ESRF	**Experiment title:** Internal strain evolution during plastic deformation of cubic metals with different grain sizes	**Experiment number:** ME-647
Beamline: ID11	**Date of experiment:** from: 1^{st} November 2004 to: 4^{th} November 2004	**Date of report:** 31^{st} August 2004
Shifts: 9	**Local contact(s):** John Whright	*Received at ESRF:*

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Report:

The aim of this experiment was to study early plasticity in cubic structured metals. More specifically we aimed to investigate the evolution of intergranular elastic strain (obtained from diffraction peak position) and peak shape during the onset and early plasticity.

Capturing plastic yield requires continuous deformation. This is usually not possible to do in a diffraction experiment because of the long counting times required. Thus we chose to carry out this experiment on ID11 and use a 2D detector. This allowed diffraction patterns to be captured every 2 seconds allowing continuous testing. The drawback of using a 2D detector is that measurement resolution is poorer than that possible with a position sensitive detector. In order to maximise resolution, the detector was moved as far away from the sample whilst still being positioned on the swinging arm to allow easy lateral movement. This put the detector 2.1 meters away from the sample. This lateral movement is required to allow the capture of different orders of reflection to help with peak profile analysis. To minimize the impact of not having an analyser crystal and receiving slits, the incoming beam was narrowed to $200\mu m$, helping keep instrumental broadening to a minimum. This set up generated a diffraction profile whose peaks had a typical FWHM of 0.02 degrees 2θ. Peaks were fitted using a pseudo-Voigt function. The peak position values thus obtained allowed intergranular strain to be calculated with a typical uncertainty uncertainty of 5 $\mu\epsilon$. An important limitation of this experimental set-up was that each measurement, at a given detector position and measurement direction, was carried out at a different time and on a different sample. Two metals were tested: Ni and Fe. Unfortunately, due to processing issues only one grain size was available for nickel. Two types of steel were tested one with 2 μm grains and one with 20 μm grains.

The elastic strains measured during early plasticity in the Nickel samples were consistent with modelling predictions in all but a couple of cases. In these cases the behaviour demonstrated by the first order peaks was different from the on exhibited by the same reflection at higher orders. This variation is probably due to the high texture sensitivity of the response of some grain families. This high sensitivity can be demonstrated using FE. We were particularly susceptible to because we used different samples for different order reflections and had a small gauge volume. Any small local texture variation can cause the observed deviations. The measured lattice strain evolution is plotted alongside modelling predictions in figure 1

The variation in peak width observed was surprising. In the longitudinal direction, the peak width decreases in the elastic region as the stress approaches the yield stress. Then, at yield, it increases gradually. This increase post–yield can be explained by an increase in mosaicity and dislocation density. Interestingly, different grain families show different rates of increase, i.e. peak broadening is anisotropic. The drop in peak width preceding plastic yield, however, is difficult to explain. There are no experimental reasons for it and it is also not a peak fitting artefact. Peak breadth, measured by integrating the diffraction profile directly, shows the same behaviour. Interestingly, FEM also predicts a drop in the standard deviation of elastic strains, in the longitudinal direction. Although the two might be related, they are significantly different in magnitude. The predicted drop in the spread of elastic strains cannot, by itself, account for the observed drop in peak width.

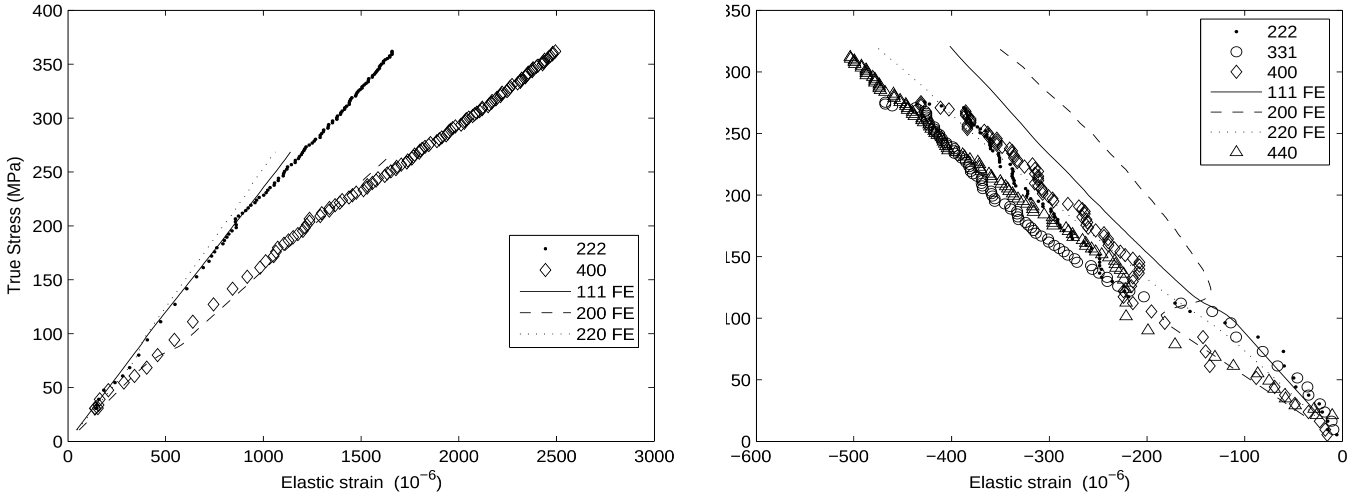

Figure 1: Longitudinal and transverse mean elastic strain evolution for four nickel grain families during uniaxial tensile testing, plotted along with crystal plasticity finite element modelling.

Mean elastic strain evolution observed for the steel samples also showed good agreement with predictions, although discrepancies were observed at yield. These seem to be a result of discontinuous yielding, which, at present, can only be modelled with great difficulty. As with the nickel, the evolution of peak width with applied strain showed unexpected behaviour (figure 2). Peak narrowing during the initial stages of loading was again observed, this time followed by a very sharp increase and then a drop during deformation for some peaks and an gradual increase for others. The sharp increase is much larger in the fine grain material than in the coarse grain material. It must be related to stress redistribution due to discontinuous yielding but further work is required before more definite conclusions are drawn.

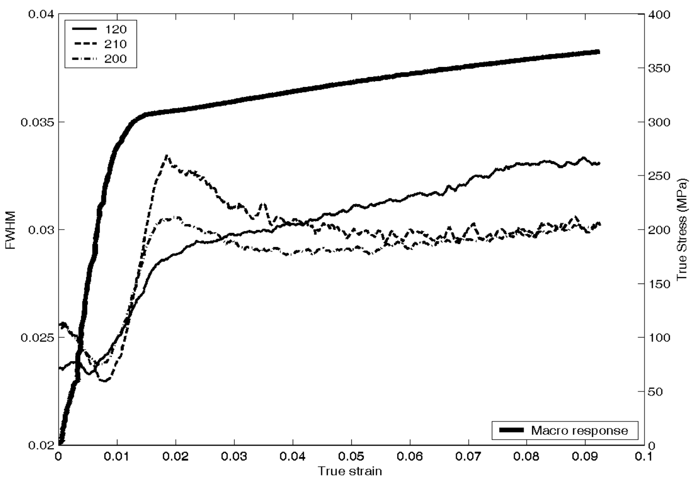

Figure 2: Change in FWHM during the onset of plasticity of a ferrite sample deformed in uniaxial tension, monitored in the straining direction.

Analysis of this data, coupled with modelling, is still ongoing and two journal publications are being drafted to report these results to the scientific community.