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Fatigue at the micron scale: Is dislocation motion and storage reversible?

Summary:
Aim of the proposed experiment was to understand the fatigue properties of micron sized single crystalline copper samples during *in situ* µLaue experiments. The experiment was performed as proposed with 7 samples beeing fatigued *in situ*. The maximum load cycle number of one sample is 35.

Report:
Ten roughly 7micron sized fatigue samples and the corresponding counterbody had been prepared using our focused ion beam (FIB) microscope in our home facility. During the experiment, the samples were:

1) Raster scanned with a stepsize of 1 micron to investigate the initial density of geometrical necessary dislocations (GNDs)
2) The primary beam was focused to the neutral fiber and the several load cycles had been applied in dispalcement controlled mode.
3) Raster scan similar as (1) had been made all 5 load cycles in order to study the global change of GND densities.

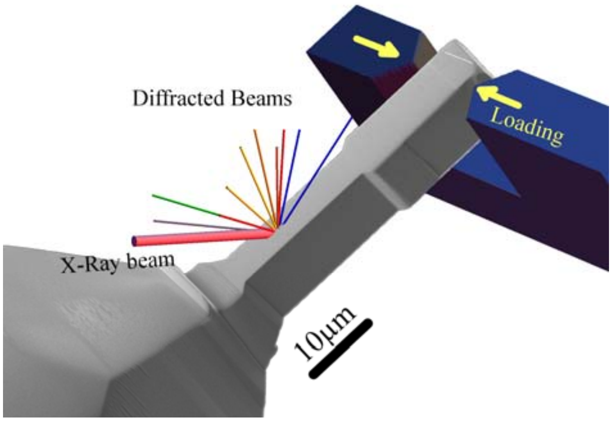

Fig. 1) Schematic setup at BM32

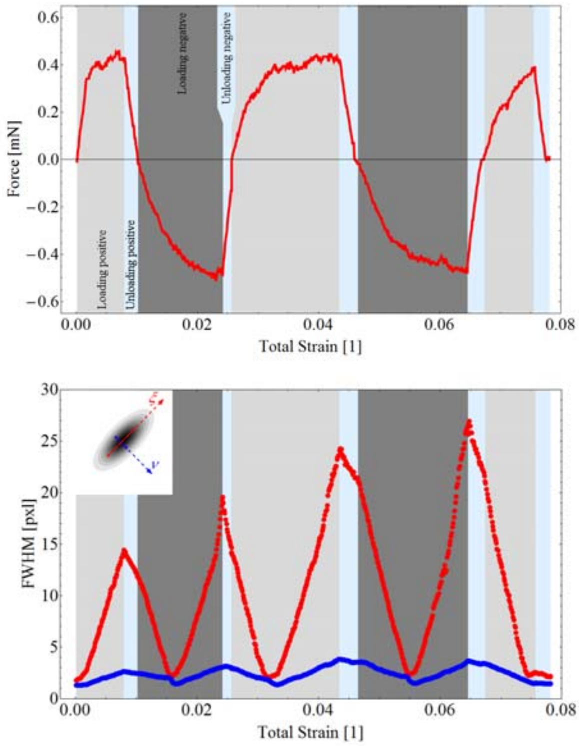

Fig. 2) Force-strain and FWHM strain curves during the experiment. One can clearly see the increase and decrease of the peak width during the experiment – always reaching the same peak width in the straight condition.

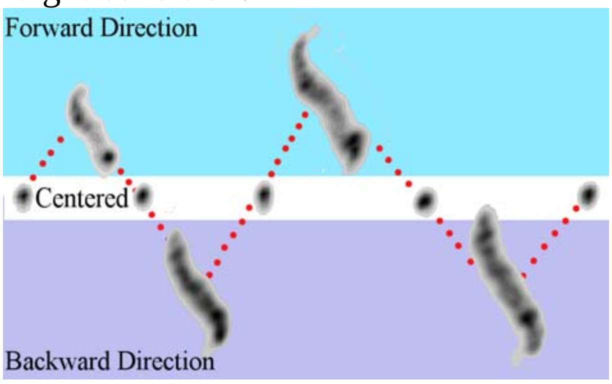

Fig. 3) change of peak width during back and forth-bending

We were able to see a continous increase and decrease of peak streaking accompanied by the formation of a "persistant" sub-grains.

The microstructure thereby evolves during the first one or two load cycles and then reaches a steady state without significant changes in the Laue pattern.

The force-displacement data simoultaneously recorded supports this behavior showing a slight load decrease during the first cycle.

In the straightened beam we do not see any sub-structures of the peak, indicateing that either all dislocations rearranged (paired) or were able to leave the crystal. In both cases the net Burgers vector is close to zero and no significant peak width increase had been noticed.

The results indicate the strong influence of dislocation pile-ups, which partly dissolve due to the inner stress fields already during unloading (see peak width decrease in the blue part of Fig.2b).

In the future it is important to cut transmission electron microscopy foils out of the samples and to study the dislocation structure in the straight bending beam – where Laue diffractin is obviously not sensitive enough to capture all details of the deformation pattern, still x-ray μLaue diffraction is an ideal tool to investigate the fatigue behavior of micron sized objects.

We are currently finalizing the data evaluation and are looking forward to a publication soon.