

Plasmonic System with In-Plane Magnetic Anisotropy for Plasmon Based Magnetic Switching

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Abstract: Profile-modulated permalloy films are promising for magneto-optical applications. We show that such systems demonstrate plasmonic properties and have uniaxial in-plane anisotropy, which may allow sharp magnetization switching using SAM of light. © 2019 The Author(s)

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Opportunity to use plasmonic systems to control magnetization at nanoscale presents interest for various applications in spintronics, including fast magnetization switching and all-optical control of magnetic memory. Strong fields associated with plasmonic structures provide a new playground for studying fundamental condensed matter physics problems related to the definition of conserved quantities (such as momentum, angular momentum, etc.) of optical fields in a medium and transfer of these quantities to matter. As it has been shown in previous research of the plasmon drag effect (PLDE) [1], photoinduced electric effects in flat plasmonic films are mainly associated with the linear momentum transfer from plasmons to electrons. However, in strongly nanostructured plasmonic surfaces, transfer of the spin angular momentum of plasmons is expected to play a significant role resulting in plasmo-galvanic effects [2].

As it has been recently discussed in literature [2-4], a surface plasmon polariton (SPP) propagating along a metal-dielectric interface possesses a spin angular momentum (SAM), associated with rotation of the optical electric field polarization in the metal. The direction of SAM is perpendicular to the SPP propagation. Transfer of SAM from light to matter can be described in terms of a torque acting on the medium. In classical metals, absorption of plasmonic SAM result in pinning of the total photoinduced electro-motive force to the surface layer and an extreme sensitivity of the photoinduced electric effects to the surface geometry [2]. On the other hand, in materials with strong spin-orbital interaction, the SAM transfer could lead to spin polarization and magnetization of the material. According to Bliokh [3], the SPP possesses the magnetic moment $\mu = \frac{2\sqrt{-\epsilon}}{1+\epsilon^2} \mu_B$ per plasmon, where μ_B is the Bohr magneton, and ϵ is the dielectric permittivity of the metal. The transfer of such a moment to a material via spin-orbital interaction or due to induced dc magnetic field [3] can result in a substantial dc magnetization. In magnetic materials for the efficient SAM transfer the plasmon drag effect might be very different than the nonmagnetic plasmonic materials. Light induced magnetization in plasmonic systems was recently reported and discussed in terms of the inverse Faraday effect [5]. However, microscopic origin of this phenomenon is not yet clear.

Thin magnetic films with uniaxial in-plane anisotropy demonstrate sharp magnetization switching upon a small increment of magnetic field [6]. The switching is associated with the dramatic change of orientation of equilibrium magnetization at a certain orientation of the sample. Such systems can be very promising to achieve all optical control of magnetization using SAM transfer. The goal of this study is to develop systems having both plasmonic and magnetic properties with uniaxial in-plane magnetic anisotropy. As was shown in [7], profile modulated films can provide such anisotropy.

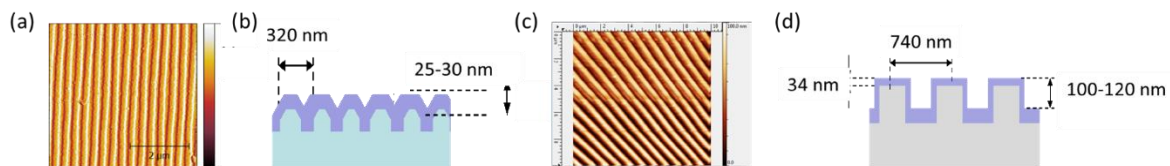


Fig. 1. Bluray-permalloy sample, (a) AFM image, (b) profile geometry; DVD-permalloy sample (c) AFM image, (d) profile geometry.

