Magnetization reversal and domain structures in perpendicular synthetic antiferromagnets prepared on rigid and flexible substrates

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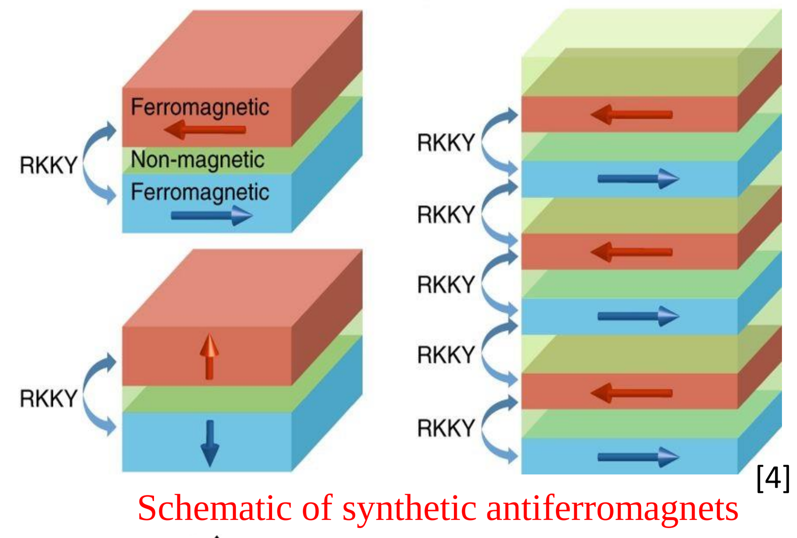
Introduction and Motivation

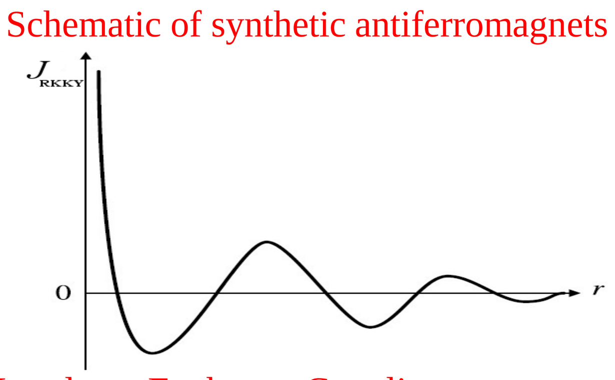
❖ Using a synthetic antiferromagnet(SAF) structure as either the free layer or the pinned layer has the advantage of producing an adjustable net magnetic moment and reduced magnetostatic interaction between the layers and also provides a good field sensitivity. [1, 2]

❖ Synthetic antiferromagnets (SAFs) are built with Ferromagnetic (FM) layers periodically interleaved with metallic or insulating spacers, where the magnetization of adjacent FM layers alternates owing to the antiferromagnetic (AF) interlayer exchange coupling (IEC).

❖ For metallic spacers, IEC is achieved via RKKY (Ruderman-Kittel-Kasuya-Yosida) type exchange interaction mediated by spin polarized charge carriers in the spacer. [3]



