

High Temperature Stamping Forging to Fabricate Fully Densified Copper Tungsten and Copper Molybdenum Heat Sink Materials

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Abstract

In this paper, we studied the effect of high temperature forging on the densification of CuW and CuMo composite material after infiltration. Using SEM x-section, ultrasonic scan and hermeticity etc. to characterize the improved CuW and CuMo parts, we found out that the forged CuW and CuMo composite bodies were 100% fully densified and the hermeticity stabilized at 5×10^{-9} atm cc/s.

Keywords: heat sinks, stamp forging, ultrasonic scan, full density, hermeticity

1 Introduction

Copper tungsten and copper molybdenum composites, preserving tungsten and molybdenum's characteristic of low thermal expansion and copper's high thermal conductivity, have been widely used in the packaging of microwave devices, optoelectronic components, integrated circuits, and many other electronic packaging applications. Their measures of thermal expansion coefficient, thermal conductivity, and electrical conductivity can easily be controlled by varying copper/tungsten and copper/molybdenum ratios. They can also be matched with semiconductor silicon, arsenic, gallium arsenide, aluminum oxide and beryllium oxide, etc.

Since tungsten, molybdenum and copper have

considerably different melting points, it is impossible to melt W and Cu into each other at high temperatures. In other words, no eutectic will be formed. Therefore, copper/tungsten and copper/molybdenum composite material can only be fabricated through powder metallurgy. At present, there are three major techniques: infiltration, high-temperature liquid phase sintering, and metal injection molding.

The state of the art CuW and CuMo material obtained from above methods are not fully densified as shown in studies by SEM micrographs and ultrasonic scan on the CuW material from the leading manufacturers. There are many micropores inside the composite body. These micropores would exhibit themselves as potential sources for

corrosion after gold plating.

Power forging is the process that the sintered blanks in advance are forged in a molding under high temperature and the process that combine the traditional powder metallurgy techniques with precision stamp forging. It can reduce the machining and full densify the blanks as well as improve the microstructure and the properties. Power forging will be the method with widely application as customer request better quality for the products. We have found few references for forging the tungsten. In this paper we have had some pilot research on the forging process of tungsten-copper heat sink and the effect on the properties.

2. Experiment methods

2.1 Sample preparation

W-Cu heat sinks were manufactured by the process of powder metallurgy. The raw material is commercial grade pure tungsten powder and OFHC copper for infiltration. The tungsten powders were compacted at 60Mpa into the module and the dimension of the coupon is 52mm x 27mm x 12mm, then infiltrated in H₂ with copper. The process of stamp forging was performed at 60T friction press machine in 850°C in reducing atmosphere..

We used Metalloscope and SEM to analyze the microstructure of the samples and the ultrasonic Sonoscan C-SAM D9500 with the transducer frequency at 50 MHz and the transducer resolution at 25 microns.

2.2 Measuring the coefficient of thermal conductivity

The coefficient of thermal conductivity(k) can not directly measured by the instruments and k was calculated from:

$$K=\alpha*d*C \quad (1)$$

Where α is diffusivities of the samples and measured at room temperature using laser flash technique and d is the density of the sample measured by Archimedes technique using water. The specific heat C was calculated from the rule of mixtures,

$$C=W_1C_1+W_2C_2 \quad (2)$$

Where W_1 , W_2 are the weight fraction of W,Cu. C_1, C_2 are the specific heat of W, Cu.

