Development of Nano-Tungsten-Copper Powder and PM Processes

Seong Lee[1,a], Joon-Woong Noh[1,b], Young-Sam Kwon[2,c], Seong Taek Chung[2,d], John L. Johnson[3,e], Seong Jin Park[4,f], and Randall M. German[4,g]

[1]ADD, Yuseong, P.O.Box 35-5, Daejon 305-660, Korea
[2]CetaTech, Inc., TIC 296-3, Sacheon, Kyungnam, 664-953, Korea
[3]Kennametal Inc., 1600 Technology Way, Latrobe, PA 15650, USA
[4]Mississippi State University, P.O. Box 5405, Mississippi State, MS 39762, USA
[a]seongl@add.re.kr, [b]jwnoh@add.re.kr, [c]yskwon@cetatech.com, [d]stchung@cetatech.com,
[e]JohnL.Johnson@kennametal.com, [f]sjpark@cavs.msstate.edu, [g]german@cavs.msstate.edu

Abstract

Thermal management technology is a critical element in all new chip generations, caused by a power multiplication combined with a size reduction. A heat sink, mounted on a base plate, requires the use of special materials possessing both high thermal conductivity (TC) and a coefficient of thermal expansion (CTE) that matches semiconductor materials as well as certain packaging ceramics. In this study, nano tungsten coated copper powder has been developed with a wide range of compositions, 90W-10Cu to 10W-90Cu. Powder technologies were used to make samples to evaluate density, TC, and CTE. Measured TC lies among theoretical values predicted by several existing models.

Keywords : themal management, thermal conductivity, thermal expansion, nano tungsten coated copper powder

1. Introduction

Increasing power requirements and decreasing size of high-performance microprocessors present heat dissipation challenges to microelectronic package designers. These factors require the management of significant amounts of power over a small physical area, leading to high power densities.

The lack of solubility between W and Cu enables composites of these materials to be processed with useful combinations of properties for electrical contacts and thermal management materials [1-4]. Composites with 10-20 wt.% (19.3-35.1 vol.%) Cu are most commonly used for thermal management due to a good thermal expansion match with silicon. In this study, the W-Cu alloy made from a new nano tungsten coated copper powder was evaluated in terms of density, TC, and CTE for thermal management applications.

2. Experimental and Results

Tungsten trioxide (WO_3) and cupric oxide (CuO) powders were mixed in a ball mill. Compositions used in this study were 85W-15Cu, 80W-20Cu, 65W-35Cu, and 20W-80Cu in weight percent. The mixed oxide powder was reduced in a hydrogen atmosphere to form W-Cu composite powder [5]. The scanning electron micrograph (SEM) of the composite powder shows that tungsten has been coated onto the copper powder, as shown in Fig. 1.

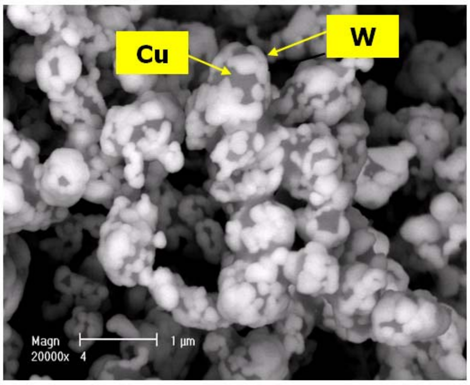
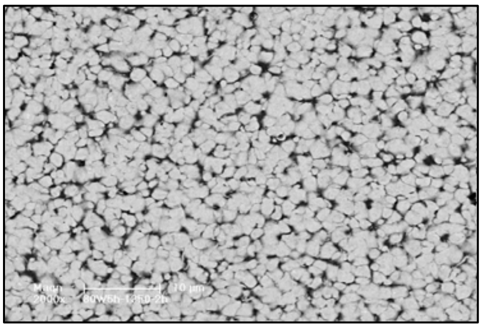


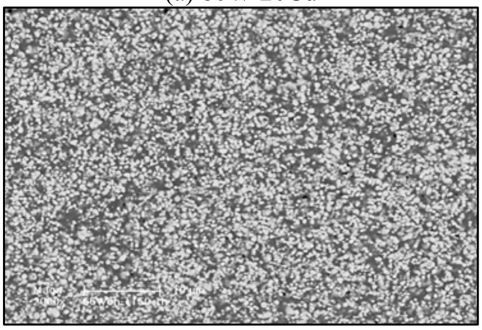
Fig. 1. SEM for 65W-35Cu composite powder.