Schematic of synthetic antiferromagnets

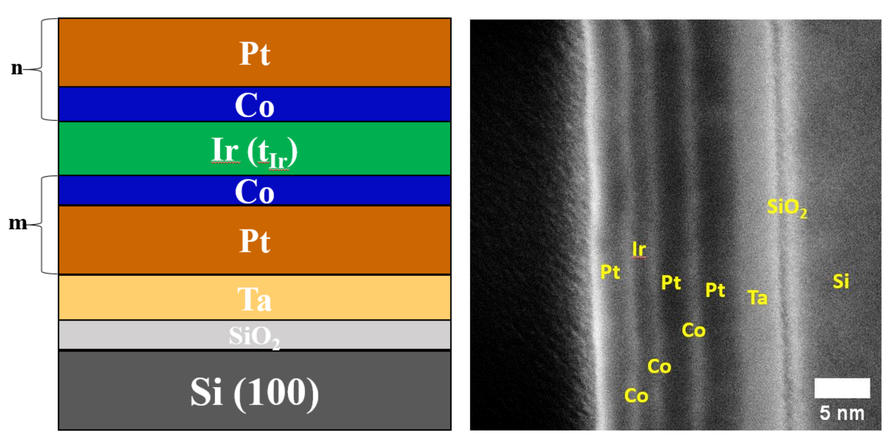


Interlayer Exchange Coupling energy as a function of thickness of spacer layer

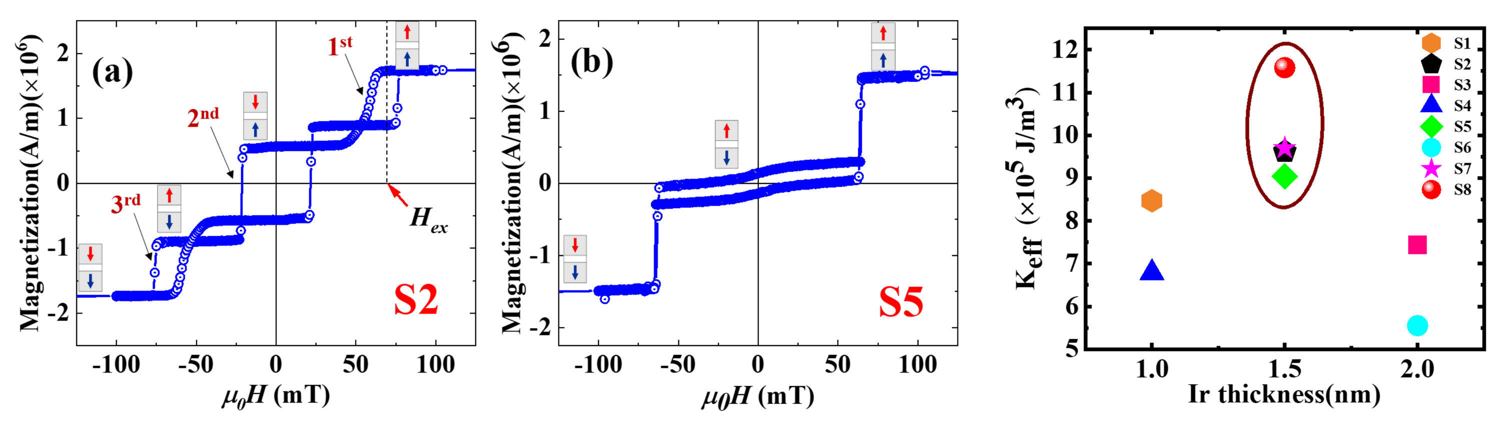
Experimental Techniques

1. Sputtering: All the films are deposited by DC sputtering.
2. Kerr Microscopy: Simultaneous observation of hysteresis loop as well as domain images are done.
3. SQUID Magnetometer: In order to quantify different parameters like M_s, H_{ex}, H_k etc., SQUID-VSM measurement is performed for all the samples.
4. TEM: For structural characterization, cross sectional TEM sample is prepared and high-resolution transmission electron microscopy (HR-TEM) is performed.

