International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-1 Issue-2, June 2012

A Novel Method to Reduce the Thermal Contact Resistance

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Abstract:- In this research work, a novel method is designed to reduce the thermal contact resistance at the interface between the heat sink and the computer processor. One of the major problems in using high conducting materials or greases as the thermal interfacial materials is, the circuitry inside the processor which is lying near the interfacial wall will get shorted and the some of the transistor may not function as intended thus leading to the failure of the processors. Hence low electrically conducting interfacial materials are preferred. Usually for most of the materials, the electrical and thermal conductivities are proportional to each other. However, the drawback in using the low electrically or thermally conducting materials is, it cannot remove the heat generated from the high speed processors fast enough thus increasing the temperature of the processor. With the raise in temperature, the performance of the processor drops down. To avoid this, low conducting grease is applied to the processor first in the order of 5 microns and highly conducting grease is applied between the processor (over the low conducting grease) and the heat sink. The performance of the two layers of the grease is measured in this work and compared with a single layer of the grease.

Keyword:- Thermal interfacial materials, grease, aluminum foils, thermal contact resistance, thermal conductivity, electronics cooling.

I. INTRODUCTION

The processor is a highly interconnected electronic circuitry with numerous electronic devices called transistors. The devices function as per the program that is being executed. by the processor. The number of transistors decides the capacity of the processor. Higher the speed of the processor, higher the speed at which these transistors function. At higher speed the processor generates hear at higher rates and then need to be removed immediately to prevent the raise of temperature of the processor. The size reduction of electronic components and the advances made in that area have increased the heat flux dissipation drastically. In the last two decades, packages have been shrunk to a hundredth of their initial size. Today, heat fluxes in computer chips are of the magnitude 100 W/cm2The most commonly used method for maximizing the thermal contact conductance consists of filling the interfacial gap with thermal grease, during the assembling phase [2]. Recently, some interstitial materials are developed, like metallic, non-metallic or phase change material (PCM)-coated foils. The purpose of the present experimental study is to compare the performance of various interstitial materials.

The surface characteristics such as flatness, waviness and roughness have a major impact on the thermal contact resistance decreases with the increase in surface flatness. In contrast, thermal contact resistance decreases with decrease in waviness and roughness [4-8]. The thermal contact resistance is usually is parted into two parts/ One with a macroscopic resistance that varies with the waviness and flatness, and other is a microscopic resistance varying with the roughness. Another important parameter that controls the thermal resistance is the hardness which affects the deformation amplitude of the surface under a load. Softer the material, lesser the thermal contact resistance. Under a given load, the asperity deformation is greater for a soft material than for a hard one. Hence, the effective contact surface area is larger and the thermal contact resistance lower. As pressure increases a greater asperity deformation happens and the thermal contact resistance reduces. Usually at lower pressures, deformations are elastic and the macroscopic resistance dominates over the microscopic one, whereas at high pressures, deformations are plastic and the inverse phenomenon occurs [4, 9-11]. Another important parameter is the interface pressure distribution over the entire surface of the joint. The heat fluxes are not uniform if there are bolted joints. In such cases, the thermal contact resistance is minimal under the bolt head and steeply increases away from the bolt centerline [12,13].

There is some research work focused on the heat flux variation with stress undergone by the contacting materials on the thermal contact resistance [14]. It proved that repeated loading unloading cycles produce a plastic deformation of the surface, so that the contact is flattened and progressively improved. The thermal contact resistance becomes stable after a certain number of cycles. Even when the load is independent of time, the material plastic flow causes a thermal contact resistance variation during the initial days after the assembly [14, 15]. The thermo physical properties of the contacting materials also play an important role on the thermal contact resistance. High values of thermal conductivity and thermal expansion coefficient

Manuscript Received on May 15, 2012.

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can have a favorable effect on the resistance. As thermal conductivity and thermal expansion coefficient vary with the temperature, the thermal contact resistance depends on the temperature at the interface [14].

