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ESTEEM Academic Journal is jointly published by the Universiti Teknologi MARA, Pulau Pinang and UiTM Press, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

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ESTEEM

Academic Journal UiTM Pulau Pinang

Volume 7, Number 1 June 2011 ISSN 1675-7939

Foreword

Alhamdulillah. First of all a big thank you and congratulations to the Editorial Board of ESTEEM Academic Journal of Universiti Teknologi MARA (UiTM), Pulau Pinang for their diligent work in producing this issue. I also would like to thank the academicians for their contributions and the reviewers for their meticulous vetting of the manuscripts. A special thanks to UiTM Press (Penerbit UiTM) for giving us this precious opportunity to publish this first issue of volume 7.

In this issue, we have compiled an array of seven interesting engineering research and technical based articles for your reading. Mazlan Mohamed, Rahim Atan and Mohd. Zulkifly Abdullah presents the simulation of three dimensional numerical analysis of heat and fluid flow through chip package. 3D model of chip packages is built using GAMBIT and simulated using FLUENT software. The authors had made comparison between three types of material in the term of junction temperature and found that the junction temperature of the nano-silver had the lowest junction temperature compared to epoxy and composite polymer. It was also found that the nano-silver had the highest value of thermal conductivity.

Solahuddin Yusuf Fadhlullah, Mohamad Adha Mohamad Idin and Mohd Halim Mohd Noor wrote an article that looks at Intrusion Detection System (IDS). In this study major and well known evasion techniques are exposed and discussed. Countermeasures are also mentioned and listed down in order to mitigate the threat of IDS evasion.

The third article written by Fairosidi Idrus et al. looked at the effect of wick structure and filling ratio to the vapour chamber performance in electronic cooling using an experimental method. The experimental results show that the rectangular wick structure gives the lowest thermal resistance and the wick structure with the working fluid and the boiling phenomenon is practically effective for a 45% fill ratio.

The article entitled "an introduction to e-ssc test kit as a new technique to characterize swelling and shrinkage potential of rock material" authored by Intan Shafika Saiful Bahri et al. A study was conducted to re-characterize the properties and behaviors of these weakly cemented rocks which were found to be very sensitive to moisture changes. A real time laboratory study determines the typical free swell and shrinkage behavior of the materials that potentially induced slope failures.

The fithth article by Rozaini Ramli and Intan Shafika Saiful Bahri examine on the determination of soil erodibility, k factor for sungai kurau soil series. The author concluded that *Tew* equation indicates the smallest error for RMSE and suggested to be the most applicable method for statistical determination of soil erodibility for Malaysian soil series.

Rizal Mat Jusoh, Sharifah Saliha Syed Bahrom and Saiful Fadzli Salian present the Skin Detection Using Color Component Subtraction and Texture Information. In this study the algorithm is tested on color images focusing on palm and face skin regions. The author concluded that the algorithm is able to achieve more than 90% of detection rate.

The last article is entitled effect of various sizes extraction of wood-wool on the properties of wood-wool cement board manufactured from kelampayan (*neolamarckia cadamba*). The authors, Mohd Azrizal Fauzi and Zakiah Ahmad found that the performance of WWCB is influenced by wood-wool size and density.

We do hope that you not only have an enjoyable time reading the articles but also find them useful. Thank you.

Soffian Noor Mat Saliah
Chief Editor
ESTEEM, Vol. 7, No. 1, 2011
(Engineering)

Three Dimensional Analysis Using Finite Volume Based CFD Simulation to Determine Junction Temperature on Electronic Components

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ABSTRACT

This paper presents the simulation of three dimensional numerical analysis of heat and fluid flow through chip package. 3D model of chip packages is built using GAMBIT and simulated using FLUENT software. The study was made for four chip packages arranged in line under different types of materials, inlet velocities and package (chip) powers. The results are presented in terms of average junction temperature and thermal resistance of each package The comparison between three types of material in the term of junction temperature has been observed and it was found that the junction temperature of the nano-silver had the lowest junction temperature compared to epoxy and composite polymer. It was also found that the nano-silver had the highest value of thermal conductivity compare to the others. The strength of CFD software in handling heat transfer problems is proved to be excellent.

