PREPARED DISCUSSION

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Tensile and Work-Hardening Behavior of Copper Foils Prepared from Rolled Material*

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Although many investigations have been carried out on the tensile behavior of metallic whiskers and vapor deposited thin films, little is known concerning the mechanical behavior of polycrystalline foils prepared from rolled bulk material. At the Franklin Institute, the yield strength, ultimate tensile strength, and elongation to fracture have been determined using shaped copper tensile foils in the thickness range $\sim 2\mu$ to 50μ.

For foils of comparable grain size, the yield stress increases with decreasing thickness, the increase being particularly marked below $\sim 6\mu$. Typical yield values for 12μ, 6μ, and 2μ foils were 4.67, 6.59, and 9.59 kg/mm^{-2} respectively. For bulk copper, yield stresses usually fall below ~ 2 kg/mm^{-2}.

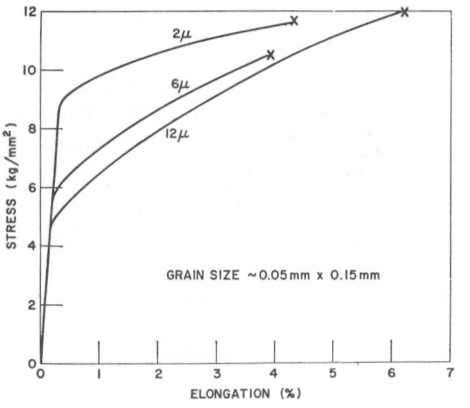

Fig. 1. Engineering stress-strain curves for copper foils of 2μ, 6μ, and 12μ thickness.

Ultimate tensile strength and elongation to fracture show no significant or systematic variation with foil thickness. A typical set of stress-strain curves for 12μ, 6μ, and 2μ foils is illustrated in Fig. 1. Up to 25μ thickness, the stress-strain curves exhibit a positive work-hardening slope to the onset of fracture, whereas foils of 50μ thickness fracture after necking down.

From Fig. 1 it is apparent that the 2μ foil work-hardens at a lower rate than the thicker foils. Values for $\left(\frac{d\sigma}{d\varepsilon}\right)$, at a strain of 1%, for the 2μ foil are ~ 1.5 kg/mm^{-2} percent elongation. Corresponding $\left(\frac{d\sigma}{d\varepsilon}\right)$ values for 6μ, 12μ, 25μ, and 50μ foils are ~ 2 kg/mm^{-2}. The decrease in work-hardening rate with decrease in thickness is consistent with the observations made by Suzuki, Ikeda, and Takeuchi[1] on single crystal copper wires of varying diameter. Thus, as the crystal diameter decreases, the range of easy glide increases, and the rate of hardening decreases.

Tests were also carried out on 12μ foils having an electro-plated coating of nickel on each face. The thickness of the coating was calculated to be <5000 Å. Compared with the uncoated 12μ foils, the yield stress is increased by a factor of 2 while the tensile strength shows only a small increase. The rate of work-hardening of the coated foils is also considerably higher than that of the uncoated material (~ 3 kg/mm^{-2}). It is, therefore, apparent that dislocation source length, active glide length, and the surface itself all contribute to the observed stress-strain behavior. The ductility of the rolled and annealed foils is markedly higher than that of whiskers or deposited films.

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Reference

1 H. Suzuki, S. Ikeda, and S. Takeuchi: J. Phys. Soc. Japan **11** (1956) 382.

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