Introducing a thin layer of oil or grease between the surfaces [2,16-19] is the most popular to reduce the thermal contact resistance. The optimum thickness of the interstitial material depends on the thermal conductivity of the grease, which can be further improved by adding metallic particles to the silicone greases. Properties of Oil and grease may be altered when they are subjected to high temperatures for a long duration because they have a tendency to migrate and vaporize out of the contact area, all the faster as the interface temperature is higher [19]. As the interstitial layer thickness becomes not uniform, the thermal contact resistance increases. Another method to improve the thermal conductance consists of introducing a thin metallic or non-metallic foil between the contact surfaces [2, 4, 16, 17, 20]. Due to the deformation of the foil under the pressure, the number of contact areas increase thereby decreasing the thermal contact resistance due to constriction of the heat flux lines. The load pressure should be an optimum one for maximum thermal contact conductance. Too low a pressure will lead to a bad contact and a too high a pressure will lead to a foil damage. Hence, the foils are recommended to be made of a soft material to conform exactly to the profile of the contacting surfaces. Thus, non-metallic foils are typically made of carbon or silicone and charged with metallic particles. Snaith et al. [16] proved that the best results can be obtained when copper; indium or lead foils are used at the interfaces. If the foil material is at the solid state for the operating conditions, migration and dry-out problems can be avoided. But, some foils are difficult to implement practically because of their fragility, their adhesiveness to crease and their bad adherence to the surfaces, leading sometimes to degradation of thermal conductance. One can use some special treatments to enhance the heat transfer between contacting surfaces like anodized coating [2,16,21] or chemical vapor deposition (CVD) [2,16,22,23]. The type of coating type depends on its hardness mainly. Thus, the CVD is the most effective, but costly treatment because the microscopic resistance dominates over the macroscopic one. As for the other processes are concerned, there is an optimum coating thickness for given maximum thermal contact conductance. A high load application may possibly lead to degradation of conductance due to the coating cracking. The main disadvantage of this method is its difficulties in practicality and cost, since CVD is performed in a vacuum environment.

II. CONTACT RESISTANCE MODELS

Experimentations were carried to find out the thermal contact resistance for different varieties of interstitial materials and combinations. An intel processor and an aluminum heat sink 37.5 mm x 37.5 mm are considered for experimentation. The processor maximum temperature at the center point of the top surface is 51C at 30W and 71C at 110 W of power rating. The temperatures of the processor at the other power ratings can be calculated based on linear interpolation and is experimentally verified. The thickness of the interstitial material at the interface between the processor and the heat sink is maintained by applying pressure and using standard shim to maintain a definite thickness.

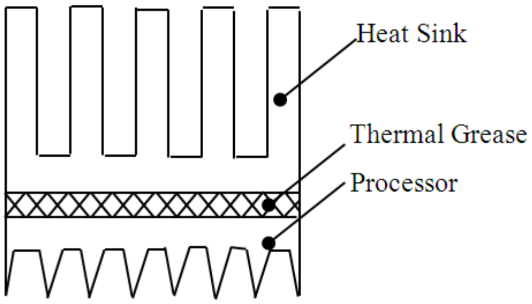

Fig. 1: Heat sink and processor with low or high conducting thermal grease as adhesive

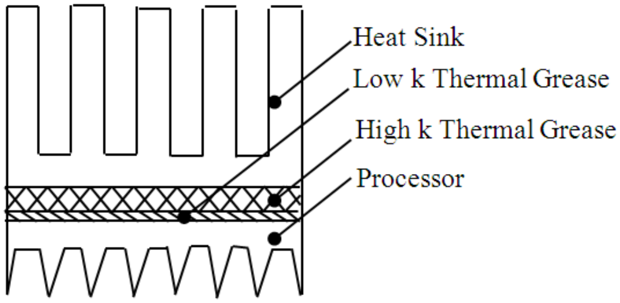

Fig. 2: Heat sink and processor with low and high conducting thermal grease as adhesives

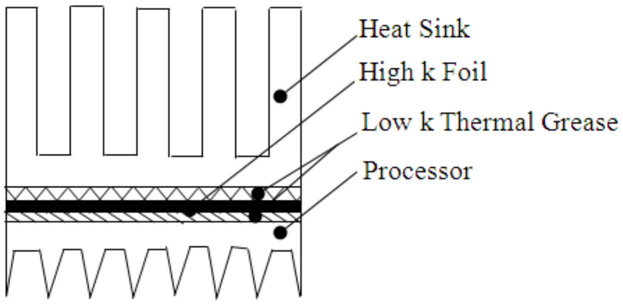

Fig. 3: Heat sink and processor with low conducting thermal grease as adhesives and highly conducting foil in between

In this experimentation, three models are tested, which are given as follows.

