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Three Dimensional Analysis of Thermal Pad made of Nanomaterial, Nano-Silver with differences of Thickness by Using CFD Software, FLUENT

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Abstract: This paper presents the thermal management of electronic components, microprocessor by using three dimensional numerical analysis of heat and fluid flow in computer using CFD Software. 3D model of microprocessors is built using GAMBIT and simulated using FLUENT software. The study was made for four microprocessors arranged in line under different thickness of thermal pad, inlet velocities and package (chip) powers. The results are presented in terms of average junction temperature of each package. It also found that the thickness of thermal pad, (chip) powers and inlet velocities are the most important elements to control and manage the junction temperature. The strength of CFD software in handling heat transfer problems is proved to be excellent.

Key words: *Plastic Leaded Chip Carrier (PLCC), Nano-Silver, Thermal Pad, Computational Fluid Dynamic (CFD), FLUENT™*

INTRODUCTION

Nowadays, the major trend in electronic industry is to make the products smarter, lighter, functional and highly compact, at the same time can reduce the heat of electronic component. This trend has necessitated stringent packaging requirements and using nanotechnology is a promising option to tackle this issue. However, a serious issue in electronic packaging is the thermal management. The electronic components made using silicon chip and the organic substrate, which generates heat and causes malfunction for some electronic components when the temperature above 70ºC. This problem is effectively solved by using suitable microprocessor power and air inlet velocity as cooling device. Conventionally the microprocessors were made by epoxy or silicon as main material in the electronic components in chip manufacturing. In this case, when electronic components operate in long period, the temperature of chip in electronic components will easily exceed 70ºC. This will cause electronic components malfunction or overheated. That why there are a lot of researchers doing study on thermal management over 30 years ago.

In electronic industries, the continuing increase of power densities in microelectronics and simultaneous drive to reduce the size and weight of electronic products have led to the increased importance of thermal management issues in electronic industry. The temperature at the junction of an electronic package has become the important factor that determines the lifetime of the package. The effective way to reduce junction temperature of microelectronics and PLCC without changing properties and behaviour of that component is by using thermal pad application. The junction temperature of PLCC and others microelectronics components can be reducing just by simply attach the thermal pad to the area that has high thermal productivity and have critical area.

In electronic industries, the continuing increase of power densities in microelectronics and simultaneous drive to reduce the size and weight of electronic products have led to the increased importance of thermal management issues in electronic industry. The temperature at the junction of an electronic package has become the important factor that determines the lifetime of the package. The thermal management had been started over 30 years ago. Initially, the studied had been conducted by experiment only. The heat transfer and pressure drop for airflow in arrays of heat generating rectangular module had been studied by Sparrow (1982). Later Sparrow (1983) made an experimental investigation of heat transfer and fluid flow characteristics of arrays of heat-generating block-like modules affixed to one wall of a parallel-plate channel and cooled by forced convection airflow. They also investigated the convective heat transfer response to height differences in an array of block-like electronic components. Gupta and Jaluria (1998) carried out experiments to study forced convection water cooling of arrays of protruding heat sources with specified heat input. Hwang (1998) investigated forced

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convection from discrete heat sources mounted flush on a conductive substrate in a rectangular duct. Molki and Faghri (2000) made an experimental investigation of forced convection air-cooling of a 4 by 3 copper rectangular block positioned along the lower wall of the test section in an in-line arrangement. Ramadhyani, Moffat and Incropera (1985) made a 2D numerical study on the conjugate analysis of forced convection heat transfer from discrete heat sources mounted on a solid substrate and exposed to fully developed laminar flow. Davalath and Bayazitoglu (1987) considered a conjugate heat transfer for two-dimensional, developed flow over array rectangular blocks representing finite heat sources on parallel plate using the cooling fluid as air.

