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Spin-transfer torque field switching of magnetization in vertically-stacked multilayers

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Theoretical and computational analysis of the magnetotransport properties and spin-transfer torque field-induced switching of magnetization density in vertically-stacked multilayers is presented. Atom-resolved magnetic moments and spin-transfer torques are computed at finite bias within linear response approximation to the spin-density reformulation of the van der Waals density functional theory. Dynamical spin excitations are computed as a function of a spin-transfer torque induced magnetic field along the magnetic easy axis, and the corresponding spin polarization perpendicular to the easy axis is obtained. A giant anisotropic magnetoresistance of 3200% is obtained in the nonmagnetic-metal-capped Fe/hBN/graphene/hBN/Pt multilayer architecture. The magnitude of the spin-transfer torque is found to increase as the tunneling spin current increases, and this activates the magnetization switching process due to increased charge accumulation. This mechanism causes substantial spin backflow, which manifests as rapid undulations in the bias-dependent tunneling spin currents. The implication of these findings on the design of nanoscale spintronic devices with spin-transfer torque tunable magnetization density is discussed. Insights from this study are expected to enhance the prospects for developing and integrating artificially assembled van der Waals multilayer heterostructures as the preferred material platform for efficient engineering of spin switches for spintronic applications.

HPC content

Spin pumping is the injection of spin into an adjacent exchange-coupled non-magnetic material from a resonantly precessing ferromagnetic moment. In this work, HPC was used to obtain solutions of the Landau-Lifshitz-Gilbert-Slonczewski equation for describing the dynamics of magnetization density in computational models of magnetic multilayer heterostructures. Our data shows that asymmetric magnetic tunnel junctions are susceptible to nontrivial spin backflow. Non-conservation of electron angular momentum in the spin pumping regime is found to cause significant spin accumulation and spin-transfer torque, which is capable of driving magnetization switching in magnetoresistive random-access memory technologies.

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