ESRF	**Experiment title:** Mechanical coupling in magnetoelectric composites	**Experiment number**: SI-2381
Beamline:	**Date of experiment**: from: 28.09.2011 to: 04.10.2011	**Date of report**: 01/03/2012
Shifts: 18	**Local contact(s)**: Laurence Bouchenoire	*Received at ESRF:*

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Report:

In our experiments we studied the mechanical coupling at the interface of magnetoelectric (ME) composites by measuring the lattice deformation in the ZnO piezoelectric substrate, using the high-resolution and high intensity X-ray beam provided by BM28 at the ESRF. The ME samples were prepared in Kiel by sputter deposition of amorphous magnetostrictive FeTb or FeCoBSi films of 50 nm thickness on the (001) surface of high quality ZnO single crystals. We investigated bulk reflections close to the interface, employing the scattering geometry shown in Figure 1a. A series of X-ray diffraction measurements on a pure ZnO substrate and the ZnO/FeTb and ZnO/FeCoBSi samples at (220) and the (4-40) specular reflections was collected, where the beam was impinging on the ZnO substrate at different distances *d* from ZnO/FeTb or ZnO/FeCoBSi interface. In Figure 1b we present typical spectra collected in these experiments with a beam size in [001] direction of 20 µm.

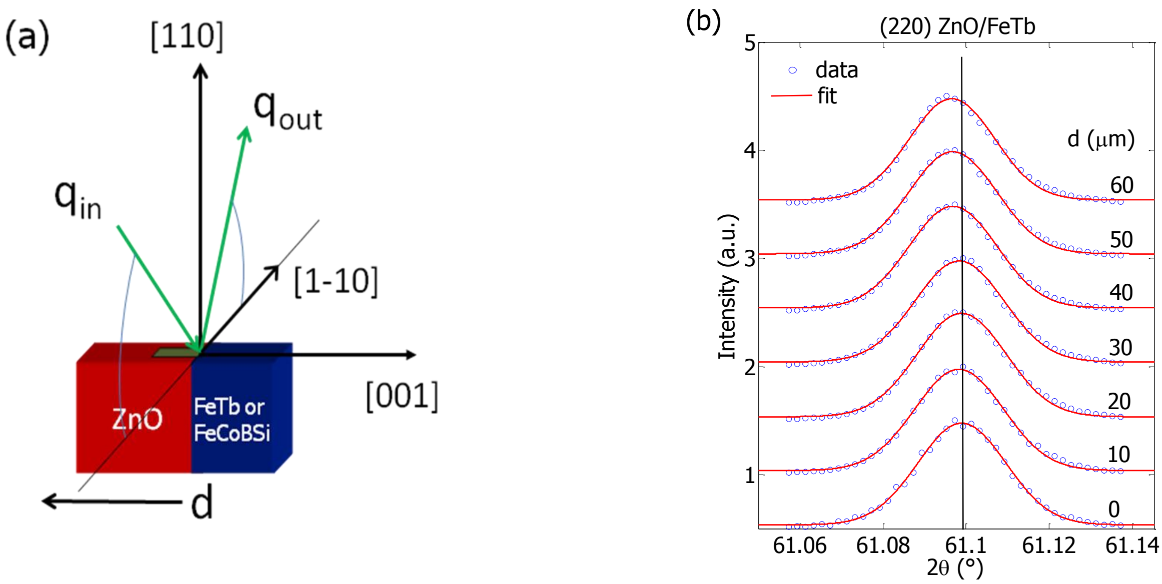

Figure 1: (a) Experimental geometry of the X-ray diffraction studies. (b) (220) ZnO Bragg peaks, measured at different positions of the beam on the ZnO/FeTb sample (for clarity individual scans are offset with respect to each other).

From the peak positions we determined the d_{220} interplanar spacing in the ZnO substrate and the corresponding strain $\varepsilon_{110} = (d_{220}-d_{220}^0)/ d_{220}^0$, where d_{220} and d_{220}^0 denote the interplanar spacing at different positions *d* of the beam relative to the interface and in the center of the ZnO sample, respectively. In the same way $\varepsilon_{1\text{-}10}$ is determined from (4-40) Bragg reflections. The results show that the ZnO substrate is under compressive strain in the in-plane [110] and [1-10] directions, reaching up to $6{\cdot}10^{-5}$ at the ZnO/FeTb interface, and fully relaxes within the first 40µm from the interface (blue color in Figure 2). The same experiment is realized by using a ZnO/FeCoBSi sample and the results are shown in Figure 2 (red color). The strain behavior is similar but his amplitude is twice smaller than the one measured in ZnO/FeTb.

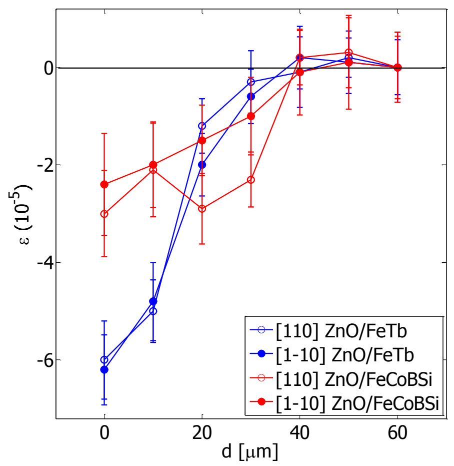

Figure 2: Strains along [110] and [1-10] directions for ZnO/FeTb and ZnO/FeCoBSi samples as a function of distance d to the sample interface.

To investigate the ME coupling at the ZnO/FeCoBSi interface, we also performed grazing incidence X-ray diffraction scans in the presence of an external magnetic field, which was provided by our home built electromagnet. A Si (111) analyser was positioned between the detector and the sample in order to increase the resolution of the experiment. We performed grazing incidence X-ray diffraction at the (2-20) ZnO reflection at an incident angle of 0.17°, which corresponds to the critical angle of the FeCoBSi-air interface at the employed photon energy. The corresponding scattering depth of the X-ray beam into the ZnO substrate is 30 nm under these conditions, i.e., only the ZnO structure near the interface is probed. The high intensity and the very small FWHM of the (2-20) ZnO reflection indicate a very high quality of the ZnO surface (Figure 3). Unfortunately, experimental problems related to the analyser crystal, leading to drift in the position of the ZnO Bragg reflections, prevented us to measure the magnetic field induced strain. Figure 3 shows this drift with the increasing time.

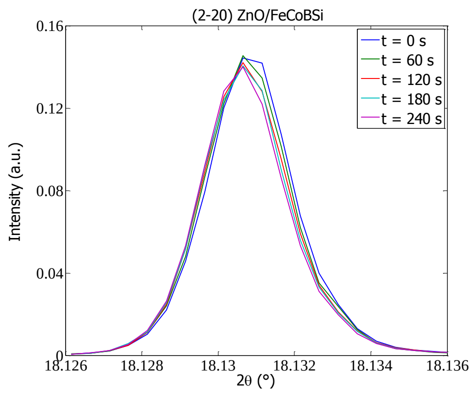

Figure 3: Plot of the (2-20) ZnO Bragg reflection at various time positions for the ZnO/FeCoBSi sample by grazing incidence diffraction.

In conclusion, we measured the intrinsic strain profile at the interface of ZnO/FeTb and ZnO/FeCoBSi magnetoelectric composites but we did not observe any magnetic field induced strain because of the dysfunction of the analyser crystal. In future work we plan to measure the magnetic field induced strain again.

We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB 855 “Magnetolectric composites – future biomagnetic interfaces”.