Project 5: Investigation of deformation mechanisms using synchrotron radiation

R. Baumbusch, P.A. Gruber, O. Kraft, T. Baumbach (LASY, Universität Karlsruhe),
H. Hahn (TU Darmstadt)

The main goal of this project is to obtain a deeper understanding of deformation mechanisms in nanocrystalline metals using synchrotron radiation. It is known that motion of full dislocations, partial dislocations, and grain boundary sliding and grain rotation may contribute to plastic deformation in nanocrystalline metals. As a result of these processes, the microstructure may be changed with respect to dislocation density, stacking fault density and texture during deformation. As shown in the literature, the formation of these defects may become completely reversible in nanocrystalline metals, and therefore, *in situ* experiments are required to identify the dominant deformation mechanisms.

In situ tensile tests on 1 µm thick Pd and Pd alloy films on polyimide substrates were performed at the MPI-MF and PDIFF beam line of the Angströmquelle Karlsruhe (ANKA) to study the evolution of lattice defects during deformation. The experimental setups comprised of area and line detectors to record several diffraction peaks simultaneously and the experiments were carried out in transmission geometry. First datasets on pure Pd films revealed complete reversibility of peak broadening, which indicates the rise and decay of micro-structural defects during deformation. The integral intensity of the (111) peak decreased reversibly on loading and unloading, while the integral intensity of the (200) peak did not vary (Fig. 1). The grain size remained constant during deformation.

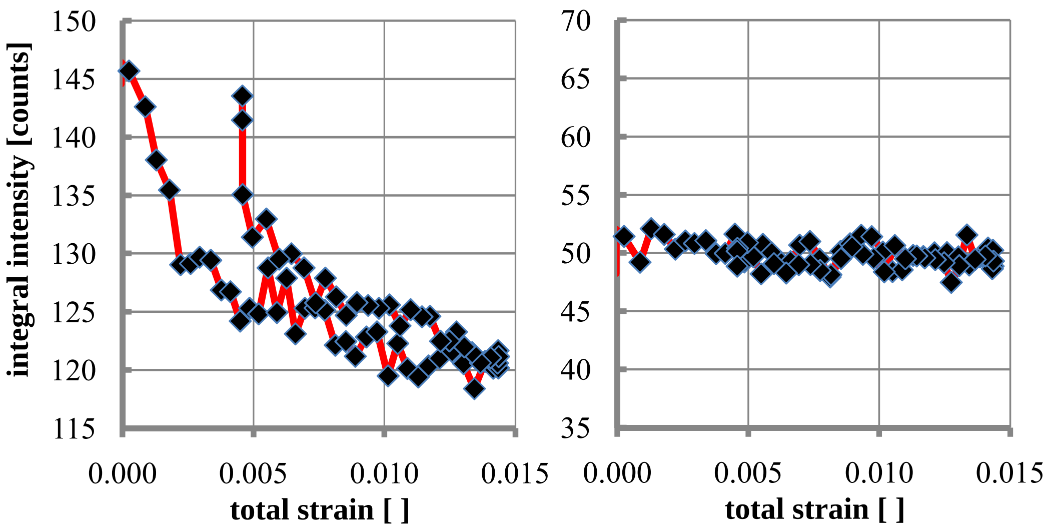

Fig. 1: Evolution of integral intensity for the Pd (111) and Pd (200) peak of a pure Pd film

Alloying with Zr induced a pronounced (111) fiber texture in the films. Pd-Zr films also showed brittle linear elastic behavior and fractured at total strains of less than 1%. As a consequence no peak broadening was observed for these films (Fig. 2). Further tests on Pd-Zr films with better microstructure will be performed, e.g. by improving the adhesion to the substrate. In addition, nanocrystalline Pd-Au films will be prepared. Au is expected to reduce the stacking fault energy in the Pd films and should promote plastic deformation by partial dislocations.