Utilization of CFD as thermal prediction tool was employed by Plotnik and Anderson (1995) and Tucker and Paul (1998) as part of design for heat transfer enhancement in electronic devices. The laminar and the turbulent forced convective flows over two sequentially heated blocks mounted on one principal wall of a channel were experimentally and numerically studied by Chen and Wang (1998). Hong and Yuan (1997) proved that a constant and uniform heat transfer coefficient across the whole package was inadequate in the accurate prediction of thermal stresses, due to the significant effect of local temperature distribution resulted from the variation of local heat transfer coefficient. Thus, they demonstrated the importance of considering the conjugate problem for electronic packages. Jayakanthan et al. (1997) carried out simulations of conjugate heat transfer associated with single and two packages mounted on printed circuit board (PCB) which was situated in a wind tunnel, using FLUENT™ for various flow conditions. This work was numerical investigation of heat transfer in plastic leaded chip carrier continued by Huat (1998) who simulated multiple chips using a 2D model. Hung and Fu (1999) designed a two-dimensional model for numerical prediction of viscous laminar flow, mixed convection and conjugated heat transfer between parallel plates with uniform block heat source and with opening on the integrated circuit board. The interest in the determination of junction temperature and thermal resistance continued to grow as is evident from the works of Tso et al. (1999), Young and Vafai (1999), and Kim and Kim (1999).

In year 2007, the development of electronic industries increase rapidly because development of electronic packaging and nanotechnology. Yusof et al. (2009) has studied the PLCC packaging by using 2 PLCC in the PLCC packaging. After that, the studied about electronic packaging about PLCC has been improved by Mazlan et al. (2010). Futhermore, nano-silver is used in electronic components to decrease temperature and increase the performance of chip processor. Nano-Silver can decrease the junction temperature of chip compare with others material like epoxy compound moulding (EMC) and Composite polymer. As the modern electronic industry is driving towards more compact systems, further research is needed to increase the performance of electronic devices. Mazlan et al. (2013) had studied the electronic packaging by using thermal pad as a medium interface between PLCC and motherboard. The thermal pad was made by using nano-silver because of high thermal resistance and thermal conductivity. Accordingly, the present study is focused on simulations of thermal pad applied on PLCC packages by using new material, nano-silver compare to the traditional one using silicon elastomer by using several inlet air velocities with different chip powers. Factors affecting the chip temperature such as coolant velocity, chip power and thermal conductivity of materials are studied and presented. Thermal pad using nano-silver as the main material in the thermal pad is a new innovation in electronic industry. Therefore this arrangement is made to see the differences in term of junction temperature in thermal pad made of nano-silver using several thicknesses. The thermal pad size is made according to the size of PLCC and the thickness for both of thermal pad is from 0.01 cm to 0.1cm.

Description of Model:

The model used in this simulation consists of a wind tunnel which encompasses the whole computational domain with a motherboard and 4 PLCC made by nano-silver, epoxy molding compound (EMC) and composite polymer .The isometric view, plan view, and front view of the simulation setup for 4 PLCC packages are shown in Figure 1. The motherboard (PCB) is set up 9 cm from the inlet of wind tunnel to make sure that the flow is fully developed when it reaches the outlet of the wind tunnel. The 4 PLCC packages, each having 2 cm × 2 cm face were mounted with 3 cm gaps on the PCB in a symmetrical manner as show in Figure 1 and 2. The setup is kept at a height of 7 cm from the bottom surface of the wind tunnel. The motherboard thickness is 0.015 cm, thickness of chips is 0.3 cm each, and thickness of thermal pad is varying from 0.01 cm to 0.1 cm made from nano-silver.

Table 1: Dimension of Components Used in Simulation.

Component	Quantity	Size(cm^3)
Wind tunnel	1	52.5x10x10
Motherboard	1	33.3x0.15x8
PLCC (Chip)	4	2x0.3x2
Thermal pad	4	2x0.1x2

Table 2: Properties type of Material used in producing Thermal Pad.

Parameter	Thermal Pad (Nano-Silver)
Specific volume (v)	1556 Kg/m^3
Specific heat (C_p)	1.025 x 10^3 J/kg/K
Conductivity (k)	4.2 J/sec/m/K

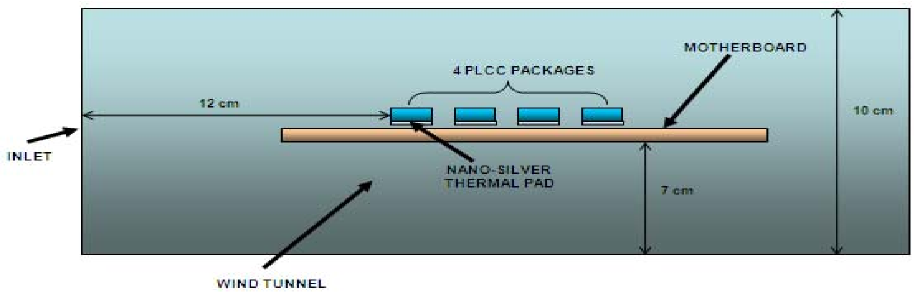

Fig. 1: Front view of the simulation setup for thermal pad made of nano-silver with different thicknesses.

