Optical control of RKKY coupling and perpendicular magnetic anisotropy in a synthetic antiferromagnet

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Synthetic antiferromagnetics (SAF) provide an excellent platform for antiferromagnetic spintronics. Recently, the voltage-control of the Ruderman–Kittel– Kasuya–Yosida (RKKY) interaction in SAFs was studied experimentally. Optical control would offer unique opportunities for the ultrafast manipulation of spin states, however, it has yet to be demonstrated. Here, using femtosecond laser excitations in a [Co/Pt]-based perpendicular magnetic anisotropy (PMA) synthetic antiferromagnet (p-SAF), we drive a reduction of the RKKY coupling and the PMA. We attribute the reduced RKKY interaction to the optically smeared Fermi wave vector of the Ru layer, which mediates the exchange coupling between the constituent ferromagnetic layers. The PMA exhibits the same amplitude of decrease as the RKKY coupling, which we associate with electron redistributions in the 3d orbitals caused by the optically smeared Fermi level. While the pump excitation process is shown to have an influence on the modulations, thermal contributions are excluded. Our study establishes a link between the RKKY coupling and the PMA in a p-SAF structure and provides an approach to tune them in parallel.

***Index Terms*—Synthetic antiferromagnetics, RKKY interaction, Optical control**

I. Introduction

Antiferromagnetic (AF) spintronics has emerged as a major field in spintronics, fueled by its remarkable attributes of high magnetic field (H-field) stability and ultrafast operation speed[1]. However, this robustness also leads to a weak response to an external magnetic fields, which hampers conventional magnetic control methods[2]. Synthetic AF materials (SAF), however, offer great opportunities for AF devices due to their relatively weak exchange coupling. Recent experiments have demonstrated that an electric field can tailor the RKKY coupling and drive transitions between AF and FM[3]. These effective modulations typically rely on changes of the Fermi level influenced by charge accumulations at the surface or ion doping by applying a voltage[4]. Optical control of the RKKY coupling is therefore preferable for its advantages of simpler fabrication, inner-interface access[5] and flexibility[6]. Manipulating the interlayer coupling by femtosecond laser pulses is key for ultrafast spin dynamics such as all-optical switching (AOS) where the RKKY coupling is reported to mediate magnetization switching as little as a few picoseconds[7].

Here, we use antiferromagnetically coupled [Pt/Co]4/Ru/[Co/Pt]2 as a prototype system to investigate optical manipulations of the RKKY interaction and the interfacial PMA. We show by time-resolved magneto-optical Kerr effect (TR-MOKE) that a fs laser pulse can simultaneously and equally tune the RKKY coupling and the PMA in the [Pt/Co]4/Ru/[Co/Pt]2 system.

Our results provide insights into how a femtosecond laser pulse modulates the RKKY interaction and PMA, thereby enabling control of magnetization switching processes in a SAF system for applications in ultrafast magnetic data storage.

II. RESULTS

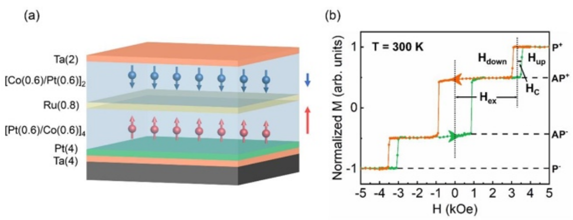

Figure 1 SAF-sample structure and the static magnetic properties. (a) SAF sample schematics. (b) Static out-of-plane hysteresis loop measured by VSM. The green and orange lines represent the process that sweeps the magnetic field from negative to positive and from positive to negative, respectively. The switching fields of the minor loop in two sweeping branches are defined as H_{up} and H_{down}, respectively.

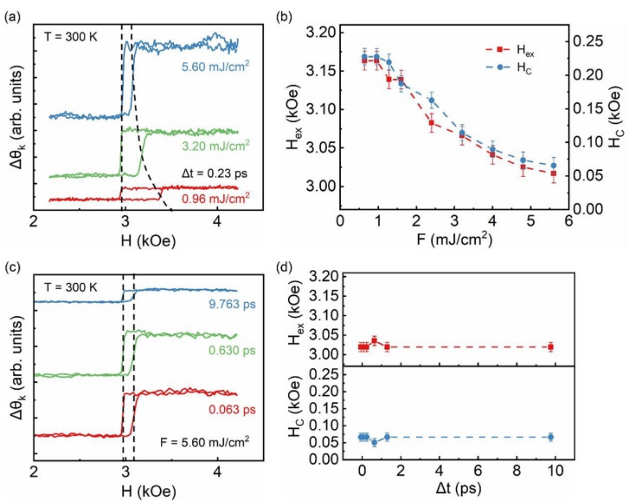

Figure 2 TR-MOKE measurements. (a) Transient minor hysteresis loops at selected pump fluences. As guided by the dashed lines, Hup shows an obvious reduction at high pump fluences while H_{down} remains unchanged. (b) Calculated Hex and HC values from the minor loops as a function of pump fluence F. Within experimental error bars they show the same trend after fs excitations. (c) Minor hysteresis loops probed at three different pump-probe delays under a fixed pump fluence of 5.60 mJ/cm2. (d) Extracted time-delayed Hex and HC from transient loops in (c), showing negligible variations within 10 ps. Error bars indicate the uncertainty in determining the displayed value from the experimentally measured data.

III. REFERENCES

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