Spectroscopic generalized magneto-optical ellipsometry of Py/Ag/Bi trilayers

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Spin-orbit coupling (SOC) is a key phenomenon in modern magnetism and spintronics. Much attention has been paid recently to the Rashba-type SOC at interfaces. Large values of the Rashba coefficient have been found at interfaces between heavy elements with strong SOC, for example, bismuth (Bi), and non-magnetic metals, for example, silver (Ag). In transport measurements, the Ag/Bi interface with a ferromagnetic permalloy (Py) layer gives rise to a very large spin-charge conversion [1)], due to the Rashba-type SOC at the interface. From the microscopic point of view, SOC is relevant to magneto-optical (MO) properties as well as to electron transport. However, MO responses in the ferromagnetic Py in proximity to a Ag/Bi Rashba interface have not yet been explored. In this contribution, we study Py/Ag/Bi trilayers using spectroscopic generalized MO ellipsometry (S-GME) [2)].

Py, Bi, and Ag layers were deposited onto silicon substrates at room temperature using magnetron sputtering with an argon gas pressure of 4.2×10^{-3} Torr. The Py, Bi, and Ag deposition rates were 0.10, 0.15, and 0.25 nm/s, respectively. In the trilayer sample labeled PSB1, a Bi layer having 10 nm in thickness was deposited on the Si substrate first, after which a Ag layer of 5 nm and a Py layer of 30 nm thickness were sequentially deposited. The other trilayer sample, which is labeled PSB2, has an inverted structure, meaning that a 5 nm thick Ag layer was sputtered onto the initially deposited Py layer, which was furthermore covered by a Bi layer of 10 nm thickness. The control sample has only a Py layer with 30 nm thickness. All samples were coated by a 2 nm thick tantalum (Ta) layer to avoid oxidization of the functional layers.

Our three samples have been characterized in detail using this S-GME setup at various wavelength λ in visible and near-infrared regions. A multiparameter least-squares fitting procedure [2)] of the acquired data enables us to extract the reflection matrix. From the reflection matrix elements, we evaluate the Kerr rotation θ_K and ellipticity ϵ_K values, we have evaluated the Kerr amplitude $|\Theta_K(\lambda)| = \sqrt{[\theta_K(\lambda)]^2 + [\epsilon_K(\lambda)]^2}$

In Fig. 1(a), $|\Theta_K(\lambda)|$ of the three samples are plotted as a function of λ. Overall, the three samples show a decrease in $|\Theta_K(\lambda)|$ at a longer λ. Experimental results in Fig. 1(a) demonstrate that the PSB2 sample (blue circles) has a smaller $|\Theta_K(\lambda)|$ than the control sample (black triangles) over all the explored spectral range. This seems to be consistent with the fact that the ferromagnetic Py layer is buried below 5 nm of Ag and 10 nm of Bi, which are not magneto-optically active themselves, and thus the overall MO signal of the sample is reduced.

Contrastingly, the PSB1 sample (red squares), in which the Py layer has an Ag/Bi underlayer, shows an enhanced $|\Theta_K(\lambda)|$ at every λ with respect to the reference sample. In order to make this enhancement clearer, we have normalized $|\Theta_K(\lambda)|$ of the PSB1 and PSB2 samples to the one of the control Py sample. The experimentally observed "enhancement factor" $|\Theta_K(\lambda)|/|\Theta_K(\lambda)|(Control)$ is shown in Fig. 1(b) as a function of λ in red squares for PSB1 and blue circles for PSB2. For PSB1, the enhancement factor for $|\Theta_K(\lambda)|$ is 1.2 at λ = 450 nm and increases up to 1.4 at a longer λ in the near-infrared region (λ = 800 nm). On the other hand, for PSB2, the enhancement factor is smaller than one for all values of λ, starting at approximately 0.5 at λ = 450 nm and increasing modestly to 0.6 for a longer λ. We therefore conclude that the presence of the Ag/Bi bilayer enhances the MO response of adjacent Py layers, particularly in the near-infrared region [3)].

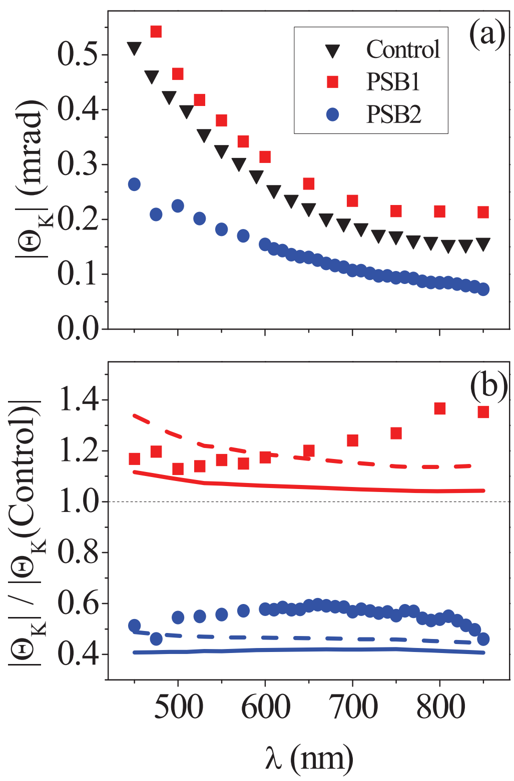

Fig. 1 (a) Kerr amplitude $|\Theta_K(\lambda)|$ of PSB1 (red squares), PSB2 (blue circles), and control samples (black triangles). (b) $|\Theta_K(\lambda)|$ of the PSB1 and PSB2 samples normalized to the control sample's $|\Theta_K(\lambda)|$.

References

1) Rojas Sánchez J C, Vila L, Desfonds G, Gambarelli S, Attané J P, De Teresa J M, Magén C and Fert A 2013 *Nature Commn.* **4** 2944
2) Berger A and Pufall M R 1997 *Appl. Phys. Lett.* **71** 965
3) Riego P, Tomita S, Murakami K, Kodama T, Hosoito N, Yanagi H, Berger A 2017 *J. Phys. D: Appl. Phys.* **50** 19LT01