RESULTS AND DISCUSSION

The results are presented in terms of average junction temperature for the packages under different operating conditions. The results of thermal pad made of nano-silver with different thickness analysis using 3-D analysis of the heat and fluid flow are having same model dimensions to see the change in junction temperature for each PLCC. The air inlet velocity used in this CFD simulation start from 0.01 m/s to 2 m/s.

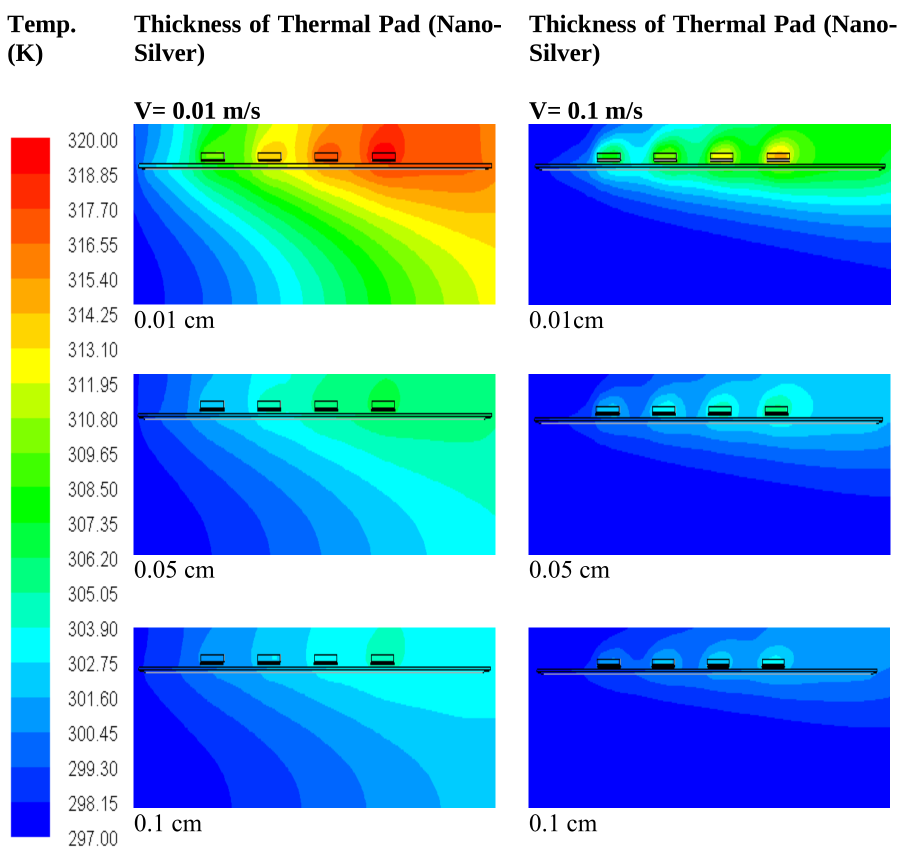

Fig. 3.1: The comparison between thicknesses of thermal pad made of Nano-Silver for 4 PLCC at 0.5 W for velocities 0.01 m/s to 2 m/s.

3.1 Comparison Between Thicknesses of Thermal Pad Made of Nano-Silver in Term of Junction Temperature in PLCC's using CFD Simulation, FLUENT^{TM}:

3.1.1 Chip Power 0.5W for 4 PLCC at V= 0.01 m/s:

Figure 2 to 4 shows the comparison between thickness of thermal pad made of nano-silver in contour of total temperature for 4 PLCC at 0.5 W for velocities 0.01 m/s