1. Heat sink and processor with low or high conducting thermal grease as adhesive (PGH: Processor-Grease-Heat sink)
2. Heat sink and processor with low and high conducting thermal grease as adhesives (PG_1G_2H: Processor-Grease-Grease-Heat sink)
3. Heat sink and processor with low conducting thermal grease as adhesives and highly conducting foil in between (PG_1FG_2H: Processor-Grease-Foil-Grease-Heat sink)

In the PGH model, grease can be a high conducting grease or low conducting grease. The advantage of low conducting grease is that it does not short the internal circuitry of the processor at the interface and hence the life of the processor is high. Some of the examples of the greases that can be treated as low conducting greases are listed in table 1. The ratings are only a recommendation and do not have any engineering proof for this naming convention. Low conducting grease should have a thermal conductivity as close as possible to that of the processor top surface. From the list of greases that were collected for the experimentation, the greases with thermal conductivity less than 1 W/mK are considered as “Low”, between 1 and 3W/mK as “Medium” and above 3W/mK as “High”.

Table 1 shows the types different interstitial materials and forms used along with their thermal conductivities.

Table 1: Interstitial materials and forms vs thermal conductivities.

Interstitial Material and Form	Thermal Conductivity in W/mK	Rating
G 641 Silicone grease Type I	0.83	Low
Crayotherm 8844 (Orcus) PCM foil with 51 mm thick polyamide support	0.63	Low
Crayotherm 8845 (Orcus) PCM foil with 76 mm thick polyamide support	0.63	Low
DC 340 (Dow Corning) Silicone grease with metallic oxide powder	0.42	Low
P 12 (Wacker) Silicone grease with metal powder	0.81	Low
Silicone grease based on polydimethylsiloxanic oil, with metallic oxide powder	0.41	Low
Eupec (Henton) Grease	0.81	Low
Unial (Henton) Grease	0.83	Low
CHO-Therm 1678 (Chomerics) Silicone foil with boron nitride	1.6	Medium
CHO-Therm 1674 (Chomerics) Silicone foil with aluminium oxide	1.7	Medium
Kerafol 86/30 (Keratherm) Polymeric foil, with alumine oxide, fibreglass and ceramic reinforced	2.1	Medium
Kerafol 86/50 (Keratherm) Silicone foil with boron nitride	2.9	Medium
Furon C675 Aluminium foil coated on both sides with acrylic adhesives	1.1	Medium
G 641 Silicone grease Type II	1.7	Medium
G 641 Silicone grease Type III	2	Medium
G 641 Silicone grease Type IV	3	High
G 641 Silicone grease Type V	5	High
Kerafol 90/20 (Keratherm) Graphite foil	4.5	High
Furon C695 Graphite foil coated on one side with acrylic adhesives	4	High
Crayofoil 8846 (Orcus) PCM foil with 51 mm thick aluminium support	207	High
Thermafoil 8843 (Orcus) PCM foil with aluminium support	207	High
domestic aluminium foil	207	High

For the PG1G2H model, there are two layers of greases. The first layer G1 is a low conducting grease on the processor. The thickness of the layer of low conducting grease is recommended to be maintained at less than 5 microns for better results. The second layer G2 is high conducting grease to be pasted to the heat sink. The heat sink and the processor to be adhered to each other with enough contact pressure so that there are no air gaps. Also, the adhesion has to be complete before the grease dries out. The thermal conductivity of G2 should be higher at least 5 times than that of G1.

