Passive Cooling Of Electronic Devices Using Infrared Transmitting Materials

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Abstract*—The Intel technologies India private limited, Bengaluru has been engaged in research of passive cooling of electronic devices using infrared material. This project reflects the temperature behaviour of electronic devices using transmitting materials. The current devices dissipate the heat majorly in the form conduction, convection and by radiation in small amount. The path of heat transfer by heat pipes, spreaders, cooling pads and heat sinks can be reduced by dominating radiation mode of heat transfer. In order to dissipate most of heat by radiation mode of heat transfer requires materials to transmit the radiation energy and to cool the processor. For daily operating temperature, infrared transmitting materials are having capability of transmitting the infrared energy from source to ambient and this will results in decrease of skin temperature of the system.*

Keywords—infrared transmitting materials; radiation heat transfer;emissivity; passive cooling and polymers

I. INTRODUCTION

In electronic devices, the heat is produced by the CPU, GPU, hard disk drive and optical disk drive etc. But SOC will dissipate most of the heat among all other components. The same heat should be removed or transported from these components otherwise it causes the overheating of components, which lead to loss of their functionality and ultimately reduces performance of the components in-turn it affects overall system performance. Ergonomically also it is essential to maintain low skin temperature as well.

There are two types of cooling systems are employed in electronic devices i.e. passive and active cooling. In the active cooling system the heat is transported by heat pipe and transferred to heat sinks. From the heat sinks the heat is removed by forced convection of air, which is generated by the fans or blowers. Passive cooling is achieved by natural convection and radiation heat transfer modes. In general, the rate of heat transfer can be increased using heat spreaders, phase change materials and heat pipes if required. In active devices, the convective mode of heat transfer is much higher compared to radiation mode of heat transfer. In case of passive devices, the radiation heat transfer is significantly high comparable to the natural convection. In order to increase the heat dissipation, the surface area of the spreaders can be increased. However, beyond certain point the increase in area no longer beneficial or it may be constrained by the adjacent components. Therefore, it is essential to investigate other means to achieve enhanced heat dissipation from the hot components. Therefore, it is essential to investigate other means to achieve enhanced heat dissipation from the hot components.

J.A.Cox [2] identified the binary and ternary systems for producing long-wave infrared transmitting glass-ceramics, and they produced glass-ceramics by using Ga2S3, GeS2, or As2S3, which are capable of transmitting LWIR. By the research of R.W.Tustison's [3], it came to know that polyethylene is having good transmitting property among all the polymers and their transmittance will decrease with their thickness.

II. MOTIVATION

Since the radiation mode of heat transfer does not require any medium to travel, enhancing radiation in passive devices or active devices is a prominent research area. From the electromagnetic radiation spectrum, based on the operating temperatures of the components, most of the radiation falls under infrared region. Therefore, adopting infrared materials for some of the chassis materials can significantly enhance the overall heat dissipation. The current research aims to study best materials suites and the associated benefits for improved cooling using infrared radiation materials.

III. INFRARED RADIATION

In the daily life, laptops, notebook and other electronic devices usually produces the heat of 30 to 100º C. In order to work on this, should know about the region for operating temperature in the electromagnetic spectrum. In order to calculate that, use Wien's displacement law about radiation heat transfer. According to Wien's displacement law,

$$\lambda * T = b = 2900\ \mu m\ k \qquad (1)$$

Since operating temperature is known, substitute and get the wavelength range for operating range by Wien's law.

Table 1. Wavelengths for different temperature

Temperature (°C)	Wavelength (µm)
30 (303k)	9.57
40 (313k)	9.26
50 (323k)	8.97
60 (333k)	8.70
70 (343k)	8.45
80 (353k)	8.21
90 (363k)	7.98
100 (373k)	7.77

Wavelength data from the table 1, clears that operating range falls in the infrared radiation region. Within infrared radiation spectrum, there are three types of infrared radiation bands classified as follows

- Short wave infrared radiations (0.7-2.5 µm)
- Mid wave infrared radiations (3-5 µm)
- Long wave infrared radiations (7.5-14 µm)

The current operating temperature falls under long wave infrared radiations (LWIR), therefore materials which are having good transmittance property in long wave infrared region have to be selected.

A. Materials in the electromagnetic spectrum

Since wave length depends on temperature, the change in wavelength subjected to change in temperature of the materials. Based on atomic activity and dislocations, different materials exhibits different wavelengths. Out of all materials listed, one can select appropriate material which best suits for the required application with good transmittance property at long wave infrared radiation region in the electromagnetic spectrum. So that, it can be implemented for dissipating the heat in electronic devices (transmit the IR in 8-12µm).

