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Effect of porosity and copper content on compressive strength of Cu/Cu_2O cermet

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In recent years, much attention has been paid to $NiFe_2O_4$ and Cu_2O based cermets for use as inert anodes for high temperature electrolysis, especially for aluminum electrolysis [1]. Cu/Cu_2O cermet is regarded as a possible replacement anode material. But to date, this cermet has still not been employed because information about its preparation and properties is very limited. In this paper we report the preparation of a Cu/Cu_2O cermet by conventional powder metallurgy (PM) method and volume reduction method, and the influence of porosity and copper content on its compressive strength.

Morphology of Cu_2O and Cu powders is shown in Fig. 1a and b. The size of Cu_2O powders is about 20–30 μm, and that of Cu powders is less than 44 μm. For the conventional PM method, Cu_2O, Cu and binder powders were mixed in a planetary type centrifugal ball mill to reach a homogeneous condition, using ethyl alcohol as a mixing medium. The milled powders are shown in Fig. 1c. For the volume reduction method, 0.5–1.5% (wt) of phenol-formaldehyde resin was added as binder and reducing agent to the Cu_2O powders. After drying, the mixed powders were cold pressed with a pressure of 300 MPa in a steel mold to form a $\phi 10 \times 10\ mm^2$ blank, which was sintered at 1050 °C for 10 h in argon. Density of specimens was calculated by volumetric method. Mass was measured by a balance with precision of 0.1 mg and size was measured by vernier caliper with precision of 0.02 mm. Compression test was conducted on an Instron materials test machine.

Fig. 2 shows the change of compressive strength with the porosity of cermets prepared by conventional PM and volume reduction methods. It is shown that for both type of specimens, the relationship between the strength and the porosity accords with the well known equation:

$$\sigma = \sigma_0 \exp(-\alpha\theta) \tag{1}$$

For Cu/Cu_2O cermets prepared by different methods, the expressions are as follows:

$$\sigma = 652 \exp(-7.77\theta) \tag{2}$$

$$\sigma = 672 \exp(-5.24\theta) \tag{3}$$

Equations 2 and 3 are for the Cu/Cu_2O cermet prepared by conventional PM method, the cermet prepared by volume reduction method, respectively. From these

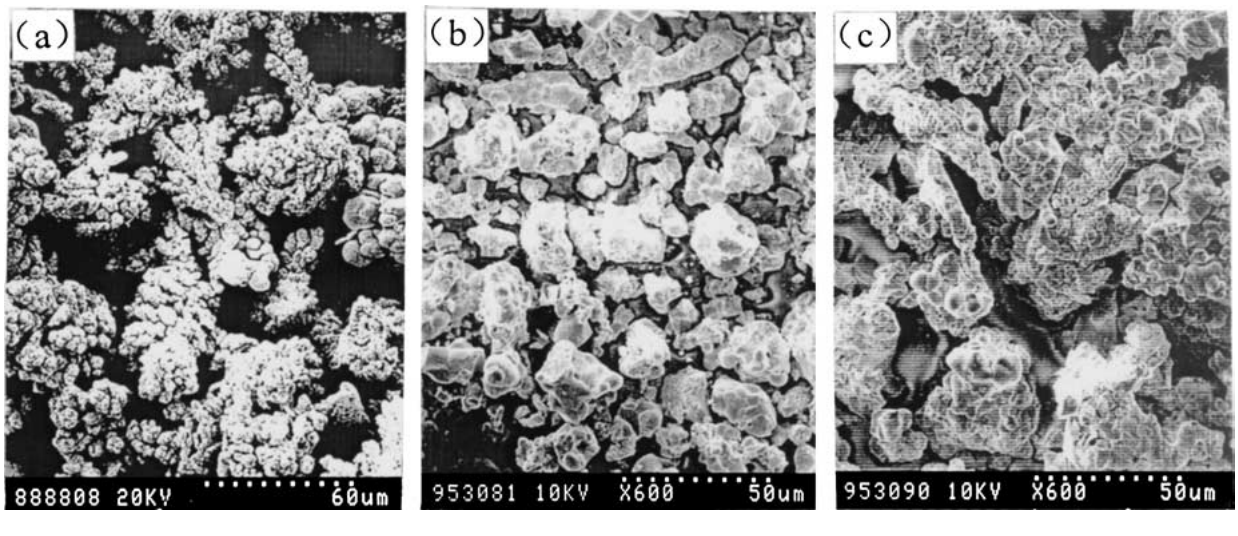

Figure 1 SEM micrographs showing morphology of different powders: (a) copper, (b) Cu_2O, and (c) milled powders.