The third model PG1FG2H has two different types of greases as in the model PG1G2H. The thermal conductivities of the G1 and G2 should be similar to the model PG1G2H. Additionally, there is a highly conducting foil in between G1 and G2. The thermal conductivity of G2 should be chosen close enough to the foil, if available.

III. EXPERIMENTAL RESULTS

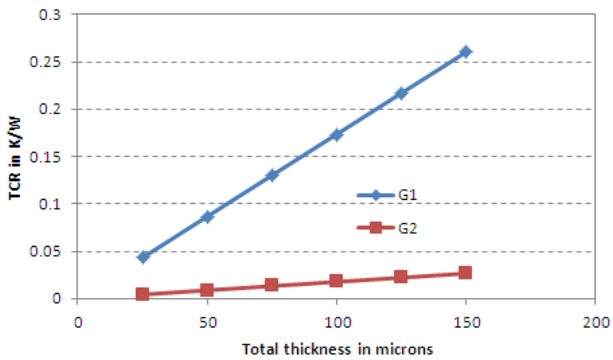

Fig. 1: Experimental Evaluation of Thermal Contact Resistance(1e$^{-06)}$ for Model PGH

Fig.1. shows the experimental evaluation of the thermal contact resistance for two types of greases namely, Silicone grease based on polydimethylsiloxanic oil, with metallic oxide powder (G1) and Furon C695 Graphite foil coated on one side with acrylic adhesives (G2).

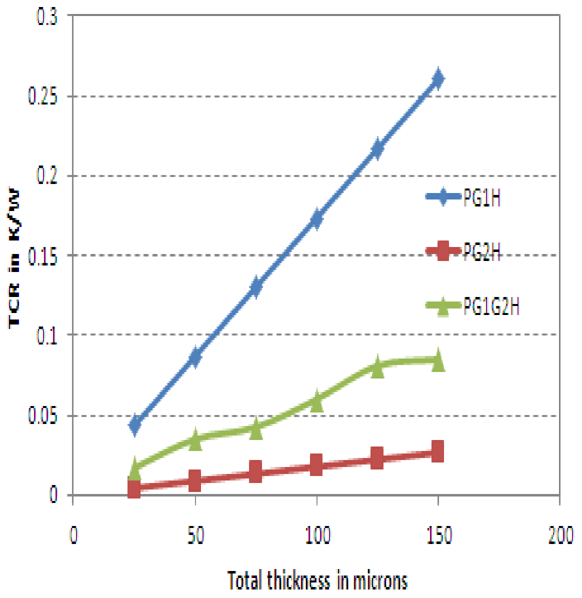

Fig. 2: Experimental Evaluation of Thermal Contact Resistance(1e$^{-06)}$ for Model PG$_1$H, PG$_2$H and PG$_1$G$_2$H

Fig. 2. shows the experimental evaluation of the thermal contact resistance for double layer of greases. The first layer G1 is 25% of the total thickness and the layer G2 is of 75%. The G1 and G2 are Silicone grease based on polydimethylsiloxanic oil with metallic oxide powder and Furon C695 Graphite foil coated on one side with acrylic adhesives respectively. The results show that with the addition of a highly conducting layer above the low conducting layer, the thermal contact resistance drops there by increasing the heat flow.

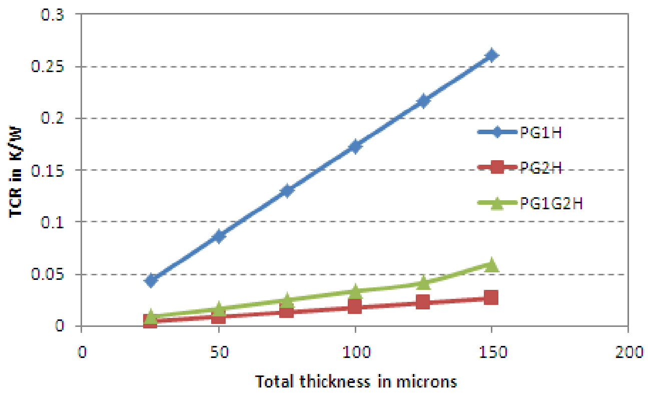

Fig. 3: Experimental Evaluation of Thermal Contact Resistance(1e$^{-06)}$ for Model PG$_1$H, PG$_2$H and PG$_1$G$_2$H

