MnGa 垂直磁化膜における二次元電子状態

Two-dimensional Electronic State in a Ferromagnetic $L1_0$ MnGa Thin Film with Perpendicular Magnetization

東大工 [1], 東大 CSRN[2], 東工大工 [3], 東大理 [4], 東大 ISSP[5], NIMS[6],
東北大理 [7], 東北大 WPI-AIMR[8], 東北大 CSRN[9], JST-PRESTO[10], KEK-IMSS[11], 早大応物 [12]
°小林正起 [1,2], N. H. D. Khang[3], 武田崇仁 [1], 荒木恒星 [1], 岡野諒 [1], 鈴木雅弘 [4],
黒田健太 [5], 矢治光一郎 [6], 菅原克明 [7,8,9,10], 相馬清吾 [8,9], 中山耕輔 [7,10], 北村未歩 [11], 堀場弘司 [11],
藤森淳 [4,12], 佐藤宇史 [7,8,9], 辛埴 [5], 田中雅明 [1,2], P. N. Hai[2,3]
Grad. Sch. Eng., Univ. of Tokyo[1], CSRN, Univ. of Tokyo[2], Tokyo Tech.[3], Dep. Phys., Univ. of Tokyo[4],
ISSP, Univ. of Tokyo[5], NIMS[6], Dep. Phys., Tohoku Univ.[7], WPI-AIMR, Tohoku Univ.[8], CSRN, Tohoku Univ.[9],
JST-PREST[10], KEK-IMSS[11], Dep. Appl. Phys., Waseda Univ.[12]
°M. Kobayashi[1,2], N. H. D. Khang[3], T. Takeda[1], K. Araki[1], R. Okano[1], M. Suzuki[4], K. Kuroda[5], K. Yaji[6],
K. Sugawara[7,8,9,10], S. Souma[8,9], K. Nakayama[7,10], M. Kitamura[11], K. Horiba[11],
A. Fujimori[4,12], T. Sato[7,8,9], S. Shin[5], M. Tanaka[1,2], and P. N. Hai[2,3]
E-mail: masaki.kobayashi@ee.t.u-tokyo.ac.jp

Ferromagnetic thin films with perpendicular magnetization are key materials for high-density magnetic recording and other spintronics applications. $Mn_{1-x}Ga_x$ thin films with the $L1_0$ (or CuAu type) crystal structure (referred to as MnGa), which show strong perpendicular magnetic anisotropy (PMA), were successfully grown by molecular beam epitaxy (MBE) in the early 1990s [1,2]. Recently, spintronic device structures using MnGa layers have been studied, such as magnetic tunnel junctions [3] and spin-orbit torque devices [4]. To understand the properties of MaGa and the heterostructures using MnGa, it is important to characterize the electronic properties of MnGa. In this study, we have performed angle-resolved photoemission spectroscopy (ARPES) with vacuum ultra-violet light on a $L1_0$ MnGa thin film with PMA to elucidate the electronic states. The sample was a 10 nm-thick $Mn_{0.4}Ga_{0.6}$ film covered by an amorphous Se layer grown on a GaAs(001) substrate by MBE. The capping layer was removed by annealing before the measurements.

Figure 1 shows an in-plane Fermi surface mapping with a photon energy $h\nu$ of 82 eV, which corresponds to the Γ-M-X plane of the Brillouin zone, measured on the MnGa thin film. The in-plane Fermi surface mapping demonstrates a diamond-like Fermi surface (FS) centered at the Γ point in the k_x-k_y (the [100] and [010] directions) plane. The large area of FS is consistent with the metallic nature of MnGa. This FS was likely independent of $h\nu$, indicating that the FS originates from two-dimensional (2D) bands. In contrast, the bulk band dispersion below the Fermi level changes with k_z. Since MnGa has the three-dimensional $L1_0$ crystal structure, the observed 2D electronic state is expected to come from surface states. To the authors' knowledge, this is the first observation of the band dispersion in a MnGa film with the clean surface using ARPES.

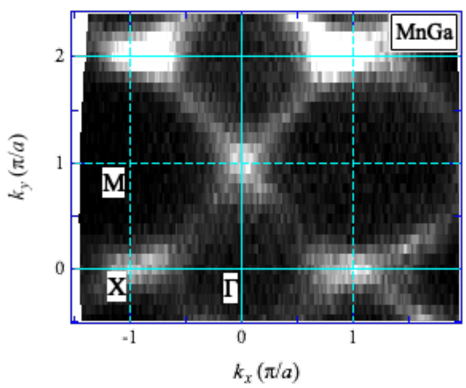

Fig. 1. In-plane Fermi surface mapping of a MnGa thin film. Solid and dashed lines are lines crossing the zone centers and the Brillouin zone boundaries, respectively.

References [1] K. M. Krishnan, Appl. Phys. Lett. **61**, 2365 (1992). [2] M. Tanaka *et al*., Appl. Phys. Lett. **62**, 1565 (1993). [3] S. Mao *et al*., Sci. Rep. **7**, 43064 (2017). [4] N. H. D. Nguyen *et al*., Nat. Mater. **17**, 808 (2018).