W-Cu composite powder was pressed into a cylindrical shape of 12.7 mm in diameter and 8 mm in height with a compaction pressure of 150 MPa. The compacts were sintered in a hydrogen atmosphere at 1110-1350°C, depending on their composition and the results of dilatometry tests. Average densities, measured by Archimedes' technique, of the sintered compacts were 13.60-16.16 g/cm^3, very close to theoretical values. The sintered microstructures of W-Cu composite powder were homogeneous without pores, as shown in Fig. 2.

Table 1 shows measured density and microhardness for several compositions. From compression testing at room temperature, we found an ultimate strength of 820 MPa and a compressive strain of 33% for 65W-35Cu.



(a) 80W-20Cu



(b) 65W-35Cu

Fig. 2. SEM for sintered compacts.

Table 1. Density and hardness.

composition (wt.%)	density (g/cm^3)	relative density (%)	hardness (HRB)
20W-80Cu	9.88	99.0	51
65W-35Cu	13.60	99.3	101
80W-20Cu	15.35	98.0	103
85W-15Cu (fine copper)	16.16	98.3	107

The room temperature thermal conductivity was determined. For disk-shaped samples, the thermal conductivity was calculated from the thermal diffusivity, which was measured according to ASTM E1461 using an Anter Flashline 5000 thermal diffusivity laser flash analysis system. Heat capacity was also measured by the same machine. The samples were machined to a thickness of 2 mm. From the thermal diffusivity α, the thermal conductivity λ was calculated according to the relationship

$$\lambda = \alpha C_p \rho \qquad (1)$$

where C_p is the specific heat and ρ is the density of the sample. Fig. 3 shows measured thermal conductivity values for several compositions with three existing models [6].

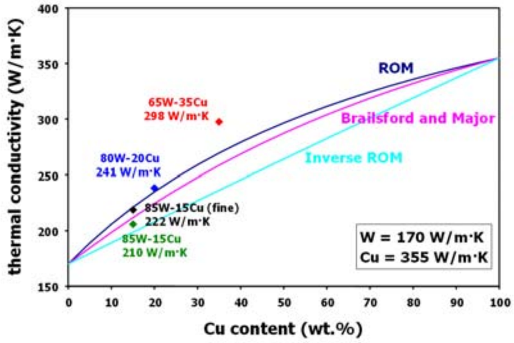


Fig. 3. SEM for 65W-35Cu composite powder.

We also measured the coefficient of thermal expansion (CTE) by dilatometer, NETZSCH DIL 402 C. 65W-35Cu alloy has a CTE of $11.6 \cdot 10^{-6}$ K^{-1} with linear behavior in the range of 36-200 °C and 85W-15Cu alloy has a CTE of $8.3 \cdot 10^{-6}$ K^{-1} with linear behavior in the range of 38-200 °C.

We measured two electrical properties, electrical resistivity and electrical conductivity, by the ASTM 4-probe method with a cubic brick sample of 5 mm × 5 mm × 40 mm. 65W-35Cu alloy has an electrical resistivity of 3.3 μΩ·cm and 85W-15Cu alloy has an electrical resistivity of 4.8 μΩ·cm. As for electrical conductivity, 65W-35Cu alloy has 52% IACS and 85W-15Cu alloy has 36% IACS.

3. Summary

In this work, a novel process to fabricate W-Cu composite powder has been presented. The microstructures of sintered product from this powder were pore-free and homogeneous, which gave thermal properties near theoretical predictions.

4. References

1. A.J. Stevens, *Powder Metall. Int.*, **17**, pp. 331-346 (1974).
2. N.C. Kothari, *Powder Metall. Int.*, **14**, pp. 139-143 (1982).
3. E. Kny, *Proc. 12th Int. Plansee Seminar*, edited by H. Bildstein and H.M. Ortner, Metallwerk Plansee, Reutte, Austria, **4**, pp. 763-772 (1989).
4. W. Neumann and E. Kny, *Proc. 12th Int. Plansee Seminar*, edited by H. Bildstein and H.M. Ortner, Metallwerk Plansee, Reutte, Austria, 4, pp. 113-137 (1989)
5. S. Lee, M.-H. Hong, J.-W. Noh, E.-P. Kim, H.-S. Song, and W.-H Baek, U.S. Patent No. 6,863,707 B2 (2005).
6. A.D.Brailsford and K.G. Major, *Brit.J.Appl.Phys.*, **15**, p. 313-319 (1963).