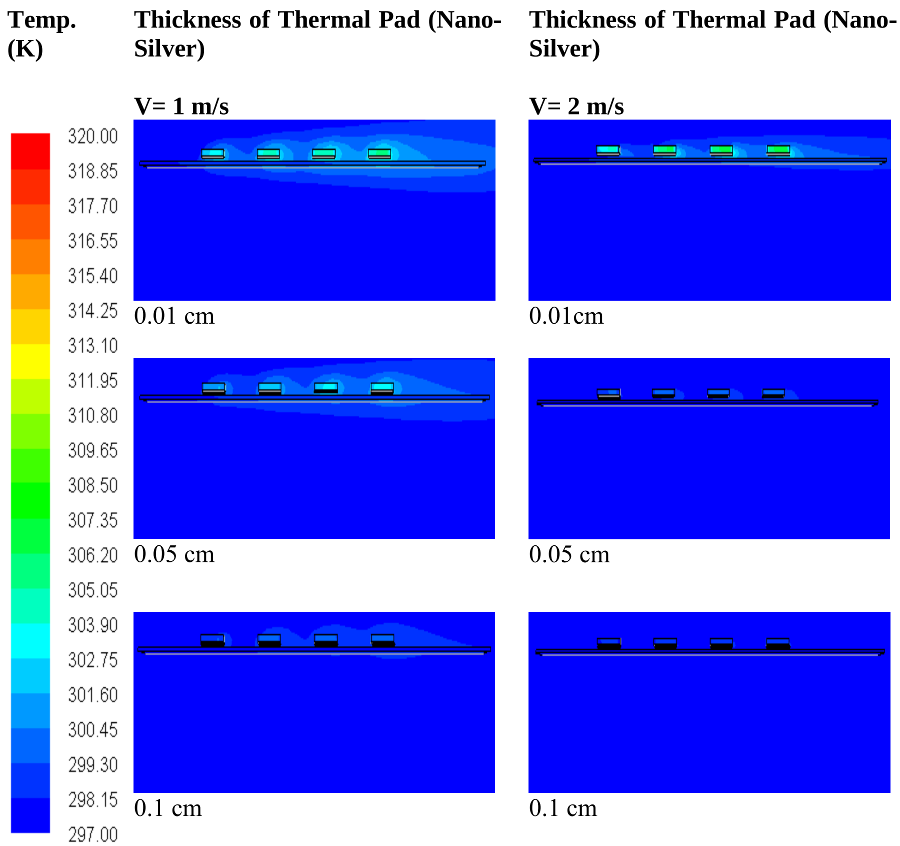

Fig. 3.1: (Continuous).

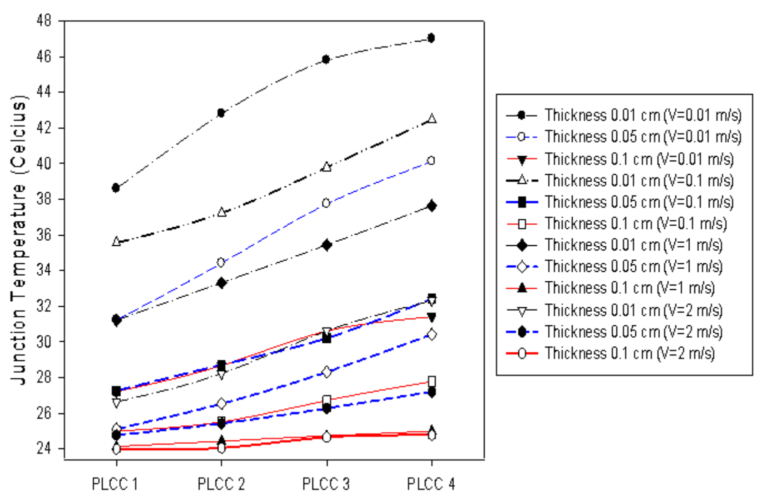

Fig. 3.2: The Comparison between Thicknesses of Thermal Pad Made of Nano-Silver for 4 PLCC at 0.5 W.

From figure 3.2, it had shown the differences between junction temperatures at 4 PLCC using different thickness of thermal pad made of nano-silver at 0.5 W. The maximum percentage of temperature different between thickness 0.01 cm and 0.1 cm is 34.56% and maximum temperature for PLCC is 47 ºC. For these three types of thickness, the thickness 0.01 cm has the highest junction temperature for all PLCC follow by thickness 0.05 cm. Meanwhile the thickness 0.1 cm has the lowest junction temperature. For example, at velocity 0.01 m/s, junction temperature decreases from 38.6 ºC to 27.22 ºC for PLCC 1 by changing the thickness of thermal pad from 0.01 cm to 0.1 cm.

