Electric field induced magnetic switching in multiferroic $BiFeO_3$ and ferromagnetic $La_{0.67}Sr_{0.33}MnO_3$ thin film tunnel junction bilayers

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Multiferroic materials are a rare case where ferromagnetism (FM) and ferroelectricity (FE) coexist, presenting exciting opportunities for scientific research and technological innovation. Bismuth Ferrite ($BiFeO_3$) is of special interest, as both properties order at room temperature and exhibit magnetoelectric coupling [1]. The opportunity for novel storage devices in particular is impressive; control of the spin state via an applied electric field opens the possibility for spintronic and other next generation information storage devices [1]. Therefore, its use in functional thin film heterostructures, like multiferroic tunnel junctions or exchange bias systems that combine multiferroic (MF) and ferromagnetic layers, such as $La_{0.67}Sr_{0.33}MnO_3$ ($LaSrMnO_3$), is of particular interest [2].

Polarised neutron reflectometry was performed on $LaSrMnO_3$ / $BiFeO_3$ bilayer thin films to investigate the magnetic profile and coupling between the multiferroic (antiferromagnetic and ferroelectric) $BiFeO_3$ layer and the ferromagnetic $LaSrMnO_3$ layer. The thin film surface area was approximately 8mm x 8mm. We measured the spin-up and spin-down polarised neutron channels to observe splitting of the reflectivity curves, which occurs as a result of the magnetic polarisation of the system. These measurements were performed at temperatures from 5 K to 300 K and under applied magnetic vertical fields of 3 kG and 80 Gauss. The incident wavelength was 2.37 Å. We achieved good statistics with scans of ~12 h, including both channels, within a Q_z range up to 0.08 $Å^{-1}$ (see Figure 1).

Analysis of the results show evidence of complex interplay physic at the interface between the ferromagnetic $LaSrMnO_3$ and multiferroic $BiFeO_3$ layers. Certain features of the PNR signal could only be modelled with the addition of an additional thin interface layer. Intriguingly, the best fit was achieved with the inclusion of a thin ferromagnetic $BiFeO_3$ layer (~4 nm) (Figure 1). This would indicate a frustrated spin state is extending into the antiferromagnetic $BiFeO_3$ layer as a result of correlation at the interface with the ferromagnetic $LaSrMnO_3$. While further careful analysis and complementary experimental techniques will be required to ensure this model is physical, the result is in agreement with recent theoretical predictions [3].

References

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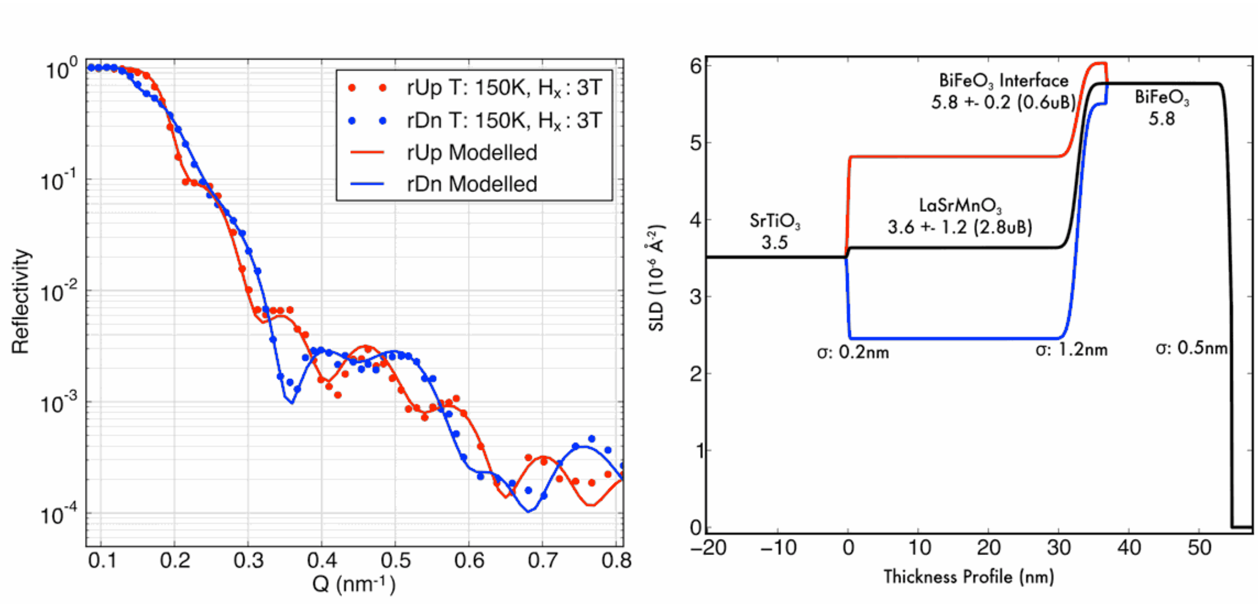

Fig. 1 (a) Polarised neutron reflectivity data at 150K and under an applied field of 3T. Includes a fitted model of the data, with $\chi^2 = 0.8$, using the SimulReflec software package[4]. (b) Scattering Length Density profile of the fitted model, indicating the 4 nm ferromagnetic $BiFeO_3$ interface layer.