Keywords: *PLCC package, Thermal Conductivity, Numerical simulation, Average junction temperature, Nano-Silver*

ISSN 1675-7939
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Introduction

Nowadays, the major trend in electronic industry is to make the products smarter, lighter, functional and highly compact and at the same time can reduce the heat generated by the electronic component. This trend has necessitated stringent packaging requirements and nanotechnology is a promising option to tackle this issue. However, a major concern in electronic packaging is the thermal management. Electronic components are made of silicon chip and the organic substrate, which generate heat and cause malfunction for some electronic components when the temperature exceeds 70°C. This problem is effectively solved by using nano-Silver in chip packaging because it can dissipate heat more effectively. Moreover, it protects the chip from moisture, ionic contaminants, radiation, thermal expansion and vibration. Conventionally the chip packages are made of epoxy or silicon as the main material in the electronic components in chip manufacturing. When electronic components are operate in long period, the temperature of the chip in electronic components will easily exceed 70°C. This will cause electronic components to malfunction or overheated. For these reasons, a lot of researchers have been conducting studies on thermal management over 30 years ago.

Nanotechnology nowadays has become a very important part in developing advanced electronic industries. 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 studies were conducted by experiment only. The heat transfer and pressure drop for airflow in arrays of heat generating rectangular module was 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 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 increased rapidly because development of nanotechnology. 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. Accordingly, the present study is focused on simulations of PLCC packages by using new material, nano-silver compare to the traditional one using epoxy moulding compound (EMC) and Composite polymer by using several inlet air velocities under natural, mixed and forced convection conditions with different chip powers. Factors affecting the chip temperature such as coolant velocity, chip power and thermal conductivity of materials are studied and presented.

Three-dimensional analysis of the heat and fluid flow over a single 84 pins PLCC package mounted on a PCB along the direction of flow is reported from Quadir, Hung, and Seetharamu (2000), and Jayakumar, Quadir, Abdullah, and Seetharamu (2002). The analysis carried out a conjugate heat transfer problem using CFD Fluent™ software. It was observed from their analysis that the increase in air flow velocity reduced the junction temperature and thermal resistance. As an extension to this work, the present study focused on simulation of 4 PLCC packages with several inlet air velocities under natural, mixed, and forced convection conditions with different chip powers.

Methodology

Governing Equations

The basic equations describing the flow of fluid are conservation of mass, conservation of momentum, and conservation of energy. The governing equations are expressed as:

Continuity equation:

$$\frac{\delta u}{\delta x}+\frac{\delta v}{\delta y}+\frac{\delta w}{\delta z}=0 \tag{1}$$

Dimensionless continuity equation:

$$\frac{\partial \hat{U}}{\partial X}+\frac{\partial \hat{V}}{\partial Y}+\frac{\partial \hat{W}}{\partial Z}=0 \tag{2}$$

Momentum equation:

x-direction

$$(u\frac{\delta u}{\delta x}+v\frac{\delta u}{\delta y}+w\frac{\delta u}{\delta z})(\rho) = -\frac{\delta p}{\delta x}+\mu\left(\frac{\delta^2 u}{\delta x^2}+\frac{\delta^2 u}{\delta y^2}+\frac{\delta^2 u}{\delta z^2}\right) \quad (3)$$

y-direction

$$(u\frac{\delta v}{\delta x}+v\frac{\delta v}{\delta y}+w\frac{\delta v}{\delta z})(\rho) = -\frac{\delta p}{\delta y}+\mu\left(\frac{\delta^2 v}{\delta x^2}+\frac{\delta^2 v}{\delta y^2}+\frac{\delta^2 v}{\delta z^2}\right) \quad (4)$$

z-direction

$$(u\frac{\delta w}{\delta x}+v\frac{\delta w}{\delta y}+w\frac{\delta w}{\delta z})(\rho) = -\frac{\delta p}{\delta z}+\mu\left(\frac{\delta^2 w}{\delta x^2}+\frac{\delta^2 w}{\delta y^2}+\frac{\delta^2 w}{\delta z^2}\right) \quad (5)$$

Dimensionless momentum equation:

X-direction

$$\hat{U}\frac{\partial \hat{U}}{\partial X}+\hat{V}\frac{\partial \hat{U}}{\partial Y}+\hat{W}\frac{\partial \hat{U}}{\partial Z} = -\frac{\partial \hat{P}}{\partial X}+\frac{1}{\mathrm{Re}_L}\nabla^2\hat{U} \quad (6)$$

Y-direction

$$\hat{U}\frac{\partial \hat{V}}{\partial X}+\hat{V}\frac{\partial \hat{V}}{\partial Y}+\hat{W}\frac{\partial \hat{V}}{\partial Z} = -\frac{\partial \hat{P}}{\partial Y}+\frac{1}{\mathrm{Re}_L}\nabla^2\hat{V} \quad (7)$$

