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Cloaking magnetic information

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During the last decade, in the field of multiferroic materials, several systems have shown the coexistence of electric and magnetic orders with coupling between them (so-called magnetoelectric coupling). In the particular class of composite multiferroics, where magnetoelectric coupling takes place owing to mechanical coupling (strain mediated) between a ferroelectric material and a ferromagnetic material, the sign of the net magnetization in the ferromagnet can not be selected uniquely by an electric field, whatever is its sign or magnitude. This is because piezoelectricity and magnetostriction (the mechanisms that trigger magnetoelectric coupling) are both even functions of electric field and strain, respectively.

Without overcoming this fundamental issue, we will show by micro and macromagnetic characterization that magnetic memory effects present in the antiferromagnetic to ferromagnetic transition of FeRh can help to circumvent it. With this purpose, we have characterised a PMN-PT/FeRh structure. PMN-PT is a relaxor ferroelectric with record piezoelectric coefficient, and FeRh presents a large change in its lattice parameters while crossing the antiferromagnetic to ferromagnetic phase transition. Thus, one can tune the magnetic order by means of electric-field, by modifying the magnetic transition temperature on FeRh via strain coupling between the piezoelectric substrate and the magnetic layer. First, we will show that FeRh phase transition shows thermal memory effect. After the FeRh magnetization is oriented in the ferromagnetic phase by an external magnetic field and FeRh is brought to the antiferromagnetic phase by cooling it, if one measures the orientation of the magnetization again in the ferromagnetic phase, it partially recovers its initial state [1]. Secondly, we also show that by the application of low electric field, we can isothermally manipulate a large amount of magnetization. Magnetic imaging reveals that the electrically stimulated memory effect occurs thanks to the same mechanism that applies for the aforementioned thermal magnetic memory effect [2], as sketched in Figure 1.

[1] J. Clarkson, …, I. Fina, et al., An invisible non-volatile solid-state memory, arXiv preprint arXiv:1604.03383
[2] I. Fina, et al., Electric-Field Adjustable Time-Dependent Magnetoelectric Response in Martensitic FeRh Alloy, ACS Applied Materials & Interfaces (2017). Online.

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