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Development of the High Performance W-Cu Components by Powder Injection Molding

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Abstract

W-Cu alloy was very useful material for a heat sink, high electric contact and EDM electrode. Powder injection molding (PIM) is the optimum manufacturing technology to provide W-Cu components with low-cost and high-volume. We used various compositions of tungsten coated copper powders (W-Cu with 10 to 80 wt-% of copper) to manufacture W-Cu components by PIM. The optimum mixing, injection molding, debinding and sintering conditions to provide the high performance W-Cu components were investigated. The thermal and mechanical properties of W-Cu parts by PIM were measured. Finally, we can verify the high performance of W-Cu components by PIM with the tungsten coated copper.

Keywords : tungsten-copper, powder injection molding, heat sink, electrode

1. Introduction

W-Cu alloy was very useful material for a heat sink, high electric contact and EDM electrode because it has high thermal and electric conductivity, high wear and arc resistance and with controlled low thermal expansion coefficients [1]. Powder injection molding (PIM) is the optimum manufacturing technology to provide complex shaped components with low-cost and high-volume [2]. We used various compositions of W-Cu composite powders (W-Cu with 10 to 80 wt-% of copper) to manufacture W-Cu components by PIM [3]. The optimum mixing, injection molding, debinding and sintering conditions to provide the high quality W-Cu components were investigated. The effects of copper wt-% on the processing conditions such as solids loading and sintering temperature were also investigated. The thermal and mechanical properties of W-Cu parts by PIM were measured and compared with the various copper wt-%. Finally, we can verify the high performance of W-Cu components by PIM with the tungsten coated copper composite powders instead of the mixed tungsten-copper powders.

2. Experimental and Results

Tungsten coated copper composite powders with 15, 25, 35 and 80 wt-% of copper were used in this work. The mean particle sizes are 1.50 m for 85W-15Cu and 1.57 m for 65W-35Cu composite powders. Fig. 1 shows the microstructure of the W-Cu composite powders and the W-Cu composite powder consisted of lots of very fine tungsten particles that have been coated onto the copper powder.

65W-35Cu powder and wax-polymer binder system was mixed to make PIM feedstock. Fig. 2 shows the variation in mixing torque with time for the 65W-35Cu feedstock. The torque becomes erratic at a solids loading of 55%, due to the higher interparticle friction. For molding, the critical solid loading was determined as 54% and the optimum solids loading was 52%.

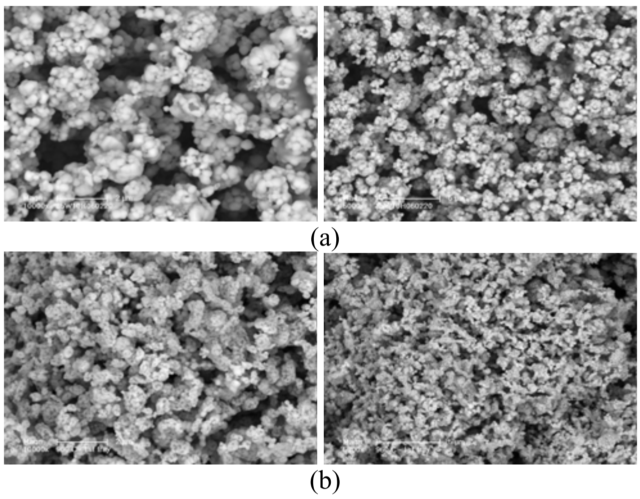

Fig. 1. Microstructure of W-Cu composite powders (a)85W-15Cu (b)65W-35Cu

The powder and binder were compounded in a twin-shaft, co-rotating mixer. After compounding, the mixture was palletized for feeding into the injection molding machine.

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The feedstock was injection molded into standard tensile specimen mold, as show in Fig. 3.

Injection-molded parts were immersed in normal hexane for 12 hours at 50 °C for solvent debinding. Thermal debinding was carried out 450 °C and pre-sintering was carried out with 900 °C for 1 hour in hydrogen.

