Surface and grain boundary electron scattering contribute significantly to resistivity as the dimensions of polycrystalline metallic conductors are reduced to, and below, the electron mean free path. A quantitative measurement of the relative contributions of surface and grain boundary scattering to resistivity is very challenging, requiring not only the preparation of suitably small conductors having independent variation of the two relevant length scales, namely, the sample critical dimension and the grain size, but also independent experimental quantification of these two length scales. In most work to date, the sample grain size has been either assumed equal to conductor dimension or measured for only a small number of grains, the quantification of the classical size effect still suffers from an uncertainty in the relative contributions of surface and grain boundary scattering.

In this work, a quantitative analysis of both surface and grain boundary scattering in Cu thin films with independent variation of film thickness (28 nm to 158 nm) and grain size (35 nm to 425 nm) in samples prepared by sub-ambient temperature film deposition followed by annealing is reported. Film resistivities of carefully characterized samples were measured at both room temperature and at 4.2 K and were compared with several scattering models that include the effects of surface and grain boundary scattering. Grain boundary scattering is found to provide the strongest contribution to the resistivity increase. However, a weaker, but significant, role is also observed for surface scattering. Several of the published models for grain boundary and surface scattering are explored. It is found that the experimental data are best described by a grain boundary reflection coefficient of 0.43 and a surface specularity coefficient of 0.52. This analysis finds a significantly lower contribution from surface scattering than has been reported in previous works, which is in part due to the careful quantitative microstructural characterization of samples performed. The effects of surface roughness, impurities, voids, and interactions between surface and grain boundary scattering are also examined and their importance is evaluated.

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The public is welcome to attend.