From the results above, it has shown that the thickness of thermal pad has significant influence to change the junction temperature of PLCC. The direct contact between PLCC and power source (chip power) can increase the junction temperature drastically. By applying the thermal pad in between PLCC and power source, the junction temperature can be reducing significantly. The thicknesses of thermal pad represent the thermal resistance between PLCC and power source. Higher the thickness of thermal pad, hence higher the thermal resistance. Therefore the junction temperature will reduce.

3.1.2 Chip Power 1 W for 4 PLCC:

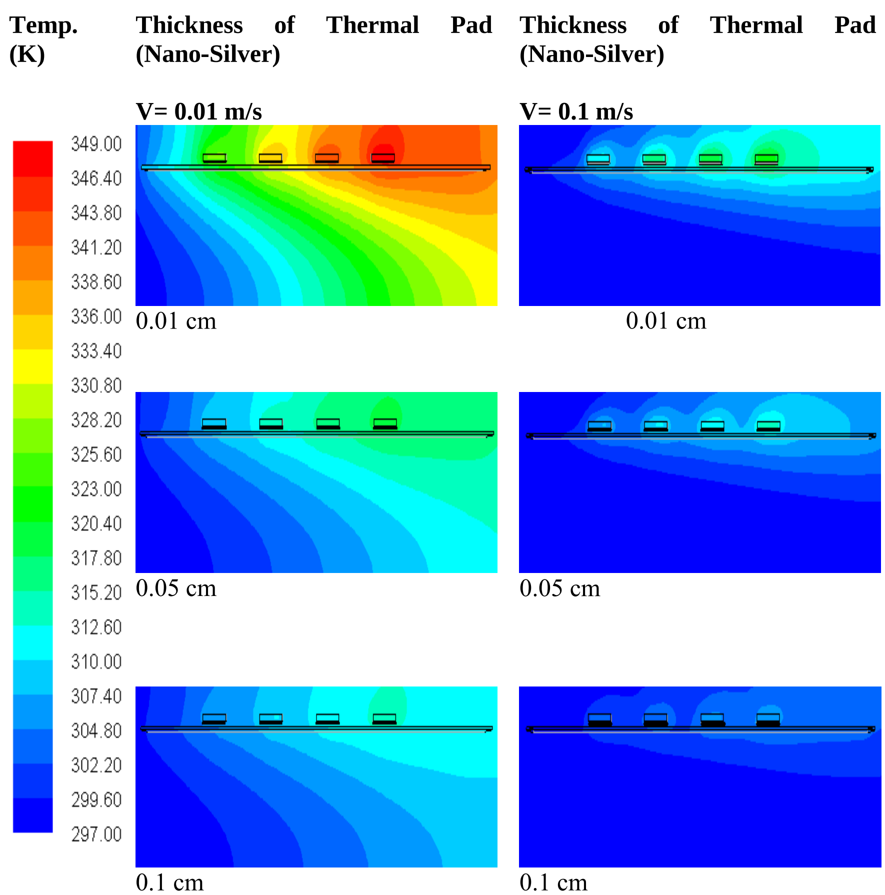

Fig. 3.3: The comparison between thicknesses of thermal pad made of Nano-Silver for 4 PLCC at 1 W for velocities 0.01 m/s to 2 m/s.

From Table 5.3, it had shown the differences between junction temperatures at 4 PLCC using different thickness of thermal pad made of nano-silver at 1 W. The maximum percentage of temperature different between thickness 0.01 cm and 0.1 cm is 46.41% and maximum temperature for PLCC is 75.24 ºC. For these three types of thickness, the same pattern has been found. The thickness 0.01 cm has the highest junction temperature for all PLCC follow by thickness 0.05 cm. Meanwhile the thickness 0.1 cm has the lowest junction temperature. For example, at velocity 0.01 m/s, junction temperature decreases from 54.12 ºC to 33.8 ºC for PLCC 1 by changing the thickness of thermal pad from 0.01 cm to 0.1 cm.

