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Perpendicularly magnetized Mn-based binary alloy films: a kind of promising materials for novel spintronic devices

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Ferromagnetic films with both high perpendicular anisotropy and good compatibility with semiconductors have great potential not only in semiconductor spintronic devices, like spin light-emitting diodes, spin field-effect transistors, and lateral spin valves with perpendicular spin injectors, but also in high-density integration of metallic spintronic functional devices like nonvolatile magnetoresistive random access memory (MRAM) on semiconductor circuits. Furthermore, ferromagnetic films with high perpendicular magnetic anisotropy (PMA) and magnetic energy product could be admirable for ultrahigh-density magnetic recording and permanent magnets. As the most promising candidates for such potential application, perpendicularly magnetized Mn-based binary alloys, like L10-MnGa and L10-MnAl have attracted special attention in recent years. However, although the growth and characterization of them have been studied intensively on various substrates in the past decades, only a few films on GaAs or MgO experimentally demonstrated PMA and relatively small coercivity (Hc). The quest for L10-MnGa and L10-MnAl films with the fascinating theory-predicted properties remains a major challenge [1].

In this talk, I will present our recent work on the high-quality Mn-based binary alloy, L10-MnGa and L10-MnAl single crystalline films with giant PMA grown on GaAs by molecular-beam epitaxy. These films show some fascinating room-temperature magnetic properties, like ultrahigh coercivity of 4.28 Tesla, giant perpendicular anisotropy of 2.17×10^7 erg/cm³, controllable magnetization from 130 to 700 emu/cc, and high magnetic energy product of 4.4 MGOe [2-4], close to theoretical predictions. Moreover, annealing studies revealed thermal stability of L10-MnGa up to at least 350℃ in contact with GaAs, indicating its compatible with current semiconductor industry technique (300℃) [3]. We unambiguously identified the pronounced influence of the chemical ordering on both the intrinsic and extrinsic contributions to the anomalous Hall effect (AHE) in L10-Mn1.5Ga [5], which help clarify the controversy over the AHE scaling and its microscopic mechanisms in this material. Very recently, we observed the orbital two-channel Kondo (2CK) effect existing in ferromagnetic L10-MnAl, providing the first evidence for the presence of 2CK effect in a ferromagnet [6]. Our experimental data indicate that these two noble-metal-free and rare-earth-free perpendicularly magnetized materials are compatible with mainstream semiconductor GaAs, and could be used not only in semiconductor spintronic devices with high thermal stability and magnetic noise immunity, but also in ultrahigh-density magnetic storage and permanent magnets.

References:
[1] L. J. Zhu, and J. H. Zhao, Appl. Phys. A 111 (2013) 379.
[2] L.J. Zhu, S.H. Nie, K.K. Meng, D. Pan, J.H. Zhao and H.Z. Zheng, Adv. Mater. 24 (2012) 4547.
[3] L.J. Zhu, D. Pan, S.H. Nie, J. Lu and J.H. Zhao, Appl. Phys. Lett. 102 (2013) 132403.
[4] S.H. Nie, L.J. Zhu, J. Lu, D. Pan, H.L. Wang, X.Z. Yu, J.X. Xiao and J.H. Zhao, Appl. Phys. Lett. 102 (2013) 152405.
[5] L.J. Zhu, D. Pan and J.H. Zhao, Phys. Rev. B 89 (Rapid Commun.) (2014) 220406(R).
[6] L.J. Zhu, S.H. Nie, P. Xiong, P. Schlottmann and J.H. Zhao, Nature Commun. 7 (2016) 10817.