Anatomy of perpendicular magnetic anisotropy in conventional and non-conventional magnetic tunnel junctions

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Magnetic tunnel junctions (MTJs) with perpendicular magnetic anisotropy (PMA) have been attracting a lot of interest due to their potential application in realizing the next generation of spintronic devices including nonvolatile memories and logic chips with high thermal stability. In particular, Metal/oxide interfaces with low spin-orbit coupling (SOC), such as Fe/MgO and Co/AlO_x, provide a convenient way to get simultaneously a large PMA required for memory retention together with weak Gilbert damping necessary for low switching current.

Using first-principle calculations, we study the microscopic origin of PMA at Fe/MgO interfaces through evaluation of layer resolved contribution as function of interfacial conditions [1]. Onsite projected analysis shows that the anisotropy energy is not localized at the interface but it rather propagates into the bulk showing an attenuating oscillatory behavior which depends on orbital character of contributing states and interfacial conditions. Then, we propose to further increase the PMA in Fe/MgO interfaces by doping the bulk of the storage layer by magnetic impurities of chromium (Cr) and/or vanadium (V). While the impurity near the interface has a drastic effect in decreasing the perpendicular magnetic anisotropy (PMA), its position within the bulk allows maintaining high interfacial PMA while reducing the bulk magnetization and correlatively the easy-plane demagnetizing energy [2]. At the same time, the interfacial spin polarization is not affected by the magnetic layer bulk doping by Cr or V impurities and even enhanced in most situations thus favoring an increase of tunnel magnetoresistance (TMR) amplitude. Finally, we present the enhancement of PMA of Co films by graphene coating. Our calculations show that graphene can dramatically boost the surface anisotropy of Co films up to twice the value of its pristine counterpart and can extend the out-of-plane effective anisotropy up to unprecedented thickness of 2.5 nm [3]. These findings point toward a possible engineering of magnetic anisotropy in conventional and non-conventional MTJs, which stands as a hallmark for future spintronic information processing technologies in a view of the long-standing challenge to promote large PMA in small size spintronic devices with weak SOC.

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