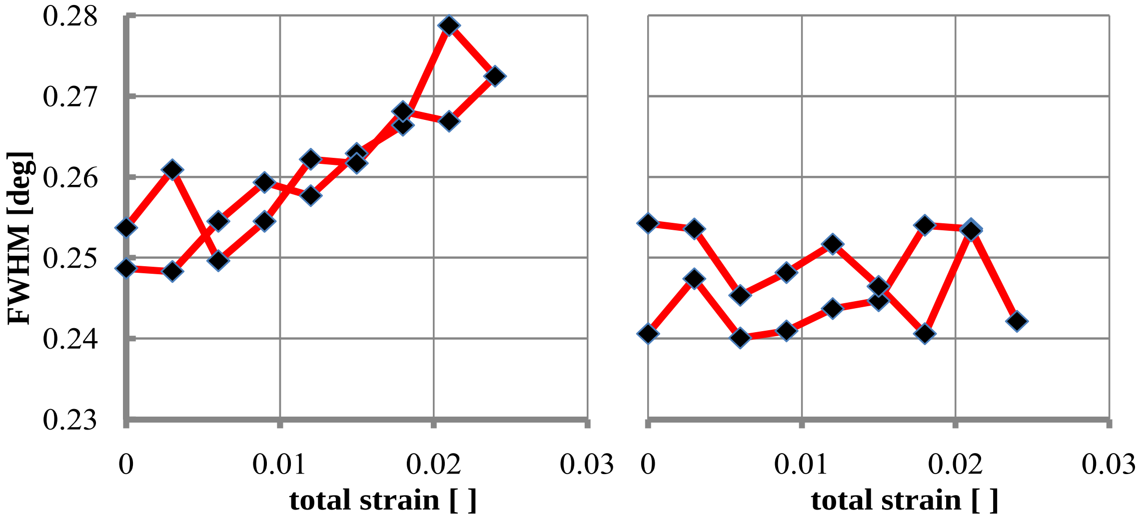

Fig. 2: Evolution of peak width for the (111) peak of a pure Pd and a Pd-Zr film.

Tensile tests at different strain rates resulted in slightly different peak broadening and peak shift (Fig. 3). At lower strain rates the peak shift and broadening were less pronounced, which may imply that diffusion processes become more important yielding to stress relaxation and less stress inhomogeneity.

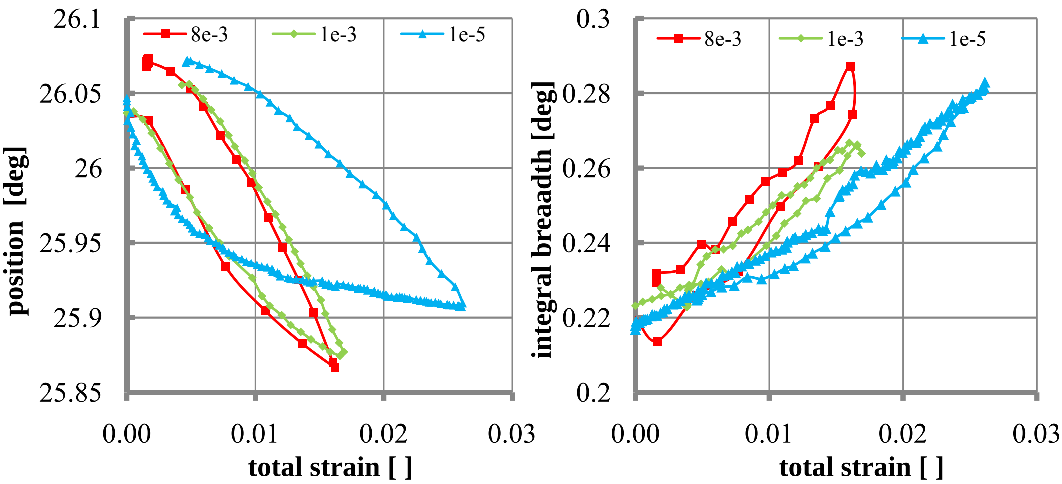

Fig. 3: Shift of Pd (111) peak position and change of peak width during tensile tests on pure Pd films at 3 different strain rates.

The results of the diffraction experiments will be further analyzed with respect to micro-structural parameters, like dislocation density, stacking fault density, and microstrain and texture evolution as well as to effects of alloying elements on the deformation behavior. Therefore we are currently working on appropriate data evaluation routines based on classical Williamson-Hall, Warren-Averbach and Rietveld methods. In addition the results will be compared to ongoing Molecular Dynamics (see DFG Research group 714 Project 2) and diffraction pattern simulations.