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The Effect of Parameter Changes to the Performance of a Triangular Shape Interrupted Microchannel Heat Sink

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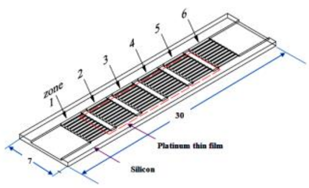
Graphical abstract



Abstract

The effect of parameter changes on triangular shaped interrupted microchannel performance was studied by simulation using FLUENT software. The parameters that were studied are total length, and the contact angle. On the other hand, the investigated effects were pressure drop and platinum film temperature. The flow in microchannel is laminar and single phase. Water was used as the working fluid and the interrupted microchannel is made of silicon. A thin platinum film plate was deposited to provide uniform heat flux. The geometry dimension of the heat sink is 30 mm in length, width of 7 mm and the thickness of 0.525 mm. From the simulation results, it is found that the improvement on heat dissipation may be achieved by increasing the microchannel length at the expense of increase in pressure drop. In addition to that, by reducing the contact angle will result to reduction in term of pressure drop and increases the improvement thermal dissipation.

Keywords: Interrupted micro channel, FLUENT, contact angle, triangular shape

1.0 INTRODUCTION

Microchannel heat sink is a promising device for cooling miniature electronic systems (Cho et. al., 2010). It is one of the microelectromechanical systems (MEMS) technologies which were developed at the early 18th century. The first microchannel concept was produced by Tuckerman and Pease in 1981, microchannel heat sinks based on silicon substrates were built and a heat sink thermal resistance of 0.09 ºC/W was reported with water a pressure drop of 2.1bars (Zhang *et al*., 2005). Since then, microchannels have been proven to be a high performance cooling technique which is able to dissipate heat flux effectively from electronic device (Vafai & Khaled, 2005). In fact, it is now one of the most extensively used methods for thermal management in electronics (Hung *et al*., 2012). Basically, the heat producing component such as computer chip or electronic device will generate an appreciable amount of heat which is needed to be dissipated. To reduce this heat, a heat sink is placed on this heat producing component. This heat sink is made from conductive material such as silicon, stainless steel or copper and the design of heat sink is necessary to meet the cooling demand from the heat producing component.

The heat that is produced from the heat producing component will be absorbed by the working fluid that is flowing inside the microchannel. The microchannel heat sink usually consists of a number of adjacent parallel microchannels. In order to design an efficient microchannel heat sink, it is necessary to understand the flow characteristics which are very important parameter in the design of microchannel (Qu, 2004).

Since the first application of microchannel for thermal management in industry, the design of microchannel heat sinks have been continuously improved. One of the significant improvements is the introduction of interrupted microchannel design. In the recent years, according to Xu *et al*. (2005), they had investigated microscale heat transfer enhancement using thermal boundary layer redeveloping concept. The research composed of parallel longitudinal microchannels and five transverse microchannels, and the transverse microchannel is used to separate the whole flow length into several independent zones. The pressure drop characteristics were enhanced for interrupted microchannel design compared to the conventional microchannel heat sink design.

Next, previous researcher Xu *et al*. (2008) compared the performance of interrupted and conventional microchannel heat sinks numerically. The computed hydraulic and thermal boundary layers were redeveloping in each separated zone due to shortened flow length for the interrupted microchannel heat sink. It was found that the periodic thermal developing flow is responsible for the significant heat transfer enhancement.

In recent years, performance analysis was also done to nanofluid-cooled microchannel heat sinks (Tsai & Chein, 2007). In addition to that, simulation on microchannel with offset fan-shaped were done successfully by Chai *et al*. (2011).

There were two effects to the pressure drop influences across the interrupted microchannel heat sink. The first is the pressure recovery effect in the microchamber and the second is the head loss when liquid leaves the microchamber and enters the next zone. In this study, the parameters that give effects to triangular shaped interrupted microchannel performance were studied numerically by using FLUENT software. The investigated effects were pressure drop and platinum film temperature.

2.0 RESEARCH METHODOLOGY

2.1 Effects on Contact Angle

The physical model referred to in this study is similar with Xu et. al. (2008) as shown in the next figures. The contact angle of the microchannels were modified by changing the width of the triangular microchannels. The width of the three different types of triangular microchannel studied were 0.26mm, 0.34mm and 0.38mm. The larger width of the triangular microchannel produces smaller contact angle.