3 Experiment results and analysis

3.1 The effect of the forging process on the microstructure of W-Cu heat sinks

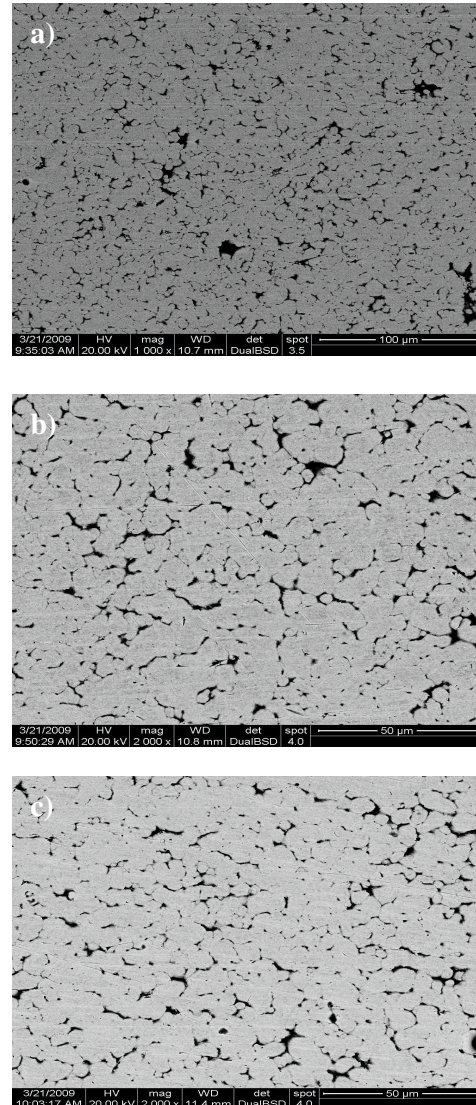


Fig 1. micrographs of W-Cu heat sinks with before and after forging (a) no forging (b) forged first time (c) forged the second time

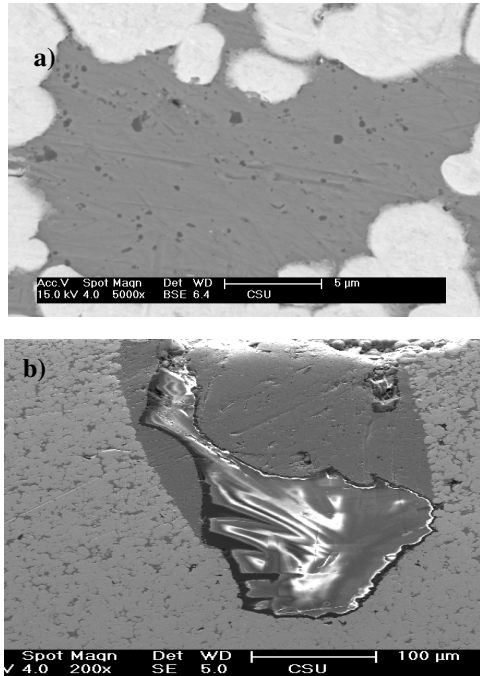


Fig 2 the pore morphology inside the copper-phase
 a) the micropores formed while copper Solidified
 b) holes formed when the liquid Copper can not completely fill

The microstructure of W-Cu heat sinks before and after the stamp forging are presented in Figure 1. It shows that there are several obvious and big regions that enriching the copper in the before stamp forging blanks and illustrate that the phase of copper shows unevenly distribution in the W-Cu heat sinks made by the process of the general powder metallurgy. These Cu enrichment region maybe result from the bridging among the tungsten powder particle when pressed or the hole formed by the unevenly distribution of lubricant. Most microholes can be fully filled by the copper after infiltration, but if the size of the Cu phase is too big, it will cause some shrinkage cavities and porosities that left the microholes in the Cu phase and it is presented in Figure 2 a) . But on the other hand, when the size of micropore is too large in somewhere, the copper can not be completely filled in the pores after the infiltration and it result as Figure 2 b). The copper only filled two-thirds space of the pore and it result that there are some micropores defects in the finished products of

W-Cu heat sinks. These defects will seriously affect the hermeticity, thermal conductivity and plating of the W-Cu products and must be avoided in the production.

Compared the microstructure of the samples before and after the stamp forging, we found that Cu and W phase of after-first-forging are more well-distributed than that of before-forging. It illustrate that the Cu phase was deformed under the pressure of forging and the porosities are closed. It caused that the size of Cu enriched region is reduced and the link strength among the powder particle is getting more tiger as well as the relative density of the sample is improved. But after the samples were forged the second time, it has no difference in the microstructure. It shows that the resistance to deformation is pretty nearly to the pressure of stamp forging and Cu phase and W phase can not deform again except the forging process is changed, such as improving the temperature or the forging pressure.

