Standard Project

Experimental Report template

Proposal title: Strain mapping and defect distribution along mechanically deformed Cu nanowires by coherent X-ray diffraction		**Proposal number:** MA-1549
Beamline: ID01	**Date(s) of experiment:** from: 21/11/2012 to: 27/11/2012	**Date of report:** 29/08/2013
Shifts: 18	**Local contact(s):** G. Chahine	*Date of submission:*

Objective & expected results (less than 10 lines):

Our goal was to study the mechanical properties of individual nanostructures and the influence of size effects using coherent X-ray diffraction. For this purpose, we randomly dispersed Cu nanowires grown along the <110> direction on a Si substrate and we plastically deformed them ex situ to different strain states. The wires themselves were located by recording the Cu-K_α fluorescence signal. The alignment of the wires in Bragg conditions is hampered due to their radial symmetry. However, μLaue diffraction studies performed prior to this experiment at the BM32 beamline gave direct access to the wire orientation with respect to the Si surface facilitating their alignment. The focused X-ray beam was scanned along the nanowires and 3D reciprocal space maps were recorded at several different positions revealing the structural changes within the wire.

Results and the conclusions of the study (main part):

The nanowires were visually located by means of the optical microscope at the ID01 beamline. During the experiment coherent 3D reciprocal space maps were recorded at several points along plastically deformed single nanowires with a diameter of 200 nm.

Figures 1(a) and (b) present scanning electron microscopy images of a nanowire with a diameter of 200 nm before and after mechanical deformation. In Fig. 1(c) the Si(004) diffraction intensity and the simultaneously recorded Cu-K_α fluorescence signal are displayed revealing the microtrenches on the Si wafer surface prepared by lithography and the deformed Cu nanowire. This approach of simultaneous acquisition of diffraction and fluorescence signal demonstrates the unambiguous detection of individual nanowires.

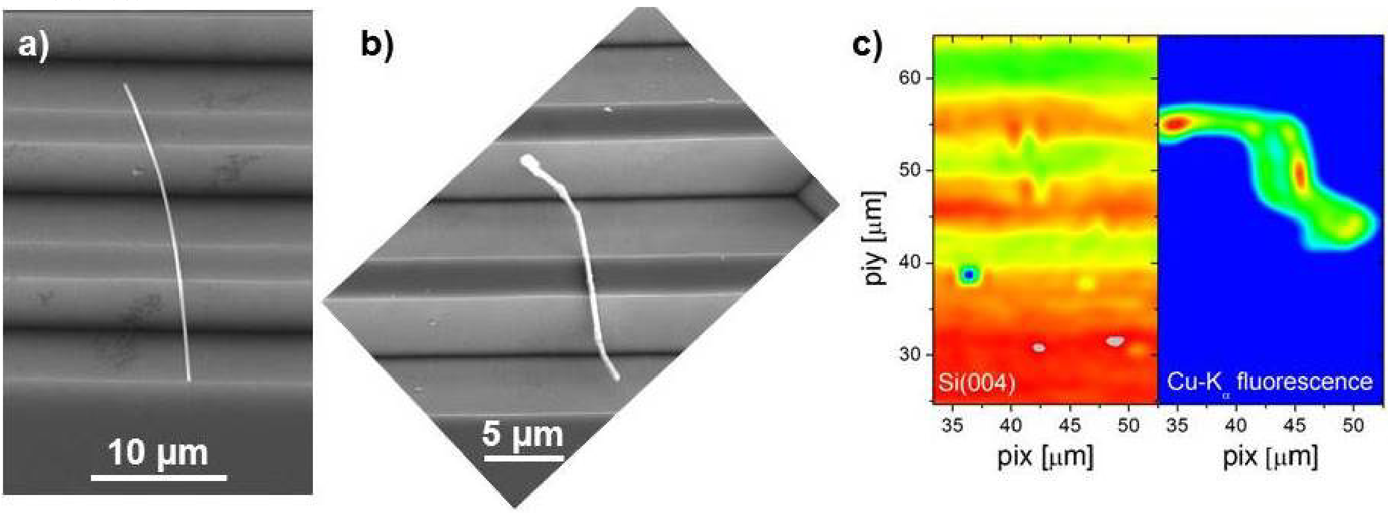

Fig. 1: Scanning electron micrographs of a Cu nanowire with a diameter of 200 nm crossing microtrenches on a Si wafer (a) before and (b) after mechanical deformation. (c) Simultaneously recorded Si(004) diffraction intensity of the Si substrate and Cu-K_α fluorescence from the Cu nanowire.

After locating a Cu nanowire, the evolution of the Cu(111) Bragg reflection along the nanowire was investigated. To maintain the nanowire in Bragg condition the incident rocking angle had to be changed by about 4° on a legnth of ~15 µm indicating a distorsion of the wire. Figure 2 presents a scanning electron micrograph of the Cu nanowire and scanning X-ray diffraction maps for various incident rocking angles showing the evolution of the Cu(111) Bragg peak along the wire. These results agree with findings from previous µLaue diffraction studies.

