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Spin orbit torque switching in ferromagnetic/antiferromagnetic systems

Exchange bias, a shift in the hysteresis loop of a ferromagnet arising from interfacial exchange coupling between adjacent ferromagnetic (FM) and antiferromagnetic (AFM) layers, is an integral part of spintronic devices. Here, we show that spin–orbit torque (SOT) generated from spin current, a promising approach to switch the ferromagnetic magnetization of next-generation magnetic random access memory, can also be used to manipulate the exchange bias. Applying current pulses to a Pt/Co/IrMn perpendicular magnetized trilayer causes concurrent switching of ferromagnetic magnetization and exchange bias, but with different underlying mechanisms. This implies that the FM magnetization and exchange bias can be manipulated independently.

Using time-resolved magneto-optical Kerr microscopy, we further show that the FM, as well as interfacial AFM spins and exchange bias, can be partially switched by sub-nanosecond current pulses, which allows the switching probabilities to be controlled at multiple levels.

Combing electrical and spectroscopic analysis, we also reveal that the exchange spring existing in FM/AFM bilayer may result in a collinear/orthogonal AFM/FM spin configuration at the interface upon switching FM magnetization upward/downward. In SOT switching, magnetization against the exchange spring features digital-like switching with a sharp transition, whereas the reverse function is characteristic of analog switching with a gradual transition tail. The dual digital-analog characteristics of the FM/AFM bilayer may be beneficial for neuromorphic applications.

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