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Twin Boundary: Strengthening or Softening?

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Traditional methodologies for strengthening materials are based on the generation of, various internal defects to resist the dislocation motions. Several commonly used strengthening approaches for metallic metals and alloys are demonstrated. However, these approaches invariably suffer from the undesirable consequence that increase in strength facilitated by dislocation interactions with internal barriers also causes reduced ductility and increased brittleness. Coherent twin boundary is a special kind of internal interface with low energy. It can serve as sink and source of dislocations, as well as barrier against dislocation transmission, which is regarded as effective strengthening internal interface for most materials. An increase in twin density with decreasing twin thickness can strengthen ultrafine-grained Cu, similar to the grain-size-dependent strengthening in nanocrystalline metals [1-2]. In this presentation, we will focus on the recent studies not only of the strengthening but also of the softening phenomena relative to the coherent twin boundaries. The effect of ultra-fine twin thickness, temperature as well as loading orientation on the strength, ductility and work hardening of Cu with nano-scale twins will be reported.

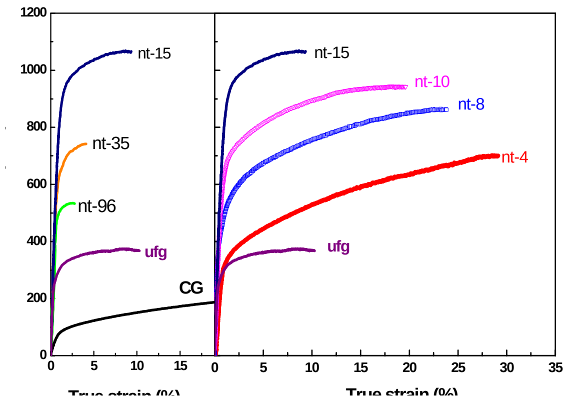

Figure 1. Uniaxial tensile true stress-strain curves for nt-Cu samples with different twin thicknesses varying from 96 to 15 nm (a) and from 15 to 4 nm (b) [3].

Figure 1 shows that the occurrence of the critical twin thickness (λ) giving the highest strength. The presence of the maximum strength in the nanotwinn Cu samples suggested that there is a transition of deformation mechanism when the twin thickness less than the critical value [3]. Both the experimental results and molecular dynamics simulations [4] indicated that the classical Hall–Petch type of strengthening due to dislocation pile-up and cutting through twin planes switches to a dislocation-nucleation controlled softening mechanism with twin-boundary migration.

A clear temperature effect was found in the nanotwinned Cu when performing the rolling process at room temperature (RT) and at liquid nitrogen temperature (LNT), respectively. The different hardness variation tendencies, obviously hardening at RT rolling and slightly softening at LNT indicate a distinct temperature effect of the plastic deformation and the different underlying deformation mechanisms [5].

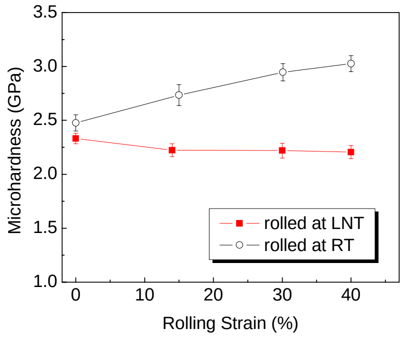

Figure 2. The variations of microhardness as a function of rolling strain at RT (open circle) and at LNT (solid square) of the nt-Cu samples. The error bar represents the standard deviation from 30 random measurements []

It is interesting to note a significant influence of loading direction on the mechanical response of the Cu sample with preferentially oriented nanoscale twins. The nanotwinned Cu samples were compressed at different loading direction with respect to the twin plane, namely 90°, 0° and 45°. Different mechanical behaviors, including yield strength, work hardening and ultimate strength were observed from the compression tests. The experimental measurements suggest that Cu samples with preferentially oriented twins exhibit substantially anisotropic deformation behaviors at different loading directions with respect to TBs。

References;

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