X-ray nanobeam diffraction studies on complex magnetoelectric microcomposites

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Magnetoelectric (ME) composites, consisting of a piezoelectric (PE) and a magnetostrictive (MS) material, are of great interest for potential applications as highly sensitive ME sensors. A large ME response is only obtained if the lattice deformation induced by an external magnetic field in the MS material can be transferred efficiently to the PE material.[1] The understanding of this mechanical coupling and its dependence on the components interface structure is still very rudimentary. This study aims at understanding this coupling by directly measuring the strain induced in the PE material in an external magnetic field employing nano focused X-ray diffraction methods as previously observed by our group in large cm-sized samples [2,3].
These in situ experiments were performed on ME microcomposites consisting of a piezoelectric ZnO single crystal and a magnetostrictive (Fe90Co10)78Si12B10 (Metglas) amorphous film, which have been shown to exhibit a large ME effect [4]. The ZnO samples are thin needles grown via Flame Transport Synthesis (FTS) on Si substrates (Fig. 1).

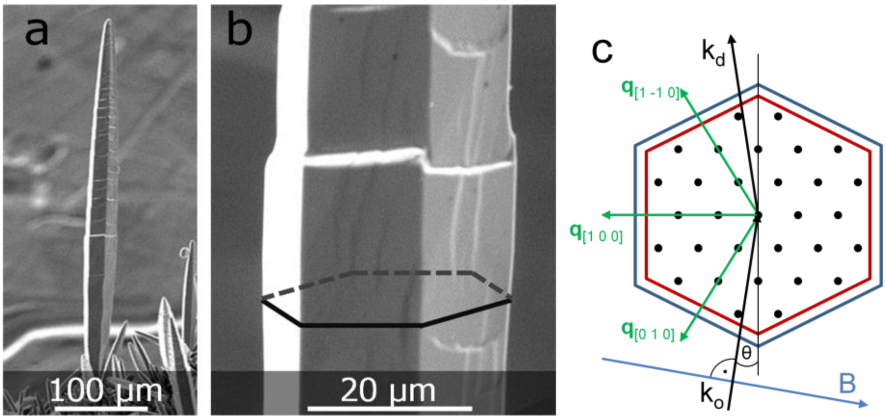

Figure 1: (a) SEM Image of ZnO microstructure (b) SEM Image showing the hexagonal shape of ZnO (c) reciprocal space geometry with the reciprocal vectors q[1-10], q[100] and q[010] corresponding to the (110), (100) and (1-10) planes, respectively.

Using X-ray diffraction it is possible to directly determine the interface coupling by measuring the strain from the shift of the Bragg peak position induced by both coating and magnetic field. Moreover, using the high intense and focused synchrotron radiation beam from the Nanofocus endstation at P03, we can locally measure the strain with mesh scans along the sample (Fig. 2). The sample was oriented perpendicular to the beam direction. An optional external magnetic field perpendicular to sample orientation and beam direction could be applied with up to 150 mT. This was achieved with permanent magnets.
We obtained information about the crystal quality as well as information about the strain distribution across the sample. The Bragg peak was always present when the beam hit the needle indicating that the samples are of high homogeneity. Differences in peak position were also visible, allowing us to get a strain profile. Our main focus in this experiment was the strain distribution across the coated sample inside a magnetic field (Fig. 3). We observed a strain relaxation of $8{\cdot}10^{-5}$ at the edges of the sample at

magnetic fields saturating close to the saturation of the magnetization of the Metglas layer (10 mT). The strain in the middle of the sample showed only a very slight increase of $1 \cdot 10^{-5}$.

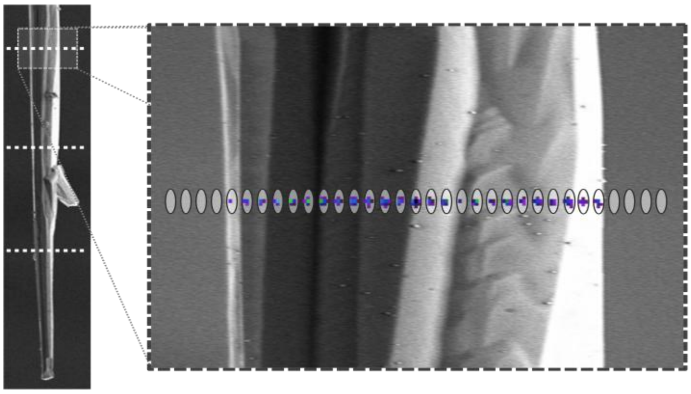

Figure 2: Principle of mesh scan (left) every point represents the actual Bragg peak resulting from the mesh scan (right).

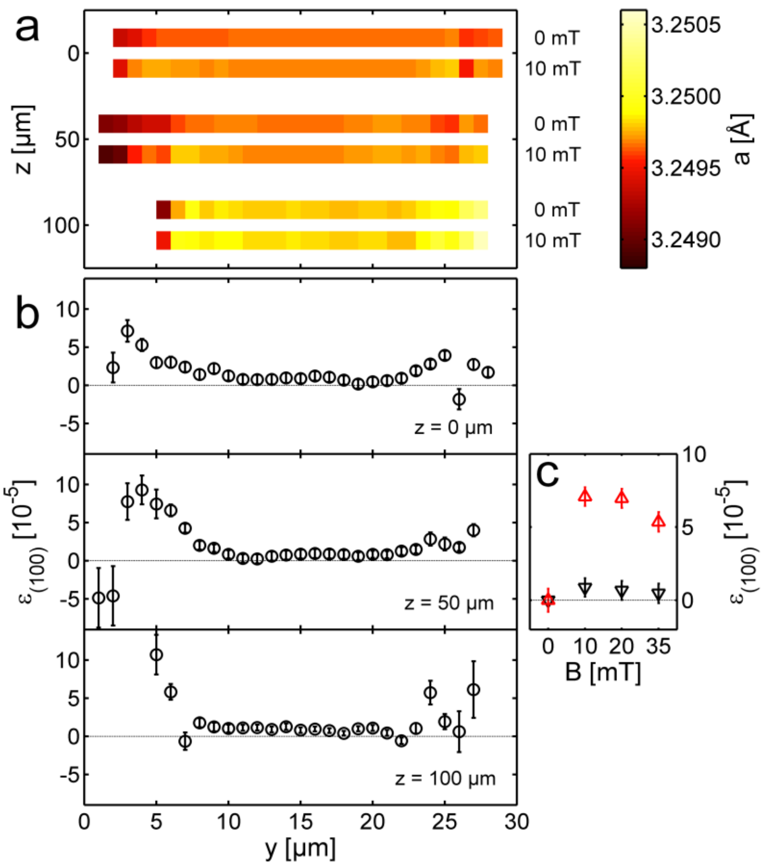

Figure 3: (a) Map shows the lattice parameter *a* at the actual position on the coated ZnO. Three cross-section scans across the sample with no magnetic field applied as well as 10 mT. (b) relative strain between 0 and 10 mT. Previously strained locations on the sample seem to be relaxed inside the magnetic field. (c) Marker in red shows the edge, marker in black shows the center of the sample. Increasing the amplitude of the magnetic field up to 35 mT does not seem to increase the strain relaxation.

References

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