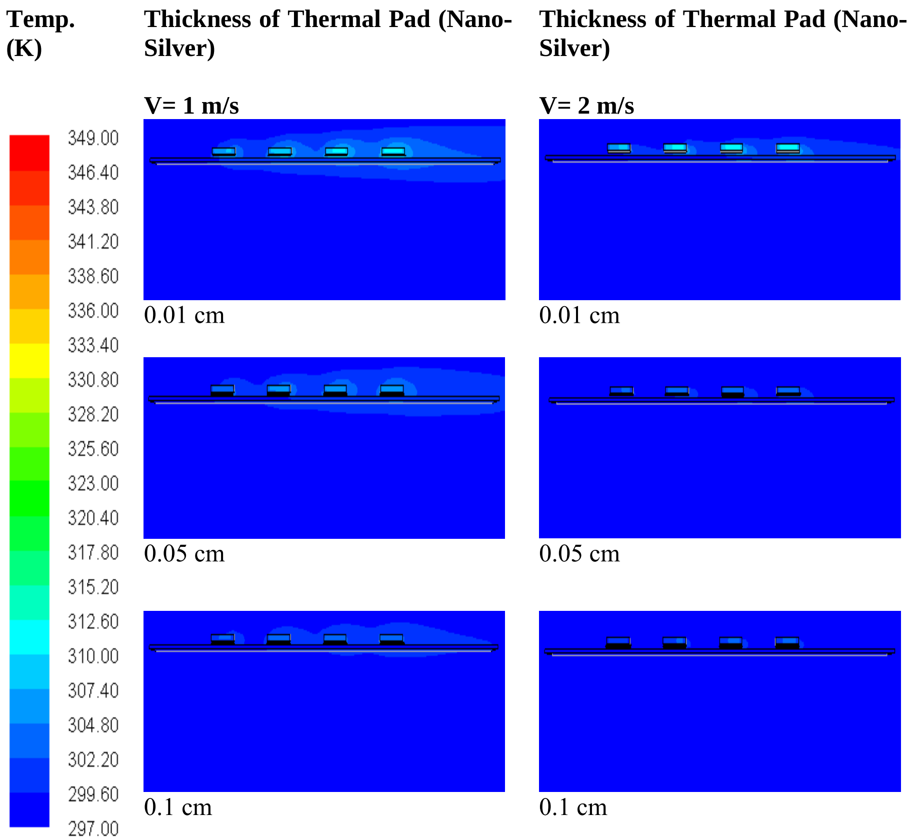

Fig. 3.3: (Continuous).

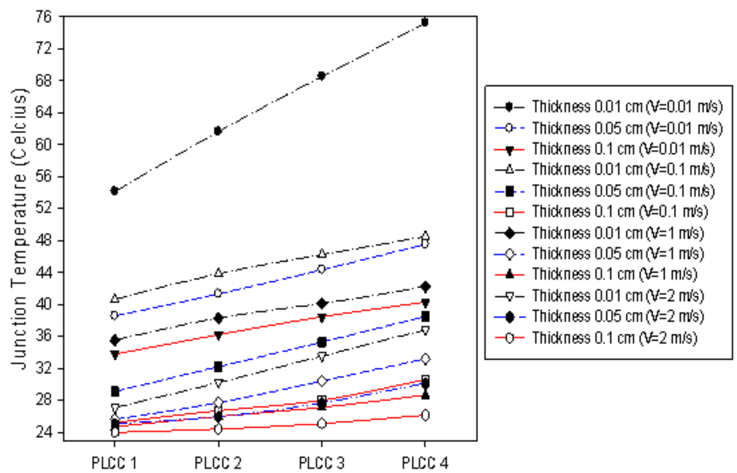

Fig. 3.4: The Comparison between Thicknesses of Thermal Pad Made of Nano-Silver for 4 PLCC at 1 W.

From the results above, it has shown that the thickness of thermal pad has significant influence to change the junction temperature of PLCC. By increasing the chip power, the junction temperature at thickness 0.01 cm (PLCC 4) has exceeded 70 ºC. That means the smaller thickness like 0.01 cm disable to reduce junction temperature effectively and can cause the PLCC to overheat and malfunction. By increasing the thermal pad to suitable thickness to 0.1 cm, the junction temperature was able to reduce and in permissible temperature.

