Highly Textured and Twinned Cu Conductors

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Introduction
The importance of high strength, high conductivity materials to the design of high field resistive and pulsed magnets cannot be over emphasized. However, when the strength increases, the ductility decreases. This embrittlement may result in the premature failure of the conductors. The purpose of this research is to reverse this relationship by increasing both the strength and ductility or elongation of Cu while maintaining its high conductivity. This is accomplished by producing the proper alignments of grains and the high density of nanotwins in the Cu films fabricated by pulsed electrodeposition (PED).

Experimental
Cu films, consisted of textured and nanotwinned Cu pyramids, were prepared by the originally designed PED processes [1]. The as-deposited Cu films were examined by X-ray diffraction, scanning and transmission electron microscopes, conventional four-probe technique, Vickers hardness tester and tensile test machine.

Results and Discussion
We have systematically studied the influence of peak current densities (PCDs), substrates on crystallographic textures; twin densities; electrical transport and mechanical properties of the PED Cu films. Highly textured and twinned Cu films with new kinds of textures, microstructures, unique mechanical and electrical properties were obtained. A typical TEM micrograph in Fig. 1a shows a Cu sample with an average twin spacing smaller than 100 nm.

The salient feature of this work is that material properties of the Cu films can be manipulated by engineering the textures and twin densities rather than grain sizes. In this way, both the ultimate tensile strength and the ductility are simultaneously improved and electrical resistivity can be controlled, as shown in Fig. 1 b and c. The texture formation in the Cu films results from the combined effects of both the textures of the substrates and the PCDs. When the PCD ≤ 0.75 A/cm², the {110} out-of-plane texture component of the substrate results in a quasi-epitaxial growth of Cu so that the deposited Cu produces fine twins and the same texture as that of substrates. Such Cu has the most favorable properties. Increasing the PCD reduces the twin spacing and re-orientates the textures eventually to {111} that has no defined orientation with the substrates so that electrical resistivity, elongation at failure and mechanical strength are increased. Proper selection of the substrate orientation can even enhance the strength further without increasing the electric resistivity.

![Fig. 1a. Transmission electron microscopy image shows twinning in Cu materials;](image1)

![Fig. 1b. Relationship between the resistivity and the strength;](image2)

![Fig. 1c. Stress-strain curves show that both strength and elongation are enhanced by reducing the twin spacing.](image3)

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References