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INVESTIGATION ON HEAT TRANSFER CHARACTERISTICS OF LOCAL HOT SPOT ON THE HIGH-POWER ELECTRONIC CHIP SURFACE

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1. ABSTRACT

The heat dissipation of local hot spots with high heat flux is always a serious challenge, which will seriously threaten the service life and operation efficiency of high-performance electronic devices. In this work, we proposed to utilize the conceptual design of local variable density for the micro-jet heat sink to achieve accurate and effective cooling of local hot spot areas. The hybrid of the local variable density design of the jet nozzle and the micro pin fin arrays can significantly improve the cooling performance of the local hot spot region. The research results show that the novel design can solve the heat dissipation of 700 W/cm^2, and the design concept exhibits excellent cooling characteristics in both thermal and hydraulic performance.

2. INTRODUCTION

The sharp growth in the integration of transistors on electronic chips poses a huge challenge to the heat treatment of electronic equipment [1]. How to quickly and effectively cool the heat generated during the operation of electronic devices is currently one of the major bottlenecks limiting the development of chip integration. More seriously, due to the uneven arrangement and integration of semiconductors on the chip, which will cause uneven power and temperature distribution resulting in local hot spots frequently on the chip surface [2]. The local high temperatures and high-temperature gradients caused by local hotspots pose a great challenge to the lifetime of operation, which can cause the performance of electronic systems to drop drastically [3]. Therefore, conducted a systematic study on the cooling of local hotspots on the chip surface is very necessary, so as to effectively prevent the thermal failure problem of chips by developing an excellent cooling method. In this work, we propose to utilize the conceptual design of local variable density for micro-jet heat sink, which can only solve the effective heat dissipation of high heat flux density, but also achieve accurate and effective cooling of local hot spot areas. The micro-jet heat sink that we proposed was designed and investigated via 3D modeling and CFD numerical simulation. The micro-jet heat sink is mainly composed of a jet chamber and an outlet chamber. The jet nozzles on the diverter plate were designed in the jet chamber and the micro pin fin arrays on the jet surface were designed in the outlet chamber. The hybrid of the local variable density design of the jet nozzle and the micro pin fin arrays on the jet surface were designed and analyzed.

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3. METHDOLOGY

Figure 1 illustrates a physical model of a hybrid micro-jet heat sink. The numerical calculations were based on the Reynolds-Averaged Navier-Stokes (RANS) in ANSYS CFD in this work. The turbulence model selected was RNG k- ε. The continuity, momentum, and energy equations are used to calculate the cooling performance of the local hotspots for the heat sink. The boundary conditions of the micro-jet heat sink were also set during the numerical simulation. The momentum and energy equations used a second-order upwind discretization, while the SIMPLE algorithm realized the coupling between pressure and velocity. The mesh elements were designed as an unstructured and the mesh independence was verified, a detailed description of the model can be found in [4].

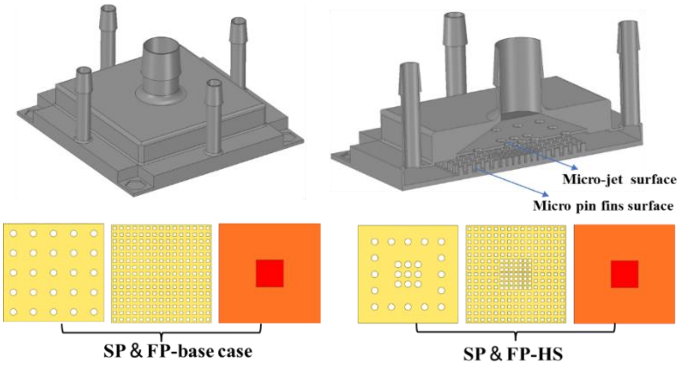

Figure 1. The physical model of the hybrid micro-jet heat sink

4. RESULTS

Figure 2 illustrates the visualized temperature contours of the local hotspot and the background region on the heating surface for SP＆FP-Base Case and SP＆FP-HS (SP＆FP-Base Case represents a uniform distribution of jet nozzle and micro pin fin arrays and SP＆FP-HS represents a local variable density). It can be clearly seen that the hybrid of the local variable density design has a significant effect on the cooling of the local hotspots compared to the uniform one. In addition, the results showed the local heat flux limits of the hybrid variable density designs can reach to 700 W/cm^2 when the background heat flux is 60 W/cm^2. Another good aspect is that the local variable density design did not increase the power consumption during the operation of the micro-jet heat sink.

