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Tuning the magnetic properties of Co thin films by oxygen ion implantation

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Ion irradiation/implantation has been extensively used to manipulate the magnetic properties of materials [1]. In contrast, the use of nonmagnetic ion implantation (e.g., H, O or N) to control the magnetic properties of materials is far scarcer. Ion implantation has been shown to be a suitable approach to form antiferromagnetic oxides embedded in a ferromagnetic matrix. Specifically, implantation of O ions into thin ferromagnetic Co films locally induces the formation of antiferromagnetic CoO, giving rise to low-temperature exchange bias [2]. Recently, it has been demonstrated that the O depth distribution can be tuned by properly designing the implantation conditions and the layer stack of the samples (capping, buffer and Co layer thickness) [3]. Taking advantage of such control of the O depth profile, sandwiched Co thin films with a controlled gradient of O concentration along the Co layer can be prepared. These optimized O-profiles result in highly improved low temperature properties with respect to Co/CoO bilayers and O-implanted Co thin films with a Gaussian-like O depth profile, with enhanced exchange bias loop shifts, improved loop homogeneity, increased blocking temperature and reduced relative training effects [3,4]. Interestingly, the presence of CoO can also be used to manipulate the room temperature magnetic properties of the films (i.e., above the Néel temperature of CoO, T_N = 290 K). In particular, O-implantation has been observed to induce a change of the easy axis from mainly in-plane for the as-deposited Si(100)/450nm SiO_2/10nm Au/30nm Co/15nm Au sample to a progressively more out-of-plane easy axis in the implanted samples. This is mainly ascribed to the preferential direction of the implantation (perpendicular to the sample surface) which results in a preferential alignment of the Co–O bonds and ultimately causes an enlargement of the extent of hybridization of Co atoms at the interface between Co and CoO [5]. Moreover, the room temperature coercivity increases significantly after implantation. This is ascribed to the increase in the number of defects, the decrease of both exchange and dipolar interactions between grains (due to the formation of CoO at the grain boundaries and the concomitant reduction of the Co grain size) [3].

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