ESRF	**Experiment title:** Depth resolved study of electric field driven modification of magnetic state in Fe layers on BaTiO3 crystal	**Experiment number**: HE-3470
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Report:

The aim of the experiment was to study the evolution of the local magnetic state of an Fe layer at the interface of a ferroelectric $BaTiO_3$ substrate. This system is a composite "artificial" multiferroic, where an applied electric field on the ferroelectric can influence the magnetic state of the ferromagnetic layer. The goal was to use the unique isotope sensitivity to ^{57}Fe of the nuclear resonant scattering technique to obtain depth resolved and/or interface specific informations on the local magnetic state of the Fe layer. For that purpose, we have grown a series of samples by molecular beam epitaxy in our laboratory. On one side, samples with a fixed Fe thickness of 2, 5, and 10 nm where grown with each time two 0.5 nm ^{57}Fe probe layers placed at the FM/FE interface and further away from it. One sample was grown as a wedge, *i.e.* the ^{57}Fe thickness was continuously varied from 1 to 5 nm from one edge to the other edge of the substrate. We also prepared films of 2, 5 and 10nm on $LiNbO_3$ substrate, which is another ferroeletric.

The experiment was carried at the ID22N beamline at room temperature. Helmholtz coils were used to precisely control the magnetic field at the sample position (no hysteresis effects) and voltage was applied through two macroscopic contacts placed on the top and at the backside of the sample respectively.

The biggest part of the experiment was carried out on the wedged sample. The experimental procedure was as follow. We started to record timespectra at different magnetic field along the magnetic hysteresis curve of the sample. At each field value, three positions along the wedge where measured to be compared afterwards. Then the

voltage was raised by 50V and the same procedure repeated. The general trend is that a slightly higher field is needed to switch the layer's magnetization when an electric field is applied, and this for all layer thicknesses. This means, as it is observed with conventional techniques, that the coercivity of the layer increases. However, we also have seen that the beating frequency remains exactly the same whatever the voltage that is applied or the layer thickness probed. This indicates that this change in coercivity is not really associated with a change of the magnetic state of the Fe layer, but rather with a structural change that induce a different anisotropy. Precise data analysis is currently going on and will yield more quantitative information concerning the thickness dependence of this phenomenon. Another phenomena was observed on the $LiNbO_3$ based samples. Indeed we see for the 2 nm thick CoFe layer that the fast magnetic beating in the timespectra gradually disappear as we apply the voltage. When the voltage is released, the magnetic beats do not reappear. Since the frequency of the magnetic beat do not change but only their intensity decreases, we can conclude that this irreversible change leads to the formation of a magnetically dead layer at the interface, probably due to a structural disorder induced by the additional interfacial strain.

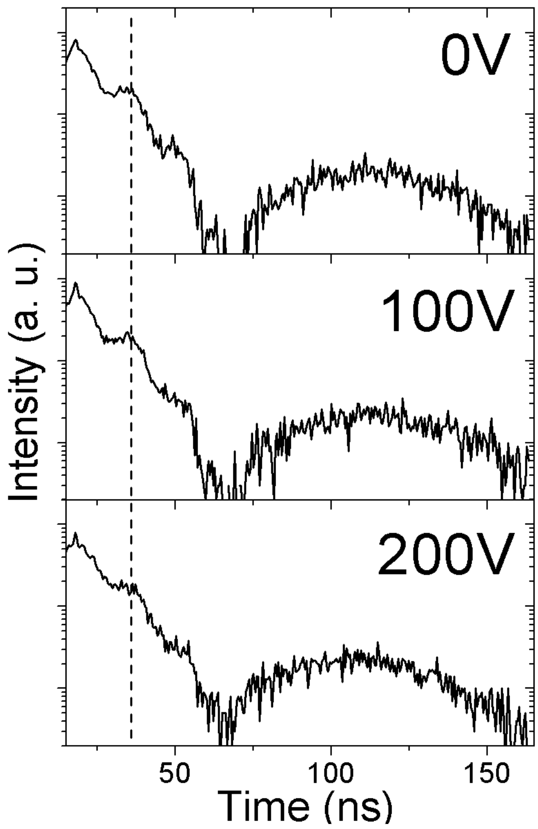

Figure 1 Timespectrum recorded on a 2nm ^{57}Fe film deposited on $LiNbO_3$ with increasing voltage. The high frequency magnetic beats gradually disappear.

This first experiment proves the importance of accessing interfacial properties in the field of ferroelectric-ferromagnetic composites. In this view, nuclear resonant scattering, in conjonction with macroscopic characterization methods proves to be very efficient.

The complete analysis of the data gathered during this experiment will give further insight into the model systems investigated here.