Dislocation/coherent twin boundary interactions: new insights from quantitative in-situ TEM tensile testing

Hosni Idrissi[1,2*], Vahid Samaee[2], Dominique Schryvers[2]

*hosni.idrissi@uclouvain.be
[1]Institute of Mechanics, Materials and Civil Engineering. Université catholique de Louvain (UCLouvain) – Place Sainte Barbe 2, bte L5.02.02, 1348 Louvain-la-Neuve, Belgium
[2]Electron microscopy for Materials research (EMAT), University of Antwerp (UA) – Groenenborgerlaan 171 2020 Antwerpen, Belgium

Ultra-fine grained materials often exhibit an outstanding strength, but unfortunately a detrimental low ductility. One exceptional case are nano-twinned materials which combine both, high strength and ductility [1]. This is associated with the presence of twin boundaries (TBs) though the underlying mechanisms of increased ductility are still not fully understood. Efforts have been devoted in the past to investigate dislocation-TB interactions using conventional static and dynamic TEM, MD simulations and more recently quantitative in-situ compression of pillars inside SEM and TEM [2]. However, tracking the intrinsic dislocation/TB mechanisms with quantitative in-situ TEM tensile testing remains absent in the literature. In this study, very clean small bi-crystal Ni samples with preselected single {111} coherent TB (CTB) have been prepared using an original preparation method [3], see Fig. 1a. These samples were deformed in tension in-situ using the PI-95 TEM picoindenter holder and the Push-to-Pull (PTP) device (Bruker.Inc), see Fig. 1b. The interactions between dislocations nucleated from single arm sources with the CTB have been observed and quantified in-situ. For screw dislocations interacting with the CTB, the results revealed transition from slip transmission across the CTB to dislocation absorption inside the boundary. The absorption process involves the dissociation of the incoming screw dislocations into pairs of twinning/anti-twinning dislocations that glide in the same direction leading to CTB sliding. Image force of the CTB was measured by observing repulsive interactions between non-screw dislocations with the CTB. Finally, fracture of the sample at steps at TB was observed. The method used here open windows for more accurate characterization of the fundamental mechanisms controlling the interaction between dislocations and other types of GBs.

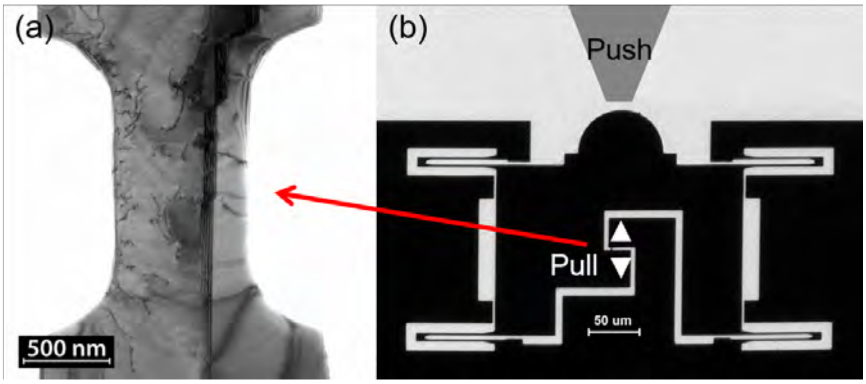

Figure 1: (a) Small-sized tensile sample with single CTB. (b) The Push-To-Pull device used for quantified in-situ TEM tensile testing. The compression of the semicircular end induces uniaxial tension in the middle gap where the sample is fixed with Pt using the FIB/SEM dual-beam instrument. This allows one-to-one relationship between tensile stress-strain curves and defects behaviour.

[1] L. Lu et al., Science, 304. (2004) 422-426.
[2] P.J. Imrich et al., JOM, 67.8. (2015) 1704-1712.
[3] V. Samaee et al., Sci.Rep., 8 (2018) 12012 (1-11)