Table 2 shows the properties of materials with transmittance Vs wavelength. In the table 2 the different materials which are capable of transmitting infrared radiation through them are listed with their transmittance value and the wavelengths corresponding to them. In the listed materials zinc selenide and zinc sulfide are having good transmittance properties among all in the long wave infrared region. Even though magnesium is having good transmittance, it can be used in long wave infrared region.

Table 2. Transmittance properties of materials

Materials	Transmittance (%)	Wavelength range(µm)
Germanium	45	3-15
Silicon	40-60	5-10
Zinc selenide	70	.6-12
Calcium fluoride	95-90	1-8
Magnesium fluoride	93-95	1-6
Sodium chloride	90(WS)	5-10
Potassium bromide	90(WS)	1-20
Zinc sulfide	72	1-14

By observing the table 2, Silicon, calcium fluoride and magnesium fluoride can't be used, since these are not capable to transmit the infrared radiation effectively for a long wave infrared region (8-12µm). Even though sodium chloride and potassium bromide having around 90% transmittance, there utilization is going to limit because of their water solvable property. Water solvable materials can't be used in electronic gadgets.

B. Polymers

The polymers were another option for IR materials since metallic IR material are costlier compared to polymers, this is also one of the parameter for choice of polymer based IR material. Studied different polymers, compared their transmittance and shown in the below figure 1.

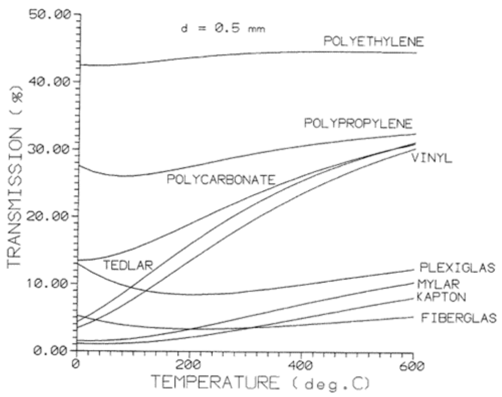

Figure.1: Variation of transmittance with different polymers

From the figure 1, it shows that polyethylene is having good transmittance among all polymers. Even though polypropylene having good transmittance, it is lesser than that of polyethylene. And in the case the polymers, transmittance decreases with increase in thickness.

Using polymers with thickness more than 0.72 mm will affects the transmittance property of the material.

Because the increase in thickness will adds more atoms, which will block the incident radiation.
The metallic IR materials were too costlier and by using polymers, material cost can be reduced thereby cost of device will be decreased.

IV. EXPERIMENTATION

As shown in the figure 2, Place the thermocouples on the testing materials and insulate them using kapton tape. By using the power source, supply the specified power to the heaters. Thermocouples are integrated to the DAQ module to read the temperatures. DAQ module assists the DAQ logger to read the temperature in the electrical form and same will be sent to net data logger software to read the temperature.

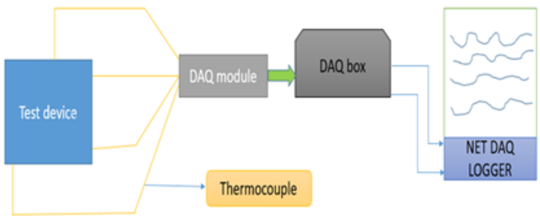

Figure 2: line diagram of Experimental set up for thermocouple testing

V. RESULTS

The temperature reading were left to stabilize for 15 min to have temperature variation of less than 1ºC. And the experimental data for the test material is given below in the table number 3 for 2W power supply to the device. Where, thermocouple 1 – on the junction, 4 – on the IR material, 11 – on the skin (surface of enclosure), 12 – on the skin and 15 – on the skin are placed.

Table 3. Temperature data for different thermocouple on test device

thermocouple	Temperature in degree celcius			
	NO IR	2110a	2020	2058
1	86.01	85.47	85.2	84.63
4	35.85	42.56	44.94	44.11
11	34.95	34.21	33.82	33.42
12	34.69	33.81	33.44	33.03
15	34.72	34.39	33.79	33.55

Thermocouples in the IR region are experienced more temperature than no IR condition. Two thermocouples on the surface other than IR region are experienced low temperature. The increase in temperature at IR region is showing the heat dissipation. As a result to this, the temperature of junction also got reduced and the surface also experienced less temperature than no IR case, the results are plotted and shown in figure 3 for analysis.

