Orbital Hall Effect and Orbitronics in Magnetic Multilayers

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Orbitronics is an emerging field based on orbital currents, or the flow of orbital angular momentum, just as spintronics is based on spin currents. Analogous to the spin Hall effect (SHE) where a charge current produces a transverse spin current, an orbital Hall effect (OHE) can generate a transverse orbital current. Recently, magneto-optical measurements detected orbital accumulation at the surfaces of Ti [1] and Cr [2], providing the most direct evidence for the OHE. Currently, many of the basic properties of orbital currents are being established. Here, we report results on (1) the generation of torques on a magnetic layer from orbital currents and (2) the transparency of interfaces to orbital currents.

In the first study, we utilize magneto-optic Kerr effect (MOKE) to measure the orbital torque generated by an in-plane charge current in Cr/Fe bilayers. In the Cr layer, the charge current is converted to a transverse orbital current via OHE. After the orbital current enters the Fe layer, it is converted to a spin current by spin-orbit coupling, which in turn imparts a torque on the Fe magnetization through the exchange interaction. We call this the “orbital torque.” Interestingly, the orbital torque increases with the Fe thickness, which suggests that the orbital current is able to penetrate deeply into the Fe layer. Repeating the study on Pt/Fe bilayers where both spin currents and orbital currents are present, the Fe thickness dependence suggests that the torque from spin current is more interfacial in nature while the orbital torque is more bulk-like within the Fe layer.

In the second study [3], we utilize MOKE to investigate the transparency of orbital currents across interfaces. In Cr/X/Ni trilayers, where layer X is varied across the periodic table, we quantify the effect that the X layer has on the orbital torque on the Ni layer. Figure 1 shows the orbital torque efficiency in Cr/X/Ni (ξ_E). Comparing to the value without the X layer gives the transmission of orbital current across the X layer. Similar experiments on Pt/X/Ni investigate the transmission of spin current across the X layer. Comparing the results for Cr/X/Ni and Pt/X/Ni indicates that the transparency of orbital currents is similar to or greater than the transparency of spin currents for several X layers.

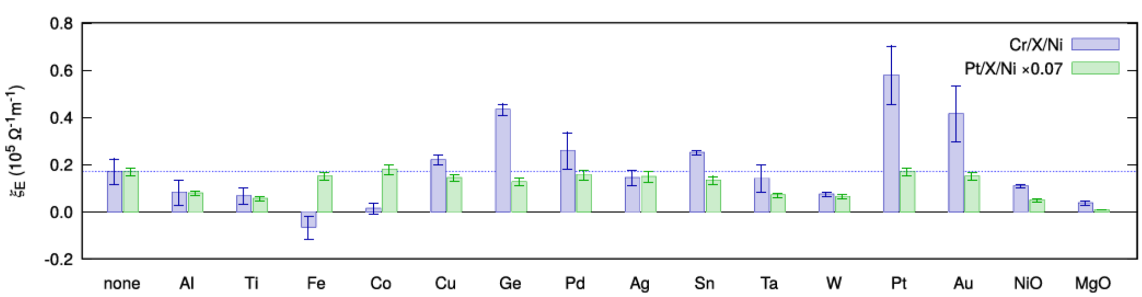

Figure 1. Damping-like torque efficiency ξ_E for Cr/X/Ni and Pt/X/Ni.

[1] Y. -G. Choi et al., Nature 619, 52 (2023).
[2] I. Lyalin et al., Phys. Rev. Lett. 131, 156702 (2023).
[3] I. Lyalin and R. K. Kawakami, Phys. Rev. B 110, 104418 (2024).