convection Heat Sink.

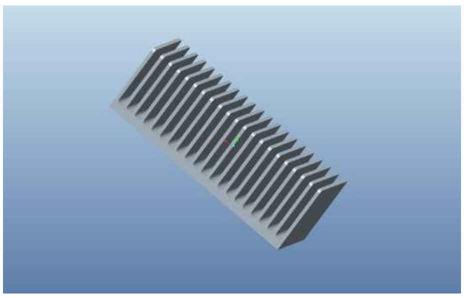

Fig. 3: Natural Convection and Extruded Heat Sink.

III. Phase Change Materials:

Phase change materials are considered as smart materials whose special property is used for the thermal management. Since it uses latent heat of fusion for storing and releasing of heat energy by changing the phase from solid to liquid and liquid to solid, allowing temperature to be nearly constant while storing and releasing heat energy. These days PCMs are used for the thermal management in various engineering fields like passive heating and cooling in buildings (Burch, S.D., 1995), reducing cold start emission in automobiles (Mondal, S., 2008), laptop cooling pad and providing high class human comfort in textiles.There is more than 500 (synthesis and natural) PCM are available in the market.

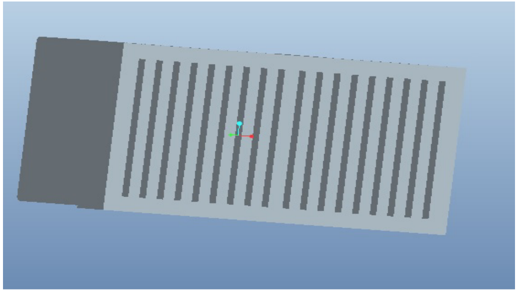

Fig. 4: Flooded Heat Sink.

Fig. 5: Paraffin Wax.

Fig. 6: Paraffin Wax in Solid Form.

3.1. Selection of Phase Change Materials:

Selection of PCM is mainly based on the melting temperature range. Some other factors like availability, chemical stability and price effective is also considered during selection. For this experiment paraffin wax is selected because it is more cost effective and available in suitable melting temperature range. Paraffin wax bought form a chemical shop in Chennai is shown in the Fig.5.

3.1.1. Preparation of Material:

The paraffin wax bought from the market is in inactive phase. The solid form of paraffin is shown in Figure 6. Phase Change Materials can only work in active phase. To make it active, PCM is heated up to 70 ^{0}C and then immersed in water for 6 to 7 hours. The PCM obtained after the preparation is in active phase. The same methods had used for the preparation of paraffin wax.

3.1.2. Testing of Materials:

DSC is used for the testing of phase change materials. Properties of paraffin wax sample were tested by Netzsch Technologies India Private Limited, Chennai

- Instrument Used: DSC 200F3 Maia.
- Temperature Range: RT-200^{o}c-RT

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- Atmosphere: Nitrogen
- Sample Crucible: Aluminium crucible with lid pierced and sealed.
- Amount of Paraffin wax tested: 3.57mg

Results obtained from the testing showed that the melting of paraffin starts at 58.8 ^{0}C and ends at 67.2 ^{0}C and in its reverse process solidification starts at 61.7 ^{0}C and ends at 58.2 ^{0}C. The heat absorbed during melting is 138 J/g while heat release during solidification is 135.2 J/g which is shown in Figure 7.

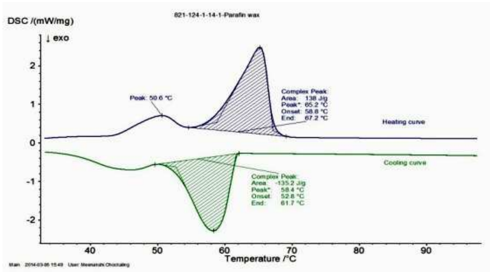

Fig. 7: Heating and Cooling Curve of the DSC of paraffin wax.

3.2. Working of PCM in Heat Sink:

PCM helps heat sink to improve the performance and increase the temperature limit. Phase change materials absorbs the heat when temperature of heat sink crosses the melting temperature limit of PCM with very small temperature change which helps heat sink to control the temperature and keeps it under limit.

IV. Experimental:

The Phase Change Material is placed between the junction box and fins, Aluminium sheet is provided for the encapsulation which will stop PCM flow in the liquid phase. The proposed system is installed in the computer CPU and a temperature sensor is placed on top of the heat sink. Computer is run for two hours and temperature is monitored and plotted. The temperature variation of heat sink without PCM was taken earlier.

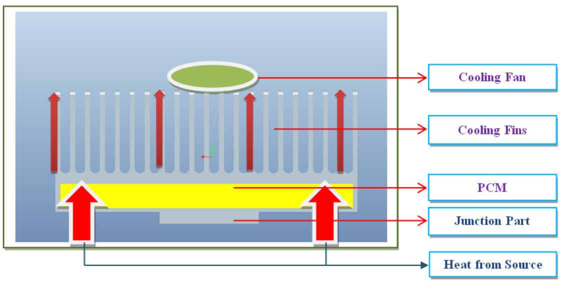

Fig. 8: Proposed System for Heat Sink with PCM.

The proposed system of heat sink using PCM for reducing the heat is given in Figure 8. In this system PCM is used between the fin and junction for increasing the temperature range. It is a force convection system because cooling fan is used in this system. In this proposed system 0.1 mm Cu tape is used for the encapsulation of PCM where the flow should be stopped during melting state. The result obtained from the experiment is shown in the below Figure 9 and which concludes that using PCM in the heat sink, ability of heat retention has been increased. By using the PCM in the heat sink the cooling capacity is also increased.

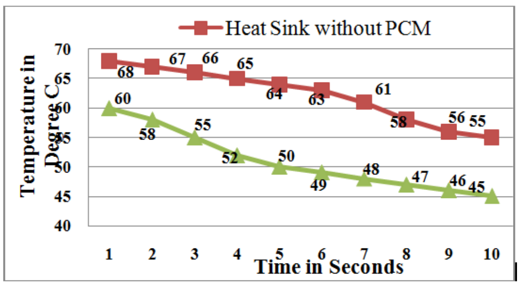

Fig. 9: Temperature Difference of Heat Sink.

V. Conclusions:

Compactness in the electronic device is a big concern because it leads to increase in the rate of heat generation. Electronic devices are very sensitive to heat and the temperature above the limit would harm the system very badly. This article reveals the application of PCM with heat sink and result clearly indicates that the temperature of the heat sink can be controlled effectively by using PCM. Here the authors have used PCM in the heat sink only. Similarly PCM can also be used for the other electronic devices where heat is produced. The heat generation in CPU is a big concern in mobile applications and PCM with heat sink can also be used in the mobile CPU for obtaining better cooling effect.

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