Can twin boundaries act as dislocation sources?

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Nanotwinned materials are known for their high strength and ductility [1]. The fundamental origin of their damage tolerance is yet not fully clear: While the high strength can be explained by the obstruction of dislocation motion caused by numerous twin boundaries, the origin of the unexpected ductility and the origin of detwinning remains unclear. Since high strength materials typically do not exhibit pronounced strain hardening, slip localization – hence failure – sets in at low strains. But why doesn´t that happen in nanotwinned materials?

We investigated the dislocation source behavior of coherent Σ3 twin boundaries using spherical nanoindentation [2]. Our experiments show that the stress for operating a pre-existing dislocation source in the vicinity of a TB is substantially lower than the one for dislocation source operation in the grain (see Fig. 1). We propose, that slip localization in nanotwinned materials is suppressed by a unique dislocation multiplication process occurring at imperfections of the otherwise coherent Σ3 TBs. This dislocation multiplication process can only operate one time at a single imperfection, which suppresses slip localization and facilitates damage tolerance. Finally, the proposed mechanism also can explain detwinning.

Keywords: dislocation, indentation, slip localization, detwinning, nanotwinned

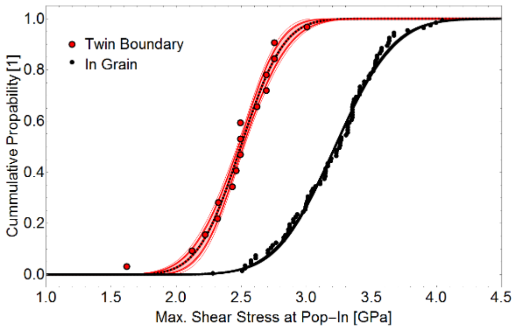

Fig. 1 Cumulative probability of the shear stress at pop-in in the grain and at the boundary

[1] L. Lu, X. Chen, X. Huang, K. Lu, Revealing the Maximum Strength in Nanotwinned Copper, Science, 323, 2009, 607-610
[2] J. Li, G. M. Pharr, C. Kirchlechner, Quantitative insights into the dislocation source behavior of twin boundaries suggest a new dislocation source mechanism, Journal of Materials Research, 36, 2021, 2037-2046