Nanometer-sized objects are attracting large attention nowadays due to their breakthrough mechanical properties such as high hardness, crack propagation resistance and high elastic limit in comparison of the bulk state of the studied material [1]. Moreover, these nano-objects exhibit large plastic deformation under high load; this was not expected for certain materials and especially for ceramics. Large numbers of studies nowadays are dedicated to plastic deformation of Metals at the nano-scale, and few are reported on ceramics [2, 3].

The origin of this plastic deformation is still not very well defined. Mechanisms proposed are size dependent, and link this behavior to dislocations nucleation at surfaces and slipping on certain planes depending on the crystal orientation with respect to the solicitation direction. Another mechanism proposed is the mechanical twinning via full dislocations dissociations into partial Shockley dislocations that glide on a slipping plane (the denser) of the crystal.

A protocol consisting of in situ TEM nano-compression tests of isolated nanoparticles coupled with data processing by Finite Elements and Molecular Dynamics simulations has been developed [2], and applied to the study of spherical alumina nanoparticles. Identification of deformation mechanisms remains quite difficult since the orientation of the nanoparticle on the substrate prior to compression is not controlled.

In this study, we will present in situ TEM nano-compression experiments on MgO nanocubes. The main advantage of studying such nanocubes lies in the fact that their crystallographic orientation with respect to the indenter tip is fully known. It will be shown that MgO can undergo large plastic deformation, more than 50%, without any fracture. Then, we will propose a mechanical behavior law from the analysis of the images and curves followed by Finite Elements simulation. Finally, deformation mechanisms will be identified from the comparison between the contrasts in the images and Molecular Dynamics simulations [4].

Fig. 1: 100 nm edge size, MgO Nanocube before compression in situ in TEM

Fig. 2: 100 nm edge size, MgO Nanocube After compression in situ in TEM

Fig. 3: Stress-strain curve Obtained from Load-Real displacements curve of the nanocube compressed in situ