In-situ observation of magnetic anisotropy energy of FeNi thin films

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The $L1_0$ type FeNi multilayer has attracted much attention as one of the candidate materials for rare metal-free perpendicularly magnetized films. The $L1_0$ ordered structure consists of alternate stacking of two different atomic planes along the fcc [001] direction. Since it is difficult to optimize the growth condition, appropriate perpendicular magnetic anisotropy (PMA) has not been realized. In order to clarify the origin of the magnetic anisotropy energy (MAE) of the whole film, it is necessary to investigate each MAE of Fe and Ni layers. In the present study, we applied the x-ray magnetic circular dichroism (XMCD) and the polar magneto-optic Kerr effect (MOKE) to alternately layered FeNi thin films. We performed *in-situ* analysis at growth process element specifically. The depth-resolved XMCD technique [1] was also applied to separately obtain the signal from the surface and buried layers.

All the experiments were performed *in-situ* in an ultra high vacuum chamber at the beamlines BL-7A and 16A of the Photon Factory, Japan. The Ni and Fe layers were grown at room temperature by the electron bombardment evaporation of Ni and Fe rods. Fe and Ni layers were alternately grown on a wedged-shaped Ni(4-20 MLs)/Cu(001) substrate. Polar MOKE was measured for *n* MLs FeNi thin films grown on Ni(10 MLs)/Cu(001), where *n*=2-7. PMA realized at the thinner FeNi layers especially for the Fe-terminated films, but it diminishes with adding of FeNi layers. We estimated the total MAE from the XMCD analysis. Although surface Fe is known to show strong PMA, we found that the Ni-sandwiched Fe layer has a tiny MAE of 10±40 μeV, while the Fe-sandwiched Ni layer has a positive MAE of 60±30 μeV. This leads to an oscillatory behavior of the total MAE [2].

[1] K. Amemiya, S. Kitagawa, D. Matsumura, H. Abe, T. Ohta and T. Yokoyama, Appl. Phys. Lett. **84**, 936 (2004).

[2] M. Sakamaki and K. Amemiya, Appl. Phys. Express, **4**, 073002 (2011).