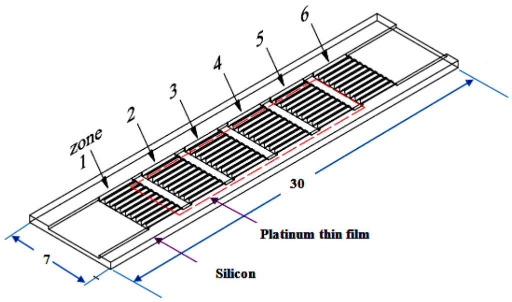


Figure 1 Three dimensional views of microchannel wafer (dimensions in mm). (Xu *et al*, 2008)

The microchannel design is shown in Figure 1. Figure 2 shows the cross-sectional view for transverse microchannel. Next, Figure 3 depicts the triangular shape longitudinal microchannel while Figure 4 shows the three types of different contact angle triangular shape microchannel that were used for this project compared with Xu *et al*. (2008).

The microchannel wafer has five transverse of the microcchamber separating the whole longitudinal microchannels into six separated zones. The silicon microchannel wafer has total length of 30 mm and width of 7 mm, with the thickness 0.525 mm. Total lengths of 10 longitudinal microchannels is 21.45 mm and the width is 4.35 mm. There is a thin platinum film been deposited at the backside of the silicon microchannel wafer with the total length of 16 mm and width of 4.2 mm. The referred triangular microchannel depth is 0.212 mm; width is 0.3 mm and contact angle is 54.72º . The pitch distance of the two longitudinal microchannel is 15 mm.

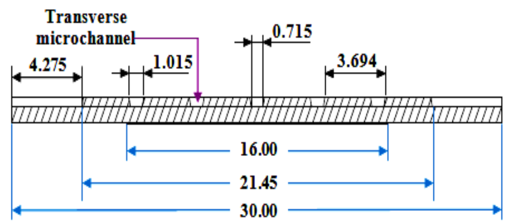


Figure 2 Cross-sectional view for transverse microchannel (dimensions in mm) (Xu *et al*. 2008)

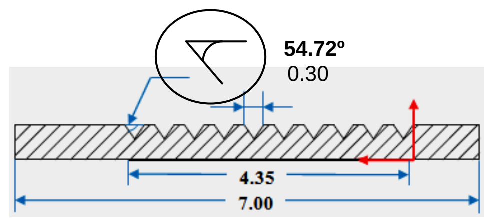
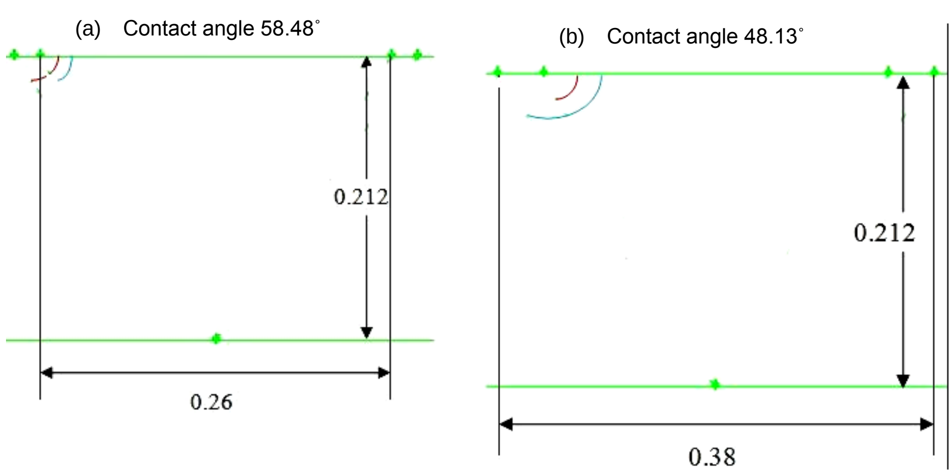


Figure 3 View for triangular shape longitudinal microchannel (dimensions in mm) (Xu *et al*. 2008)

The referred model uses 54.72º contact angle of parallel longitudinal triangle shape. In this research; the microchannel is geometrically the same with the referred model except for the triangular contact angle. The contact angles used are 48.13 º , 51.27 º and 58.48 º . The contact angle 48.13 º is considered as the smallest contact angle while contact angle 58.48 º is considered as largest contact angle.