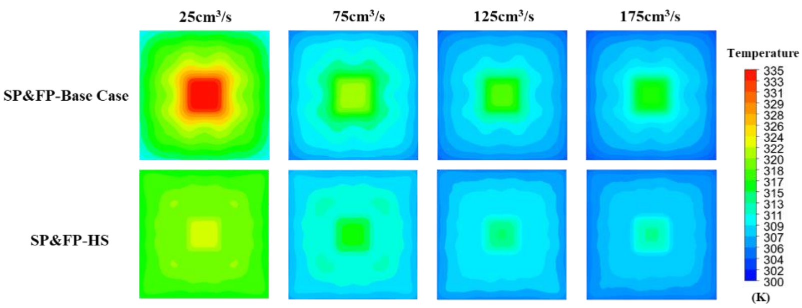

Figure 2. Temperature contours in the local hotspot and background surface for SP＆FP-Base Case and SP＆FP-HS, the background heat flux density is 60 W/cm^2 and the local hot spot is 150 W/cm^2.

Figure 3 illustrates the average temperature (T_w) of local hotspot for SP＆FP-Base Case and SP＆FP-HS for the considered flow range. The results shows that the hybrid of the local variable density design of the jet nozzle and the micro pin fin arrays can significantly decrease the average temperature of the local hotspots and can substantially increase the heat transfer coefficient of the heated surfaces in comparison to the uniform design under the considered flow range, the average temperature for the local hotspot of the SP＆FP-Base case is about 5-10K higher than that of SP＆FP-HS, which indicated that the local variable design concept exhibits excellent cooling characteristics in both thermal and hydraulic performance.

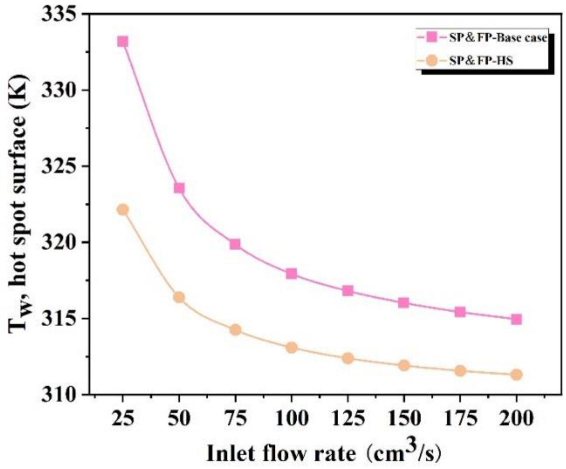

Figure 3. Average temperature (T_w) of local hotspots for SP＆FP-Base Case and SP＆FP-HS, the background heat flux density is 60 W/cm^2 and the local hot spot is 150 W/cm^2.

5. CONCLUSIONS

In this work, the hybrid of the local variable density design of the jet nozzle and the micro pin fin arrays on the impact surface of the micro-jet heat sink is utilized to achieve the effective cooling of the local hotspots with high heat flux on the chip surface. The results that the hybrid of the local variable density design has a significant effect on the cooling of the local hotspots compared to the uniform one and the local variable density design does not increase the power consumption during the operation of the micro-jet heat sink. This design concept can achieve the ‘Point to Surface’ and ‘Local to Overall’ thermal management mode and will be of strategic significance to improve the operating life and performance of electronic devices in the future.

ACKNOWLEDGMENT

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