Sample structure and TEM image



SQUID measurement



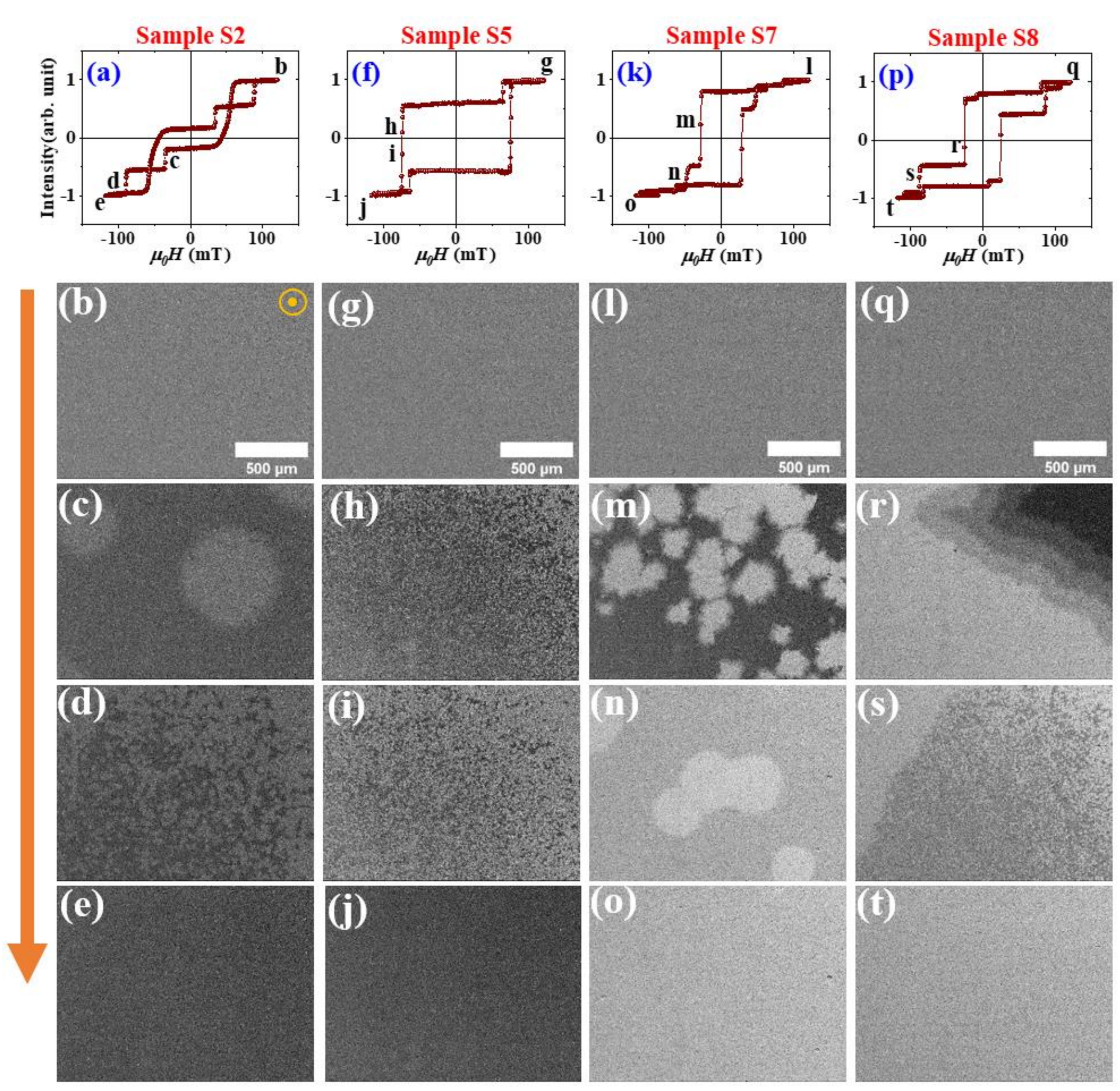
Sample name with t_{Ir}	(m, n)	Type of coupling	M_s (emu/cc)	H_{ex} (Oe)	$J_{ex} = H_{ex}M_st$ (erg/cm2)
S1(1.0)	(2, 1)	FM	1755		
S2(1.5)	(2, 1)	AFM	1758	701	0.296
S3(2.0)	(2, 1)	FM	1782		
S4(1.0)	(1, 1)	FM	1743		
S5(1.5)	(1, 1)	AFM	1590	646	0.164
S6(2.0)	(1, 1)	FM	1763		
S7(1.5)	(1, 2)	AFM	1644	695	0.274
S8(1.5)	(2, 2)	AFM	1781	800	0.456