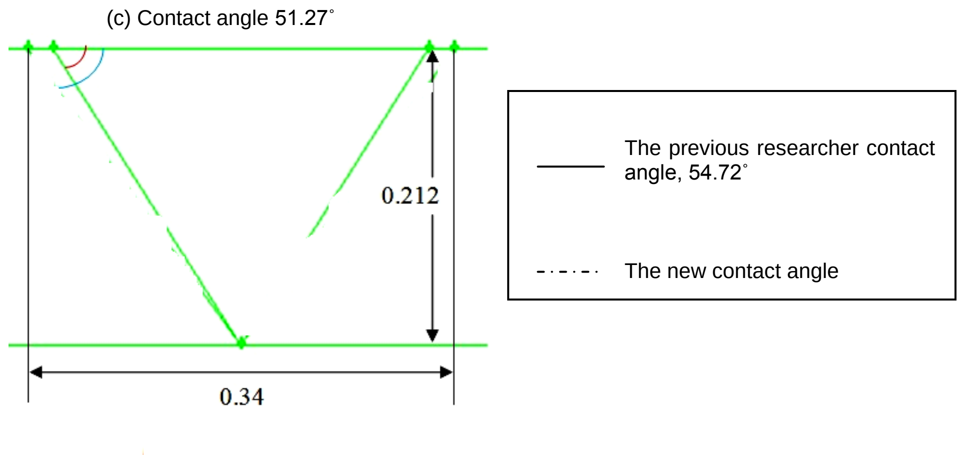


Figure 4 Comparison of the new contact angle with the previous researcher contact angle (all dimensions are in mm)

2.2 Effects on Microchannel Length

In this study, the microchannel wafer will have four , five and six transverse microchamber separating the whole longitudinal microchannels into five, six and seven separated zones respectively. The six separated zones silicon microchannel wafer has a total length of 30 mm and width of 7 mm, with a thickness of 0.525 mm. The total length of its 10 longitudinal microchannel is 21.45 mm and the width is 4.35 mm. There is a thin platinum film that has been deposited at the backside of the silicon microchannel wafer with the total length of 16 mm and width of 4.2 mm. The triangular microchannel depth is 0.212 mm; width is 0.3 mm and contact angle is 54.72°. The pitch distance of the two longitudinal microchannel is 15 mm.

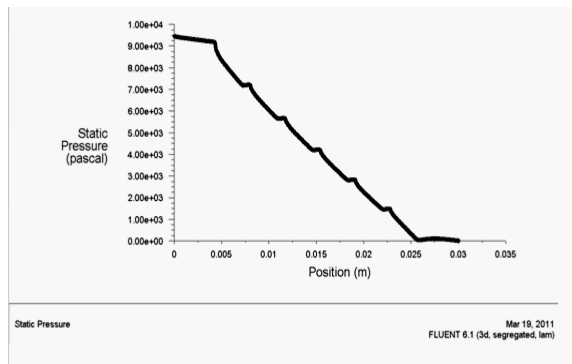


Figure 6 Graph of pressure drop for contact angle 48.13° model

3.0 RESULTS AND DISCUSSION

3.1 Comparison of Pressure Drop for Each Contact Angle

The contact angle 58.48° model pressure drop result is the highest compared to the others as shown in Figure 5 below. On the other hand, the contact angle 48.13º has the least pressure drop as shown in Figure 6. Meanwhile, Figure 7 depicts the pressure drop with contact angle of 51.27°. It can be deduced from the obtained results that, for each model, there is a slight pressure recovery effect before entering the next longitudinal direction microchannel. Then, there is an entrance head loss leading the next pressure drop. Reducing the contact angle may reduce the pressure drop in a triangular shape interrupted microchannel.

