Magneto-Optical Detection of the Orbital Hall Effect in Chromium

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The Hall effect was discovered by a PhD student Edwin Hall and his advisor Henry Rowland in 1879. Since then, the family of Hall effects has grown considerably. The anomalous Hall effect, integer and fractional quantum Hall effects, spin Hall effect, quantum anomalous Hall effect are fundamental physics phenomena of great importance. The orbital Hall effect (OHE) with giant orbital Hall conductivities has recently been theoretically predicted [1-4], however its direct observation is a challenge. Here, we report the magneto-optical detection of current-induced orbital accumulation at the surface of a light 3d transition metal, Cr. The orbital polarization is in-plane, transverse to the current direction, and scales linearly with current density, fully consistent with the orbital Hall effect. Comparing the thickness-dependent magneto-optical measurements with *ab initio* calculations, we estimate an orbital diffusion length in Cr of 6.6±0.6 nm. Along with Choi *et al.* study of the OHE in Ti [5], our work [6] provides strong evidence for the OHE. The detection of the orbital Hall effect in light metals can have important consequences for future spintronics applications that could utilize orbital currents rather than spin currents.

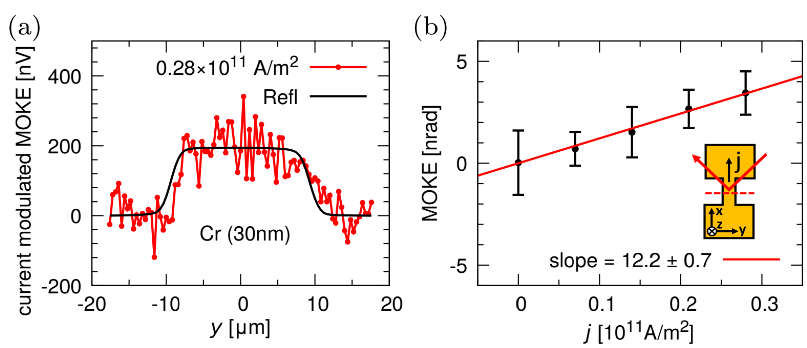

Figure 1. Magneto-optical Kerr rotation induced by the orbital Hall effect. (a) MOKE line scan across a 20 µm wide, 30 nm thick Cr wire. (b) MOKE signal as a function of current density.

[1] T. Tanaka et al., Phys. Rev. B 77, 165117 (2008).
[2] H. Kontani et al., Phys. Rev. Lett. 102, 016601 (2009).
[3] D. Go, D. Jo, C. Kim, and H.-W. Lee, Phys. Rev. Lett. 121, 086602 (2018).
[4] D. Jo, D. Go, and H.-W. Lee, Phys. Rev. B 98, 214405 (2018).
[5] Y.-G. Choi et al., Nature 619, 52 (2023).
[6] I. Lyalin et al., arXiv:2306.10673 [cond-mat] (2023) (accepted to Phys. Rev. Lett).

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Supplementary Information:

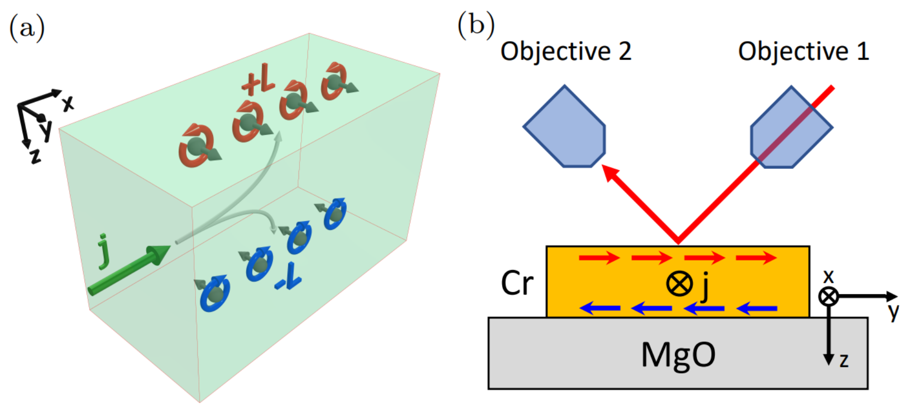

Figure 2. (a) Schematics of the orbital Hall effect. The charge current j generates a transverse orbital current, leading to orbital accumulation on the sample's surfaces. (b) Measurement setup utilizing the longitudinal MOKE to detect the in-plane orbital accumulation.