Z-direction

$$\hat{U}\frac{\partial \hat{W}}{\partial X}+\hat{V}\frac{\partial \hat{W}}{\partial Y}+\hat{W}\frac{\partial \hat{W}}{\partial Z} = -\frac{\partial \hat{P}}{\partial W}+\frac{1}{\mathrm{Re}_L}\nabla^2\hat{W} \quad (8)$$

Energy equation:

Energy balance equation with negligible radiation and distribute energy source in the fluid field is given as:

$$\rho c_p(u\frac{\delta T}{\delta x}+v\frac{\delta T}{\delta y}+w\frac{\delta T}{\delta w}) = k\nabla^2 T \quad (9)$$

In the dimensionless form:

$$\hat{U}\frac{\partial \hat{T}}{\partial X}+\hat{V}\frac{\partial \hat{T}}{\partial Y}+\hat{W}\frac{\partial \hat{T}}{\partial Z}=\frac{1}{Pe}\nabla^{2}\hat{T} \tag{10}$$

where

$$(X,Y,Z)=\frac{(x,y,z)}{L},\quad (\hat{U},\hat{V},\hat{W})=\frac{(u,\upsilon,w)}{V_{\infty}},$$

$$\hat{P}=\frac{p}{\rho V_{\infty}^{2}} \quad \text{and} \quad Pe=\frac{V_{\infty}L}{\alpha} \tag{11}$$

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 moulding 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. 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 and the thickness of chips is 0.3 cm each, both made from nano-silver and compare with PLCC made from epoxy moulding compound and composite polymer.

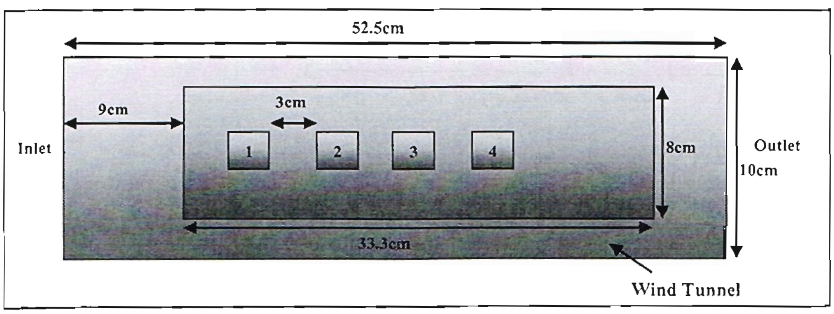


Figure 1: Simulation Setup for 4 PLCC Packages

Table 1: Dimension of Components Used in Simulation

Component	Quantity	Size (cm^3)
Wind tunnel	1	52.5 cm × 10 cm × 10 cm
Motherboard	1	33.3 cm × 0.15 cm × 8 cm
Chip	4	2 cm × 0.3 cm × 2 cm

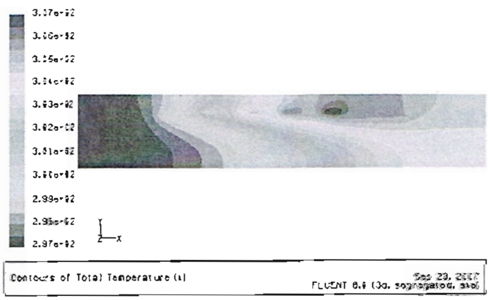
Results and Discussion

The results are presented in terms of average junction temperature and thermal resistance for the packages under different operating conditions. The results of nano-silver are comparable with epoxy moulding compound and composite polymer where 3-D analysis of the heat and fluid flow are similar and having same model dimensions. The difference between the previous research and the one that is conducted is the used in contrast to the nano-silver material used to optimize and to decrease junction temperature for each PLCC packages with different values of input velocity. The natural convection falls in the range of 0.001 m/s to 0.01 m/s, mixed convection from 0.01 m/s to 0.1 m/s and forced convection from 0.1 m/s to 2 m/s.

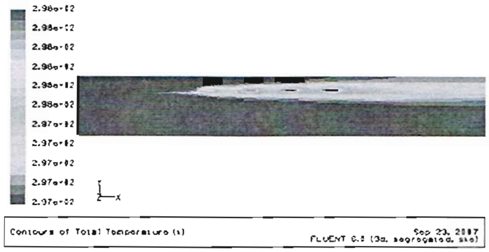
Differences between Nano-Silver, Epoxy Moulding Compound and Composite Polymer on Average Junction Temperature

a. Chip Power 0.5 W

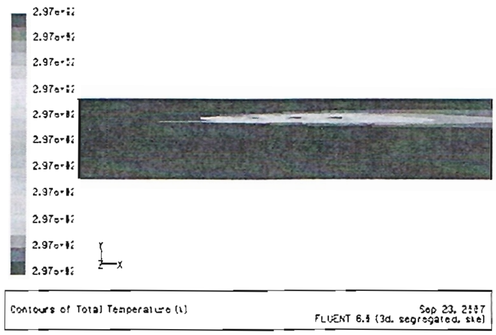
Figure 2 shows the comparison between epoxy, composite polymer and nano-silver in contour of total temperature for 4 PLCC at 1 W for velocities 0. 1 m/s.



