Why does dislocation climb makes thin films harder?

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1. Introduction

Metallic thin films on the order of (sub)-micrometers are one of the main building blocks of various small electronic devices. Their reliability is intimately tied to the mechanical properties at this length scale. Discrete Dislocation Dynamics (DDD) framework in contrast to conventional continuum theories is an accurate modelling tool on the order of micrometers to study plastic deformation by way of individually taking dislocations into consideration. In this study we incorporate the dislocation climb mechanism to DDD framework and investigate climb assisted dislocation glide. This allows to study complex time-dependent processes in precipitation-hardened thin Al-Cu films.

2. Problem Description

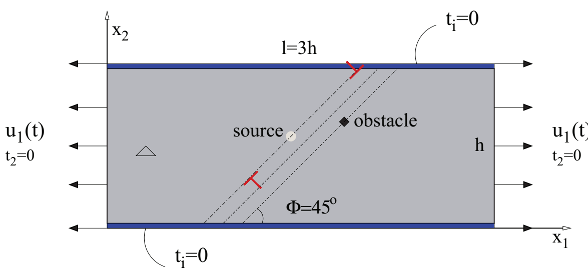


Figure 1: Schematic illustration of 2D plane strain problem. Single crystal is stretched in uniaxial tension.

Passivation layers are present at the top and bottom. where friction stress τ_f is counteracting on the resolved shear stress τ^{ϕ} which drives dislocation motion. Dislocation I gets stuck at the interface until $\tau^{(I)} \geq \tau_f$.

3. Stress vs. Strain Response

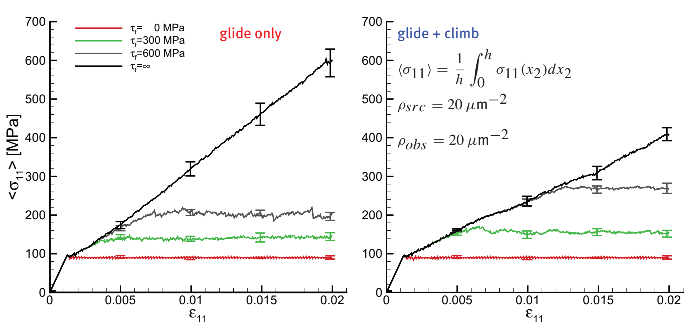


Figure 2 : Stress strain curves for $h = 0.5\ \mu m$.

4. Dislocation Structure & Stress

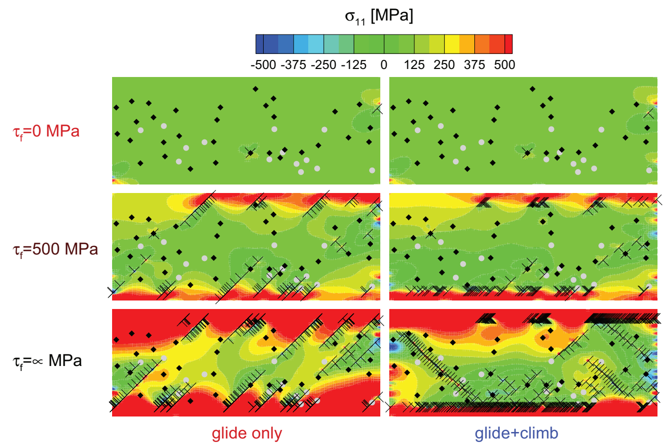
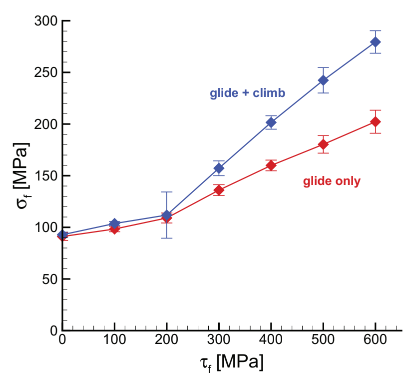


Figure 2: σ_{11} distribution across the film and superimposed dislocation structure.

- In climb assisted glide dislocations do not form pile-ups at hard boundaries but instead spread out of their original slip plane. Dislocation walls are formed.
- When climb mechanism is present at a finite τ_f, few dislocations can exit from the surface due to lower local stress at the interface.



5. Conclusion

For self passivated thin films (e.g. Al-Cu), climb assisted glide gives a harder stress response, i.e. higher σ_f when compared to glide only cases. The effect of film thickness h on climb assisted glide is the focus of our ongoing research.