SWISS CONTRIBUTION

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Determination of exchange and rotatable anisotropies in Co_2FeSi/IrMn exchange coupled structures using broadband ferromagnetic resonance

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Introduction

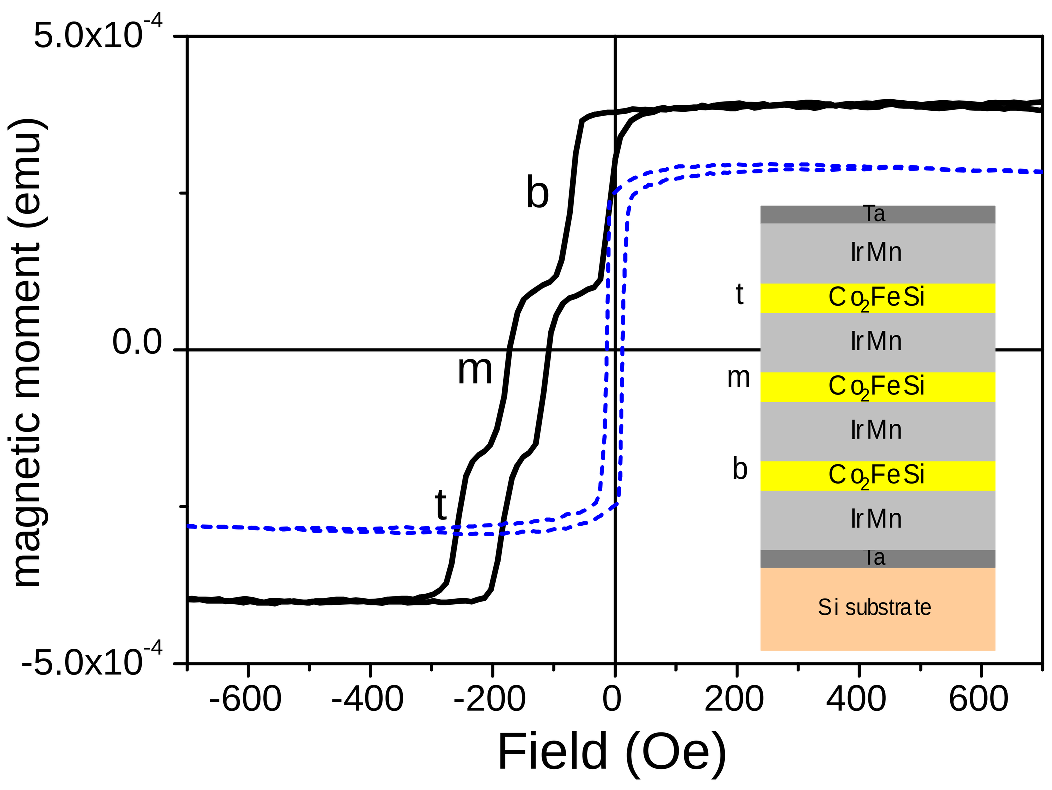
Besides the unidirectional (exchange bias) and uniaxial anisotropies, the ferromagnetic (FM)/antiferromagnetic (AFM) thin film systems with exchange bias (EB) are characterized by the rotatable anisotropy. The rotatable anisotropy comes from antiferromagnetic uncompensated spin system, which rotate with FM magnetization. In the present work we determine, using broadband ferromagnetic resonance (VNA-FMR), the anisotropy fields of multilayer systems that comprise four 20 nm IrMn and three 10 nm Co_2FeSi (CFS) exchange coupled layers.

