Magnetocrystalline anisotropy and magnetoelastic properties of the $Co_2Fe_{0.4}Mn_{0.6}Si$ (CFMS) and $Co_2FeGa_{0.5}Ge_{0.5}$ (CFGG) Heusler alloys films

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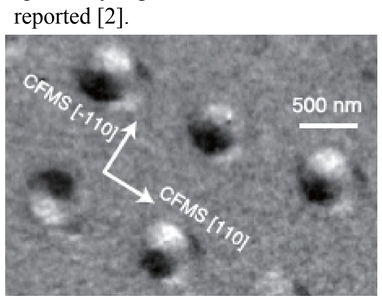
ABSTRACT

The out-of-plane magnetocrystalline anisotropy and magnetoelastic properties of series of epitaxially grown layers of $Co_2Fe_{0.4}Mn_{0.6}Si$ and $Co_2FeGa_{0.5}Ge_{0.5}$ Heusler alloys thin films deposited on MgO with chromium buffer layer were investigated by means of the ferromagnetic resonance (FMR), SQUID magnetometer, and by the strain modulated FMR technique. The magnitude of the magnetocrystalline anisotropy constant was found to decrease with increasing layer thickness. The change of the anisotropy is caused mainly by the surface effects. However, for some of the samples series, the change of chemical ordering with the change of the magnetic layer thickness was also observed. An additional silver buffer layer influence on the properties of the magnetic layer was also investigated. For all three of the investigated series of the Heusler alloys, i.e., CFMS without Ag, CFMS with Ag, and CFGG, the experimentally observed magnitude of the magnetoelastic constant increases with the increase of the magnetic layer thickness. [1]

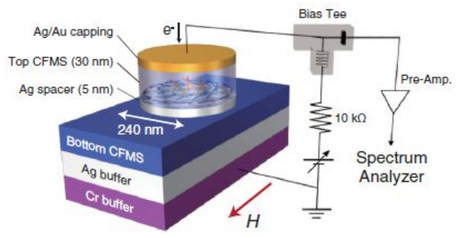
INTRODUCTION

The half-metallic ferromagnetic CFMS Heusler alloys are representative materials showing high spin-polarization of conduction electrons. They are promising materials for potential applications in both spintronic and magnonic devices.

Previously formation of magnetic vortices in nanoscale discs of epitaxially grown CFMS was reported [2].



A system of such disks was next used to construct the vortex spin-torque oscillator [3].



Schematic illustration of an STO with a CFMS vortex and a microwave measurement circuit.

SAMPLE & PREPARATION

Ultrahigh-vacuum (UHV)-compatible magnetron sputtering deposition

⇩

Cr buffer layer deposition at room temperature and annealing at 600^{0}C

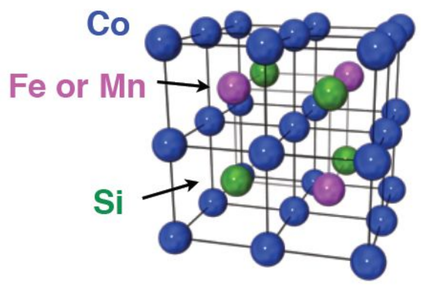
⇩

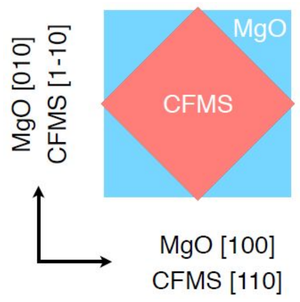
Ag layer deposition (optional)

⇩

CFMS/CFGG layer deposition at room temperature and annealing at 500^{0}C

$L2_1$-CFMS





$Co_2Fe_{0.4}Mn_{0.6}Si$

Au 5 nm
CFMS t nm
Cr buffer 20 nm
MgO (001)

t= 15, 30 and 50

MgO (001) ‖ Cr (001) ‖ CFMS (001)

$Co_2FeGa_{0.5}Ge_{0.5}$

CFGG t nm
Cr buffer 20 nm
MgO (001)

t= 30 and 50

MgO (001) ‖ Cr (001) ‖ CFGG (001)

$Co_2Fe_{0.4}Mn_{0.6}Si$ with Ag

Au 5 nm
CFMS t nm
Ag buffer 20 nm
Cr buffer 20 nm
MgO (001)

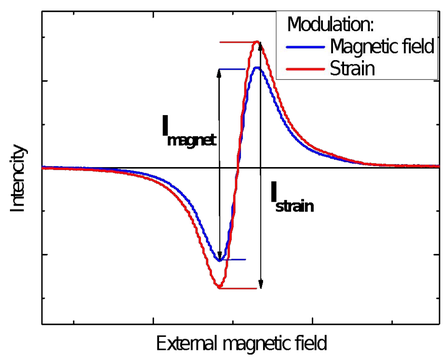
t= 30 and 50

MgO (001) ‖ Cr (001) ‖ Ag (001) ‖ CFMS (001)

STRAIN MODULATED FERROMAGNETIC RESONANCE TECHNIQUE

$$F = -\sum_{i=1}^{3} M_i H_i + 2\pi M_S^2 \alpha_3^2 + K\left(1-\alpha_3^2\right) + \sum_{i,j,k,l=1}^{3} B_{ijkl}\alpha_i\alpha_j\varepsilon_{kl}$$

