ION BEAM BIT PATTERNED MEDIA USING MnGa ALLOY FILMS

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Bit patterned media (BPM) have attracted considerable interest as future high-density magnetic recording media because they provide a promising approach for solving the problem of the superparamagnetic limit, i.e., the thermal instability of recorded bits [1]. BPM are considered to extend the areal density of magnetic recording to more than 2 Tb/in^2, and further increase of the areal density to more than 5 Tb/in^2 is expected by combining with other recording techniques such as shingled magnetic recording and energy assisted magnetic recording. However, there are several issues to be solved for the practical use of BPM. One of the major issues is the development of a low-cost and high-yield fabrication process. Ion beam irradiation technique has been proposed to pattern magnetic materials without etching process. This technique provides a bit patterned media with minimal change in topography, which is referred to as planer BPM, and ion irradiation into Co/Pt [2]-[5] and Co/Pd [6], [7] multilayers has been first reported to realize planar BPM. However, in the Co/Pt and CoPd patterned by ion irradiation, the adjacent magnetic bits are not magnetically isolated due to the exchange coupling between the bits, which will limit the ultimate density of the media. In order to realize ultrahigh density planer BPM, magnetic materials exhibiting large perpendicular magnetic anisotropy and whose magnetization is suppressed by low dose ion irradiation are required. One of the candidate materials is $L1_0$ phase MnGa, and this paper reviews ion irradiation to MnGa films and fabrication of ion beam patterned MnGa films.

$L1_0$ phase MnGa (001) films were grown onto MgO (001) substrate with Cr buffer layer. The MnGa exhibited a large perpendicular anisotropy K_u of 7 x 10^6 erg/cc [8]. Figure 1 shows 30 keV Kr^+ ion dose dependences of saturation magnetization M_s and perpendicular anisotropy K_u of as-prepared MnGa film. Both the M_s and K_u monotonically decreased with ion dose and became almost zero at doses > 10^{14} ions/cm^2 [8]. The disappearance of the ferromagnetism is due to the phase change of MnGa from $L1_0$-ordered to A1 disordered phase, which was confirmed by X-ray diffraction. The MnGa films were patterned by uniform ion irradiation through micro-fabricated resist masks by electron beam lithography technique. Figure 2 shows (a) magnetic force microscope and (b) atomic force microscope images of the ion beam patterned MnGa films with a pitch size of 80 nm. The ion dose was set to be 1×10^{14} ions/cm^2 for the patterning. As seen in the figure, magnetic contrast was observed in “bit” areas while no contrast was seen in ion-irradiated “space” regions. In contrast to MFM image, the surface structure corresponding to ion-beam patterning was not seen in Fig. 2 (b). This suggests that the low-dose ion irradiation is a promising technique to fabricate high-density planar BPM.

X-ray magnetic circular dichroism (XMCD) and low-temperature *M*-*H* loop measurements of the irradiated samples were carried out in order to discuss the magnetic properties of bit boundary of planer patterned MnGa, which is crucial to control switching field distribution of BPM [9]. One of the interesting results is temperature dependence of the coercivity H_c shown in Fig. 3. The H_c of the MnGa irradiated with the doses of ~ 10^{13} ions/cm^2 significantly increased with decreasing measurement temperature while the H_c of as-prepared (non-irradiated) MnGa film slightly increased with decreasing the temperature. These results suggest that the ion irradiated MnGa film had a composite structure in which ferromagnetic $L1_0$-MnGa nano-crystals were separated by a non-magnetic A1-MnGa matrix [9]. A bit boundary of planer patterned MnGa is considered to have a composite structure with $L1_0$ and A1 phases but no intermediate structure from the discussion mentioned above, which is expected to decrease a switching field distribution of BPM.

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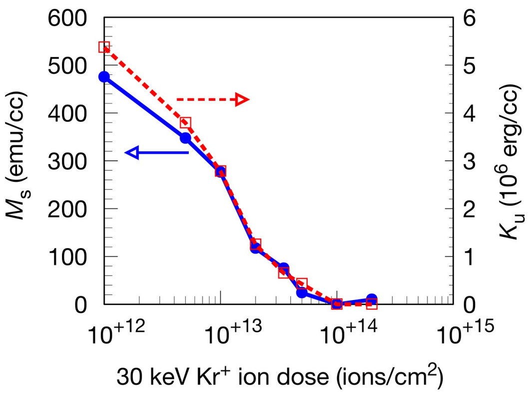

Fig. 1 30 keV Kr^+ ion dose dependence of M_s and K_u of MnGa film.

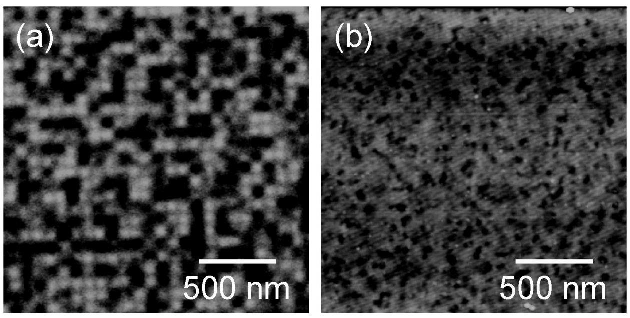

Fig. 2 (a) Magnetic force microscope and (b) atomic force microscope images of ion beam patterned MnGa film with a pitch size of 80 nm.

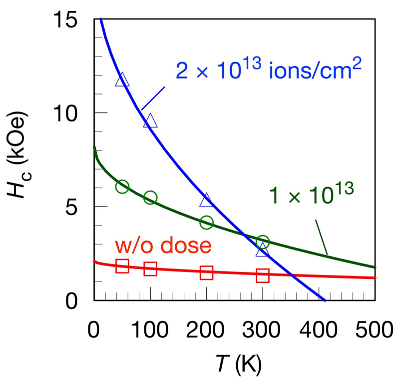

Fig. 3 Temperature dependence of the coercivity H_c of the MnGa films before and after ion doses of 1×10^{13} and 2×10^{13} ions/cm^2.