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Experimental Investigation on Thermal Performance and Effect of PCM based Heat Sink with Different Fins

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ABSTRACT: *Modern portable electronic devices have seen component heat load increasing, while the space available for heat dissipation has decreased. This requires the thermal management system to be optimized to attain the high performance heat sink. Heat sinks plays a major role for dissipating heat in electronic devices. Phase change material (PCM) is used to enhance the heat dissipation in heat sink. This paper reports the results of an experimental investigation of the performance of Pin fin heat sinks filled with phase change materials for thermal management of electronic devices. The experimental set ups are prepared with the graphical programming language with Lab VIEW (Laboratory Virtual Instruments for Engineering Workbench. Three different types of Pin fin Heat sink with and without PCM are investigated based on different operational timings and the temperature is acquired with the help of Data Acquisition Card (DAQ). The results indicated that the inclusion of the PCM could stabilize the temperature for a longer period and reduce the heating rates and peak temperatures of heat sink with increasing the number of fins can enhance the thermal performance of electronic devices.*
Keywords - *Heat sink, Phase change material (PCM), Thermal management, Electronic cooling.*

I. INTRODUCTION

The major challenge in the semiconductor field is to manage the heat in the IC chips without compromising on the performance of the device. The advancement in technology increases functionality of electronic devices, similarly decreases their size and weight. These advanced functions require more sophisticated electronics, which will generate extra heat. Heat generated in electronic devices must be dissipated to prevent immediate failure, improve long term usage and increase high performance of the chips. Thermal management is one of the most active area in the development of new microprocessors for electronic products like personal digital assistants (PDA), mobile phones, notebooks, laptops, iPods, etc. Alawadhi and Amon [1], investigated thermal energy management issues associated with portable electronic equipment. Several methods are used to reduce the temperature through heat removal from active devices. Among the various thermal management methods in electronic system [2,3] like using extended surfaces, inserting high thermal conductivity materials like paraffin wax in heat sink, and embedding PCM in porous media, extracting heat from a processor is to connect it to a heat sinks, which is air-cooled, either actively or passively are most effective techniques. Heat sinks usually have fins to increases their surface area, which increases the amount of heat that they can release to the ambient air stream. Selection of heat sink is one of the important process among the huge variety of heat sinks. According to their size, thickness and fin types, they are used in several areas like electronic devices, chipset purposes, etc. R. baby et al. [4] discussed about the larger number of uniformly distributed fins in heat sink have larger responsibility for enhancement in heat transfer. In recent trends phase change material (PCMs) have been widely examined as additional cooling methods for such transient electronic cooling applications. In PCM heat is stored (absorbed from hot component) during melting and is released to ambient during the freezing point. Heat storage capacity of PCM depends upon the latent heat and melting point. But the performance of heat sink is not sufficient for latest developments in electronic devices. Krishnan et al. [5] proposed a hybrid heat sink which combined an active plate fin heat sink with the tip immersed in a passive PCM. To increase the efficiency, PCMs are the additional substance added with heat sinks. Increases in power input increases the melting rate of the PCM [6,7]. Hodes et al. [8] studied the transient thermal management of a handset using a PCM. The thermal energy absorbed during the melting process at a constant temperature, generates the required cooling effect of PCM [9].

II. EXPERIMENTAL INVESTIGATION

2.1. Selected materials

The heat sink is made up of aluminum and the fin types are shown in Fig. 1,2 and 3. Aluminum was the early choice for a heat sink because of its relatively high thermal conductivity and ease of manufacturing. Increased needs for higher thermal conductivities led to consideration of copper. Still, both materials suffer from high thermal expansion, which provide challenges to mounting the heat sink to the silicon chips. But cost wise aluminum is best then copper. The properties of aluminum are shown in Table 2.

