Interfacial Spin-Orbit Torques and Magnetic Anisotropy in WSe_2/Permalloy Bilayers

Jan Hidding
Sytze H. Tirion, Jamo Momand, Alexey Kaverzin, Maxim Mostovoy, Bart J. van Wees, Bart J. Kooi, and Marcos H. D. Guimarães
Zernike Institute of Advance Materials, University of Groningen, Groningen, The Netherlands
Jan.hidding@rug.nl

In recent years, there has been a growing interest in spin-orbit torques (SOTs) for manipulating the magnetization in non-volatile magnetic memory devices. SOTs rely on the spin-orbit coupling of a nonmagnetic material coupled to a ferromagnetic layer to convert an applied charge current into a torque on the ferromagnet's magnetization. In this regard, transition metal dichalcogenides (TMDs) are promising materials for efficient generation of current-induced spin-orbit torques on the adjacent ferromagnetic layer. Although numerous studies were performed on SOTs using TMD/ferromagnetic heterostructures, a clear consensus on the microscopic origin underlying the spin-orbit torques observed in these bilayers is still missing; the extent to which bulk and interfacial effects contribute is unknown. To shine light on the microscopic mechanisms at play, here we perform thickness dependent spin-orbit torque measurements on the semiconducting WSe_2/permalloy bilayer with various WSe_2 layer thickness, down to the monolayer limit. We observe a large out-of-plane field-like torque with spin-torque conductivities up to 1×10^4 $(\hbar/2e)(\Omega m)^{-1}$. For some devices, we also observe a smaller in-plane antidamping-like torque, with spin-torque conductivities up to 4×10^3 $(\hbar/2e)(\Omega m)^{-1}$, comparable to other TMD-based systems. Both torques show no clear dependence on the WSe_2 thickness, as expected for a Rashba system. Unexpectedly, we observe a strong in-plane magnetic anisotropy – up to about 6.6×10^4 erg/cm^3 – induced in permalloy by the underlying hexagonal WSe_2 crystal. Using scanning transmission electron microscopy, we confirm that the easy axis of the magnetic anisotropy is aligned to the armchair direction of the WSe_2. Our results indicate a strong interplay between the ferromagnet and TMD, and unveil the nature of the spin-orbit torques in TMD-based devices. These findings open new avenues for possible methods for optimizing the torques and the interaction with interfaced magnets, important for future non-volatile magnetic devices for data processing and storage.

References

[1] J. Hidding and M. H. D. Guimarães. "Spin-Orbit Torques in Transition Metal Dichalcogenides/Ferromagnet Heterostructures." *Frontiers in Materials* 7 (2020): 383.
[2] J. Hidding et al., "Interfacial spin-orbit torques and magnetic anisotropy in WSe_2/permalloy bilayers", *Submitted*, (2021).

Figures

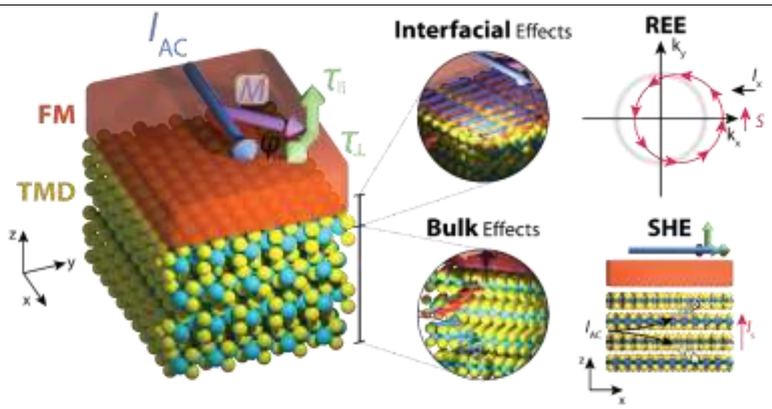

Figure 1: Schematic of a TMD/ferromagnet bilayer with the different microscopic origins underlying the spin-orbit torques at play (adapted from ref[1]).