3.1.3 Chip Power 2 W for 4 PLCC:

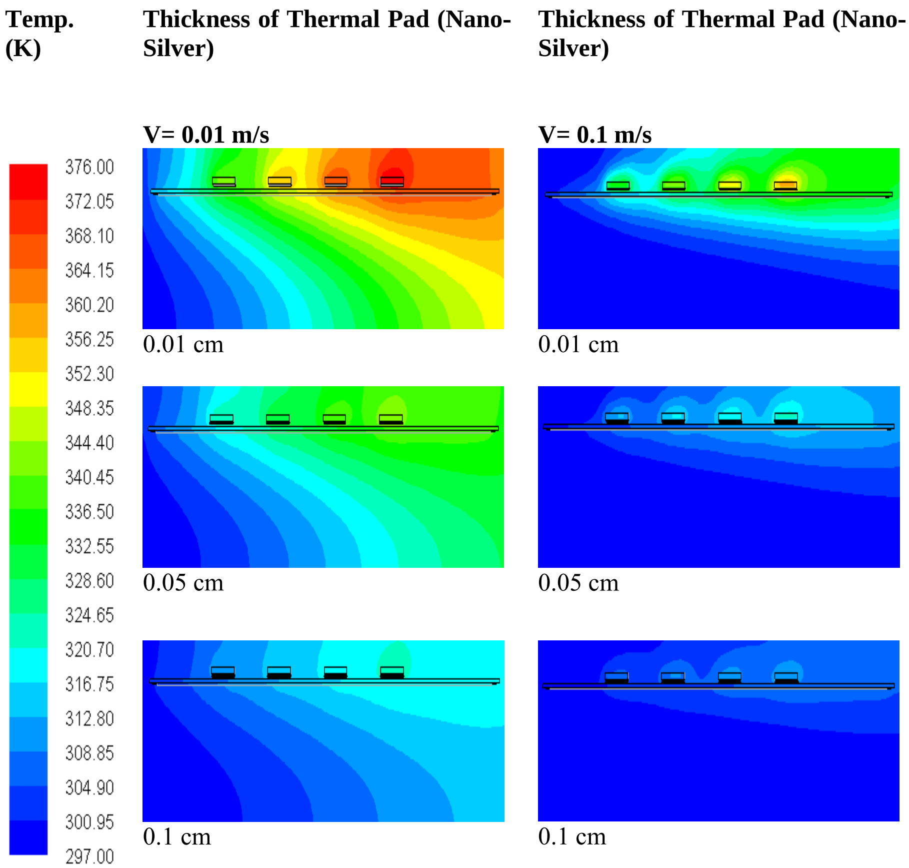

Fig. 3.5: The comparison between thicknesses of thermal pad made of Nano-Silver for 4 PLCC at 2 W for velocities 0.01 m/s to 2 m/s.

From Table 5.3, it had shown the differences between junction temperatures at 4 PLCC using different thickness of thermal pad made of nano-silver at 2 W. The maximum percentage of temperature different between thickness 0.01 cm and 0.1 cm is 58.51% and maximum temperature for PLCC is 102.54 ºC. At chip power 2 W, for these three types of thickness the same pattern has been found. The thickness 0.01 cm has the highest junction temperature for all PLCC follow by thickness 0.05 cm. Meanwhile the thickness 0.1 cm has the lowest junction temperature. For example, at velocity 0.01 m/s, junction temperature decreases from 75.24 ºC to 34.47 ºC for PLCC 1 by changing the thickness of thermal pad from 0.01 cm to 0.1 cm.

From the results above, it has shown that the thickness of thermal pad has significant influence to change the junction temperature of PLCC. By increasing the chip power from 1 W to 2 W, the junction temperature at thickness 0.01 cm for all PLCC has exceeded 70 ºC. For PLCC 4 the junction temperature not only exceeding 70 ºC but exceeds 100 ºC. That means the smaller thickness like 0.01 cm disable to reduce junction temperature effectively and can cause the PLCC to overheat and malfunction to all PLCC. Although by increasing the thermal pad to 0.05 cm, the junction temperature was for all PLCC still high. For PLCC 4, the thickness already increasing from 0.01 cm to 0.05 cm but the junction temperature for PLCC 4 still reach 62.24 ºC at air inlet velocity 0.01 m/s. Hence, the most suitable solution to solve and reduce junction temperature is using the thickness 0.1 cm.