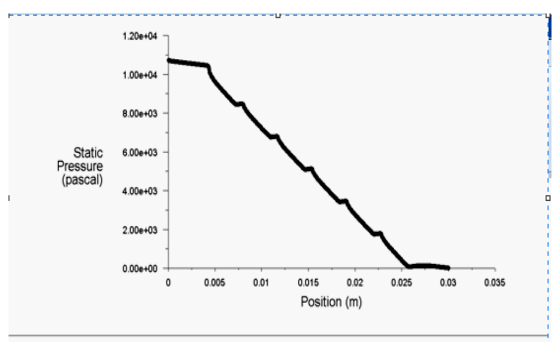


Figure 7 Graph of pressure drop for contact angle 51.27° model

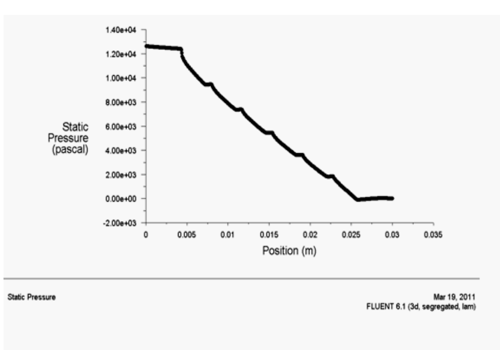


Figure 5 Graph of pressure drop for contact angle 58.48° model

3.2 Comparison of Platinum Film Temperature for Each Contact Angle

The platinum film temperature result for contact angle 58.48° model is the highest compared to the other contact angles as shown in Figure 8. This is due to the smallest surface area contact in between the microchannel and water flowing inside it for this angle. This condition slows down heat dissipation resulting in high platinum film temperature. It is obvious that the platinum film temperature is the lowest for contact angle 48.13˚ which has higher surface area contact in between microchannel and water flowing inside it. Figure 9 depicts the graph for contact angle of 48.13˚. Reducing the contact angle increases the thermal dissipation in a triangular shape interrupted microchannel.

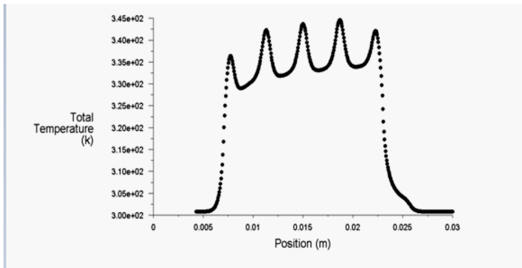


Figure 8 Graph of platinum film temperature for contact angle 58.48° model

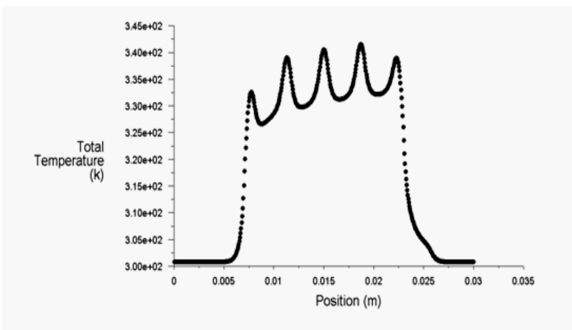


Figure 9 Graph of platinum film temperature for contact angle 51.27° model

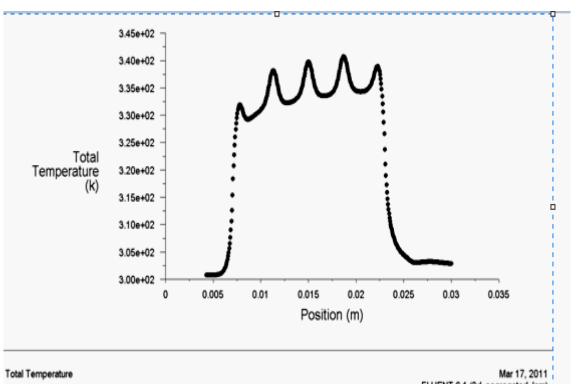


Figure 10 Graph of platinum film temperature for contact angle 48.13° model

3.3 Comparison of Platinum Film Temperature for Each Total Length

Figure 11 to Figure 13 shows the platinum film temperature with respect to total length of microchannel. With comparison to 6 zones case, the highest temperature for 7 zones decreases to about 6.3% while for 5 zones increases to about 11.4%. This is because by increasing the number of zones on the micro channel, the contact surface area for the fluid to dissipate heat is also reduced. Therefore, it is better to have more zones in improving the heat dissipation capability of the micro channel.

