ES05

Structure and Magnetic Properties of Co Epitaxial Thin Films Grown on MgO Single-Crystal Substrates

Y. Nukaga[1]*, M. Ohtake[1], M. Futamoto[1], F. Kirino[2], N. Fujita[3], and N. Inaba[3]
[1]Faculty of Science and Engineering, Chuo University, Bunkyo-ku, Tokyo 112-8551, Japan
[2]Tokyo National University of Fine Arts and Music, Taito-ku, Tokyo 110-8714, Japan
[3]Department of Electrical and Electronic Engineering, Yamagata University, Yonezawa 992-8510, Japan
*Corresponding author: Yuri Nukaga, e-mail: nukaga@futamoto.elect.chuo-u.ac.jp

Co and Co-based alloy thin films are widely employed in various magnetic device applications. In order to investigate the basic magnetic properties like magnetic anisotropy and Gilbert's damping constant, it is useful to employ well-defined single-crystal films. In the present study, Co thin films were formed on single-crystal MgO substrates of (100), (110), (111) planes heated at 300 °C by UHV-MBE to prepare epitaxial thin films with different orientations. The film growth structure and the magnetic properties were investigated.

Co epitaxial thin films were obtained on respective MgO substrates. Figure 1 shows the RHEED patterns and the XRD spectra. The film crystal structure varies depending on the substrate orientation. Co(110) epitaxial bi-crystalline films with hcp structure was obtained on MgO(100) substrates with two types of domains whose orientations are rotated about the film normal by 90 degrees each other. On MgO(110) substrates, Co(110) single-crystal films with fcc structure were formed, whereas on MgO(111) substrates Co(0001) single-crystal films with hcp structure grew. Small XRD peak shifts from the bulk Co values are recognized for these Co epitaxial films, which can be related with the lattice mismatches existing at the Co/MgO interfaces. The magnetic anisotropies of these epitaxial films reflect the magnetocrystalline anisotropy of bulk hcp-Co or fcc-Co crystal (Fig. 2). The Gilbert's damping constants of these films are determined by FMR measurements.

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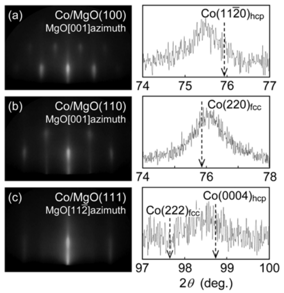

Fig. 1. RHEED patterns and XRD spectra of Co films grown on (a) MgO(100), (b) MgO(110), and (c) MgO(111) substrates.

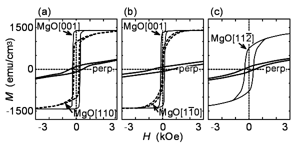

Fig. 2. Magnetization curves of Co films grown on (a) MgO(100), (b) MgO(110), and (c) MgO(111) substrates.

ES06

Effects of Substrate and Underlayer on the Growth Structure and the Magnetic Properties of Ni Epitaxial Films

K. Kuroda[1]*, T. Tanaka[1], T. Nishiyama[1], M. Ohtake[1], F. Kirino[2], and M. Futamoto[1]
[1]Faculty of Science and Engineering Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan
[2]Tokyo National University of Fine Arts and Music, 12-8 Ueno-koen, Taito-ku, Tokyo 110-8714, Japan
*Corresponding author: Kousei Kuroda, E-mail: kuroda@futamoto.elect.chuo-u.ac.jp

Ni-based multilayer films combined with noble metal layers have been widely investigated for magnetic device applications. The multilayer films are mostly oriented polycrystalline films. As single-crystal Ni or Ni-based multilayer films are considered useful to investigate the basic magnetic properties, Ni-based epitaxial thin films were prepared using single-crystal substrates heated at 300°C by UHV-MBE. The effects of substrate and underlayer material on the film growth structure and the magnetic properties were investigated. Ni films were formed directly on $SrTiO_3$(100) and MgO(100) substrates and the films were also formed on Au, Ag, and Cu underlayers hetero-epitaxially grown on MgO(100) substrates.

High-quality $Ni(100)_{fcc}$ single-crystal films were obtained on $SrTiO_3$(100) substrates. In-situ RHEED observation shows that the in-plane lattice spacing of Ni film is very close to that of the bulk Ni value from the beginning of film deposition, as shown in Fig. 1. Ni epitaxial films were also obtained on MgO(100) substrates and on Au(100), Ag(100), and Cu(100) underlayers grown on MgO(100) substrates. In the early stage of Ni layer formation on Ag(100) underlayer, the in-plane lattice spacing of Ni layer is larger than that of the bulk Ni value and decreases to the bulk value beyond 5-nm-thick deposition (Fig. 2). Ag atoms of the underlayer segregate to coexist with the Ni atoms up to around 20-nm-thick Ni deposition. In the case of Ni layer formation on Au(100) underlayer, $Ni(100)_{fcc}$ and $Ni(110)_{hcp}$ were observed. Ni-Cu solid solution alloy films were obtained on Cu(100) underlayers. The growth structure and the magnetic properties vary delicately depending on the substrate and the underlayer materials.

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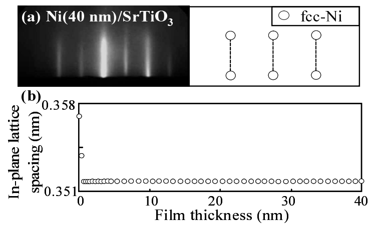

Fig. 1. (a) RHEED pattern of a 40-nm-thick Ni film grown on $SrTiO_3$(100) substrate and (b) in-plane lattice spacing as a function of film thickness observed for a Ni/$SrTiO_3$(100) specimen.

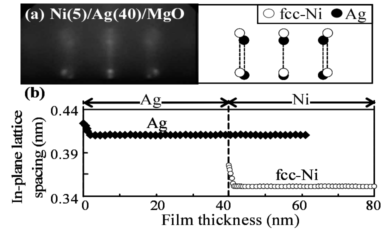

Fig. 2. (a) RHEED pattern of a 5-nm-thick Ni layer grown on Ag(100) underlayer and (b) in-plane lattice spacing as a function of film thickness observed for a Ni/Ag/MgO(100) specimen.