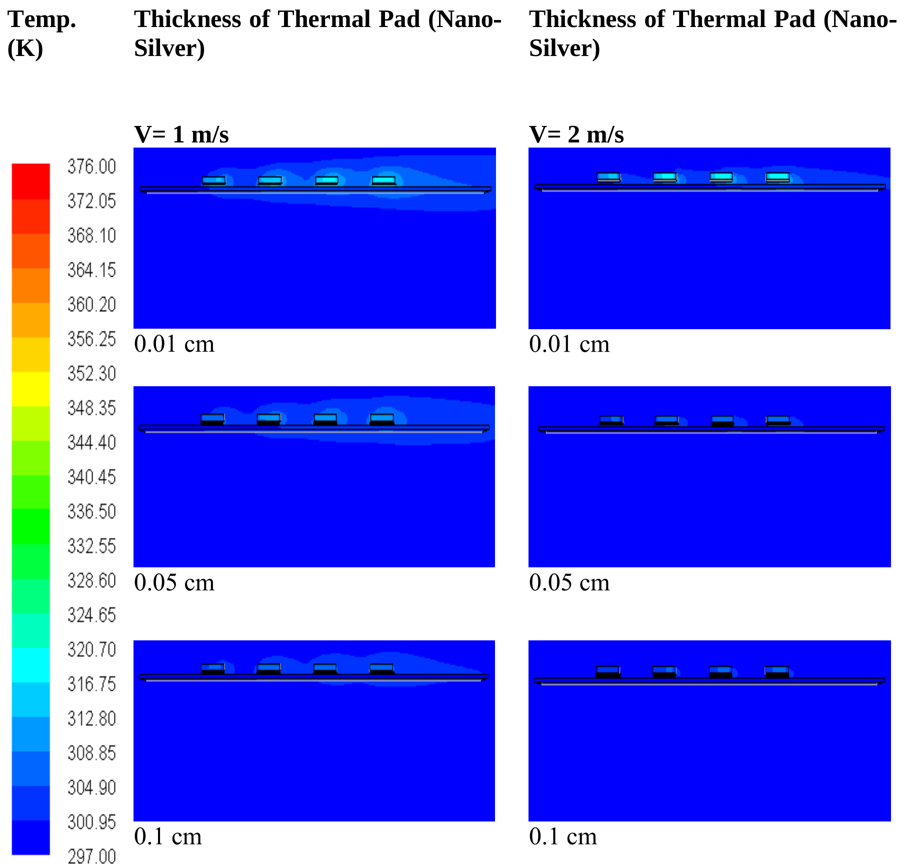

Fig. 3.5: (Continuous)

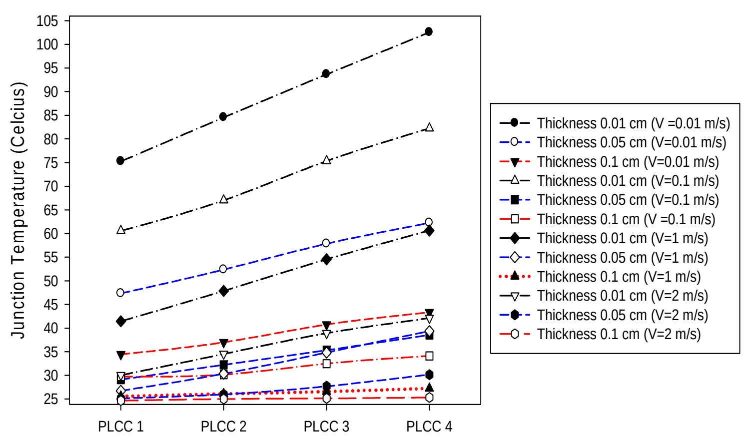

Fig. 3.6: The Comparison Between Thicknesses of Thermal Pad Made of Nano-Silver for 4 PLCC at 2 W.

4.0 Conclusion:

From the results above it can be summarizes that there are significant differences between junction temperatures at 4 PLCC using thickness 0.01 cm, 0.05 cm and 0.1 cm at air inlet velocity 0.01 m/s until 2 m/s. The maximum percentage of temperature different between thickness 0.01 cm and 0.1 cm is 58.51% and maximum temperature for PLCC is 102.54 ºC at chip power 2 W. From the previous simulation results, these three types of thickness have the same pattern where the increasing in chip power and decrease thermal pad thickness will increase junction temperature. The thickness of thermal pad also have been increase to 0.2 cm and

0.3 cm to see the reduction of junction temperature but it was found that the further increase the thermal pad will be useless and become not cost-effective. The maximum temperature reduce when thermal pad thickness increase to 0.2 cm and 0.3 cm is less than 1 % but the cost to produce thermal pad to 0.2 cm and 0.3 cm compare with 0.1 cm is double and triple. Hence, the most suitable thickness of thermal pad is 0.1 cm because of its ability to reduce heat and junction temperature more efficient and cost-effective.

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