Determination of Magnetic Directions in Multiferroic BiFeO3 (001) Thin Films.

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BiFeO3 (BFO), a ferroelectric and an antiferromagnet, is the only single phase room temperature multiferroic that is currently known. Multiferroics are interesting materials not only because of their exciting order parameters, but for the potential for parameter coupling. In order to understand the magnetoelectric coupling, the individual order parameters must first be understood. A combination of in-plane and out-of-plane piezoresponse force microscopy (PFM) allows 3D mapping of the ferroelectric polarization directions in micron-sized regions of the films. The magnetic order of BFO (001) was obtained by using x-ray linear and circular dichroism images using a high spatial resolution photoelectron emission microscope (PEEM). Temperature and angle dependent structural measurements allow decoupling of the two order parameters, ferroelectric and magnetic, contributing to the photoemission signal. Careful analysis of linear and circular dichroism images at critical angles allows determination of magnetic directions in BiFeO3. These studies reveal a strain-driven reduction in magnetic symmetry in thin films, leading to the formation of an easy magnetic axis along the [110] as opposed to the observed easy plane for bulk films. This reduction along with the previous proof of coupling between ferroelectricity and antiferromagnetism in BFO allows electrical control of its magnetic axis by an in-plane rotation of ninety degrees.