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The effect of grain size distributions on low-temperature creep in a thin film

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ABSTRACT

Thin films with microcrystalline and nanocrystalline grains are used in MEMS and thin films for electronics. These systems have mechanical properties that depend on the microstructure. Grain size is frequently reported only as mean values or bounds. It has been demonstrated, however, that a mean grain size value is insufficient to describe the microstructure of these materials and the resulting macroscopic mechanical properties. For example, deformation mechanisms at this scale demonstrate sensitivity to grain size, and variations in yield stress, hardness, ductility, and plastic behavior have all been attributed to the varying distributions of grain size in samples with identical average grain sizes. Computational models of crystal plasticity have begun to address these distributions of grain size, utilizing fast Fourier transform-based crystal plasticity models and crystal plasticity finite element models (CPFEMs). In this study, a CPFEM which tracks dislocation density and models the resulting plasticity is extended to include vacancy motion resulting from low-temperature creep. This model is then used to examine the effect of realistic grain size distributions on the creep behavior and postcreep stresses and strains in an electrodeposited nanocrystalline nickel thin film. In addition, the validity and effect of the assumption of homogeneous intragranular stresses, an assumption made in several experimental studies of creep behavior in thin films is examined.