NANOMECHANICAL TESTING STUDY OF THE ELEMENTARY DEFORMATION MECHANISMS IN THE Ti_2AlN AND Cr_2AlC MAX PHASES

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Deformation mechanisms in MAX phases are still not well understood. The complex mechanical behavior of these materials, including mechanical hysteresis, arises both from their crystallography, with a nanolayered structure alternating nitride or carbide layers with metal atoms layers, and from their macroscopic polycrystalline structure, composed of platelets-like grains. In order to distinguish from these two contributions, we focused our study at the sub-micrometer scale, in order to probe the mechanical response of individual grains.

For this purpose, nanoindentation tests were performed at room temperature and at high temperature in single grains of Ti_2AlN samples. The deformation microstructures were then investigated by Atomic Force Microscopy (AFM) through the observation of the slip lines left at the surface by the dislocations, and by Transmission Electron Microscopy (TEM) in cross section through the nanoindents. An automated mapping of crystallographic orientations was also performed using the ACOM (Automatic Crystal Orientation and phase Mapping) ASTAR technique (cf. figure 1). These experiments revealed the presence of highly disoriented domains below the indents, as well as more conventional low angle tilt boundaries associated with dislocation walls. Different possible deformation mechanisms are discussed in light of these observations. In a second approach, spherical nanoindentation tests have been performed in Cr_2AlC single crystals recently synthesized by high temperature solution growth. These samples are thin platelets of few mm^2, oriented along the basal plane. By embedding these platelets in a given orientation (cf. figure 2), it is possible to choose the crystallographic orientation of the indented surface in order to probe the plastic deformation mechanisms in specific configurations. The dislocation structures and the highly disoriented domains have been observed around a same indent by AFM and TEM, and the deformation mechanisms will be discussed in view of these observations.

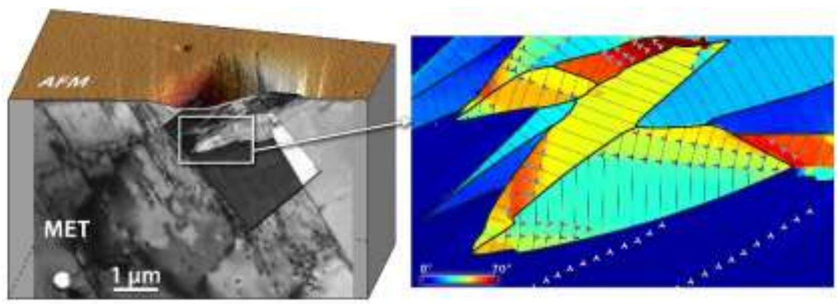

Figure 1 – AFM and cross section TEM analysis of the deformation structure around a nanoindentation imprint performed at 800°C (left side) and local crystallographic disorientations in the same area (right side).

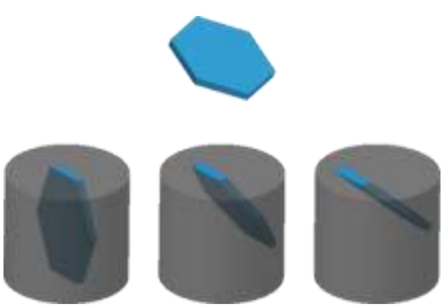

Figure 2 – Cr_2AlC single crystal *platelets embedded in a chosen orientation for nanoindentation test in cross section.*