ESRF	**Experiment title:** *In situ* piezoelectricity of single ZnO NWs measured by Laue microdiffraction	**Experiment number**: 32-02-837
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Report:

The goal of this experiment was the study of the piezoelectric properties of single ZnO nanowires by *in situ* Laue microdiffraction during the electric actuation of individual nanowires. The piezoelectric coefficients are expected to increase with decreasing nanowire diameter due to finite size effects making these nanostructures promising candidates for future energy transducers.

ZnO nanowires with a diameter of 100 to 200 nm and a length of up to 10 µm were grown by a wet chemistry method. The ZnO nanowires were detached from their growth substrate by ultrasonication that lead to a breaking of the nanowires to sections of few micrometers in length. The nanowires were then dispersed on an insulating substrate on which they were contacted elecrically using lithography methods. A scanning electron micrograph of such an electrically contacted ZnO nanowire is presented in Fig. 1(a). The nanowires were located by measuring the Zn-K$_\alpha$ fluorescence yield as illustrated by the fluorescence map displayed in Fig. 1(b) showing the same nanowire as in Fig. 1(a).

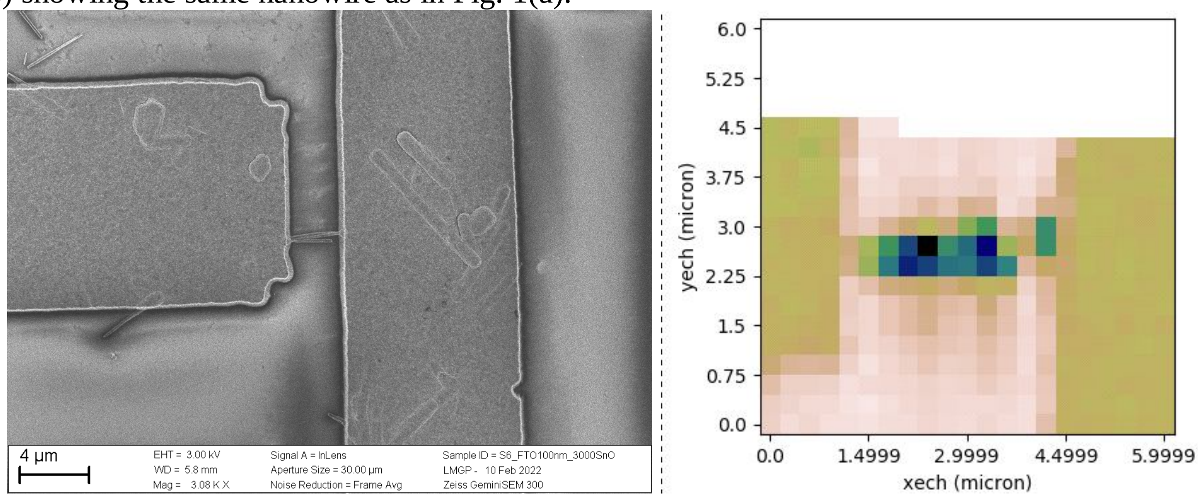

Fig. 1: a) Scanning electron microscopy image and b) Zn K$_\alpha$ fluorescence yield map of an electrically contacted ZnO nanowire.

During electrical actuation of the ZnO nanowire, Laue microdiffraction patterns were recorded *in situ*. Figure 2(a) presents a mosaic of the displacement of the ZnO (0 $\bar{1}$ 1 0) Laue spot during the application of an electric voltage. The displacement of the Laue spot along *x* and *y* on the detector is illustrated in Fig. 2(b) and (c), respectively. These Laue spot displacements indicate the reorientation of the ZnO crystal due to the applied electric potential.

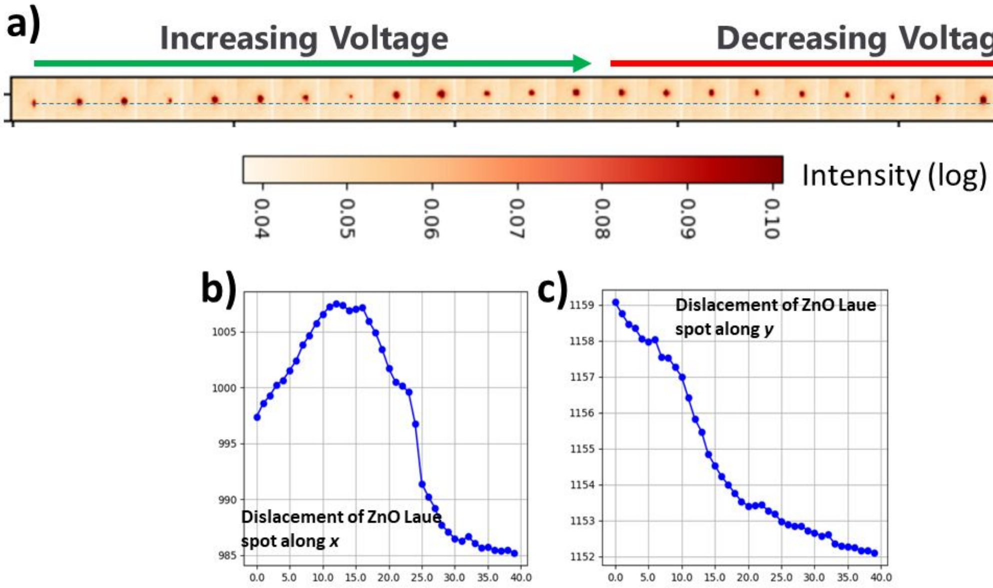

Fig. 2: a) Mosaic of the ZnO (0 $\bar{1}$ 1 0) Laue spot during the application of an electric potential. Displacement of the above mentioned Laue spot on the detector (b) along *x* and (c) and along *y*.

