In-situ XRD to investigate footprints of plastic deformation

H. Van Swygenhoven, S. Van Petegem, B. Schmitt,P.M. Derlet, S. Brandstetter, Z. Budrovic, R. Maass,

Material Science and Simulation, NUM/ASQ, WHGA/343,
Paul Scherrer Institute, CH-5232 Villigen, Switzerland

Introduction

The understanding of the mechanical properties of ultra-fine grained and nanocrystalline materials poses a fundamental challenge to materials science. With decreasing grain sizes, a transition from a plasticity dominated by dislocation nucleation and multiplication within grain interior, towards a plasticity dominated by the GB network is to be expected. At the structural length scales involved, the atomic picture starts to play a non-negligible role. Large scale atomistic simulations provide, when put in their proper context taking into account possible artefacts from the short time/high stress character of simulations and the use of empirical potentials, an excellent source of inspiration for understanding the details of deformation mechanisms in confined structures.

One of the most important revelations of MD simulations is that they suggest that in the absence of dislocations sources in grain interior, slip is generated at the grain boundaries. The life of such dislocations i.e. the nucleation procedure at the grain boundary and the details on propagation and absorption will be discussed, revealing a mechanism that does not leave dislocation debris in grain interior (Fig.1)

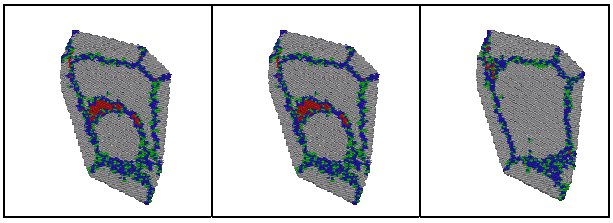

Fig. 1.
Deformation mecahnism suggested by molecular dynamics

Methods and Materials

This aspect of the deformation mechanism has inspired us to develop an in-situ deformation stage at the Swiss Light source where peak profile is followed continuously during deformation thanks to the development of a microstrip detector.

The Micro Tensile Machine (MTM) is designed to be mounted on the sample stage of the Materials Beamline at the SLS. It allows tensile testing of mini dogbones (gauge length 1.7 mm, thickness 0.2-0.25mm) as well as more conventional sized dogbones (gauge length 5.25mm, thickness 0.2-0.3mm) and all sample sizes in between. To ensure that only the gauge length is measured during the tensile test the use of a CCD camera is employed to focus on specific areas on the sample. Use of image recognition software resulted in a strain resolution of 10-6. Scans where taken during manual and automatic running of the tensile machine to optimize the strain rate and time period of the scans conducted by the microstrip detector at a beam energy of 17.5keV ensuring a wide range of reflections in the angular range covered by the microstrip detector.

Results

Profile studies can be performed during load-unload experiments in tension or compression, stress relaxations, strain rate jump tests and creep tests and this at room temperature and temperatures below. In this talk, two materials are compared, a HPT Ni sample with mean grain size of 300nm and an electrodeposited Ni sample with a mean grain size of 30nm. In-situ measurements evidenced complete reversibility of the peak broadening upon unloading of a 30nm-grained sample deformed at room temperature [1,2] and a non-reversible peak broadening for a 300nm Ni sample, as shown in Fig.2. Interesting is that the peak broadening is not reversible when the experiment is performed at 180K, but does however recover again when the sample is warmed up to room temperature [3].

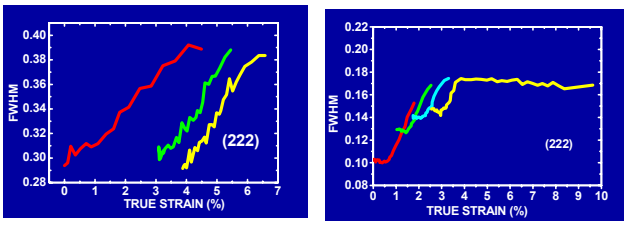

Fig.2.
Deformation mecahnism suggested by molecular dynamics

The details of the experiment will be presented together with the results on HPT and ED-Ni, the latter being discussed in the framework of dislocation mechanism suggested by molecular dynamics.

[1] H. Van Swygenhoven, B. Schmitt, P.M. Derlet, S. Van Petegem, Z. Budrovic, S. Brandstetter, A. Bollhalder, M. Schild, Rev. Sci. Instrum. 77, 013902 (2006).

[2] Ž. Budrović, H. Van Swygenhoven, P. M. Derlet, S. Van Petegem and B. Schmidt, Science 304, 273 (2004).

[3] Ž. Budrović, S. Van Petegem, P. M. Derlet, B. Schmitt, H. Van Swygenhoven, E. Schafler, M. Zehetbauer, App. Phys. Lett. 86, 231910 (2005).

[4] S. Brandstetter, Ž. Budrović, S. Van Petegem, B. Schmitt, E. Stergar, P. M. Derlet, H. Van Swygenhoven, App. Phys. Lett., 87, 231910 (2005).