World Academy of Science, Engineering and Technology
International Journal of Physical and Mathematical Sciences
Vol:19, No:09, 2025

Two-Dimensional Van-Der Waals Heterostructure for Highly Energy-Efficient Field-Free Deterministic Spin-Orbit Torque Switching at Room Temperature

Authors : Pradeep Raj Sharma, Bogeun Jang, Jongill Hong

Abstract : Spin-orbit torque (SOT) is a novel and efficient approach for manipulating the magnetization of ferromagnetic materials (FMs), providing improved device performance, better compatibility, and ultra-fast switching with lower power consumption, compared to spin-transfer torque (STT). Among the various materials and structural designs, two-dimensional (2D) van-der Waals (vdW) layered materials and their heterostructures have been demonstrated as highly scalable and promising device architecture for SOT. In particular, a bilayer heterostructure consisting of fully 2D-vdW-FM, non-magnetic material (NM) offers an innovative platform for controlling the magnetization using SOT because of the advantages of being easy to scale and less energy to switch. Here, we report filed-free deterministic switching driven by SOT at room temperature in a bilayer consisting of perpendicularly magnetized 2D-vdW material Fe3GaTe2 (FGaT) and NM WTe2. Pulse current-induced magnetization switching with an ultra-low current density of about 6.5×105 A/cm^2, yielding a SOT efficiency close to double-digits at 300 K is reported. These values are two orders of magnitude higher than those observed in conventional heavy metal (HM) based SOT and exceed those reported with 2D-vdW layered materials. WTe2, a topological semimetal possessing strong SOC and high spin Hall angle can induce significant spin accumulation with negligible spin loss across the transparent 2D bilayer heterointerface. This promising device architecture enables highly compatible, energy-efficient non-volatile memory and lays the foundation for designing flexible, miniaturized spintronic devices that could facilitate quantum computing.

Keywords : spintronics, spin-orbit torque, spin Hall effect, spin Hall angle, topological semimetal, perpendicular magnetic anisotropy
Conference Title : ICMSE 2025 : International Conference on Magnetism and Spin Electronics
Conference Location : San Francisco, United States
Conference Dates : September 27-28, 2025