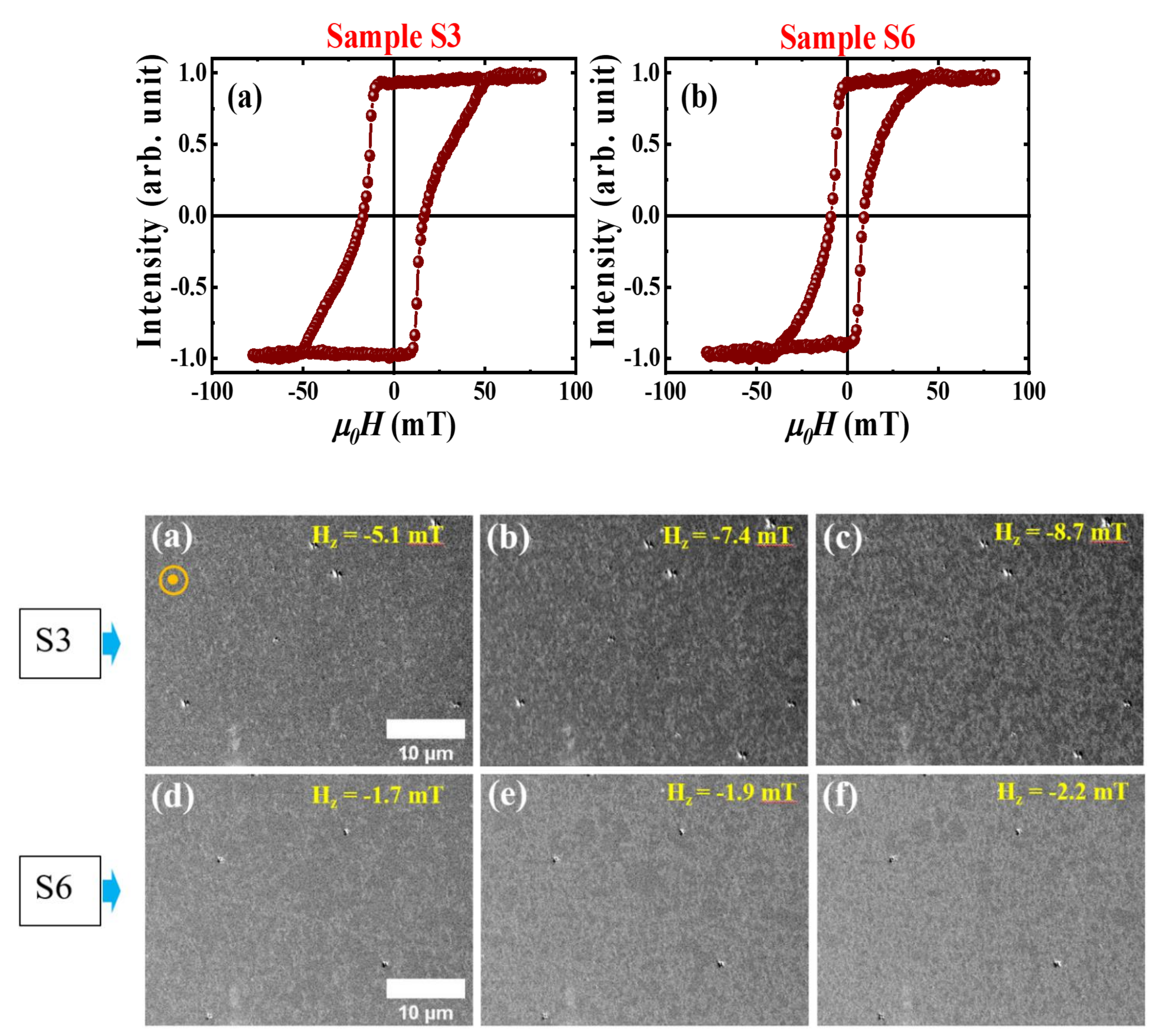
Reference sample : Si/Ta(3)/[Pt(3.5)/Co(0.8)]$_2$/Ta(3)
Samples for SAF :
Si/Ta(3)/[Pt(3.5)/Co(0.8)]$_m$/Ir(t_{Ir})/[Co(0.8)/ Pt(3.5)]$_n$
(t_{Ir} = (1.0, 1.5, 2.0))
Flexible sample: Si/Ta(15)/Pt(3.5)/Co(0.8)/Ir(1.5)/Co(0.8)/ Pt(3.5) (numbers in the bracket are thicknesses in nm)

✓ The steps in the hysteresis loops indicate AFM coupling between the FM layers below and above the Ir spacer layer.

