TEXTURE, TWINS, AND ELECTRICAL PROPERTIES OF COPPER BY PULSED ELECTRODEPOSITION

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Introduction

Pulsed electrodeposition (PED) has the potential to produce high strength high conductivity conductor or high thermal conductivity materials for high field magnets. By adjusting the parameters of PED, one is able to tailor the grain size, crystalline shape, and texture, in order to achieve optimized strength, conductivity, hardness, and chemical stability, etc [1,2]. High-purity Cu with ultrahigh strength, high electrical conductivity and random grain orientations has been reported to be achievable by PED.[3] In order to make this technology reproducible and feasible for magnet conductors, one has to establish the relationship between crystallographic texture, microhardness, and electrical properties. Unfortunately, limited work has been reported on this aspect.[3,4] This research studies the influence of substrate, peak current density and electrolyte concentration on crystallographic texture, twins, microhardness, and electrical resistivity of Cu prepared by PED.

Experimental

PED was carried out galvanostatically in an electrolyte of $CuSO_4$ solution using cathodic square wave pulses by turning off the current periodically, i.e. using an on-time of 0.02 s and an off-time of 2 s. The peak current density ranges from 0.25 to 2 A/cm^2 while the $CuSO_4$ concentration ranges from 5 to 50 g/L, and pH value is 1. A copper sheet was used as the soluble anode. The cathode/deposition substrate is 304 stainless steel or high strength MP35N alloy. The samples were checked by X-ray diffraction, transmission electron microscope, conventional four-probe technique, and Vickers hardness tester.

Results and Discussion

Three different strong crystallographic textures, i.e. out-of-plane (110), (001), (111) textures, and the random crystal structure, were clearly observed in the deposited Cu samples, as shown in Fig1.a, b, d and c, respectively. TEM observations (Fig.2) indicated that the Cu grains contain a high density of growth twins of the {111}/[112] type. Fig.2 shows that the twins in each grain have various thicknesses. Thickness of the twin lamellae is between 50 and 300 nm.

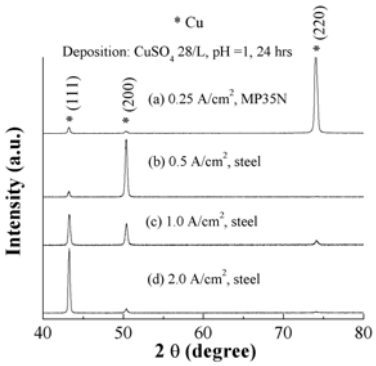

Fig. 1. XRD patterns of Cu samples.

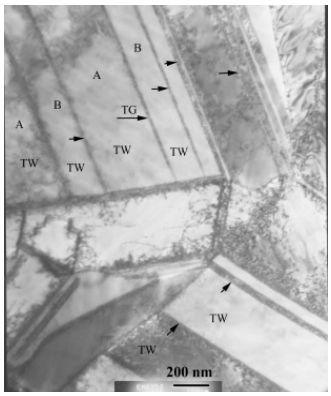

Fig. 2. TEM image of sample in Fig.1c.

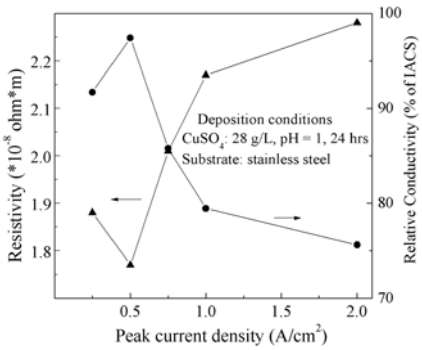

Fig. 3. Resistivity of the samples in Fig.1.

Figs.1 and 3 relate the conductivity of the deposited Cu samples to crystallographic textures and the current densities. Dependence of the hardness on peak current densities is similar to that of relative conductivity. The highest relative conductivity is 97.5 % IACS (International Annealed Copper Standard, 1.7241 μΩcm) or the electrical resistivity is 1.77 μΩcm. It is known that a higher current density results in a formation of more twins with smaller average thickness of the twin lamellae, and also more porosity. A high density of twins can increase both the hardness and strength. Whereas, the twins with lamellae thickness smaller than the free path of electron drastically decreases the conductivity of Cu. Porosity decreases both hardness and conductivity of the deposited Cu samples but enhances the thermal conductivity in liquid He.

Conclusions

Highly textured and highly twined Cu and its composite were successfully prepared by pulsed electrodeposition technique.

References

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