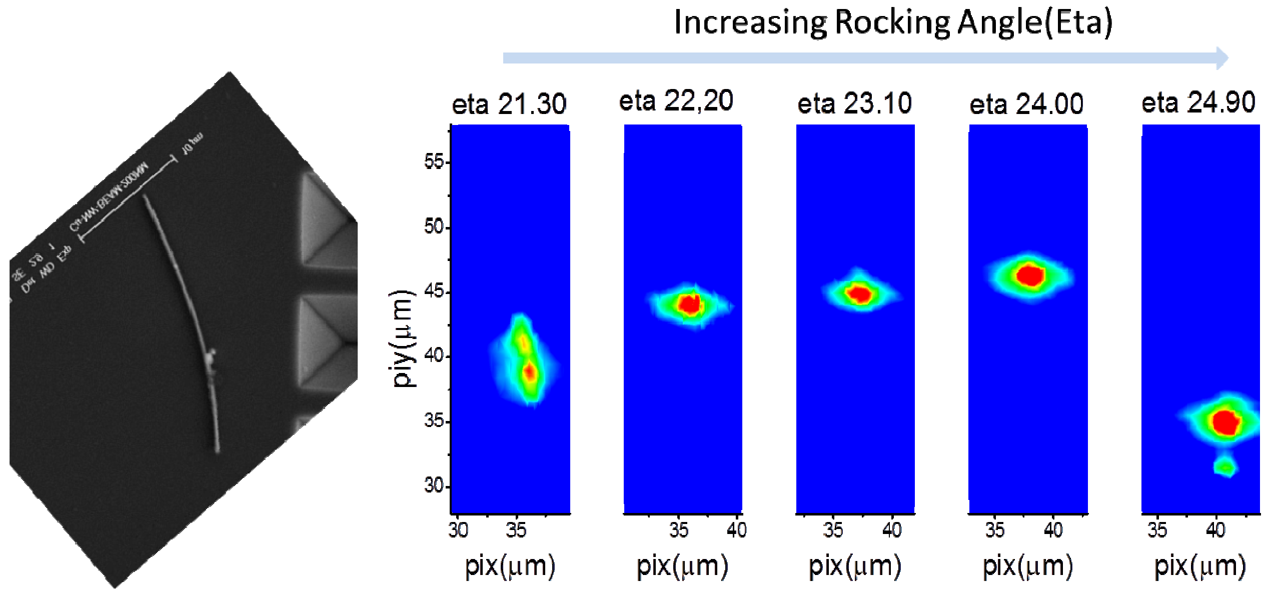

Fig. 2: Scanning electron microscopy image of the Cu nanowire and scanning X-ray diffraction maps for various incident rocking angles indicating a continuous rotation along the nanowire.

Figure 3(a) presents a 3D recirprocal space map recorded along one of the Cu nanowires. This 3D-RSM shows a bar-code pattern indicating stacking faults within the wire. These findings agree well with transmission electron microscopy studies on similar Cu nanowires as shown in Fig. 3(b).

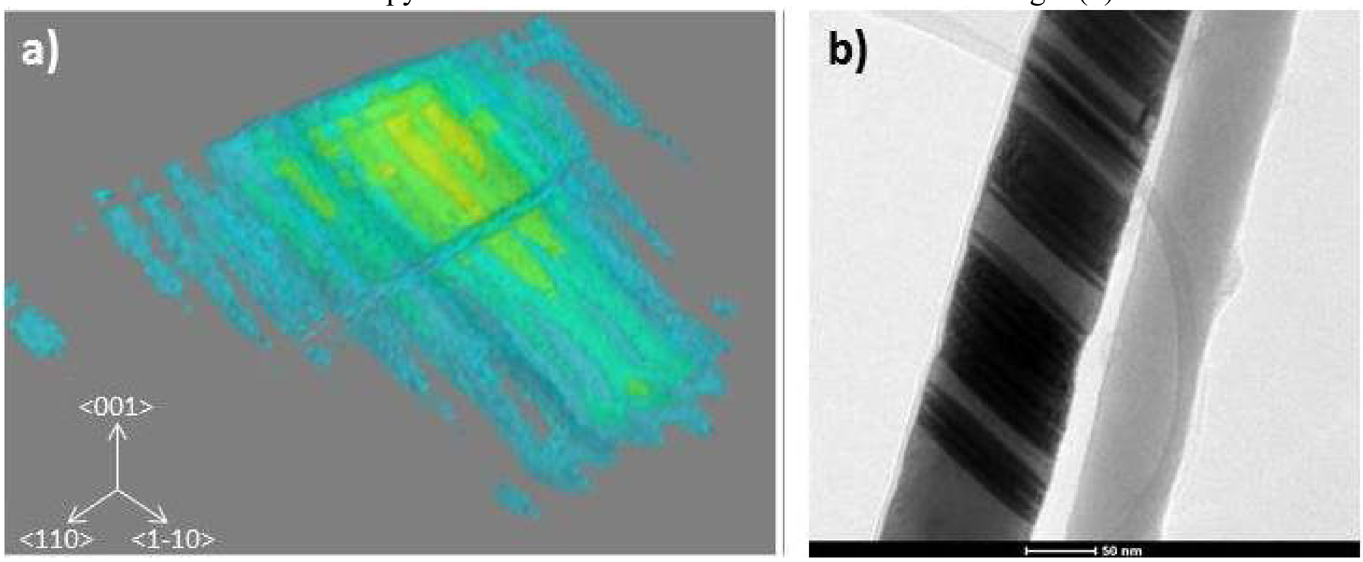

Fig. 3: a) 3D reciprocal space map of Cu(110) Bragg reflection and b) transmission electron micrograph a Cu nanowire.

Justification and comments about the use of beam time (5 lines max.):

For studying single wires the coherent X-ray beam at ID01 was focused down to 300 x 600 nm^2 employing a Fresnel zone plate. Thanks to the fluorescence detector and the MAXIPIX detector present at the beamline the Cu-K_a radiation and the diffraction signal of the wires were recorded simultaneously allowing for locating the different nanowires unambiguously while translating the sample through the beam. The acquisition of 3D RSMs give access to defects present in the nanowires.

Publication(s):

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