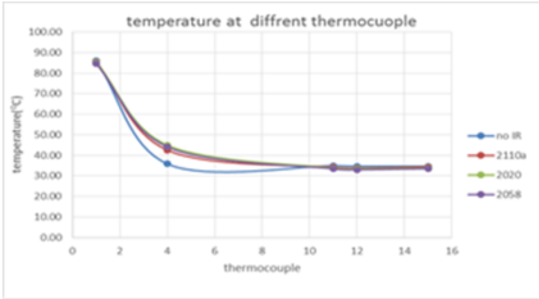

Figure 3: temperature variation with different regions on the test device.

A. Capturing the IR images

In order to see the temperature distribution in the setup, captured the IR images in the infrared camera to analyze the temperature distribution. Heat the material with a heat source and take the temperature value when it attains constant temperature by the help of thermocouples. At the same time, set this temperature in IR camera and point it on to the material. By setting same temperature, IR camera will show the emissivity of material. Now, by setting emissivity in IR camera, can get the temperature measurements of IR materials and hottest regions. The IR images captured for the 2w power supply for both with IR and without IR case to have a comparison between the two cases and are shown below in the figure 4 and 5.

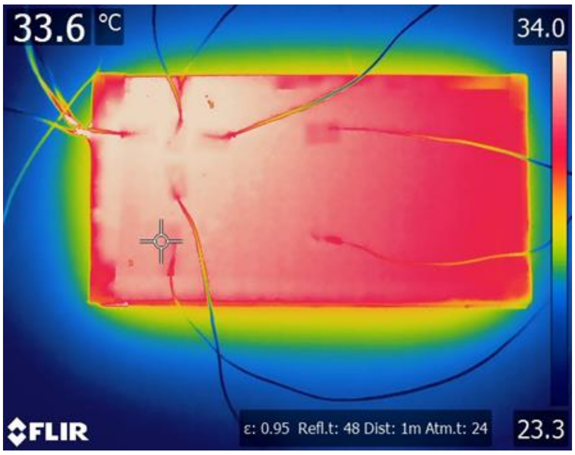

Figure 4: IR image of test device without IR material

The figure 4 showing temperature distribution at the enclosure of the device by indicating that with red colour and showing that temperature of the enclosure is the highest value among the area captured in the IR camera at 24ºC of atmospheric temperature for the emissivity of 0.95 for the chassis material used in the enclosure of the test device. The IR image should be taken within two meters distance for better results, so

IR images are captured at 1m apart from the test device at laboratory condition.

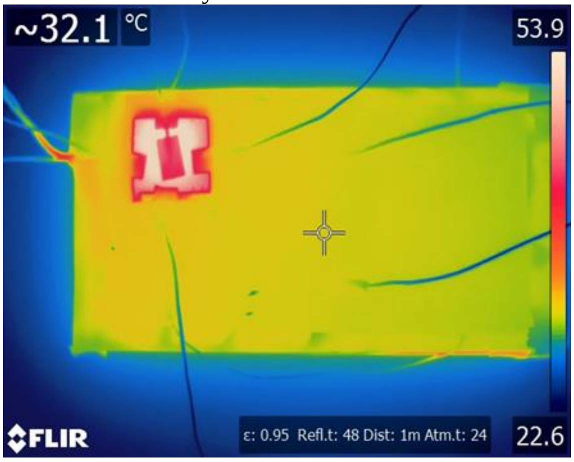

Figure 5: IR image of test device with IR material in the enclosure.

In the figure 5 the IR image is showing 32.1ºC for IR implemented enclosure. By observing the two figures it clears that, the surface temperatures are low in case of IR materials compared to no IR case. Only at IR region it's showing red colour that means, IR materials are dissipating the heat through them and their by reducing the temperature of the surface.

VI. CONCLUSION

From the experiments, the temperature at IR region is more as it is transmitting more radiation energy. As a results of this, source & device's surface temperatures are lower when compared with the condition in which IR materials were not used.

VII. FUTURE RECOMMENDATION

With smaller IR samples, it's able to achieve 1ºC lesser temperature at the source. The cooling can be increased by increasing the area of IR material and Metallic IR materials such as Ge/Zn S can be a good choice, as they are having good transmittance and rigidity compared to polymers.

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