The optimum sintering conditions of W-Cu MIM samples with various compositions were determined based on the dilatometry results. The 65W-35Cu samples were sintered at 1148°C for 1 hour in hydrogen.

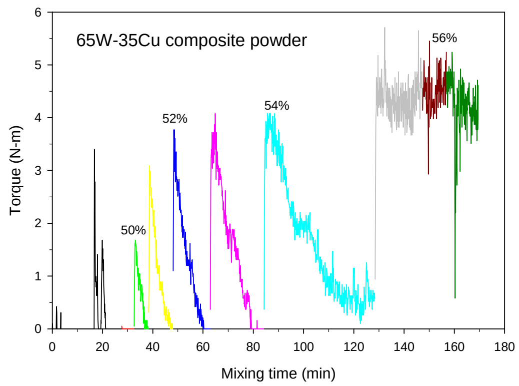


Fig. 2. Mixing torque as a function of the mixing time at various levels of solids loading.

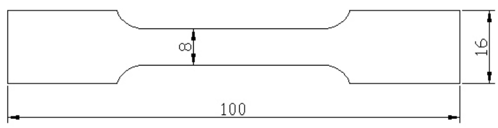


Fig. 3. Mold dimensions of tensile test specimen (thickness = 4mm).

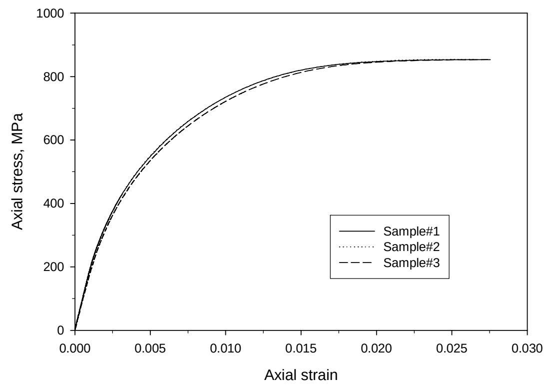
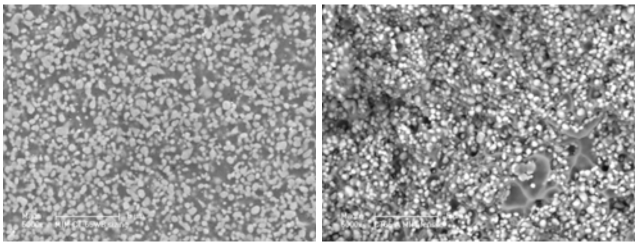


Fig. 4. Stress-strain relation for 65W-35Cu MIM tensile samples.

The final density of sintered samples was 13.69 g/cc (99.9% of theoretical density). The tensile tests were performed to evaluate the mechanical properties of the sintered tensile samples. Fig. 4 shows the stress-strain relations of three 65W-35Cu samples during tensile tests. The average mechanical properties of 65W-35Cu MIM samples were 854 MPa of tensile strength and 2.7% of elongation.

Fig. 5 shows the microstructure of 65W-35Cu MIM tensile samples. Fig. 5 shows the very fine and uniform microstructure of 65W-35Cu MIM tensile sample and the fineness and uniformity resulted in the high performance and uniform mechanical properties as in Fig. 4.



(a) (b)

Fig. 5. Microstructure of 65W-35Cu MIM tensile samples (a)cross section (b)fracture surface.

The thermal conductivity of W-Cu MIM samples was measured by laser flash method with the disk-shaped sample of 12.5mm diameter and 3mm thickness and that were prepared by cutting the sintered tensile samples. The coefficient of thermal expansion (CTE) was measured by dilatometer. The electrical conductivity was measured by the ASTM 4-probe method with a cubic brick sample.

3. Summary

The mechanical, thermal and electrical properties of MIM W-Cu samples were measured. We obtained the mechanical, thermal and electrical properties for various compositions of W-Cu alloy(W-Cu with 10 to 80 wt-% of copper) and can verify the excellent properties of W-Cu components by powder injection molding with the tungsten coated copper composite powders.

4. References

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