IN-SITU X-RAY DIFFRACTION STUDY OF NANOCRYSTALLINE METALS

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It is well known that the strength of metals increases with decreasing grain size, a behaviour that is well described by the phenomenological Hall-Petch relation down to grain sizes of 100 nm and even lower. Deformation mechanisms in coarse grained metals are based on a dislocation mechanism where dislocations are created during deformation with their propagation and multiplication being an essential mechanism for the resulting ductility and strength. Molecular dynamics simulations suggest that in nanocrystalline materials slip is generated at the grain boundaries (GB); dislocations nucleated at GBs propagate through the grains and are absorbed at the opposing GB, leaving no dislocation debris in the grain interiors (Acta Mat 54(2006)1975.

In order to understand the elastic and plastic deformation properties of nanocrystalline metals we have developed an in situ synchrotron x-ray-diffraction technique which allows the simultaneous measurement of many diffraction peaks continuously during mechanical testing, providing a direct link between the evolving microstructure and the macroscopic mechanical data (Rev. Sci. Instr. 77 (2006) 013902).

In this talk we will present new in-situ results obtained for nanocrystalline NiFe with a mean grain size of 20nm and compare them with results obtained from former in-situ experiments on electrodeposited Ni with mean grain sizes of 30nm.

For Ni we showed that during plastic deformation peak broadening is reversible upon unloading; hence, the deformation process does not build up a residual dislocation network (Science 304 (2004) 273). Furthermore it is shown that when the samples are deformed at 180K peak broadening is not fully reversible anymore. However, by then warming the sample to 300 K, peak broadening recovers to a great extent and all subsequent plastic deformation load/unload cycles are characterized again by a reversible peak broadening. The temperature-dependent residual peak broadening provides explicit evidence of a thermal component in the nanocrystalline deformation mechanism (Appl. Phys. Lett. 87 9(2005) 231910). By performing multiple load/unload cycles it is shown that different strain-hardening mechanisms in the micro- and macroplastic regimes are evident, and that the generally used 0.2% yield criteria does not correspond to the onset of macroscopic plasticity in all materials (Adv.. Mater. 18 (2006) 1545). The findings are discussed in light of recent results obtained from calculated x-ray diffraction spectra from computer generated atomic configurations (Acta Mat 56(2008) 165).