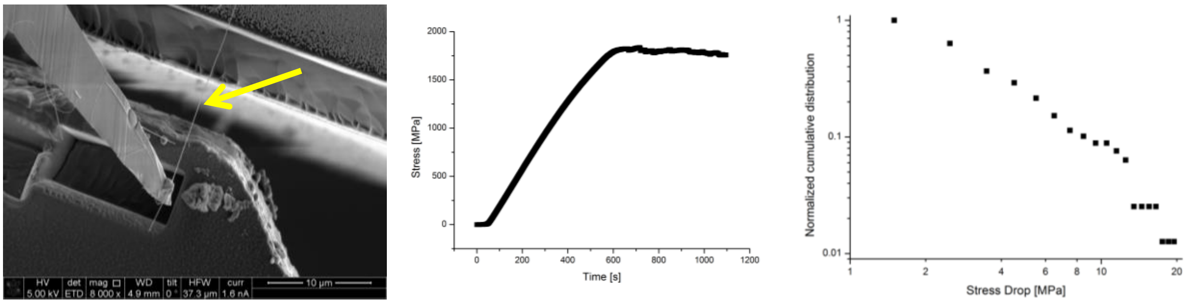
Dislocation Avalanches in Gold Nanowires

The deformation of single crystal Au nanowires is controlled by surface nucleation of dislocations. The dislocations then glide through the wire and exit through the opposite side, resulting in a small shear offset and a reduction or drop in stress. It has long been believed that each dislocation is nucleated in a thermally-activated, independent process. However, a preliminary study of the distribution of stress drop sizes (see right Figure) suggests that dislocation nucleation is correlated: when one dislocation is nucleated it causes others to be nucleated, resulting in a dislocation avalanche. Such correlated behavior lies at the heart of many intermittent processes such as earthquakes and magnetization dynamics. The goal of this project is to investigate the stress drops that occur during tensile deformation of Au nanowires performed in-situ in the SEM.



Left: 100 nm diameter Au nanowire (indicated with arrow) during mounting on a straining stage inside a Scanning Electron Microscope (SEM). Middle: Stress in the nanowire while straining at a constant rate. After reaching a stress of almost 2 GPa, the wire starts to plastically deform. Right: Cumulative distribution of the stress drops (indicating the number of dislocations in each avalanche).

Work Plan:

The Au nanowires are first transferred from the growth substrate to a tensile stage using a micromanipulator inside the SEM (see left Figure). The nanowire is glued in place using electron beam enhanced deposition. Piezo electric actuators are used to strain the nanowire under tension while a sensor is used to measure the force. The actual strain along the nanowire is determined using image analysis in the SEM to obtain stress-strain curves (e.g. middle Figure). The stress-strain curves for nanowires tested under different strain rates and straining protocols will be compared. In particular, we will try to maximize the strain to failure; from previous studies we believe this is achieved by using very steady and slow straining. Once suitably large ranges of plastic straining are achieved, the stress drops in the plastic regime will be analyzed to determine the extent to which dislocation nucleation is correlated in the nanowires.

Experimental Methods:

The following methods will be learned and used independently by the student: Scanning Electron Microscope (SEM) imaging and in-situ micromanipulation; in-situ micro-scale tensile stage; data and statistical analysis; and conventional Transmission Electron Microscopy (TEM).

The Master Thesis may be written in either English or German.

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