Topology-driven spin-orbit torques in Weyl Semimetal/Ferromagnet Heterostructures

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Weyl Semimetals (WSMs), materials with three-dimensional topologically protected electronic states, show highly interesting physical properties including surface Fermi-arcs, the chiral magneto-transport anomaly and extremely high electron mobilities. One promising application field of WSMs is spin-orbitronics, as the Fermi-surface is expected to play an important role in the spin-to-charge conversion efficiency, according to theoretical investigations [1,2].
In this work, we report the growth of epitaxial, single-crystalline NbP and TaP Weyl Semimetal thin films [3] by means of molecular beam epitaxy, and their successful integration in spin-torque devices. We have assessed the structural quality of the films (Fig.1a) featuring an atomically flat surface, essential for the observation of topological bands by photoemission (Fig. 1b). Furthermore, we rely on the preparation of high-quality in-situ TaP/NiFe interfaces to investigate the spin-orbit torques produced by the topological WSM by means of spin-torque ferromagnetic resonance (ST-FMR). The TaP/NiFe/MgO devices show signatures of large spin-orbit torques induced by the Weyl Semimetal: (i) a very strong symmetric component of the voltage lineshape across the resonance related to damping-like torques (Fig.1c) (ii) a clear scaling of the resonance linewidth by applying an external DC bias through the bilayer (Fig. 1d). **The connection between Fermi-surface topology and spin-to-charge conversion** is addressed by performing angle-resolved photoemission on the TaP surfaces prior to the *in-situ deposition* of the magnetic layers, and probing the spin-torque efficiency along the high-symmetry directions of the WSM. A drastic enhancement of the spin-orbit torque efficiency is observed when the current is driven along Γ-X and Γ-Y direction, where the topological surface states are located.

References

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Figures

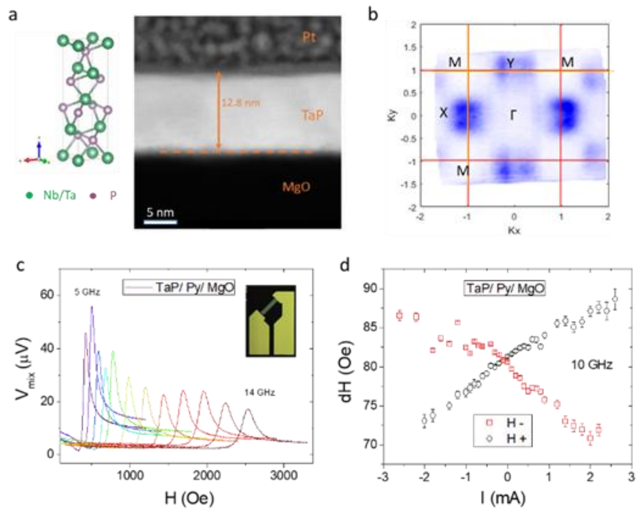

Figure 1: (a)Transmission electron microscopy image of a TaP thin film, showing ordered epitaxial lattice planes and an atomically flat surface. The crystal structure is drawn for clarity. (b) Angle-resolved photoemission measurements of the TaP thin films, showing four-fold symmetric electronic pockets at the Fermi-energy. (c) Frequency-dependent ST-FMR of a TaP/Py/MgO device, evidencing a strong symmetric lineshape component indicative of damping-like spin-orbit torques. Inset: Optical image of ST-FMR device. (d) Linewidth dependence of the ST-FMR signal, showing a consistent scaling with applied DC bias. The slope is proportional to the magnitude of the induced spin-orbit torques per charge unit.