Demagnetizing — Zeeman contribution — Magnetic anisotropy — Magnetoelasticity



$$m_\sigma = m_0 \frac{G_0}{G_\sigma}\frac{I_{strain}}{I_{magnet}}$$

$$\Downarrow$$

$$m_\sigma = \Delta H_\sigma = H_{strain} - H_{magnet}$$

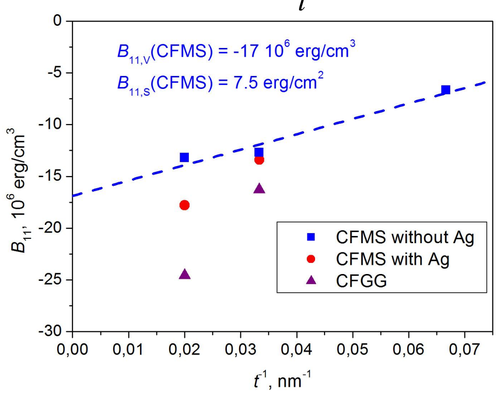
$$\Downarrow$$

magnetoelastic constant B

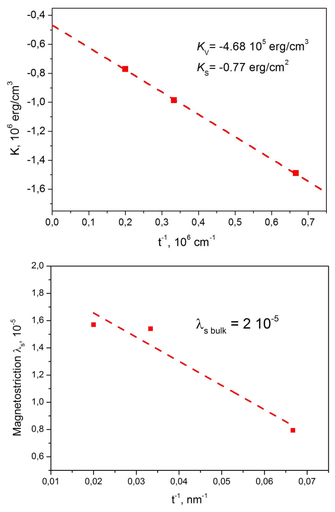
MAGNETOELASTICITY AND MAGNETIC ANISOTROPY

$$B_{11} = B_{11,volume} + \frac{2B_{11,surface}}{t}$$

$$K = K_{volume} + \frac{2K_{surface}}{t}$$



Magnetoelastic constants of CFMS and CFGG thin films

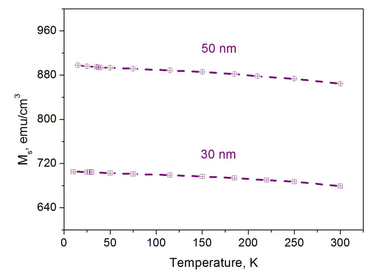


Magnetic anisotropy constant K and magnetostriction of the CFMS thin films without Ag layer

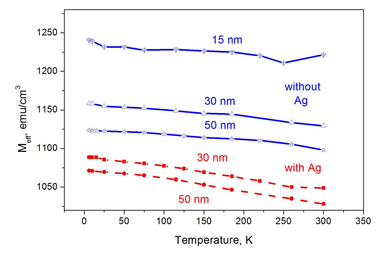
- For MgO/Cr/CFMS/Au, MgO/Cr/Ag/CFMS/Au and MgO/Cr/CFGG samples, the out-of-plane magnetocrystalline anisotropy, magnetoelastic, and magnetostriction constants were determined.
- All the CFMS layer samples without Ag have similar degree of chemical order. For CFGG and Ag-buffered CFMS films, degree of chemical order improves with increase of the film thickness.
- For CFMS layer samples without Ag, investigated properties can be correlated mainly with the surface effects.
- For CFGG and Ag-buffered CFMS, it is difficult to separate the surface effects from those related to the change of chemical order with increasing thickness.

MAGNETIZATION STUDIES

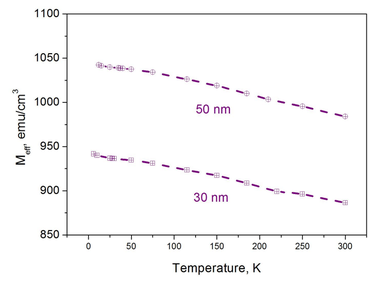
Saturation magnetization of CFMS samples



Saturation magnetization of CFGG samples



Effective magnetization of CFMS samples

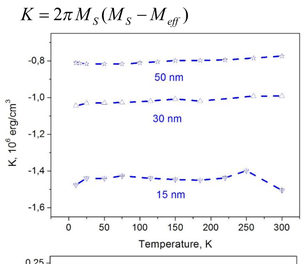


Effective magnetization of CFGG samples

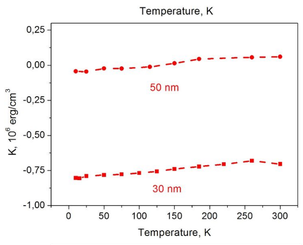
MAGNETIC ANISOTROPY CONSTANT

$$K = 2\pi M_S(M_S - M_{eff})$$

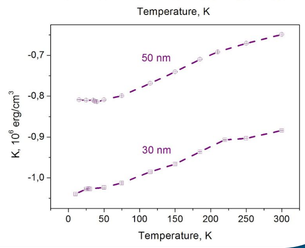
$Co_2Fe_{0.4}Mn_{0.6}Si$ without Ag



$Co_2Fe_{0.4}Mn_{0.6}Si$ with Ag



$Co_2FeGa_{0.5}Ge_{0.5}$



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[1] O. M. Chumak, A. Nabiałek, R. Żuberek, I. Radelytskyi, T. Yamamoto, T. Seki, K. Takanashi, L. T. Baczewski , H. Szymczak, IEEE Trans. Magn., Vol. 53, Issue 11, 2501906 (2017).

[2] T. Yamamoto, T. Seki, M. Kotsugi, and K. Takanashi, Appl. Phys. Lett., Vol. 108, Issue 15, 152402 (2016).

[3] T. Yamamoto, T. Seki, and K. Takanashi, Phys. Rev. B, Vol. 94, Issue 9, 094419 (2016).

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