Experimental Investigation of Microchannel Copper Plate Surfaces on Manufacturing and Wettability

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Abstract. In this study, static contact angle measurement experiments were conducted on smooth copper surface and microchannel structure surfaces under different droplet sizes. The results showed that shallow processing will more easily lead to the deformation of the processed interface. And the wettability of the microchannel surfaces with the same width and different depth were obviously different. Moreover, the contact angles on three microchannel surfaces were almost the same when the size of droplet was 12 μl due to action of gravity. The optimal droplet size is 9 μl to measure contact angle in this study.

1. Introduction

Microstructure and wettability present great potentials on high integration electronics cooling. Therefore, many scholars devoted themselves to improving the heat transfer of metal surface from surface structure or wettability in recent years[1]. However, the influence of metal surface wettability on heat transfer had been discussed and debated in recent researches[2, 3]. Recent simulations[4, 5] and experimental studies[6, 7] have proved that the essential effect of wettability on heat transfer was the structure morphology of metal surface. A surface of the microchannel structure with the same width and different depth enhanced the heat transfer by increasing the solid-liquid contact area[8]. In order to study the optimal heat transfer surface design and the influence of microchannel depth on wettability, three microchannel surfaces with different depths were designed to compare with a smooth surface. S.Y.Misyura had performed the comparisons by different methods in a wide range of droplet sizes in order to determine the contact angle on the smooth and structured wall surface[9, 10]. Abdullah et al. showed that droplet adhesion on micro-post array surface was presented and the influence of droplet size on the heat transfer and droplet internal flow characteristics was examined[11]. Their results showed that the influence of droplet size on wettability measurement was obviously. Therefore, the effects of four commonly droplet sizes (3 μl, 6 μl, 9 μl, and 12 μl) were set to measure wettability on all surfaces in this study.
2. Experimental procedure

2.1. Surfaces design and manufacturing
The copper plates with size of 20mm×20mm×2mm were used in the study. All the copper plates were ground into mirrors before being processed. The structure of studied surfaces, including a smooth mirror surface (surface 0) and three microchannel surfaces (surface 1-3), were designed as shown in Fig. 1. The micro-channels are rectangular grooves of 0.18mm in width, 20mm in length and 0.1mm in distance. The depth of microchannel from surface 1 to surface 3 are 0.1mm, 0.15mm and 0.2mm, respectively. Three microchannel surfaces were manufactured by Five-axis linkage CNC machine tools. Photos of the surfaces used in this study were shown in Fig.2.

![Figure 1. Channel structure parameters of all the surfaces.](image1)

![Figure 2. Photos of all the surfaces: (a) copper smooth surface 0, (b-d) channel structure surfaces 1-3.](image2)

2.2. 3D morphology of microchannel copper plate surfaces
The morphology of microchannel surfaces was measured by profilometer as shown in Fig. 3. The depth of microchannel in surfaces were significantly different. As can be seen from the black circle marks in Fig. 3, with the increase of machining depth, the deformation of the machining interface on the surface of copper plate decreased.

![Figure 3. 3D morphology of microchannel copper plate surfaces.](image3)

2.3. 2D morphology of microchannel copper plate surfaces
The 2D morphology of microchannel surface 1-3 were showed in Fig. 4. Obvious deformed protrusions appeared at the machining interface of surface 1 which was marked by red circle in Fig. 4(a). But this phenomenon did not appear on surface 2-3. That’s to say, when the processing conditions and parameters are the same, shallow processing will more easily lead to deformation of the interface than deep processing. However, at the bottom of the microchannel on surface 2-3, gouges caused by the cutter were clearly visible, which were marked by red circles in Fig.4(b-c). In addition, as can be seen from the marking of red ellipses in Fig. 4, the roughness of surface 1 fluctuated greatly but it was uniform along the Y-axis, while the roughness of surface 2-3 fluctuated unevenly along the Y-axis. With the increase of the processing depth, the roughness of bottom of microchannel surfaces non-uniformity increased.
2.4. Wettability measurement of microchannel copper plate surfaces
In order to investigate the effect of droplet size on wettability measurements, four different droplet sizes were selected to measure the contact angles of all surfaces. Due to the unavoidable error of wettability measurement, the contact angle measurement of each surface and each droplet size was repeated 3-5 times, and the final value was the average of all measurements. Snapshots of different droplet sizes on all the surfaces for static contact angles measurement were showed in Fig. 5.

3. Results & Discussion
Statistics of their static contact angle measurement results were showed in Fig. 6. The contact angles of microchannel surfaces were all larger than that of the smooth surface. And the contact angle was about 76° on surface 0. The contact angle of surface 1 was the largest, which was greatly related to the protruding deformation formed on the machining interface. What’s more, when the droplet was larger than a certain value (12μl), the action of gravity was so strong that the contact angles of surface 2 and 3 were the same (133°). When the droplet size was 6μl or 9μl, the contact angles of surface 1-3 were significantly different. Since the contact angles of the three microchannel surfaces under 9μl were significantly different, 9μl was optimal droplet size for measuring the wettability of surfaces in this experiment.
Figure 4. 2D morphology of microchannel copper plate measured by profilometer
Figure 5. Snapshots of different droplet sizes on all the surfaces for static contact angles measurement: (a) surface 0, (b) surface 1, (c) surface 2, (d) surface 3.

Figure 6. Static contact angles of all the surfaces with different droplet sizes
4. Conclusions
Three microchannel surfaces designed to enhance surface heat transfer were machined by Five-axis linkage CNC machine tools. And the experimental study of wettability measurement on a smooth copper plate surface and three microchannel surfaces has been carried out. The conclusion are as follows,

- The deformation of the machining interface is easy to form in the processing of shallow microchannel.
- In the static contact angle measurement experiment, when the droplet is larger than a certain value, the contact angle measurement will be inaccurate due to the effect of gravity.
- The optimal droplet size is generally 6μl and 9μl, and in this experiment, the optimal droplet size is 9μl.

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