Tailoring the magnetic anisotropy of antiferromagnetic thin films in epitaxial multilayer systems and ferromagnetic / antiferromagnetic nanostructures

In this thesis, the interaction between antiferromagnetic (AFM) and ferromagnetic (FM) thin films in various epitaxial multilayer systems is investigated. The first study examines a NiO(111)/Fe(110) bilayer, where the stabilization of two magnetic states with orthogonal spin orientations in the AFM NiO layer is documented. Field-free, reversible switching between these states is demonstrated, which was achieved by the precise tuning of interface magnetic anisotropy (MA), thermal hysteresis of spin reorientation transition, and interfacial FM/AFM exchange coupling. The potential for field-free switching of AFM magnetic moments is highlighted, potentially opening up new possibilities in heat-assisted magnetic recording technology. Furthermore, it is found that the magnetic moments in NiO can be rotated within the NiO(111) sample plane, with the MA and spin orientation in NiO being influenced by the underlying FM Fe layer. By varying the Fe thickness, temperature, or applying a small external magnetic field, modification of the magnetic state and anisotropy of the AFM NiO layer is achieved.

Next, the investigation delves into exchange bias and interfacial AFM spin orientation in CoO(111)/Fe(110) bilayers. The results reveal that exchange bias occurs in the zero-field-cooled system and is determined by the in-plane magnetic state of the Fe sublayer above the Néel temperature (T_N) of CoO. The direction of interfacial frozen AFM CoO spins within the CoO(111)/Fe(110) sample plane is dictated by the uniaxial MA of the Fe layer. Selecting a specific magnetic state of the Fe sublayer when passing the T_N of CoO allows for control over both the axis and direction of interfacial AFM spins within the sample plane.

Lastly, the influence of a nonmagnetic Au spacer on the interaction between FM Fe(110) and AFM CoO(111) sublayers is explored. The findings demonstrate that the thickness of the Fe and Au layers can be adjusted to modify the effective anisotropy of the Fe layer and the strength of the exchange bias interaction between Fe and CoO sublayers. The MA of the FM above the T_N of the AFM plays a crucial role in governing exchange bias and interfacial CoO spin orientation at low temperatures. Furthermore, it is shown that

exchange bias can act as the dominant MA source for the FM, allowing for a 90-degree rotation of the easy axis compared to the initial, exchange bias-free orientation.

Overall, these studies provide insights into the intricate interaction between AFM and FM components of epitaxial multilayer systems. The understanding and control of these interactions can potentially find new applications in novel magnetic devices and technologies.

The research conducted in this thesis have led to publishing 5 papers:

- M. Ślęzak, P. Dróżdż, W. Janus, H. Nayyef, A. Kozioł-Rachwał, M. Szpytma, M. Zając, T. O. Menteş, F. Genuzio, A. Locatelli, and T. Ślęzaka. Fine tuning of ferromagnet/antiferromagnet interface magnetic anisotropy for field-free switching of antiferromagnetic spins. Nanoscale, volume 12/ 18091-18095 (2020). DOI: 10.1039/D0NR04193A
- M. Ślęzak, P. Dróżdż, W. Janus, M. Szpytma, H. Nayyef, A. Kozioł-Rachwał, M. Zając, and T. Ślęzak. Tailorable exchange bias and memory of frozen antiferromagnetic spins in epitaxial CoO(111)/Fe(110) bilayers. Journal of Magnetism and Magnetic Materials, Volume 545/168783 (2021). DOI: 10.1016/j.jmmm.2021.168783
- M. Ślęzak, H. Nayyef, P. Dróżdż, W. Janus, A. Kozioł-Rachwał, M. Szpytma, M. Zając, T. O. Menteş, F. Genuzio, A. Locatelli, and T. Ślęzak. Controllable magnetic anisotropy and spin orientation of a prototypical easy-plane antiferromagnet on a ferromagnetic support. Phys. Rev. B, volume 104/ 34434 (2021). DOI: 10.1103/PhysRevB.104.134434
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15.12.2023, Kraków