Photoemission studies on ferromagnetic alloy showing all optical magnetic switching

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In recent years there has been huge interest in possibility of using optical pulses to trigger magnetization reversal in materials instead of magnetic field [1]. It has been demonstrated that a short and strong circular polarized fs-laser pulse can deterministically reverse magnetization in ferrimagnetic alloys having perpendicular magnetic anisotropy (PMA) [2,3]. This all optical helicity dependent switching (AOS) of magnetization is expected to push magnetic data storage towards unexpected speed. Although extensive studies have been carried out to understand the influence of the optical excitation parameters like pulse chirp, pulse duration etc on the AOS process, but an extensive investigation of underlying electronic structure in these materials is missing.

Recently it was shown that in Tb_xFe_{100-x} thin films, AOS ability is observed for intermediate Tb concentrations between 22 at.% to 34 at.%, such that magnetization switching in this regime is dependent on the helicity of light [3]. While below 22 at.% and above 34 at.% of Tb, the magnetization alteration is independent of the light helicity and originates from pure thermal demagnetization (PTD) [3]. Such dependence of magnetization switching ability on alloy composition indicates an electronic structure related origin of AOS. These findings in Tb_xFe_{100-x} thin films strongly suggest the need to investigate the underlying electronic structure of the material with respect to the AOS behaviour.

In this report we have carried out electronic structure of amorphous Tb_xFe_{100-x} thin films, for varying Tb concentrations, by employing valence band hard X-ray photoemission spectroscopy (HAXPES) sensitive to magnetic circular dichroism. Four samples were studied with the Tb concentration chosen in three different regimes: (i) low concentration showing PTD, x = 21 at.% (ii) intermediateconcentration showing AOS, x = 30,31 at.% (iii) higher concentration again showing PTD, x = 38 at.%. HAXPES measurements were performed using 5.95 KeV circularly polarized X-rays at a grazing incidence angle of 7◦ relative to the film plane. In this geometry, the photon spin angular momentum lies almost in the sample plane; the photoemission signal is therefore sensitive to the in-plane magnetization component of the films [4, 5]. The measurements were carried out at the undulator beamline P09 of PETRA III (Hamburg,Germany) [6, 7] using a SPECS PHOIBOS 225 HV hemispherical electron energy analyzer. The X-rays were monochromatized by a combination of a Si(111) doublecrystal primary monochromator and a Si(333) channelcut post-monochromator. The total energy resolution of this configuration was ~150 meV. Circular polarization was produced by a 400 μm thick diamond phase retarder.

Our results show that the valence band spectra of the Tb_xFe_{100-x} thin film is dominated by the Tb 4f and Fe 3d states. The Tb 4f levels exhibit well-known final state multiplet structure resulting in pronounced spectral features $^8S_{7/2}$, $^6I_{5/2}$, $^6G_{5/2}$, $^6H_{5/2}$ [8]. Furthermore, the valence band spectra for Tb_xFe_{100-x} thin films of different stoichiometry recorded for left (σ^-) and right (σ^+) circularly polarized light show significant magnetic circular dichroism for certain Tb concentrations, as

observed by the difference in intensity depending on the light helicity around the $^{8}S_{7/2}$, $^{6}I_{5/2}$, and $^{6}G_{5/2}$ Tb levels. This effect is seen for only those materials compositions which also exhibit AOS ability. Because of the experimental geometry the appearance of a clear dichroism signature in the photoemission of the AOS sample indicates the presence of a significant in-plane component of the magnetization, in addition to the known strong out-of plane magnetization component.

To summarize, our results show that AOS is observed for films that have a significant in-plane component of magnetization that weakens outside the AOS regime. These findings have crucial implications as they point to invoking a transverse component of the magnetization in the origin of AOS, which has been commonly neglected in the modeling of the AOS mechanism.

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