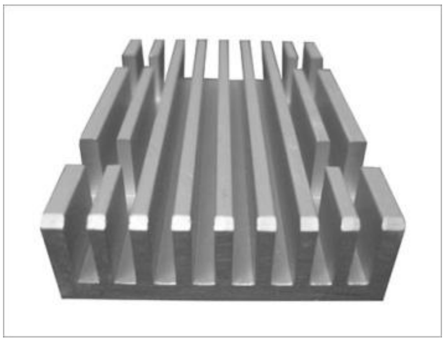

Fig. 1. Aluminum heat sink with thickness 3.5mm (64mm×61mm×20mm)

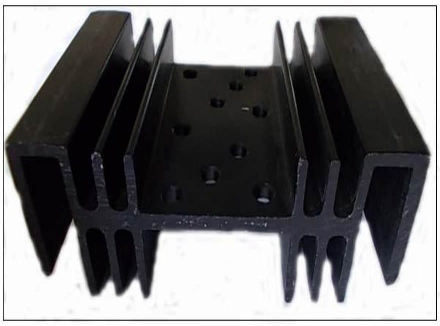

Fig. 2. Aluminum heat sink with thickness 3mm (93mm×64mm×35mm)

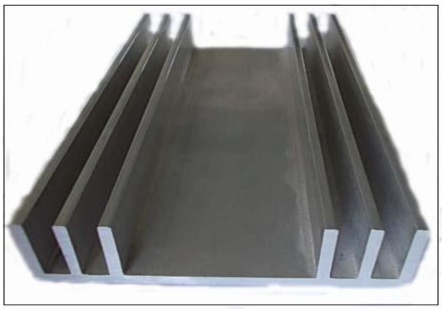

Fig. 3. Aluminum heat sink with thickness 2.5mm (125mm×67mm×18mm)

In this experimental investigation Paraffin wax is used as the phase change material (PCM). The properties of paraffin wax is shown in Table 1. Heat transformation in PCM is very efficient and nearly whole amount of phase change material absorbs excess heat immediately after thermal disturbance from the device is proved by Maciej Jaworski [10]. Inclusion of PCM could stabilize the temperature of electronic devices for a longer period of its usage [11]. Lowest melting temperature shows the best performance in terms of lowest operating temperature and longest duration of low heat sink temperature [12]. The use of PCM is a passive cooling option [13]. The inclusion of PCM in the base and cavities of heat sink will increases the thermal performance of the electronic system are discussed by Xiang-Qi Wang et al. [14] and R. Kandasamy et al. [15] respectively. Tan and Tso [16], found that the effectiveness of heat storage unit depends on the amount of PCM used. The transient phase change process depends upon i) The heat flux from the base, heat capacity of PCM and fin dimensions, this statement is proposed by V. Shatikian et al. [17,18]. From Yue-Tzu Yang et al. [19] PCM based heat sink have more stable operation temperature. The optimal PCM percentage depends on the number and length of fins, heat flux of the heat sink [20]. The effectiveness of PCM-based heat sink depends on the amount of PCM being used in the heat sink [21].

Table 1: Properties of Paraffin Wax

Property	Value	Unit
ρ_l	750	kg/m^3
ρ_s	900	kg/m^3
k_l	0.12	W/m K
k_s	0.21	W/m K
c_p	2890	J/kg K
T_m	46-48	$^{\circ}C$
L	173,400	J/kg

Table 2: Properties of Aluminum

Property	Value	Unit
k	180	W/m K
ρ	2700	kg/m^3
c_p	963	J/kg K
T_m	660.4	$^{\circ}C$

2.2. Setup

The real time experiments sets are prepared in accordance to the theoretical structure. The setup consist of heater with power supply, which is used to generate the heat and transfer to heat sink. A heater with 2 mm thickness is used to mimic the heat generation in electronic chips. Aluminum heat sink is placed near the heater. To prevent from the excess heat the heat sink is placed with atmospheric conditions, it is covered with a box, which is made up of fiber glass material. Thermocouples are used to measure the temperature, one end is connected with the heat sink and other end is connected with temperature DAQ (Data Acquisition). The DAQ card is connected with the desktop computer, the heat dissipation takes place in heat sink is measured with the help of DAQ Assistant among the functions is used in order to transfer the values, read by the data acquisition card, into Lab VIEW environment. The experimental setup of this investigation is shown in Fig. 4.

