Mid-infrared Spectroscopy Characterization of Spintronic Structures

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Spectroscopic ellipsometry (SE) is a non-destructive and non-invasive optical characterization technique which commonly applies to thin film heterostructures. Perhaps, most people know SE as a powerful technique to obtain accurate information about the thickness of thin films and surface roughness, however, when the same spectroscopic technique is applied in a broad energy range and incidence angle, it is possible to obtain valuable information of the nature of each layer and interfaces, particularly when working in the far-infrared (1meV - 24meV) and mid-infrared (25meV - 500meV) regions. Since 2019, we are in a collaboration project, in which so far, we have used mid-infrared SE to study the properties of a two-dimensional electron gas (2DEG) at the interface between a polycrystalline nonmagnetic metal (Cu) and an oxide (Bi_2O_3). Particularly, we extracted the interfacial conductivity, relaxation lifetimes and the spin orbit coupling [1]. Commonly, similar information can be obtained by angle resolved photoemission spectroscopy (ARPES), however, ARPES demands a minimum of crystalline quality of the samples, leaving behind polycrystalline and/or amorphous heterostructures. Notably, mid-infrared SE has more to offer to the field of spintronics and magnetism. The now renowned Professor Toru Moriya, at the end of the 1960's turned his attention to study the absorption and scattering of light by magnetic crystals [2], which propelled the use of Brillouin light scattering spectroscopy (BLS). However, part of Moriya's interest was to study not only the scattering of light by magnetic samples, but study in-depth the frequency dependence of the electrical conductivity, which can show deviations from the Drude formalism at specific frequency values [3]. We tasked ourselves to characterize by mid-infrared SE the well-known magnetic heterostructure heavy metal (HM)/CoFeB/MgO [4], extracting for the mid-infrared range the dielectric function of $Co_{20}Fe_{60}B_{20}$, that is lacking in literature, (ii) detection and determination of the dielectric tensor properties of a 2DEG forming at the non-magnetic metal and the CoFeB interface, (iii) identification of a discrete feature assigned to spin-orbit coupling (SOC). Perhaps more important to the forthcoming studies is the fact that, in this last study [4] we proved the feasibility of studying magnetic and interfaces using mid-infrared SE, which can be readily applied to Garnets.

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