3.2 The analysis of the Sonascan Bulk-Scanning on the forged samples

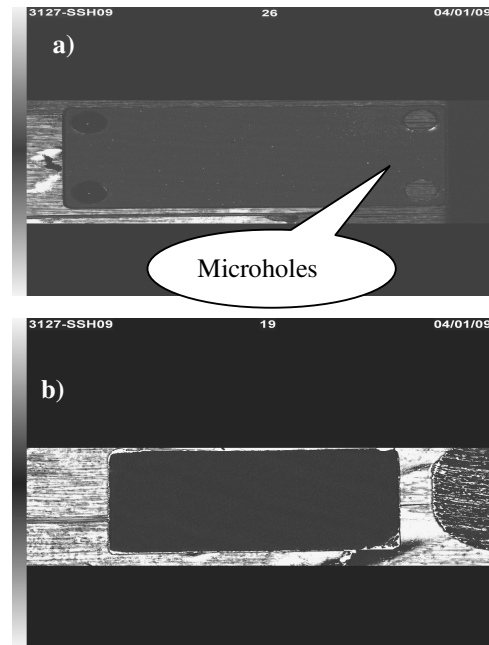


Fig 3 Sonascan Bulk-scan for forged samples
 a) no forging b) forging in 850°C after one time

The results of ultrasonic Sonscan Bulk-Scan on the forged samples are presented in Figure 3. Bulk-Scan is an ultrasound imaging modalities that can scan the sample between the upper and lower surfaces of the entire region. If there have defects in this region like holes, delamination, or crack, which form the interface will reflect a strong ultrasound in the corresponding ultrasound images, the defect will show a stronger reflected signal gray or white. Therefore, the Bulk-Scan scan up from the overall characterization of W-Cu material defects within the distribution, quantity, and even can detect the specific location, not as metallography or scanning electron microscopy can only be partially reflected in the defect situation. Figure 3-a) can be clearly seen that there are many white dots in no forged samples, indicating that the region has more than 25-micron pores, cracks, or delamination, as the dot shape from the image is judged that the main defects in material samples are holes. From Figure 3 (b) it can be seen that there have few white dots in the samples after forging and the sample scanned images were uniform. It shows the pores of the sample after forging closed or reduce 25 microns or less as well as the density is significantly improved. In the other hand, although it is poor to W-Cu materials processing performance, the samples after high temperature forging did not crack inside the W-Cu material, which indicate that the process with high-temperature forging on the W-Cu material is appropriate. Therefore, Sonscan Bulk-scan showed that forging can really make a significant densification of W-Cu materials.

3.3 The effect of the forging process on the properties of W-Cu heat sinks

The effect of the forging process on the properties of W-Cu heat sinks is presented in table 1. It is inferred that the density, hermeticity and the thermal conductivity can be obviously improved as the inside pores in the heat sinks decrease and the density increased. But it is limited to the density by adding the number of forging because it has a certain resistance inside the powder particles. The

results suggest that high-temperature forging can be greatly improved density W-Cu materials, and as a packaging material required for the various physical properties, especially the preparation of high-hermetic package of electronic packaging materials, forging is a very good process measures.

Table 1 The effect of the forging process on the properties of W-Cu heat sinks

	No forged	One time forged	Two times forged
Density (g/cm ³)	16.26	16.43	16.46
Hermeticity (10 ⁻¹⁰ Pa.m ³ /s)	27.0	4.4	4.5
TC (W/m.K)	181.0	195	194

4 Conclusion

- 1) Forging process can significantly reduce the W-Cu composite material defects within the cavity, so that W-Cu electronic packaging materials within the microstructure is more uniform, dense, the relative density of close to 100%;
- 2) Forging process can improve the properties of W-Cu heat sinks, such as hermeticity from 27×10^{-9} atm cc/s to 4.4×10^{-9} atm cc/s, thermal conductivity increased from 181.0 W/mK to 195W/mk.

5 References

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