Cross-verification of thermal characterisation of a micro-cooler

Extended abstract

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1. Introduction

The thermal behaviour of a micro-cooler has been investigated using two different measurement methods to verify their feasibility. The measurement sample was a square nickel plate micro-cooler holding 128 micro-channels in radial arrangement. In our previous studies it was attached to a power transistor which was used as a dissipator and a temperature sensor. The thermal transient response to a dissipation step of the transistor was recorded in the measurement. The measured transients (cooling curves) were transformed into *structure functions* from which the *partial thermal resistance* corresponding to the cooling assembly was identified. In the current study the measurement setup was completed by a heat-flux sensor in between the dissipator and the micro-cooler to be able to verify the results extracted via structure functions.

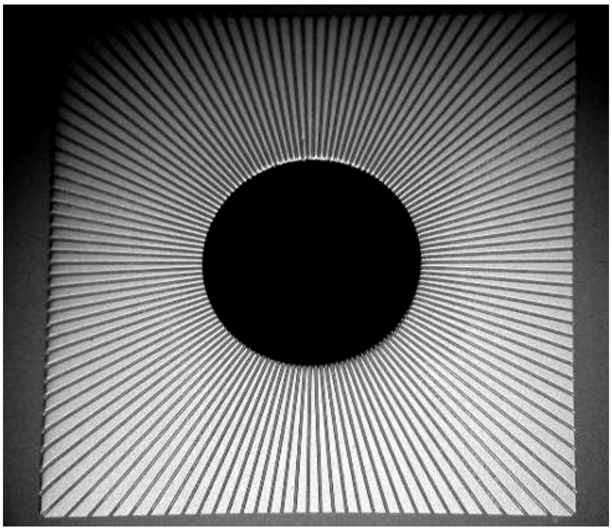

Figure 1 Photograph of the microchannel plate

2. The structure of the microchannel plate

The device (see Figure 1) was designed to be used in microelectronic packaging cooling applications. The nickel-based microchannel cooling plate was fabricated on a glass substrate using a two-layer electroforming process borrowed from the UV-LIGA (UV Lithography, Electro-forming, Replication) process. For more details on the process and on the devices' flow characteristics (measured and simulated) refer to [1]. Forced convection of air or liquid is scheduled to be used for cooling in this microchannel plate. The width of the square plate is 15mm. The thickness of the whole microchannel plate is 130μm. The centre of the plate is a 6mm-diameter hole for the micro-fan to be fitted in. The plate holds 128 radial channels. The length of the channels varies from 4.5mm to 6.36mm The width of each channel is 100μm, the depth is 70μm.

3. Thermal transient measurement of the device

The efficiency of a cooling device – like in our case that of the microchannel cooler – is characterized by its thermal resistance (conductance) towards the ambient or by its heat-transfer coefficient. The thermal resistance can be easily identified: the microcooler has to be attached to an active device like to a conventional power transistor, such as shown in Figure 2. As the micro-fan that will be used in the final device was not yet available the measurement characterising the cooling capabilities of the microchannel was completed by using a custom made platform that was capable of holding the microcooler plate and ensured the necessary cooling gas supply to it.

The method of obtaining the *partial thermal resistance* corresponding to the microcooler and its support assembly *only* was based on using the *structure functions*.

In order to obtain the structure functions thermal transient measurements have to be carried out. The thermal transient recorded contains all available information about the junction-to-ambient heat-conduction path. In our case this means the junction of the power transistor while the "ambient" is realized by the microcooler and its support assembly. In our setup we ensured that most of the dissipated power was directed towards the microcooler. The power transistor was placed onto an insulating pedestal; thus the dominant heat-flow from the junction took place in upward direction, towards the microchannel cooler.

This work is well documented in a previous article [2].

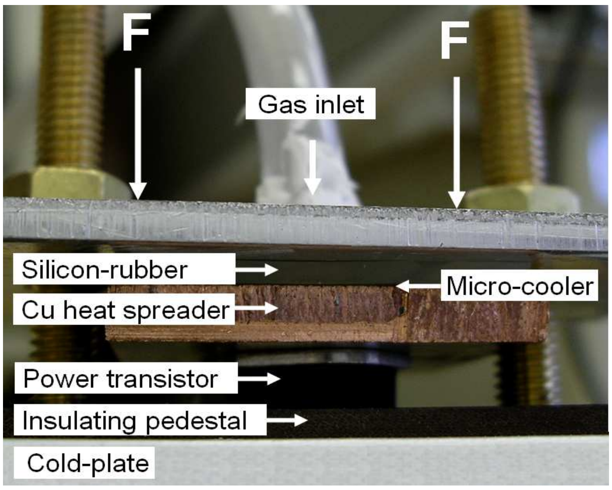

Figure 2 The microcooler attached to a power transistor (BD245C) and protected by a silicon-rubber layer

