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Study of slip in high purity single crystal niobium for accelerator cavities

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ABSTRACT

One of the ultimate goals in particle accelerator cavity design is to establish a model that integrates the grain orientations of an ingot slice, slip activity during deep drawing, and dislocation substructure evolution because of slip system interactions, which governs subsequent recrystallization. In order to understand the slip behavior during deep drawing of large grain Nb, it is first necessary to know how slip occurs in the uniaxial tension of single crystal Nb. In this study, the slip behavior of Nb samples taken from an ingot slice before and after an 800ºC/2h anneal is compared. The as-cut specimens were deformed monotonically to 40% engineering strain using a tensile tester (Instron 4302). The heat treated specimens were deformed in an SEM in situ using an Ernest Fullam stage, with strain increments of ~10%, and held in a loaded condition while microscopy measurements were made. After the heat treatment, the yield strengths decreased significantly for almost all specimens, and there was no longer a slight drop of flow stress between yield and 15% strain which is present in several of the as-received specimens. This implies that the dislocations initially present in the ingot play an important role in deformation, and that the heat treatment effectively removed many dislocations. In most cases, the deformation paths for corresponding specimens exhibit a different sense of rotation, even though the specimens have nearly identical starting orientations. This implies that pre-existing dislocations affected which slip systems were activated during deformation. Although the initial orientation differences were small, the pre-existing dislocations led to final orientations that differed by more than 10? after 40% strain. There is a noticeable prevalence of {110} slip in the heat treated specimens as compared to a dominance of {112} slip for the as-received specimens. This provides evidence that existing dislocations lead to conditions that favor operation of slip on {112} planes. Very linear slip traces were observed on the heat treated specimens, while there was a range of slip trace inclinations observed in the as-received group, which suggests that pre-existing dislocation entanglements may have led to bursts of slip on different planes in the same Burgers vector direction.