Detecting interfacial quadrupoles at Fe/MgO interfaces by X-ray magnetic linear dichroism

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Magnetic tunnel junctions using MgO barrier have been developed by exploiting the strong perpendicular magnetic anisotropy (PMA) of 1.4 MJ/m^3 at the interfaces between MgO and Fe [1]. As a fundamental understanding of PMA induced at the interface between ferromagnetic layer and MgO barrier layer, the electronic and magnetic structures of the interfaces have to be clarified explicitly. There are numerous studies for the interfacial PMA between MgO and Fe including x-ray magnetic circular dichroism (XMCD) and the first-principles calculations [2,3]. For investigating the PMA energy, it is necessary to evaluate the anisotropy of orbital magnetic moments along parallel and perpendicular directions to the surface. Recent study by theoretical calculation suggests the existence of quadrupole moments at the Fe/MgO interface through the interfacial strain [2]. In order to investigate the detailed site- and element-specific magnetic properties, we focus on the novel technique using x-ray magnetic linear dichroism (XMLD) for PMA interfaces which enables to detect the quadrupole and magnetic anisotropy. In this presentation, we report the XMLD technique adopting for PMA at Fe/MgO interfaces and discuss the origin of PMA beyond the anisotropic orbital moments.

Samples grown by electron-beam evaporation methods on MgO substrates are stacked as Cr buffer layer and the 0.7-nm-thick Fe layer with MgO capping layer. Post annealing was performed to enhance PMA, which was estimated to be 1.2 MJ/m^3 at room temperature. XMLD measurements were performed at KEK Photon Factory BL-16A at room temperature using linear polarized beams.

Fe $L_{2,3}$-edge X-ray absorption spectra exhibit clear metallic line shapes. XMLD intensities of 2.7 % are detected by the difference where the magnetization coupled with and without linear polarization in electric field of incident beam. XMLD sum rule suggests that the integrals of XMLD line shapes are proportional to quadrupole moment Q_{zz} [4], where the magnetic dipole term m_T is defined by $m_T = -Q_{zz}\langle S\rangle$ using spin angular momentum S. Further analysis also deduces the PMA energy by XMLD. We confirmed that the sign of Q_{zz} is positive; that is, 3dz^2 orbitals are slightly elongated to out-of-plane direction. Therefore, the results of XMLD are consistent with those analyzed by XMCD line shapes. As for the origin of PMA in Fe/MgO interfaces, we found that orbital moment anisotropy can be a main factor for PMA with the small contribution of m_T. These results are comparable with the theoretical calculations [2]. In the presentation, we discuss the site-specific magnetic and quadratic properties of Fe/MgO interfaces using novel XMLD technique.

References:

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