a) 0.1 m/s, 0.5 W, 4 PLCC (Epoxy)



b) 0.1 m/s, 0.5 W, 4 PLCC (Composite Polymer)



a) 0.1 m/s, 0.5 W, 4 PLCC (Nano-Silver)

Figure 2: The Comparison between Epoxy, Composite Polymer and Nano-Silver in Contour of Total Temperature for 4 PLCC at 0.5 W for Velocities 0.1 m/s

Table 2: Junction Temperature for Epoxy, Composite Polymer and Nano-Silver Material in PLCC Packages

Power (Watt)	Velocity (m/s)	Junction temperature (K)		
		Nano-Silver	Polymer	Epoxy Moulding Compound (EMC)
0.5	0.001	310.52	316.53	326.54
	0.01	306.85	309.82	312.94
	0.1	299.74	304.92	307.1
	1	293.28	297.38	299.45
	2	292.23	295.28	297.34

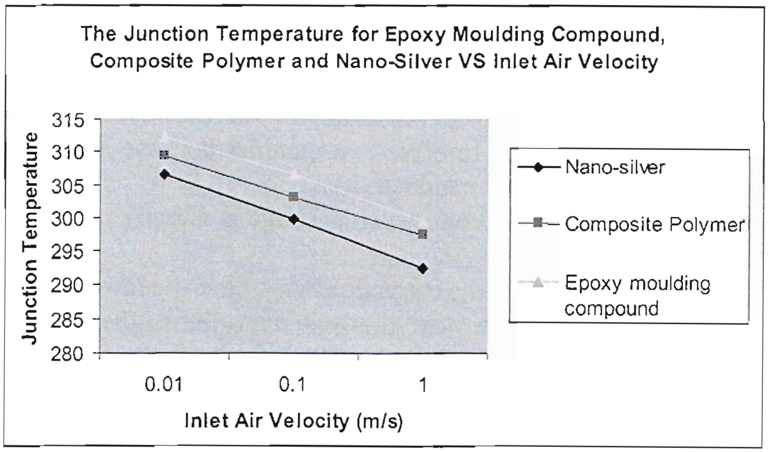


Figure 3: The Graph of Comparison between Epoxy, Composite Polymer and Nano-Silver in Contour of Total Temperature for 4 PLCC at 0.5 W for Velocities 0.01 to 0.1 m/s

The above results show that the junction temperature of each chip decreases with increase in inlet velocity, at a constant chip power. The junction temperature for nano-silver is lower than epoxy moulding compound (EMC) and Composite Polymer for air inlet veloctity at 0.01 m/s and 0.1. The junction temperature of PLCC's reduced from 10-20 % by using nano-silver compared to other materials. This happens due to the characteristic of nano-silver that has a good thermal absorption and resistance. The junction temperature for PLCC 1 is the lowest compared to the other packages whereas PLCC 4 has highest junction temperature. This phenomenon happens due to the flow resistance offered as the air passes over successive PLCC packages. In the simulation model, the arrangement of the packages begins with the PLCC 1 located in front of motherboard followed by 2, 3 and 4. This makes the inlet air velocity to be minimum for PLCC 4 and hence maximum junction temperature.

Conclusion

A three dimensional conjugate analysis of heat and fluid flow over four 84-pin PLCC packages mounted on a printed circuit board is simulated by using commercial CFD code, FLUENT™. The cooling fluid considered is air. The performance of the packages under different package chip powers and various air inlet velocities is predicted numerically and found in good agreement with that of previous workers. From the analyses carried out, the following conclusions are drawn:

i. PLCC that used Nano-Silver material has the lowest junction temperature compared to other two material because Nano-Silver has the highest thermal conductivity
ii. The junction temperature for each package is directly proportional to its input power.
iii. The PLCC packages at the entrance always have the lowest junction temperature and those near the exit have the highest junction temperature owing to the variation in coolant velocity.
iv. The junction temperature of PLCC packages will become steady when the inlet air velocity is increased above 2 m/s.

The proposed numerical method is proved to be an excellent tool for the analysis of electronic packages and this study can be extended with more number of packages, and with different cooling fluids. A comparison of temperatures and heat transfer coefficients in all such cases may be made.

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