Voltage control of ferromagnetic resonance in FeRh/PMN-PT multiferroic heterostructures

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Voltage control of magnetism is promising for developing dense, fast, nonvolatile magnetic random access memory (MRAM) with low energy consumption and emerging spintronics [1]. Multiferroic heterostructures, exhibiting ferroelectricity and ferromagnetism simultaneously, have attracted much interest due to the ability of achieving electrically modulated magnetic states through magnetoelectric (ME) coupling and have led to many novel multiferroic devices [2]. Compared with conventional tunable magnetic devices, which are tuned by magnetic fields, these electrostatically tunable multiferroic devices are high-speed, compact, lightweight, and much more energy efficient.

In this study, we investigate voltage tuning of ferromagnetic resonance (FMR) in epitaxial $Fe_{0.7}Rh_{0.3}$ (FeRh)/PMN-PT multiferroic heterostructures. A $SrTiO_3$ thin layer was grown on (001)-oriented PMN-PT ferroelectric single crystals as a buffer layer using pulsed laser deposition (PLD). Subsequently, FeRh thin films were fabricated on $SrTiO_3$-buffered PMN-PT substrates using molecular beam epitaxy (MBE), followed by a 3 nm thick Rh film as a capping layer. An Au layer (100 nm) was coated on the backside of the PMN-PT substrate as a bottom electrode. Figure 1(a) shows the schematic of the FeRh/PMN-PT multiferroic heterostructures under an electric field.

Figure 1(b) depicts the frequency as a function of resonance field (H_{FRM}) of the FeRh film when the PMN-PT substrate is under positive and negative poled states. We find that the H_{FRM} strongly depends on the polarization state of the PMN-PT. In a high frequency region (f>10.5 GHz), the H_{FRM} is almost same for the different polarization states. As the frequency reduces, there are two absorption peaks in S_{21} spectra. In a low frequencies region (f<6.7 GHz), the H_{FRM} at the negative poled state is smaller than that at the positive poled state (e.g., ΔH_{FRM}=120 Oe at f=2.9 GHz). These findings reveal that the FMR can be effectively controlled by electric field through ME coupling. Voltage dependence of Kerr signal was measured to explore the coupling mechanism for this FeRh/PMN-PT multiferroic heterostructures.

Reference
1) Y. Tokunaga *et al*, Nat. Phys. 8, 838 (2012).
2) Y. Lee *et al*, Nat. Commun. 6, 5959 (2015).

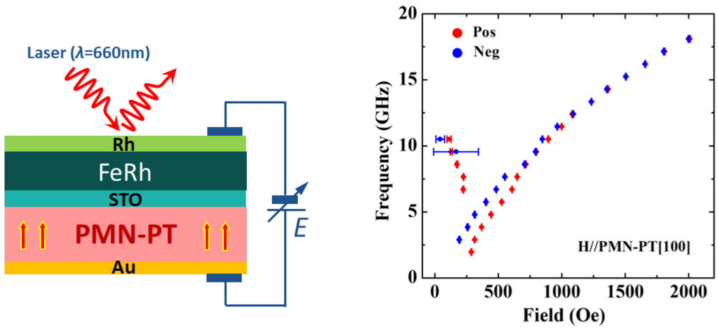

Fig. 1 (a) Schematic of the FeRh/PMN-PT multiferroic heterostructures and the electric field configuration for measurements of Kerr effect. (b) Frequency as a function of resonance field of the FeRh film when the PMN-PT substrate is under positive and negative poled states.