Experimental details

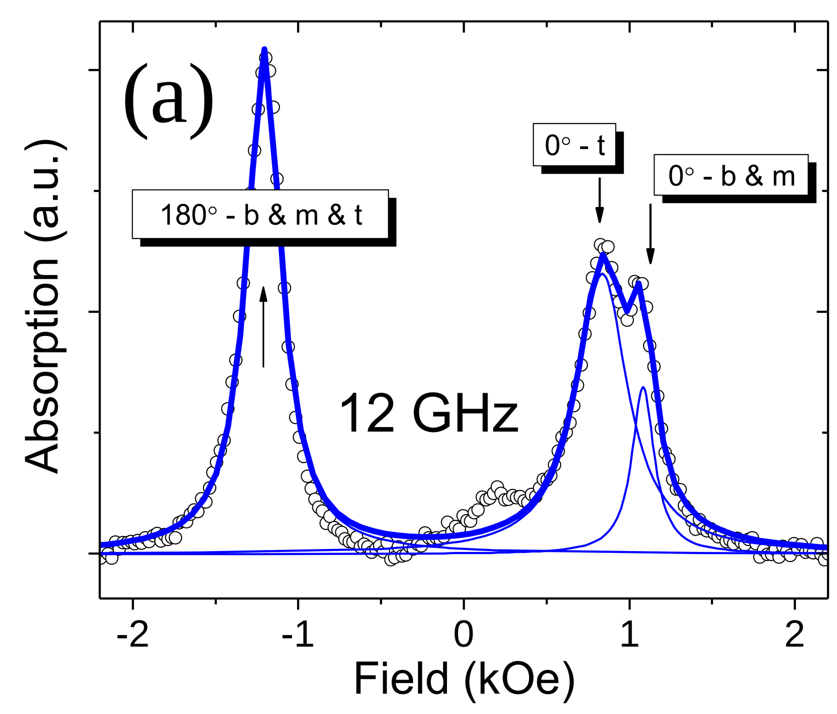
- The multilayer films were deposited in a Prevac magnetron sputtering system .
- FMR was measured with a Vector Network Analyzer (VNA) on a coplanar waveguide (CPW). Measurements were done with field-swept mode.
- Vibrating sample magnetometry (VSM) was used to obtain the magnetization hysteresis loops of the films upon magnetic fields of up to 1000 Oe.

