First-principles study of angular dependent magnetoresistance in Co/5d metallic bilayers

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Interest in magnetoresistance (MR) in bilayer films, composed of ferromagnetic and nonmagnetic heavy metals, has recently increased [1-3]. Among the MR phenomena is the novel Spin Hall magnetoresistance effect which depends on the angle between magnetization direction of film and the applied current. In the heterostructure of Co/Pt(111), for example, the MR ratio has been found to be up to 2% [4]. Although the MR has been theoretically explained by using a drift diffusion model [4], explicit estimations on the novel angular dependent MR (ADMR) effect using first principles approach are still lacking and may be further desired. Here, we carried out systematically first principles calculations for the ADMR in metallic bilayers of Co and 5d (Ta, W, Re, Os, Ir, and Pt) metal thin films, based on the generalized gradient approximation by using the Full-potential linearized augmented plane wave method [5] including spin-orbit coupling (SOC), where the ADMR ratio is defined as a difference in electric resistance (assuming a constant-relaxation approximation) when the magnetization orients between the out-of-plane and in-plane directions. The results predict that the ADMR ratios of the Co bilayers with Ta, W, Re, Os, Ir, and Pt thin films are -1.9, -4.0, -0.2, +0.6, -1.8, and -2.6%, respectively. We observe that the ADMR ratio in the Co/ Pt fairly agrees with experiments [4] although that in the Co/W is overestimated. Moreover, the ADMR is found to behave differently to the magnetization direction depending on the film planes, namely *xz* and *yz* planes where the current is applied on the *x*-direction. In order to further clarify the role of atomic layers at the interface, we calculated the MR by artificially switching on and off the SOC of atoms. When the SOC in the Pt layer is switched off, the MR ratio turns to be almost zero while when that of Co is switched off, the MR ratio remains to -1.6%, closing to the original value of -2.6%, in which the SOC at the Pt layer plays an important role for driving the ADMR. The detail discussion will be presented.

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