Bluray, DVD and CD have well known periodic structures. The nanostructured feature is revealed by carefully taking out the polymer, plastic, silver and protective coating layers. The substrate is cleaned and cut into pieces and processed for thin film deposition. The 34 nm thick permalloy is deposited on glass, DVD, Bluray and CD substrates by using e-beam evaporation. The profile modulated nanostructured features are characterized with AFM and SEM system. The atomic force microscopy confirms that the bluray-permalloy has the modulation height of 25-30 nm with

periodicity of about 320 nm, Fig. 1(a), whereas in the DVD-permalloy the periodicity is 740 nm with the modulation height of 100-120 nm, Fig. 1(c). The schematic of the Bluray and DVD permalloy sample are shown in fig. 1(b) and (d) respectively.

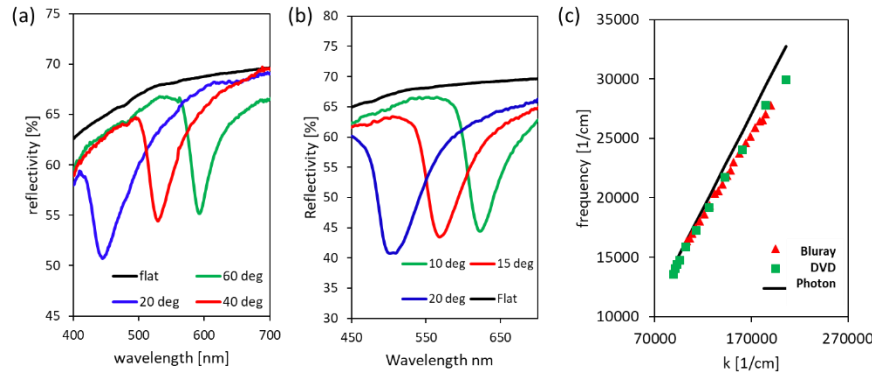


Fig. 2 Angular dependence of the reflectivity for (a) Bluray-permalloy, (b) DVD-permalloy; (c) Dispersion curves for SPPs in Bluray-permalloy, DVD-permalloy and a photon line.

The angular dependence reflection measurements are taken with Perkins Elmer UV-Vis spectrophotometer. The well pronounced angular dependent SPP resonance dip is observed in the reflection spectra for both Bluray and DVD-permalloy samples, see Fig. 2 (a) and (b) respectively. The Q-factor of the plasmon resonance calculated from the spectra is in the range of 7-10 depending on the wavelength. The dispersion curve derived from the position of the dip is shown in Fig. 2 (c).

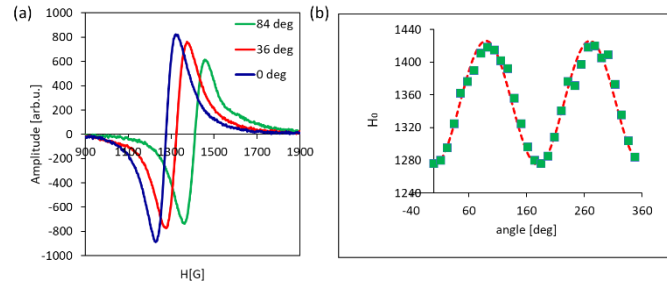


Fig. 3 (a) Angular dependence of the FMR spectra for DVD-permalloy (b) The angular dependence of the resonant field for the DVD-permalloy system.

Ferromagnetic resonance (FMR) measurements are accomplished by Bruker EMX EPR spectrometer at 10 GHz microwave frequency. FMR spectra are taken with the external field H_0 aligned in the sample plane at different orientations of the sample. (The sample is rotated around the normal to the film plane). The FMR signal from the bluray-permalloy systems is very weak and does not show noticeable angular dependence. However, the signal from the DVD-permalloy samples is significantly greater and demonstrates an angular dependence typical for uniaxial anisotropy, see Fig. 3 (a) and (b). Anisotropy fields estimated for two different DVD-permalloy samples are around 80 Oe, which is on the borderline of the range where the sharp magnetization reorientation effect can occur [6].

In conclusion, the permalloy thin films deposited on DVD substrates shows both in-plane magnetic anisotropy and plasmon resonances. This is a promising system to study a possible magnetization switching caused by spin angular momentum of plasmon. The experiments are underway.

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