The Effect of Powder Characteristics on the Permeability of Copper Powder Wicks in Heat Pipe Applications

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Abstract

The thermal dissipation performance of sintered heat pipes is usually determined by the capillarity and permeability of the Cu powder wicks. Since the capillary provided by the Cu powder is usually large enough to draw water from the condenser end to the evaporator end, the permeability has become the controlling factor. In this study, Cu powders with different particle sizes and shapes were loosely sintered, and their permeabilities were compared. The results show that more complicated shapes, finer particle sizes, lower porosities, and rougher pore surfaces give lower permeability and thermal dissipation.

Keywords : copper powders, heat pipe, permeability, porous materials

1. Introduction

Recent developments in computers are heavily focused on thermal management due to the high heat generated by the powerful integrated circuits. To improve the heat dissipation performance, heat pipes have been used widely, particularly the sintered types using Cu powders as the wick material.

The amount of water flowing into the Cu powder wicks is estimated as follows following Darcy's law. [1]

$$\Delta P_l = \frac{\mu_l L_l}{AK} Q \quad (1)$$

where Q is the flow rate, ΔP_l is the applied pressure difference, μ_l is the dynamic viscosity of the liquid, L_l is the length of the specimen, A is the cross section area, which the liquid flows into, and K is the permeability. The permeability has been estimated using an empirical equation given below, which has taken into account the porosity and the powder diameter. [3]

$$K = \frac{d^2 \varepsilon^3}{150(1-\varepsilon)^2} \quad (2)$$

where d is the mean diameter of spherical powders and ε is the porosity.

The objective of this study is to further understand the effects of the powder shape and particle size on the permeability and the resultant heat dissipation of the sintered Cu powder wicks.

2. Experimental and Results

To prepare the specimen for permeability tests, Cu powders of different shapes and particle sizes were filled into graphite mold cavities 13mm in diameter and 14mm in height. After the graphite molds were tapped for 1 minute, the Cu powders were heated at 5℃/min to different temperatures between 750℃ and 950℃, and then held at those temperatures for 1 hour in hydrogen. The permeabilities of sintered Cu slugs were then measured by calculating the amount of water that flowed through under a pressure head of 147.5mmHg.

Figure 1 shows the quantity of the water that flowed through the sintered specimen. The slopes of the curves, which represent the permeability, indicated that coarse spherical powders (124.0μm) had a higher permeability than did fine spherical powders (52.0μm).

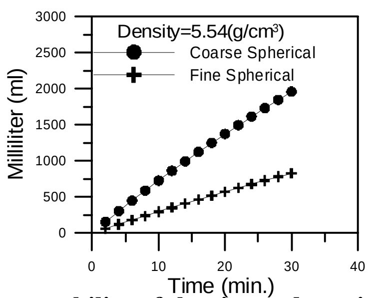


Fig. 1. The permeability of the sintered specimen using Cu powders with different particle sizes.

This is mainly due to the larger pore size in the sintered wicks using coarse powders.The data also match equation 2, showing that the permeability is proportional to the particle size when the porosity remains the same.

Besides the particle size, the powder shape also influences the permeability. Figure 2 shows that fine spherical powders have the highest permeability as compared to those of dendritic and water atomized powders. These differences were also attributed to the pore size in the sintered wicks. Table 1 shows the average particle sizes of the three Cu powders and their resultant average pore sizes after sintering. The fine spherical powders had the largest pore diameters.

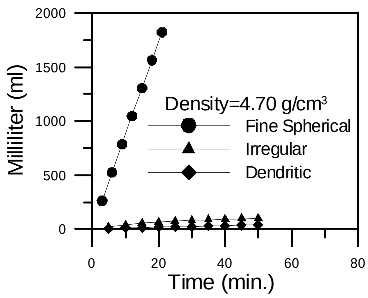


Fig. 2. The permeability of the sintered specimen using Cu powders with different shapes.

Table 1. The average particle diameters and average pore diameters of the different powder shapes

	Dendritic	Irregular	Fine spherical
Average Particle Diameter (μm)	21.4	46.2	52.0
Average Pore Diameter (μm)	3.7	10.0	22.0

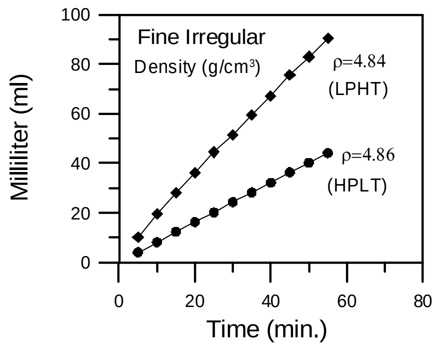
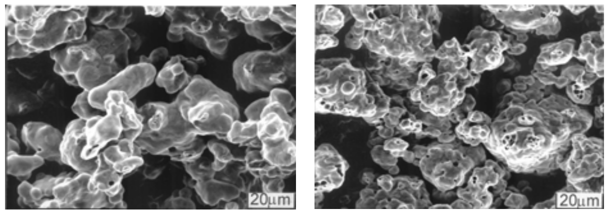


Fig. 3. The permeability of the sintered specimen using different processing.

The processing parameters can also influence the permeability. In this study, loose powder sintering at 800℃ (LPHT) was employed, and the results were compared to that of using high compacting pressure, 3MPa, and low sintering temperature, 700℃ (HPLT). Figure 3 shows that the permeability of the LPHT specimen was higher than that of the HPLT specimen. Figure 4 shows that the LPHT specimen has smoother surfaces, while the HPLT specimen has rougher surfaces. The rough pore surfaces caused an increase in the flow resistance of the liquid and resulted in the low permeability.



(a) (b)

Fig. 4. The fracture surface of sintered Cu wicks using different process parameters (a) LPHT and (b) HPLT.

To summarize the effects of particle size, powder shape, and processing conditions, the sintered wicks were compared for their heat dissipation performance. Sintered Cu wicks 200mm x 19.5mm x 1.4mm were fixed vertically with the bottom end immersed into the water bath to a depth of 15mm. The temperature at the top end, which was heated at 50 watts, was measured. Table 2 shows that fine spherical powders that are loosely sintered give the best performance due to the large pore size.

Table 2. The temperatures of the different powder shapes in the heat dissipation

	Dendritic	Irregular	Fine spherical
Temperature (℃)	165	150	119

3. Summary

Three different powders, electrolytic, water atomized, and gas atomized Cu powders, were examined to determine their effects on the permeability of sintered wicks. The results show that higher porosities, larger particle sizes, and less complicated shapes give higher permeability. The surface roughness of the pore also affects the permeability. Parts prepared with high compacting pressures and low sintering temperatures give rougher pore surfaces and more irregular pore shapes, which result in lower permeability.

4. References

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