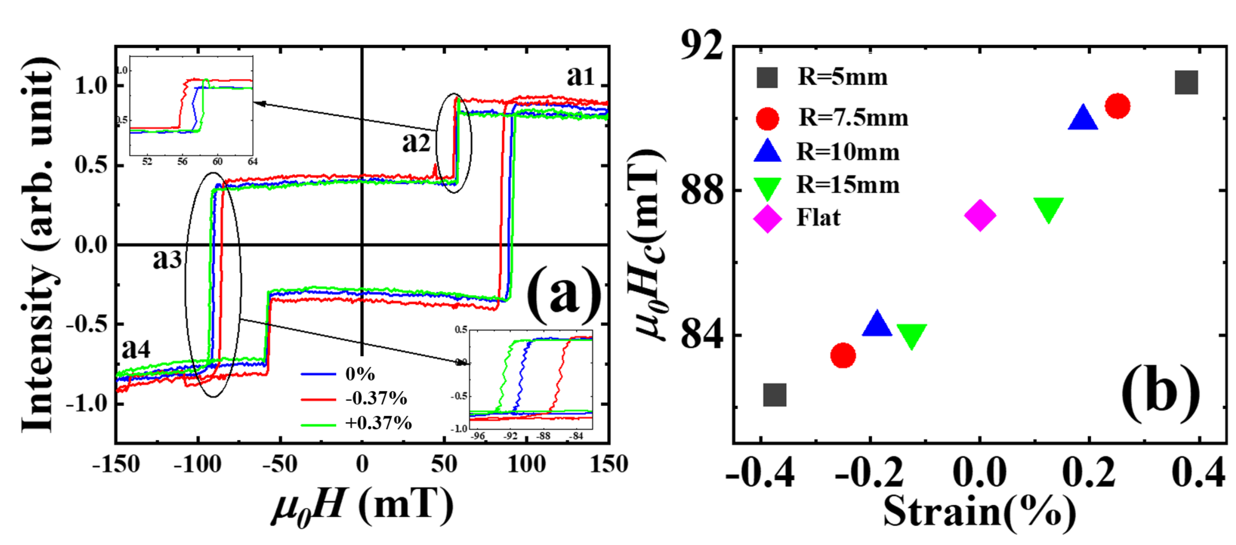
✓ The anisotropy energy of the samples are higher than the IEC energy (J_{ex}/t) resulting in a smaller intermediate angle between the magnetic moments of the two layers. [5]

Kerr microscopy measurement





Effect of strain



✓ To generate tensile and compressive strains, the flexible sample has been fixed using Kapton tape on both convex- and concave-shaped molds, respectively.

✓ Under 0.37% tensile stress, we observe an increase in coercivity of 2.03 mT while the compressive stress decreases the coercivity by 4.41 mT.

Conclusions

❖ We have successfully fabricated the Co/Pt based synthetic antiferromagnetic samples by varying the thickness of spacer Iridium layer 1.0, 1.5, 2.0nm.

❖ AF-IEC is found with Ir thickness 1.5nm.

❖ By applying strain, the SAF coupled samples shows a change in coercivity as well as exchange coupling field.

References

1. **Z. Zhao,** *Phys. Rev. B,* 71, 104417 (2005).
2. **M.D. Stiles,** J. Magn. Magn. Mater. 200, 322 (1999)
3. **B. Chen,** *Science*, 357, 6347, 191-194 (2017).
4. **R. A. Duine,** *Nat. Phy.*, 14, 217–219 (2018).
5. **S. Mohanty,** *JOM*, 74, 2319–2327 (2022)

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