Fig.3. shows the experimental evaluation of the thermal contact resistance for double layer of greases. The first layer G1 is 10% of the total thickness and the layer G2 is of 90%. The G1 and G2 are again Silicone grease based on polydimethylsiloxanic oil with metallic oxide powder and Furon C695 Graphite foil coated on one side with acrylic adhesives respectively. The results show that with the increasing the % of thickness of a highly conducting layer (or it can be maintained as it is without increasing the thickness) and reducing % of the low conducting layer, the thermal contact resistance drops there by increasing the heat flow. The lower the thicknesses of the layers, the better it is.

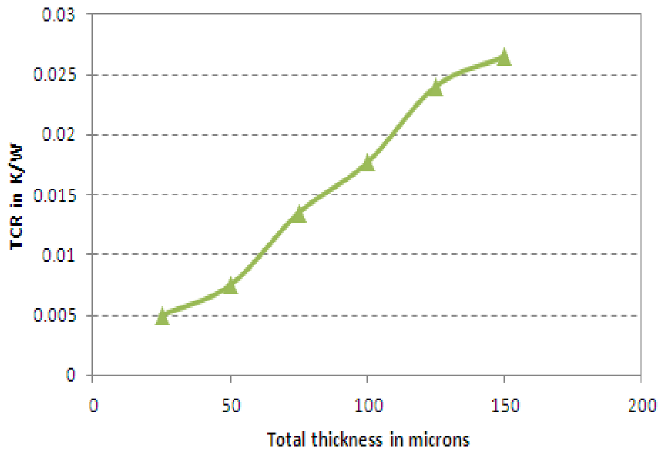

Fig. 4: Experimental Evaluation of Thermal Contact Resistance(1e$^{-06)}$ for Model PG$_1$FG$_2$H

Finally,Fig..4.Shows the experimental evaluation of the thermal contact resistance for double layer of greases with a domestic aluminum foil in between. The first layer G1 is 5% of the total thickness, the aluminum foil is of 90% thickness and the layer G2 is of 5%. The G1 and G2 are Silicone grease based on polydimethylsiloxanic oil with metallic oxide powder and Furon C695 Graphite foil coated on one side with acrylic adhesives respectively. The results show that with the addition of a highly conducting layer above the low conducting layer, the thermal contact resistance drops there by increasing the heat flow.

V. CONCLUSION

In this research work, a novel method is presented to improve the thermal conductance at the interface between the heat sink and the computer processor. Three different types of models are verified in this work, namely, PGH, PG_1G_2H and PG_1FG_2H. In the PGH model, grease G is high conducting grease or low conducting grease. The advantage of low conducting grease is that it does not short the internal circuitry of the processor at the interface as explained above and hence the life of the processor is high. The other two models have been devised to improve the conductance while protecting the processor with a low conducting grease. It is proved experimentally that by adding additional highly conducting layers the thermal resistance drops. Also it is verified that by reducing the thickness of the layer next to the processor, the thermal conductance improves.

REFERENCES

[1] R. Hopkins, A. Faghri, D. Krustalev, Flat miniature heat pipes with micro capillary grooves, J. Heat Transfer 121 (1999) 102-109.

[2] L.S., Fletcher, A review of thermal enhancement techniques for electronic systems, Intersociety Conference on Thermal Phenomena (1990) 136-148.

[3] J.P. Bardon, Introduction aÁ l'eÂtude des reÂsistances thermiques de contact, Rev. GeÂn. Therm. 125 (1972) 429-446.

[4] L.S. Fletcher, Recent developments in contact conductance heat transfer, J. Heat Transfer 110 (1988) 1059-1070.

[5] M.J. Edmonds, A.M. Jones, S.D. Probert, Thermal contact resistances for hard machined surfaces pressed against relatively soft-optical ¯ats, Applied Energy 6 (1980) 405-427.