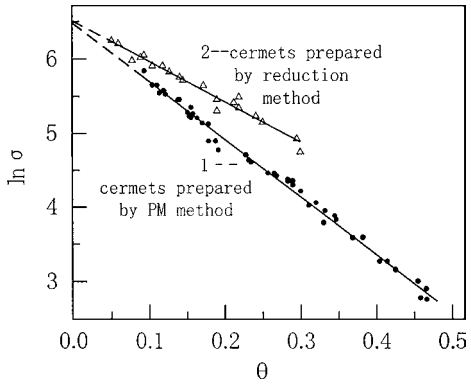

Figure 2 The change of compressive strength with the porosity of Cu/Cu_2O cermets prepared by conventional PM and volume reduction methods.

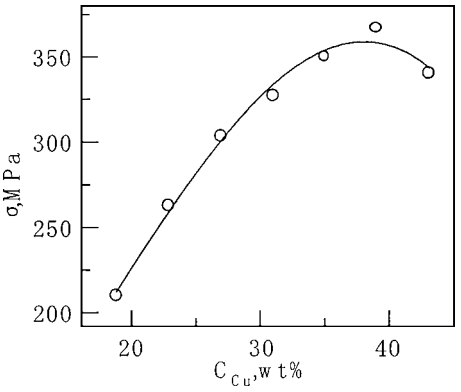

Figure 3 The change of strength with the copper content for Cu/Cu_2O cermets prepared by conventional PM method.

equations, theoretical strengths of the two kinds of specimens with no porosity are 652 MPa and 672 MPa, respectively, and slopes of the two lines are 7.77 and 5.24, respectively. These results show that strength of the cermet prepared by volume reduction method is higher and its sensitivity to the porosity is lower than that of the cermet prepared by the conventional PM method. This suggests that copper distributes more uniformly in the Cu_2O matrix of the former, which is verified by results of electric and thermal conductivities measurements [2].

It should be noted that the relation between the compressive strength and the porosity for all cermets prepared by the volume reduction method in this studies follows Equation 3 irrespective of composition. This implies that the compressive strength of Cu/Cu_2O cermet has no strong relation with the copper content, which is not expected from the behavior of cermet materials reported in the literature. However, the relation between the compressive strength and the porosity is expressed by Equation 2 only for the cermet with a composition of Cu_2O-31 (wt)% Cu prepared by conventional PM method, which confirms previous reports that the strength of cermets conventionally prepared changes with the copper content [3].

The change of strength with the copper content for cermets prepared by conventional PM method is shown in Fig. 3. The porosity of all specimens is about $10 \pm 2\%$. There is a peak in the curve in Fig. 3, which is caused by the change of volume fraction of different phases and the change of phase boundaries. A similar kind of relationship between the strength and the metallic phase content has also been observed for other kinds of cermets, such as Co/WC [4] and Cr/Al_2O_3 [5].

From results of this study, it can be concluded that the strength of Cu/Cu_2O cermets prepared by volume reduction method is higher and its sensitivity to the porosity is lower as compared with that of cermets prepared by conventional PM method. Furthermore the strength of Cu/Cu_2O cermets prepared by volume reduction method has no strong dependence on the copper content.

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References

1. V. BLINOV, P. POLYAKOV, J. THONSTAD, V. IVANOV and E. PANKOV, *Aluminium* **5** (2998) 349.
2. W. Z. SHAO, V. V. IVANOV and D. Z. YANG, *Mater. Sci. Techn. (in Chinese)* **7** (1999) 109.
3. V. V. IVANOV, V. I. ALESCHENKO and V. V. SLABKO, *J. Adv. Mater.* **5** (2001) 65.
4. M. G. LUSAK, "Strength and Permanence of Hard Alloys" (Science Press in Kiev (in Russian), 1984) p. 324.
5. P. C. KISLII, "Cermets" (Science Press in Kiev (in Russian), 1985) p. 92.

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