The microdiffraction patterns were indexed using the LaueTools software and the LaueNN neural network recently developed at the BM32 beamline. By means of the obtained UB orientation matrices the rotation of the crystal was calculated. Fig. 3(a) shows the rotation angle as a function of the applied voltage for the three orthogonal lattice planes (0 0 0 1), (0 $\bar{1}$ 1 0) and the (2 $\bar{1}$ $\bar{1}$ 0), which was deduced from the Laue microdiffraction patterns using the LaueTools software. The orientation of the three aforementioned lattice planes within the hexagonal ZnO nanowire is schematically illustrated in Fig. 3(b). Considering the rotations of the three lattice planes, the nanowire mainly rotates around the [0 0 0 1] axes when increasing the voltage indicating a nanowire rotation or torsion. When decreasing the applied voltage, however, a more complex deformation occurs affecting all three orthogonal directions, which might actually originate from the interaction of the nanowire with the substrate via van-der-Waals forces that inhibit the nanowire to rotate back. The rotation/torsion of the nanowire may be due to a reorientation of the nanowire within the applied electric field rather than due to a piezoelectric deformation. In the future, suspended nanowires will be prepared in order to avoid sticking of the nanowire to the substrate.

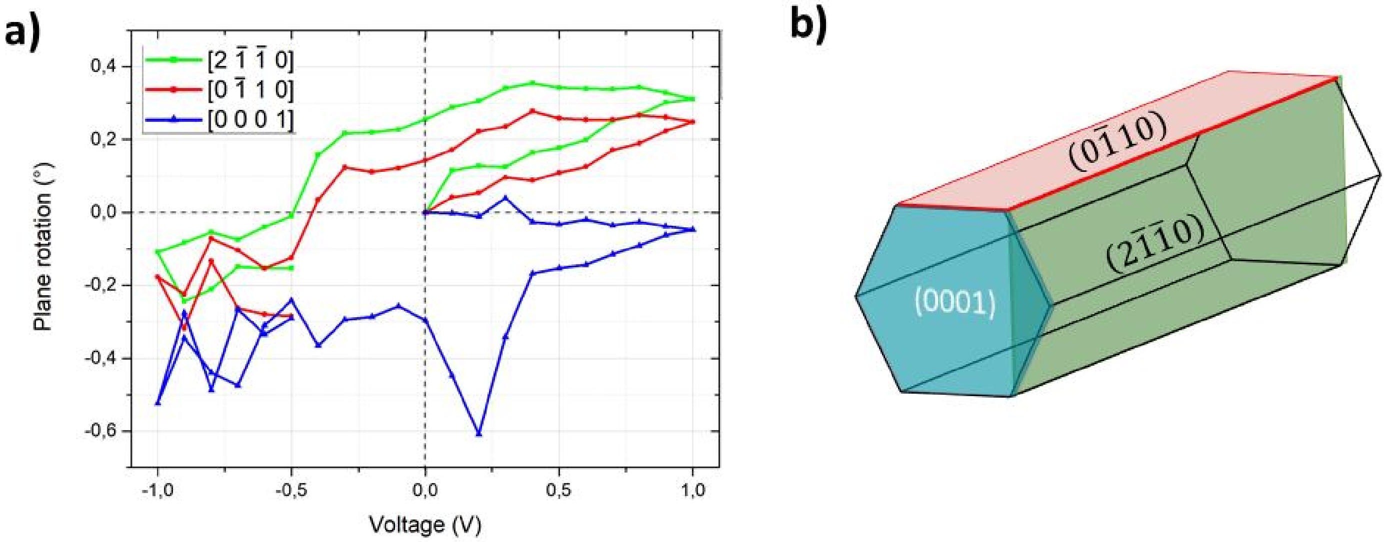

Fig. 2: a) Rotation of the three orthogonal lattice planes (0 0 0 1), (0 $\bar{1}$ 1 0), and (2 $\bar{1}$ $\bar{1}$ 0) of a ZnO nanowire as a function of an applied voltage inferred from *in situ* Laue microdiffraction. b) Schematic of the orientation of the (0 0 0 1), (0 $\bar{1}$ 1 0), and (2 $\bar{1}$ $\bar{1}$ 0) lattice planes in a hexagonal ZnO nanowire.

It should be noted that *post-mortem* SEM analysis revealed that the nanowire actually disintegrated into a chain of few pearls which might originate from a Rayleigh instability due to Joule heating caused by an electric current passing through the nanowire. This might also explain the irregular rotation and the loss of the diffraction intensity for negative applied voltages.