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Research Article

Cooling System of Electronic Devices using Microchannel Heat Sink

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Abstract

Increase in working speed of micro or macro electronic devices requires manufacturing of microprocessor with large number of transistors. It causes increase in heat generation. Thus thermal issues are the key elements which limit the processor's maximum performance. It is the major obstacle in the development of advanced electronic products. If no precaution is taken to develop more effective and innovative cooling methods, temperature rise will cause reduction in mean- time to failure and performance degradation. One promising solution to the problem is liquid cooling incorporating microchannel heat sink. Hence, it is necessary to have efficient cooling systems of micro or macro electronic devices.

Keywords: *Microchannel heat sink, Transistors, Thermal issues, Aspect ratio, Heat transfer coefficient.*

1. Introduction

One of the greatest successes of the 20th Century is the silicon revolution. Because of which engineers now are able to manufacture microprocessors with large number of transistors. As the number of transistors increases, the heat generated increases. Thermal issues are the key elements which limits the processors' maximum performance. It is the major obstacle in the development of advanced electronic products. According to the International Technology Roadmap for Semiconductors (ITRS), the peak power consumption of high-performance desktops will rise by 96% (147 W–288 W) in 2016, and by 95% (91 W–158 W) in lower-end desktops in 2016. If no action is taken to develop more effective and innovative cooling methods, temperature rise will cause reduction in mean-time-to failure and performance degradation. One promising solution to the problem is direct liquid cooling incorporating microchannels. Microchannel heat transfer has the potential of cooling high power density microchips. One can expect that as the size of the channel decrease, the value of convective heat transfer coefficient (h) becomes increasing in order to maintain a constant value of the Nusselt number (*hd/k)*. Two- phase cooling has a potentially higher heat removal capacity, but it involves complex issues such as saturation temperature, condensation, nucleation site activation, critical heat flux etc. For intermediate heat fluxes, single-phase cooling offers an alternative that is simpler to implement and is thus preferable. With regard to single-phase cooling, due to the reduced feature size of microchannels and the increased influence of surface tension, high flow rates (or equivalently, high Reynolds numbers) will cause a sharp increase in pressure loss and hence pumping power. The coolant flow through microchannels is invariably laminar, and turbulent convective heat transfer, which is a more efficient mode of heat transfer, is not viable. Use of microchannel cooling for extremely high power density electronic cooling applications was first described in the classical paper by Tuckerman and Pease. Their work sparked off tremendous research interests in the application of microchannel based heat sinks for electronic cooling. A conventional microchannel heat sink generally employs straight channels in which the streamlines of the coolant are nearly straight. The resultant fluid mixing is poor and the heat transfer is inefficient. Furthermore, significant temperature variations across the chip can persist since the heat transfer performance deteriorates in the flow direction in conventionally straight microchannels, as the boundary layers thicken. Moreover, the heat flux in a chip may be not uniform, thus resulting in hot regions which are not easy to remove using conventional microchannel heat sinks. These in turn will compromise the reliability of the ICs and can lead to early failures.

2. About microchannel?

2.1 What is microchannel?

It acts like an heat exchanger, which is used for dissipating heat from electronics devices. A microchannel is defined as a channel with hydraulic diameters in the range of 200µm to 10µm. It has been proved that as hydraulic dimeter decreases, heat transfer rate increases. This principle gave birth to the concept of microchannels.

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Channels of various cross sections and sizes have been used for various heat transfer purposes as heat sinks.

These channels can be classified on the basis of their hydraulic diameters as follows:-

Table 1 Classification of channels

Channels	Hydraulic diameter (Dh)
Conventional channels	Dh > 3mm
Minichannels	3mm ≥ Dh ≥ 200μm
Microchannels	200μm ≥ Dh ≥ 10μm
Nanochannels	10μm ≥ Dh ≥ 1μm

2.2 Why use microchannels?

An electronics component generates heat fluxes that will cause the circuit to exceed its allowable temperature limit. Therefore the major cause of an electronics chip failure is due to temperature rise (55%) as against other factors which accounts 20% vibration, 19% humidity and 6% dust (fig.1). So it's a great challenge for the engineers to remove the heat from the electronics chips very effectively. Microchannel heat sinks remove heat 50 times more efficiently than conventional methods.

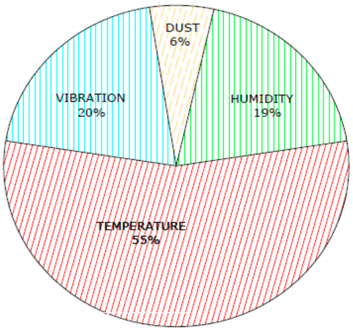

Fig.1 Major causes of electronics failure

2.3 Profiles used in microchannels

Profile in microchannel signifies the path of the fluid moving thorough it. So, mainly, it has two types of profile configurations, i.e, straight and wavy profile. In straight configuration, stream lines produced are straight, while it is of wavy nature in the other one. Due to this, proper mixing of fluid occurs in wavy than in staright, which enhances the heat transfer. The wavy microchannels result in an enhanced heat transfer performance due to increased area of heat dissipation.

