

MECHANICAL HYSTERESIS OF THE MAX PHASE Ti_2AlN : A NANO-MECHANICAL TESTING STUDY

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MAX phases are nano-lamellar ternary carbides and nitrides, with a hexagonal crystallographic structure. These materials combine several properties of metals and ceramics, which give them a high potential for technological applications. Their mechanical properties are characterized by a high stiffness and a relatively low yield strength. More surprisingly, deformation tests on MAX phases reveal a mechanical hysteresis. At a macroscopic scale, in polycrystalline samples, several studies have shown that this behavior could be related to load transfers from grain to grain. However, a mechanical hysteresis is also observed in single crystals.

In this work, the mechanical hysteresis and the plasticity of the MAX phase Ti_2AlN has been studied at small scale by using nanoindentation tests with a spherical tip and micro-pillar compression tests. In both cases, cyclic loadings have been applied in single grains, for different crystallographic orientations, previously determined by EBSD. These cyclic loadings, with partial unloadings (cf. figure 1), have revealed a same behavior in nanoindentation tests and in micro-pillars compression test. In both cases, the unloading curves show an elastic behavior followed by a plastic recovery at low load. Furthermore, this mechanical hysteresis is related to the crystallographic orientation since the energy dissipated during the cycles is shown to be minimum when the basal plane is perpendicular or parallel to the indentation (or compression) axis.

The dislocation structure associated to this hysteretic behavior has been investigated by surface slip lines analysis by AFM (for the indents) and by SEM (for the pillars). The different configurations between nanoindentation and micro-pillar compression tests (in terms of stress field, free surface, deformed volume...) have provided complementary information to explain the mechanical hysteresis in terms of dislocation mechanisms.

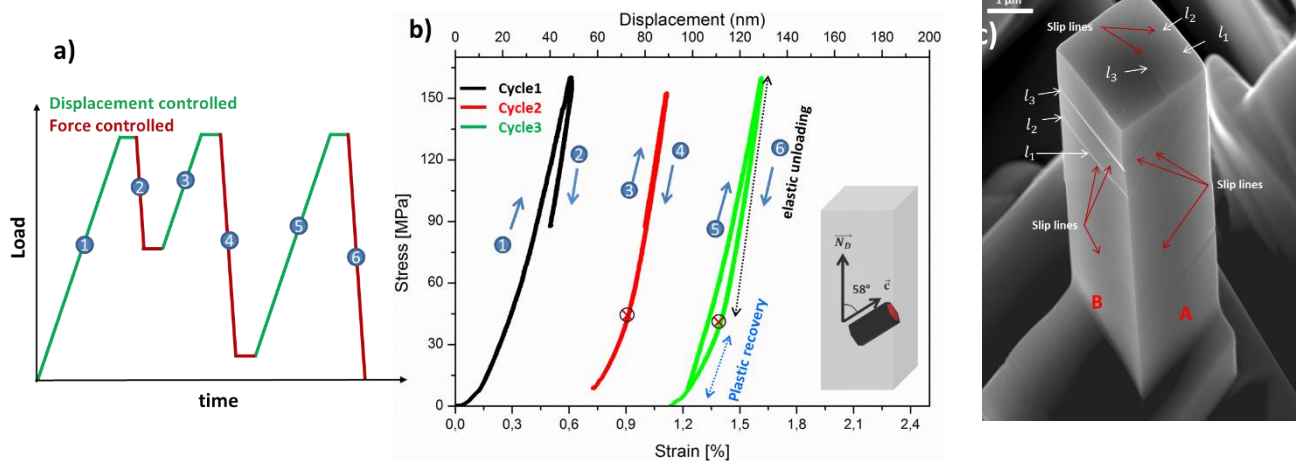


Figure 1 – a) Micro-pillar loading sequence, b) Stress-strain curve obtained on a $8 \mu m$ Ti_2AlN micro-pillar (cycles 2 and 3 have been shifted to the right for more clarity), c) typical Ti_2AlN micro-pillar after deformation.