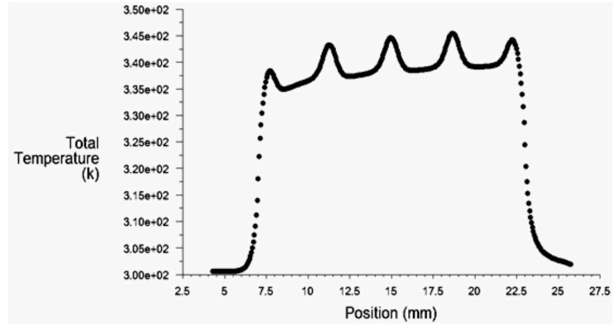


Figure 11 Platinum film temperature for 6 zones

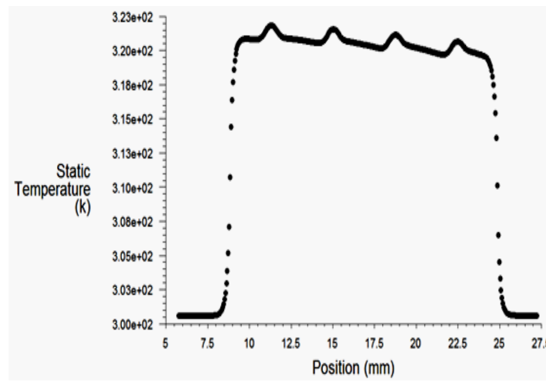


Figure 12 Platinum film temperature for 7 zones

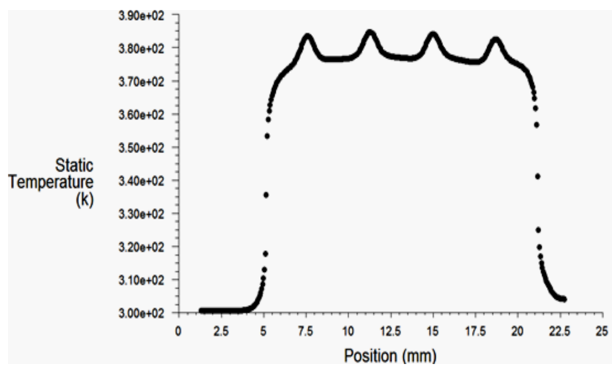


Figure 13 Platinum film temperature for 5 zones

3.4 Comparison of Platinum Film Temperature for Each Total Length

Next, the pressure drop along the longitudinal microchannel for each case is also predicted. Figure 14 up until Figure 16 shows the results of pressure drop along different length of microchannel. With comparison to 6 zones case, the pressure drop for 7 zones indicated an increase of about 26.3% while 5 zones indicated a decrease of about 16.9%. This condition occurs due to the increase of friction along the channel when the total length increases. More power is required to overcome the friction and push the working fluid forward.

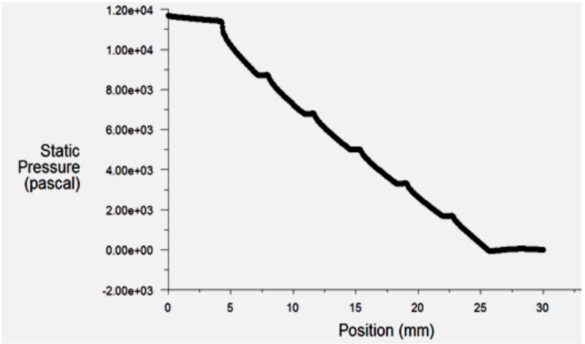


Figure 14 Pressure drop along microchannel for 6 zones

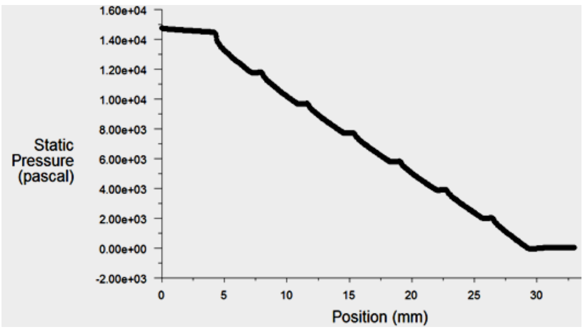


Figure 15 Pressure drop along microchannel for 7 zones

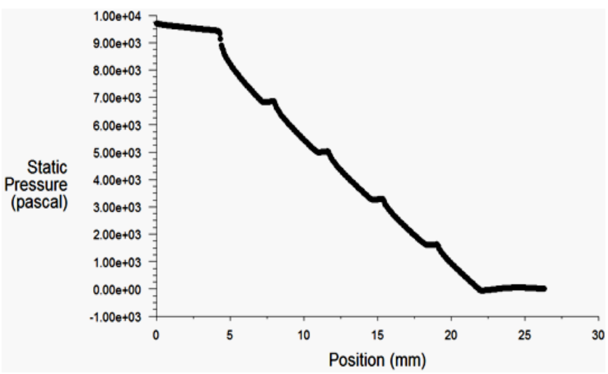


Figure 16 Pressure drop along microchannel for 5 zones

4.0 CONCLUSION

From the simulation result, pressure drop and thermal dissipation is the highest for contact angle 58.48° and 48.13 ° respectively. In short, by reducing the contact angle reduces the pressure drop and increases the thermal dissipation. Apart from that, the effect of total length on interrupted microchannel has been also demonstrated. It is found that, improvement on heat dissipation may be achieved by increasing the microchannel length at the expense of increasing in pressure drop. Therefore, increasing platinum film surface area only while maintaining the number of zones on the microchannel may provide more optimum condition. However, the effect of this modification in design requires further understanding and studies.

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