Ultrathin magnetic films with high perpendicular anisotropy for applications in magnetic recording

Two iron based thin films systems were studied: FeNi and FePt. Both systems are interesting in view of possible practical applications in perpendicular magnetic recording.
FeNi thin films were grown by sputtering method in IMR on MgO(100) monocrystalline substrate and Fe/Pt multilayers were prepared by MBE on sapphire substrates in IPPAS in Warsaw. In both systems studied the aim is to obtain the ordered phase $L1_0$ with high perpendicular anisotropy. Sputtered FeNi thin films were deposited directly on MgO substrate without any buffer layer to avoid any interdiffusion during post growth annealing by RTA method. Fe/Pt multilayers were ion irradiated with different energies and doses in order to create $L1_0$ phase.

The aim of the study within the scientific collaboration between IMR and IPPAS is to obtain metallic magnetic thin films with high perpendicular magnetic anisotropy for application in magnetic recording. Two iron based thin films systems were studied: FeNi and FePt. I was collaborating with prof. M. Mizuguchi on FeNi and with prof. T. Seki on Fe/Pt system in the prof. K. Takanashi Magnetic Materials Laboratory at IMR.
FeNi thin films were grown by sputtering method at IMR on MgO(100) monocrystalline substrate and Fe/Pt multilayers were prepared by MBE on sapphire (0001) substrates at IPPAS in Warsaw. Sputtered FeNi thin films were deposited directly on MgO substrate without any buffer layer to avoid any interdiffusion during post growth annealing at 300 C by RTA method and in order to have a simple, not costly as MBE and easy method of growing of $L1_0$ FeNi phase. The long-range chemical order parameter (S) was precisely estimated by grazing incidence X-ray diffraction (GI-XRD) using synchrotron radiation at SPring-8 in the Japan Synchrotron Radiation Research Institute. S parameter was estimated from the intensity ratio between a superlattice (110) peak and fundamental (220) peak seen on the diffraction pattern. However the highest value of S of about 0.3 was obtained what is significantly lower than for MBE grown films on a relevant buffer layers[1,2]. Another type of substrates such as spinel and SrTiO3 with smaller misfit values were tried but with no success – lower S values were found or no superlattice (110) peaks were observed. For now the reason for such behavior is not clear. In the next stage of the study based on theoretical predictions, the addition of 2-5 % of Ti and V replacing Ni in the multilayered for MBE sample with large Ku constant and structure was tried. Vanadium addition didi not help at all the formation of $L1_0$ FePt alloy phase and Ti addition helped but only in a limited way. Further studies and experiments are in progress. Ferromagnetic resonance FMR and Strain Modulated SMFMR experiments were performed on sputtered and MBE FeNi multilayered samples. From SMFMR magnetostriction values were obtained and λs differ from 1.97 to 5.2 $x10^{-6}$ depending on the sample heat treatment. FMR measurements revealed peculiar in plane symmetry –two-fold four-fold and even six- fold depending on the preparation method.

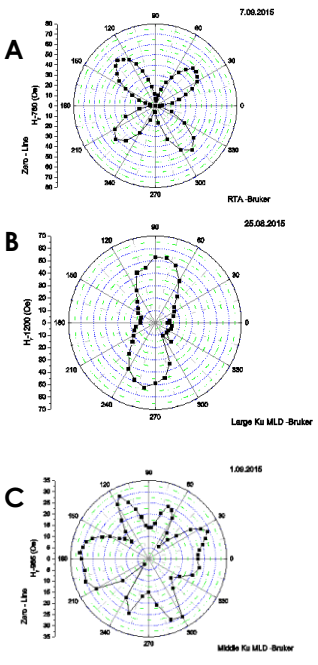

Figure 1. Angular in-plane dependence of the resonance field measured by ferromagnetic resonance (FMR).
In Fig.1 some examples of the sin-plane symmetry are presented. Fig 1A is for sputtered sample annealed by RTA, Fig 1B is Fig 1C is for MBE sample with middle Ku

constant.
Angular L-MOKE experiments were performed in order to compare with FMR results and also domain structure was measured as a function of magnetic field amplitude. The results need to be analyzed now and compared with X-ray in plane diffraction experiments to be performed on the same samples at Spring 8 synchrotron.
It is clear that a formation of $L1_0$ ordered phase of FeNi alloy is quite complicated and not so easy so more work and effort is still needed.
Another collaboration axis was established – it concerns a study of structural and magnetic properties of Heusler alloys: CFMS and CFGG type. SMFMR and FMR experiments are planned in collaboration with prof Seki and his phD student T. Yamamoto.
Changes of magnetic properties of irradiated Fe/Pt multilayers were studied in order to verify a possibility of $L1_0$ structure formation in the intermixed regions. Six series of Fe/Pt multilayers of different bilayer thickness and total number of bilayers were grown using MBE and subsequently irradiated with Ne+ ions of different energies and doses evaluated a priori with TRIDYN simulations. RHEED, LEED and STM in-situ measurements revealed epitaxial growth and good quality of interfaces. All as grown multilayers showed in-plane magnetization easy axis as revealed by VSM M(H) measurements. Full switching of magnetization easy axis from in-plane to out-of-plane direction was not achieved after ion irradiation but certain amount of perpendicularly magnetized phase appeared in most of irradiated samples.
The Fe/Pt samples irradiated with Ne ions of 15 keV energy and different doses ($1x10^{15}$ to 5×10^{16}) were annealed using RTA method at different temperatures. Next polar micro-MOKE measurements were performed in order to observe an evolution of hysteresis loops. Increase of remanence and coercive field was noted but a complete reorientation into out of plane direction was not achieved probably due to high shape anisotropy of $2\pi M_s$ and also due to (111) growth direction where the easy axis is tilted 35 deg to the sample plane. Further studies are planned – growth on MgO (100) to have (001) growth direction of ordered phase and use of different cover layer instead of Pt It was revealed that intermixing with Pt overlayer causes a formation of Pt_3Fe phase beside ordered $L1_0$ FePt one. New Fe/Pt multilayers of identical composition were grown by MBE and irradiated by Ne ions at elevated temperatures form 150 to 350 C in order to combine the effects of ion irradiation and temperature annealing.
Longitudinal and polar MOKE experiments were performed and they revealed oscillatory behavior of coercivity depending on ion dose and irradiation temperature. Structural analysis is in progress to explain the observed effect.
Common publication is in preparation on Fe/Pt results.

References

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