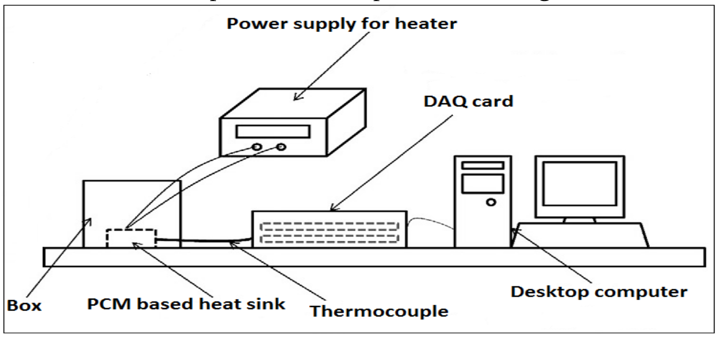

Fig. 4. Experimental setup

2.3. Procedure

The ordinary heat sink (without PCM) is heated with the help of heater and the measure of temperature in heater and heat sink are noted. By changing the heat sinks with different fin types, the corresponding values are measured. To investigate the better performance of PCM-based heat sink, heat dissipation takes place in ordinary heat sink is measured. Different fin configuration and the thickness of heat sink play a major role in heat dissipation from electronic devices. The transient phase change process depends upon the heat capacity of PCM, heat flux from the base and fin dimensions of the heat sink. Then the PCM is heated up to the molten state and is applied on the surface of the heat sink. The heat sink with PCM is made to be kept some times for cooling. The same procedure is carried out to measure the heat dissipation takes place in PCM-based heat sink. Graphs are drawn by the measured reading.

III. NOMENCLATURE

Symbols	Specifications
ρ_l	Liquid density
ρ_s	Solid density
k_l	Thermal conductivity (liquid)
k_s	Thermal conductivity (solid)
T_m	Melting temperature
L	Latent heat
c_p	Specific heat

IV. RESULT AND DISCUSSION

In result we are going to compare three heat sink with PCM and without PCM. The thermal properties of each heat sink differs by their thickness and fin types.

4.1. Effect of heat sinks without PCM

To find the heat dissipation takes place in heat sink without PCM, the different heat sinks are taken as three samples are taken and they are tested by varying their time at constant temperature. This results that the temperature rise up to certain level and gradually decreases with respect to time. The heat dissipation takes place in heat sinks differs with each other.

4.2. Effect of heat sinks with PCM

The sample heat sinks are coated with paraffin wax. Then the PCM based heat sinks are tested to find the heat dissipation takes place in it. By comparing the values of heat sinks with and without PCM, the performance of PCM-based heat sink is greater than normal heat sink. The overall (average) performance of heat sink with and without PCM are plotted in Fig. 5.

4.3. Effect of heat sinks with different fin types

In different fin type, the heat dissipated by the heat sink differs according to their thickness and variety of fins. Decrease in thickness increases the heat dissipation capacity of heat sink. By comparing fins, the cuttings in linear fins Fig. 1. has higher performance in heat dissipation process than other two heat sinks.

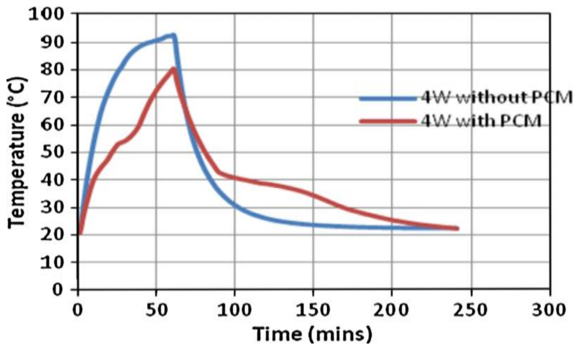

Fig. 5. Overall (average) performance of the heat sinks

V. CONCLUSION

To overcome the drawbacks in electronic thermal management system this experimental investigation is carried out. From this investigation the performance of heat sink is enhanced. On the bases of this experiment, the thermal performance of PCM-based is greater than the normal heat sink (without PCM). Then according to the effect of different fin types, heat dissipation in heat sink with complex structure shows less performance. Heat sink with cuttings in its linear fin type (Fig. 1.) gives the higher performance than other heat sinks. The heat sink with greater thickness consumes more heat and dissipate it quickly than other heat sinks. The results indicate that the operational performance of electronic device can be significantly improved by the use of pin fins in heat sinks filled with PCM.

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