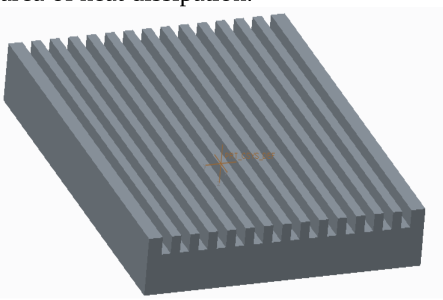

Fig. 2 CAD model of straight microchannel

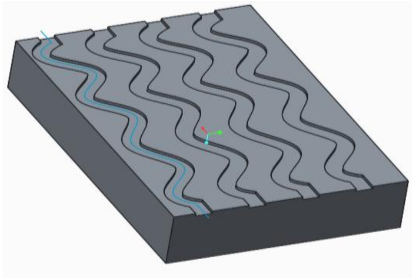

Fig. 3 CAD Model of wavy microchannel

2.4 Equations used

$$Nu = \frac{h \times D_h}{K_f} \quad (1)$$

$$D_h = \frac{2 \times W_{ch} \times H_{ch}}{W_{ch} + H_{ch}} \quad (2)$$

$$P_{pump} = \Delta p \times Q \quad (3)$$

$$m = \sqrt{\frac{2h}{K_s \times W_w}} \quad (4)$$

$$\eta = \frac{\tanh(m \times H_{ch})}{(m \times H_{ch})} \quad (5)$$

$$Re = \frac{\rho \times V \times D_h}{\mu} \quad (6)$$

Where
D_h Hydraulic diameter,
H_{ch} Height of channel,
W_{ch} Width of channel,
W_w Width of wall,
R_{th} thermal resistance,
P_{pump} pump power,
Δp Pressure drop,
Q Volume flow rate,
V velocity,
μ dynamic viscosity,
h heat transfer coefficient,
K_f thermal conductivity of fluid,
Re Reynolds number,
Nu Nusselt number,
η efficiency,
Aspect Ratio = H_{ch}/ W_{ch} .

3. Graphs

As fig. 4 shows that with respect to increase of aspect ratio, correspondingly decrease in thermal resistance is found to be occurring. This is happen due to as an aspect ratio increases means height of channel increases or width of channel decreases that means less surface area is in contact with the fluid. Hence, Thermal resistance is decreases with increase in aspect ratio.

Also from fig.5 we can say that Pumping power increases with increase in aspect ratio. This is happen due to cross sectional area of channel is increases means amount of flowing water through channel is increases, for that requirement we increases the flow rate due to that Pumping power is increases.

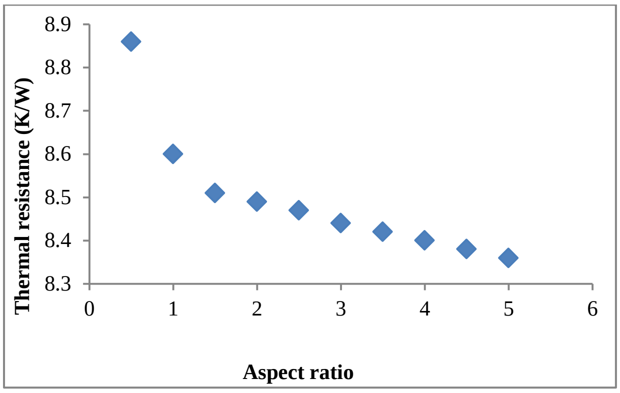

Fig. 4 Aspect ratio versus thermal resistance

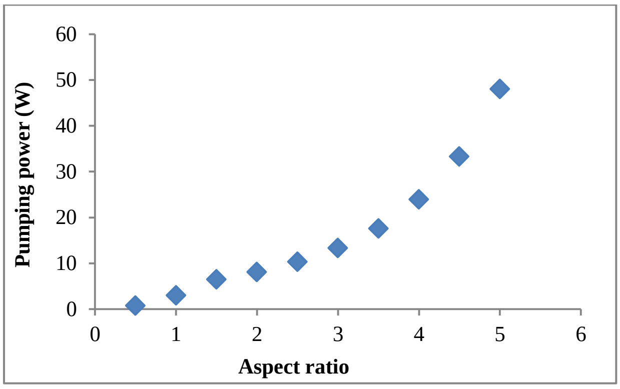

Fig. 5 Aspect ratio versus pumping power

4. Applications

1) Microchannels and Minichannels are found in many biological systems providing very high heat and mass transfer rates in organs such as the brain, lung, liver and kidney. Many high flux cooling applications are effectively utilizing their high heat transfer capabilities of these channels.
   i. For rapid separation and detection of pathogens.
   ii. For drug delivery research.
2) High heat flux cooling of lasers and digital microprocessors. For electronics, inkjet printing.
3) For electronics, inkjet printing.
4) For displays and biomedical applications.
5) Controlled drug delivery systems.
6) Biosensors: rapid and sensitive detection of specific bio-molecules such as certain proteins or DNA, present in biological fluids.
7) The Aerospace sector, where micro-heat-sink devices are increasingly used to control temperature in on board avionics.
8) Process, Automotive, Air separation/Cryogenic industries, Heat treatment of metals, drying of paper.

Conclusions

1) Due to the use of microchannel in electronic devices, performance, life span and effectiveness of those devices increase to a greater extent.
2) Also, heat generated in the devices decreases due to their use.
3) From graph, it is found that, as dimensions of channel decreases, it causes corresponding increase in heat transfer coefficient.
4) As the input wattage increases, more & more heat flux is given by the heater. Due to conduction through copper, chip temperature increases and more heat is transferred by convection to water.
5) As the flow rate increases, velocity of molecules increases so that friction between them increases and pressure drop increase. Also heat transfer enhancement can take place. The thermal resistance is inversely proportional to flow so it decreases with increase in the flow.
6) Nusselt number is function of thermal entrance length, Prandtl number as flow rate increase it increase linearly.

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