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Quantitatively Probing the Mechanical Behavior of Submicron-sized Metal Pillars in the TEM

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Recently, Hysitron have developed an *in situ* TEM nanomechanical testing apparatus which enables to develop a one-to-one relationship between imposed force/stress and individual deformation event with a time resolution equal to that of the video record device [1-4]. In this talk, we reviewed our recent progress in the application of this unique *in situ* TEM device for probing the mechanical behavior of individual single crystal nickel and titanium alloy pillars [5, 6].

Prior to the deformation tests, the Focused Ion Beam (FIB) fabricated nickel pillars were observed to contain a high density of defects. However, quite unexpectedly, the dislocation density was observed to decrease dramatically during the deformation process and, in some cases, even resulted in a dislocation-free crystal. The phenomena, which we termed as "mechanical annealing", is the first direct observation of the dislocation starvation mechanism and sheds new light on the unusual mechanical properties associated with submicron- and nano- scale structures [5].

The compression tests on [0001] oriented α-Ti alloy pillars [6] find that the stress required for deformation twining increases drastically with decreasing sample dimension (d) until d is reduced to $d_c \sim 1$ μm, below which the DT is overtaken altogether by less correlated, ordinary dislocation plasticity, as shown in Fig. 1. Accompanying the transition in deformation mechanism, the maximum flow stress of the submicron-sized pillars was observed to saturate at a value close to titanium's ideal strength. A "stimulated slip" model is developed to explain the strong size dependence of DT. The large sample size in transition is easily accessible in experiments, making our understanding of size dependence highly significant for applications [7].

References

[1] A. M. Minor *et al.*, *Nature Materials* **5** (2006) 697.
[2] O. L. Warren *et al.*, *Materials Today* **10** (2007) 59.
[3] Z. W. Shan *et al.*, *Physical Review B* (2008) 155419.
[4] Z. W. Shan *et al.*, *Nature Materials* **7**(2008) 947.
[5] Z. W. Shan et al, *Nature Materials* **7** (2008) 115.
[6] Q. Yu *et al.*, *Nature* **463** (2010) 335.
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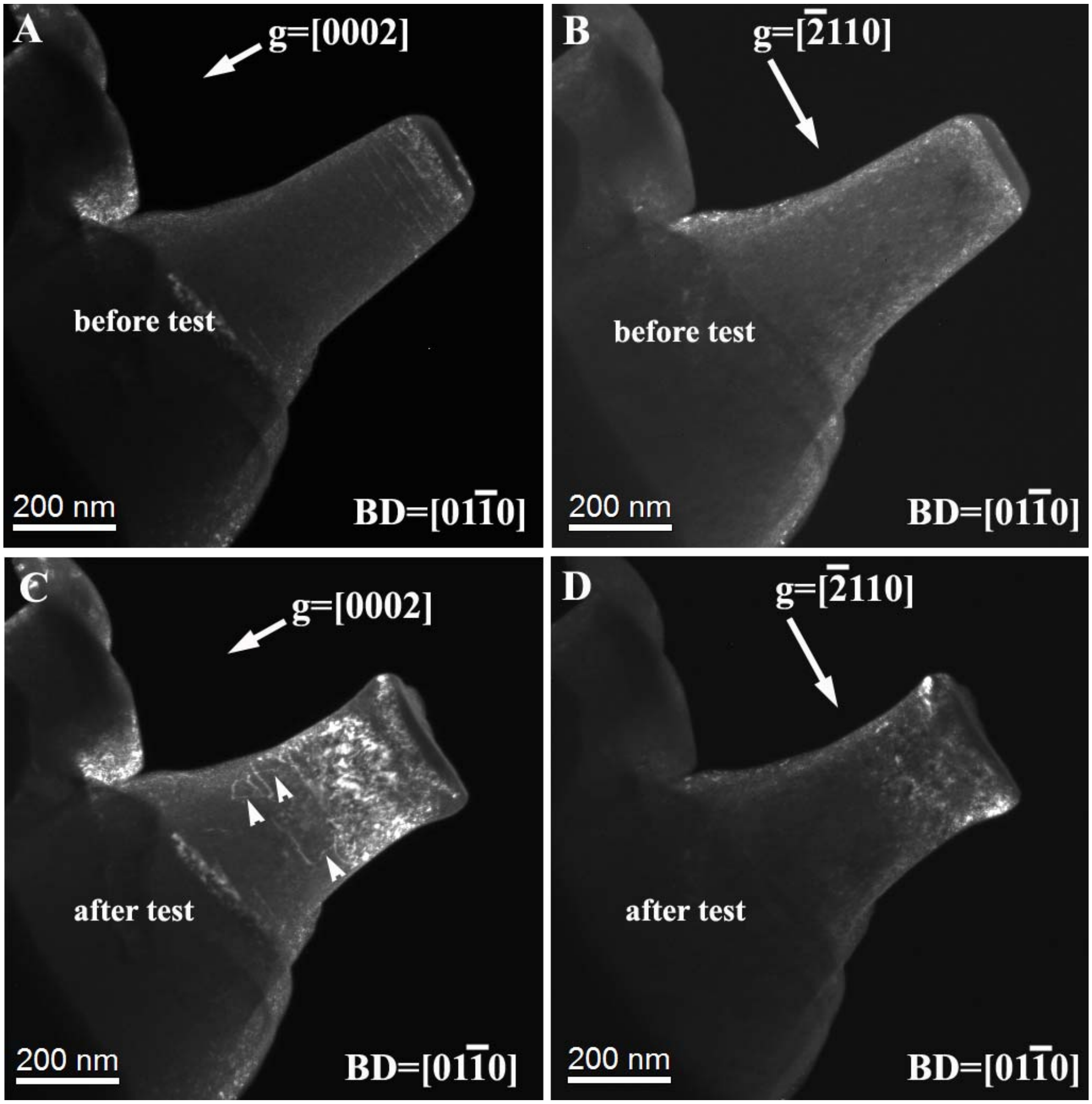

FIG. 1. Dark field TEM images of the 0.25μm diameter single crystal α-Ti alloy pillar before and after the in situ compression test. Corresponding diffraction vectors are labeled on each image. Note that those individual dislocations shown in (A) and (C) become invisible in (B) and (D). Analysis showed that the Burgers vector of these dislocations is of the (0001) type. The dislocations shown in (A) are edge dislocations. However, as indicated by the white arrows in (C), the dislocations ahead of the heavily deformation volume do include screw components. No deformation twinning was observed.

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