SIZE-DEPENDENT COHERENT TWIN BOUNDARY STRENGTH CONTRIBUTION IN CU MICROPILLARS

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Recent works using micropillar compression has shown that the stress for ideal dislocation slip transmission through a coherent twin boundary (CTB) in copper is similar to the stress required for dislocation cross-slip. Malyar et al. stated that the difference in shear stress during deformation of single and bi-crystalline micropillars ($\Delta\tau_{2\%}$) can be as low as 7 MPa for 3 µm sized pillars. A double-hump dislocation curvature was proposed to explain this unexpectedly low difference, where an additional dislocation curvature in bi-crystalline micropillars is necessary to form the perfect screw dislocation required for cross-slip-like transmission [1]. This alignment of the dislocation near the CTB causes the dislocation line to form a double-hump shape.
The aim of the current study was to investigate if the double-hump hypothesis correctly describes the strengthening effect of a CTB in micropillar deformation. We employed focused ion beam machining to mill more than 90 micron-sized single (Sxx) and bi-crystalline (Bxx) pillars with a single vertical Σ3(111) CTB in 3 different nominal sizes of 1, 3 and 5 µm diameter. Subsequently, *in situ* microcompression experiments inside a scanning electron microscope (SEM) as well as post-mortem imaging using SEM were performed.
It was found that bi-crystalline pillars follow the same size scaling law as typically observed in micropillars, i.e. smaller pillars are substantially stronger. Importantly, $\Delta\tau_{2\%}$ was observed to decrease with the increase of pillar diameter. A thorough statistical analysis was performed to develop a joint analysis to describe both data sets (Sxx and Bxx) in one relation. The joint analysis allowed us to successfully separate the size-dependent CTB strength contribution according to the double-hump model from the general size-scaling in micropillars.

[1] N. V. Malyar, B. Grabowski, G. Dehm, C. Kirchlechner, Dislocation slip transmission through a coherent Σ3{111} copper twin boundary: Strain rate sensitivity, activation volume and strength distribution function, Acta Mater. 161 (2018) 412–419. https://doi.org/10.1016/j.actamat.2018.09.045.

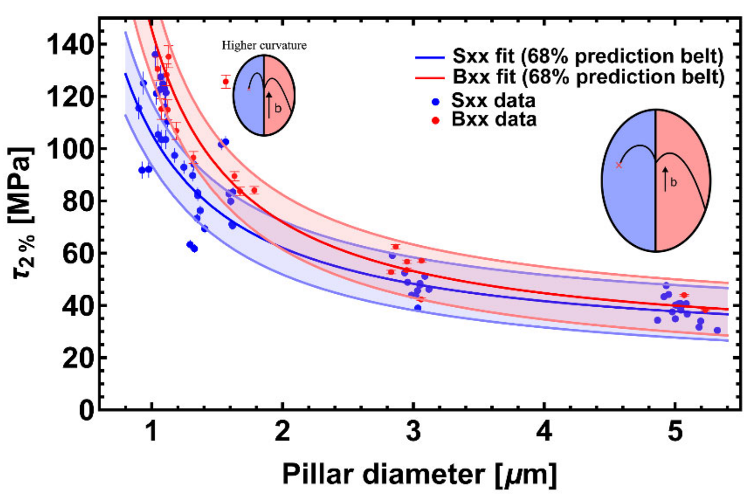

Figure 1 – The shear stress at 2% strain vs. pillar diameter of single crystalline (Sxx) and bi-crystalline (Bxx) pillars. The best fit model ($\boldsymbol{\tau_{2\%} = \tau_0 + \frac{k}{d^n}}$) for each pillar type and the 68% confidence band (standard error of the fit) are also shown. The varying shear strength difference between Sxx and Bxx ($\Delta\tau_{2\%}$) in different diameters shows that the strength contribution of a twin boundary is size dependent.