Nanomechanics of dislocations and interfaces revisited with new dedicated in-situ TEM tensile method

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Due to its site selectivity and its micro machining ability, Focused ion beam (FIB) is widely used to prepare small-scale samples for nano/micro mechanical testing. However, FIB induced damages can significantly affect the mechanical behaviors and plasticity mechanisms of micro/nano scale samples [1]. The present work describes a new dedicated method used to improve in-situ TEM tensile tests in small-sized Ni specimens. Twin jet electro-polishing, FIB, and in-situ TEM heat treatment (400 °C, 3 h) were combined to prepare the samples, Fig. 1, while the Pi 95 PicoIndenter instrument (Brucker.Inc), Fig. 2 (a), coupled with the Push-to-Pull device, Fig. 2 (b and c), were used to perform the in-situ TEM tensile tests [2]. In addition to the absence of FIB induced defects in the structure of the tensile samples, the design-ability of the tensile sample in terms of crystallographic orientations and containing defects such as interfaces or dislocations is the main advantage of the new sample preparation technique.
Defect-free tensile samples allowed observing the intrinsic fundamental deformation mechanisms in a quantified manner. The results obtained in a single crystal Ni sample with very low density of dislocations, Fig. 2 (d), revealed novel nanomechanics of an individual single arm source which strengthens upon nucleation of new dislocations during deformation while similar experiments performed on a bi-crystal Ni sample with a single coherent twin boundary (CTB), Fig.2 (e), allowed direct observation of the mechanisms controlling the dislocation/twin boundary interactions in which dislocations cross-slip in the twin boundary and dissociate into partial dislocations without causing migration of TB. In the single crystal case the tensile direction equals $[\bar{5}\,\bar{4}\,\bar{1}]$ while for the bi-crystal this was chosen as $[5\,4\,1]$ which is parallel to the CTB plane.

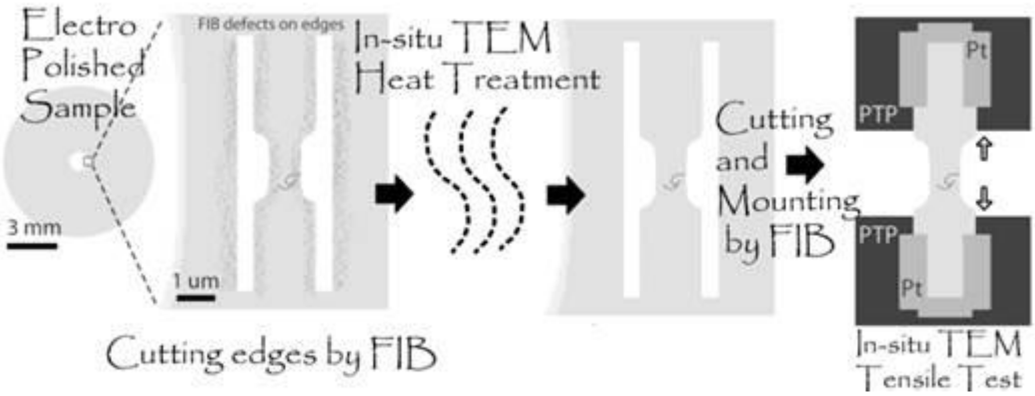

Fig. 1. (a) Schematic illustration of the sample preparation steps.

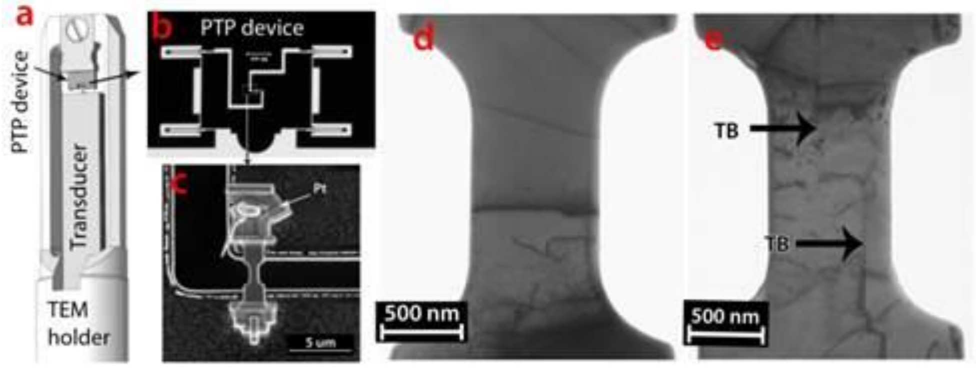

Fig. 2. (a) Schematic of the tip of the Hysitron holder and the PTP device, (b) the BF image of a PTP device, (c) the SEM image of the mounted sample on a PTP device, (d) and (e) the BF images of the single and bi-crystal Ni sample containing CTB, respectively.

1. Shim, S., et al., Effects of focused ion beam milling on the compressive behavior of directionally solidified micropillars and the nanoindentation response of an electropolished surface. Acta Materialia, 2009. 57(2): p. 503-510.
2. Samaeeaghmiyoni, V., et al., Quantitative in-situ TEM nanotensile testing of single crystal Ni facilitated by a new sample preparation approach. Micron, 2017. 94: p. 66-73.