Magnetoelectric imaging of multiferroic heterostructures

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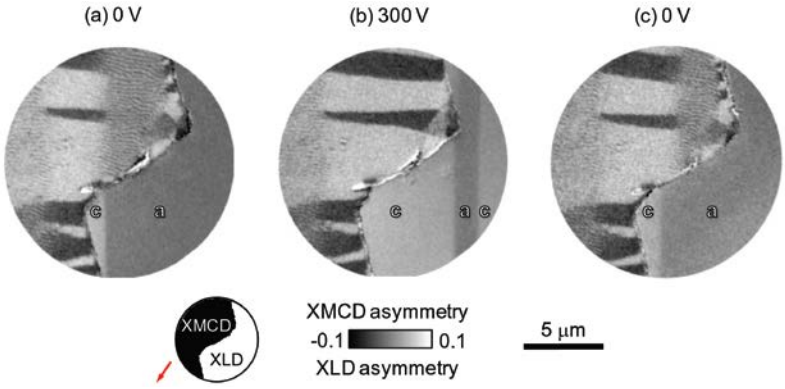
Electrical control of magnetism has been demonstrated in multiferroic compounds and ferromagnetic semiconductors, but electrical switching of a substantial net magnetization at room temperature has not been demonstrated in these materials. This goal has instead been achieved in heterostructures comprising ferromagnetic films in which electrically driven magnetic changes arise due to strain or exchange bias from ferroic substrates, or due to charge effects induced by a gate.

We have previously demonstrated voltage control of the local perpendicular magnetisation associated with magnetic stripe domains[1]. PEEM with alternate contrast from X-ray linear or X-ray magnetic circular dichroism clarified that the electrically driven creation and annihilation of the magnetic stripes in a Ni film was due to the uniaxial in-plane stress generated by 90° ferroelectric domains switching in the tetragonal $BaTiO_3$ (BTO) substrate (Fig.1).

Here we will show that strain associated with the motion of 90° ferroelectric domain walls in a BTO substrate can switch the magnetization in an array of overlying single-domain Ni dots. By contrast, we found only small macroscopic magnetoelectric effects in continuous Ni films on BTO, because 90° switching in BTO is somewhat inhibited by stress from other domains and is therefore not ubiquitous.

We will show that by replacing BTO with ferroelectric relaxor PMN-PT, the macroscopic magnetoelectric response of overlying Ni and $Ni_{81}Fe_{19}$ films is increased substantially leading to a giant magnetoelectric coupling coefficient and a striking correlation between local and global magnetoelectric effects. We have also compared $Ni_{81}Fe_{19}$ films on PMN-PT substrates with and without buffer layers of Cu, whose presence precludes charge-mediated coupling. $Ni_{81}Fe_{19}$ has virtually zero magnetostriction, but sufficiently thin films show large magnetostriction, and thus, on increasing film thickness through the threshold for zero magnetostriction, we have sought out the crossover from charge-mediated to strain-mediated coupling.



References

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