[6] R.R. Somers, J.W. Miller, L.S. Fletcher, An experimental investigation of the thermal conductance of dissimilar metal contacts, in: 4th Intersociety Conference on Thermal Phenomena in Electronic Systems, Washington, May, 1994, pp. 280-299.

[7] D.V. Lewis, H.C. Perkins, Heat transfer at the interface of stainless steel and aluminum. The influence of surface conditions on the directional e€ect, Int. J. Heat Mass Transfer 11 (1968) 1371-1383.

[8] M.M. Yovanovich, Overall constriction resistance between contacting rough, wavy surfaces, Int. J. Heat Mass Transfer 12 (1969) 1517-1520.

[9] M.R. Sridhar, M.M. Yovanovich, Thermal contact conductance of tool steel and comparison with model, Int. J. Heat Mass Transfer 39 (4) (1996) 831-839.

[10] M.R. Sridhar, M.M. Yovanovich, Elastoplastic contact conductance model for isotropic conforming rough surfaces and comparison with experiments, J. Heat Transfer 118 (1996) 3-9.

[11] B.B. Mikic, Thermal contact conductance; theoretical considerations, Int. J. Heat Mass Transfer 17 (1974) 205-214.

[12] M. Mittelbach, C. Vogd, L.S. Fletcher, G.P. Peterson, The interfacial pressure distribution and thermal conductance of bolted joints, J. Heat Transfer 116 (1994) 823-829.

[13] L.S. Fletcher, G.P. Peterson, C.V. Madhusudana, E. Groll, Constriction resistance through bolted and riveted joints, J. Heat Transfer 112 (1990) 857-863.

[14] L.R. Jeevanashankara, C.V. Madhusudhana, M.V. Kulkarni, Thermal contact conductances of metallic contacts at low loads, Applied Energy 35 (1990) 151-164.

[15] L.G. Hays, Thermal conductance of alumina±nickel interfaces at elevated temperatures, Int. J. Heat Mass Transfer 13 (1970) 1293-1297.

[16] B. Snaith, P.W. O'Callaghan, S.D. Probert, Interstitial materials for controlling thermal conductances across pressed metallic contacts, Applied Energy 16 (1984) 175-191.

[17] L.J. Salerno, P. Kittel, A.L. Spivak, Thermal conductance of pressed metallic contacts augmented with indium foil or Apiezon grease at liquid helium temperatures, Cryogenics 34 (8) (1994) 649-654.

[18] A.L. Peterson, Silicones with improved thermal conductivity for thermal management in electronic packaging, in: 40th Electronic Components and Technology Conf., Las Vegas, May, 1990, pp. 613-618.

[19] W. Jamison, G. Sears, G. Larsen, R. Hunadi, Thermally conductive, water cleanable greases, in: Proc. Technical Conference, Int. Electronic Packaging Conf., 1991, pp. 190-203.

[20] T. McWaid, T.E. Marschall, Thermal contact resistance across pressed metal contacts in a vacuum environment, Int. J. Heat Mass Transfer 35 (11) (1992) 2911-2920.

[21] B.B. Mikic, G. Carnasciali, The e€ect of thermal conductivity of plating material on thermal contact resistance, J. Heat Transfer (1970) 475-482.

[22] T.K. Kang, G.P. Peterson, L.S. Fletcher, Effect of metallic coatings on the thermal contact conductance of turned surfaces, J. Heat Transfer 112 (1990) 864-871.

[23] A.H. Howard, J.M. Ochterbeck, G.P. Peterson, Effects of metallic vapor deposition process and the overall coating thickness on thermal contact conductance, J. Heat Transfer 117 (1995) 828-834.

[24] C.R. Hicks, K.V. Turner, in: Fundamental Concepts in the Design of Experiments, 5th Ed., Oxford University Press, Oxford, 1999, p. 576.

[25] C.V. Madhusudana, Thermal contact conductance and recti®cation at low joint pressures, Int. Comm. Heat Mass Transfer 20 (1993) 123-132.

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