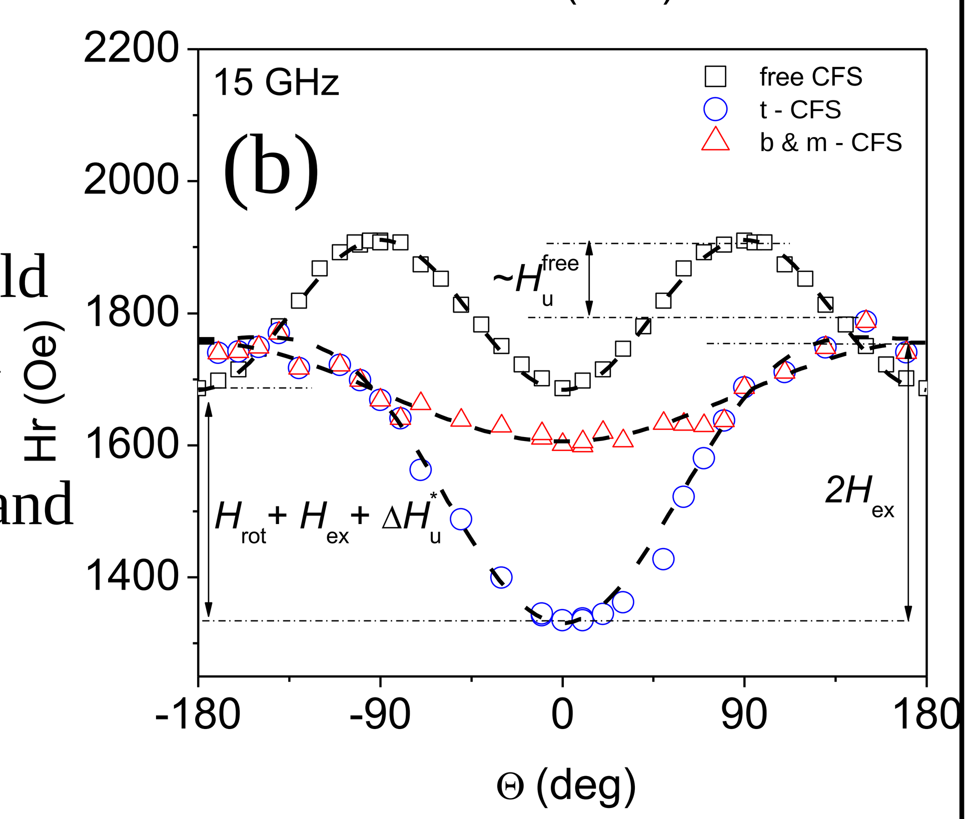
Results

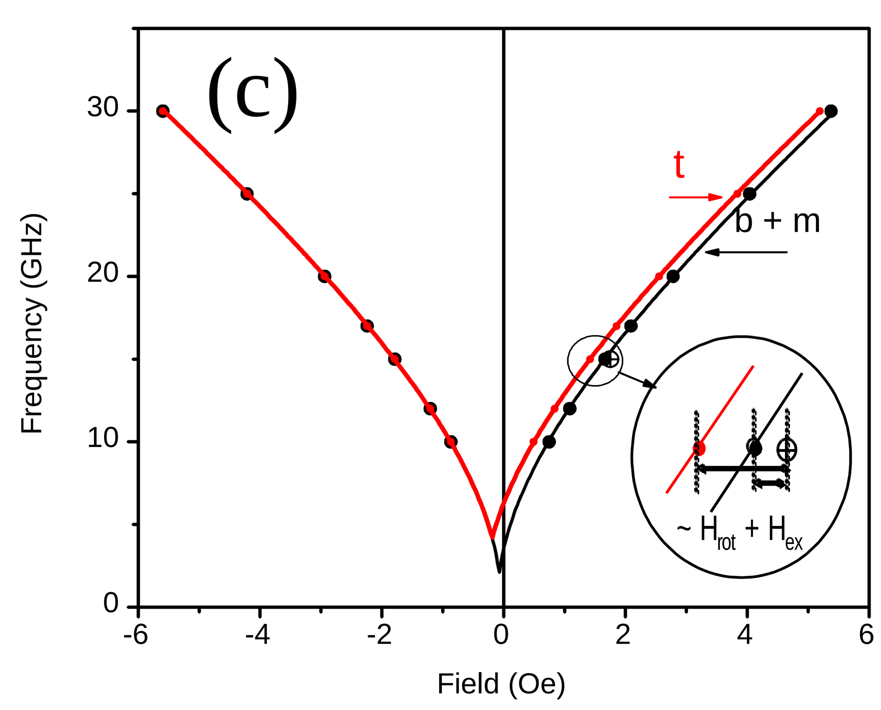
- Multilayered films consist of Ti(5 nm)/IrMn/bottom (b)-CFS /IrMn/middle (m)-CFS/IrMn/top (t)-CFS/IrMn/Ti (5 nm)
- Typical M(H) loops of our structures are presented below for a single CFS with no IrMn (dashed lines) and [CFS/IrMn] (continuous lines) samples.
- We checked with independent magnetooptical Kerr magnetometry (which is surface sensitive) that the top CFS has the highest EB.



- Figure (a) shows typical spectra for 12 GHz. Only two peaks are observed for parallel direction, which corresponds to (b+m)- and (t)-CFS layers.
- Angular dependance of resonance field for the (b+m)-CFS, (t)-CFS layers and the free CFS film is shown in figure (b)
- Figure (c) presents the field dependencies of the FMR frequencies (dispersion relations) for the (b+m)- and (t)-CFS layers (black and red dots).
- Parameters Hu, M, Hex, Hrot were obtained by fitting (formula below) to experimental data for 0, 90, 180, 270 degrees.







$$H_r(\theta) = \{[2\pi M + \frac{H_u}{4}(1+3\cos 2\theta)]^2 + (\frac{\omega}{\gamma})^2 - [4\pi M + \frac{H_u}{2}(1+\cos 2\theta)] \times H_u \cos 2\theta\} - 2\pi M - \frac{H_u}{4}(1+3\cos 2\theta) - H_{ex}\cos\theta \cdot$$

TABLE I. Magnetization and magnetic anisotropy fields of the bottom (b), middle (m) and and top (t) CFS layers in the [CFS/IrMn] multilayer system.

Layer	M (G)	H_{ex}^{VSM} (Oe)	H_C^{VSM} (Oe)	H_{ex}^{FMR} (Oe)	H_U^{FMR} (Oe)	H_{rot}^{FMR} (Oe)
(b)-CFS	970	30	30	72	24	80
(m)-CFS	970	140	30			
(t)-CFS	960	214	37	190	39	148
free	980	0	12	0	118	0

Conclusion

- The quality of CFS/IrMn interfaces (resulting in increasing number of the pinned AFM spins at the interfaces) improves during deposition of the subsequent layers.
- The number of the stable spins increases from the bottom to the top CFS, so the number of unstable resulting in the rotatable anisotropy should equivalently decrease [3].
- The trend observed in our [CFS/IrMn] structures is quite opposite: H_{rot} increases with the increase in H_{ex}.

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