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Voltage controlled magnetic anisotropy in magnetic tunnel junctions

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Recently, voltage controlled magnetic anisotropy (VCMA) in 3d transitional ferromagnets (FM) has attracted a great deal of attentions. VCMA has traditionally been explored in multiferroic materials and diluted magnetic semiconductors, but not in metals because of the anticipated negligible effects since the electric field would be screened within 1-2 Å at the metal surface. However, a voltage may exert marked effects if the magnetic properties of ultrathin films are dominated by interfacial magnetic anisotropy. Here we demonstrate a large VCMA effect in perpendicular MgO magnetic tunnel junctions (p-MTJs) with very thin CoFeB layers. The p-MTJs have the key structure of Co40Fe40B20(1.2-1.3nm)/MgO(1.2-2nm)/Co40Fe40B20(1.6nm) exhibiting at room temperature tunneling magnetoresistance in excess of 100%. The perpendicular magnetic anisotropy (PMA) in this system is believed to be stabilized by hybridization between the out-of-plane 3d orbitals of the FM and oxygen 2p orbitals. We show that both the magnitude and the direction of the electric field can systematically alter the PMA of the thin CoFeB layers interfaced with the MgO barrier. Furthermore, under a given electric field, the two CoFeB layers on either side of the MgO barrier respond in the opposite manner as expected. By exploiting the combined effect of spin transfer torque and VCMA in CoFeB/MgO/CoFeB nanopillars, we have accomplished voltage controlled spintronic devices, where the MTJ can be manipulated by a unipolar switching process using consecutive negative voltages less than 1.5 V in magnitude. In this manner, voltage can access the high resistance or the low resistance state of an MTJ with very small current densities. Wang, W.-G., Li, M., Hageman, S. & Chien, C. L. Electric-field-assisted switching in magnetic tunnel junctions. Nature Materials 11, 64 (2012).

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