4. The heat-flux sensor

For the heat-flux sensor a temperature gradient based sensor was used that exploits the Seebeck-effect [3]. The sensor cell consists of a thin silicon layer with homogeneous doping concentration metalised on both surfaces (see Figure 3). The heat current flows through this sandwich structure, resulting in a very small temperature drop between the upper and the lower surfaces. Since both sides of the silicon die are covered by metal, these form two thermocouples with the silicon, connected in anti-series. The output voltage of the two thermocouples is proportional to the temperature difference between the two sides, that is proportional to the heat flux.

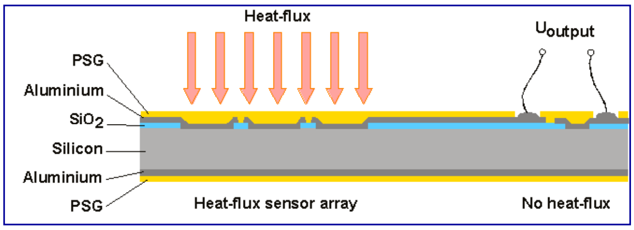

Figure 3 The structure of the sensor

The sensor used during the measurement was built of 42 cells in a 7x6 array arrangement. Beside our primary goal of verifying another measurement method using this sensor array allowed to obtain the distribution of the heat flow on the micro-cooler surface.

5. The new measurement setup

The setup shown in Figure 2 was completed with a heat-flux sensor placed between the microcooler and the copper heat-spreader. Actually a thin BeO ceramics plate separates the sensor from the heat-spreader as for the correct operation of the sensor it should be electrically isolated from the transistor. For the thermal transient measurements the ***T3Ster*** (thermal transient tester) equipment was used. To ensure the necessary input levels a calibrated low-noise pre-amplifier (A_u = 90) processed the output of the heat-flux sensor. Nitrogen was used for cooling. The pressure at the gas outlet and the gas flow rate were measured. A BD245C power transistor was used as a dissipator element. The microcooler was mounted such that the channels were facing the heat-flux sensor. The gas supply tube, seamlessly joined to a silicone rubber sheet ensured the cooling gas flow to the central (fan) hole. The rubber sheet protected the fragile microcooler plate from breaking. The powering of the transistor, sensing its temperature change and recording the heat-flux signals were carried out by the thermal test equipment.

Each measurement took about one hour, as the exact thermal transient measurement requires the steady state to be reached. First the transistor was heated up, after this the cooling transients at different flow rates were re-corded. The power-step applied to the device was 6.9 W.

6. Expected results

At the moment the measurement and evaluation are not finished yet. The heat-flux map of the microcooler is shown in Figure 4. After evaluating the results we will prove or disprove the feasibility of extracting thermal parameters from the structure function in case of gas/liquid cooled systems.

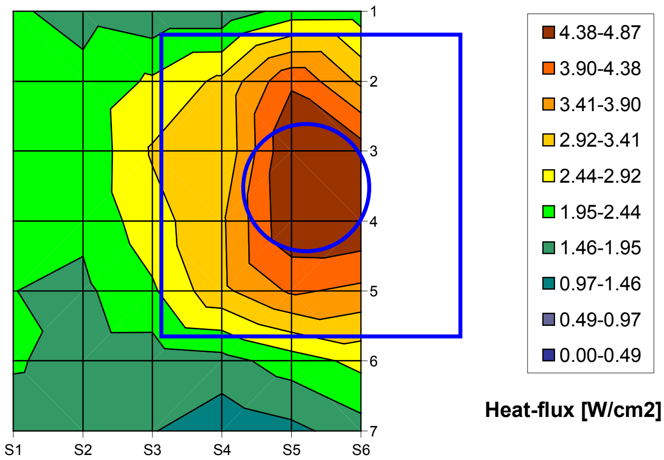

Figure 4 The heat-flux map at the micro-cooler

References

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[2] Gy. Bognár, Gy. Horváth, Zs. Kohári, A. J. Pang, M.P.Y. Desmulliez, A. Poppe, M. Rencz, V. Székely: Thermal characterization of a radial micro-channel cooling plate. *Proceedings of the XXIst SEMI-THERM Symposium*, March 15-17, 2005, San Jose, CA, USA, pp 135–140.

[3] E. Kollár, V. Székely, M. Ádám, M. Rencz: Heat-flux sensor array for package characterization, *Proceedings of the 10th THERMINIC Workshop*, 29 Sept-1. Oct 2004, Sophia Antipolice, France, pp 37–42.