

Atomic-Scale Structure and Magnetic Order in Novel 2D Materials

J. Fischer¹

¹Institute of Physics II, University of Cologne, Germany

Intrinsic magnetism in atomically thin materials has expanded the scope of 2D physics, yet exfoliation remains limited to bulk-derived phases. Molecular beam epitaxy (MBE) overcomes this constraint, enabling the synthesis of structurally distinct single-layer materials [1,2]. Controlled MBE growth of chromium sulfide and iron sulfide on graphene/Ir results in two novel 2D materials, single-layer Cr₂S₃-2D, which adopts a covalent hexagonal structure with S–Cr–S–Cr–S stacking (NiAs structure) and h-Fe₂S₂, a single-layer polymorph with two buckled honeycomb-like planes (β -CuI structure). Both are novel 2D materials with structures without bulk counterpart and their novel magnetic order is characterized by spin-polarized scanning tunneling microscopy. In my talk, I will show that Cr₂S₃-2D is the first single-layer A-type antiferromagnet – out-of-plane magnetic moments couple ferromagnetic within each Cr plane and antiferromagnetic between Cr planes. In addition, I will show that the out-of-plane Néel vector of the antiferromagnetic order can be switched like a ferromagnet, enabled by uncompensated moments due to interface-induced charge transfer and symmetry breaking. Lastly, I will show that magnetic order in h-Fe₂S₂ is non-collinear within the 2D plane, forming an antiferromagnetic 120° Néel state. Our results demonstrate that MBE enables access to novel magnetic states beyond bulk constraints, opening pathways for engineered 2D quantum materials.

[1] Knispel et al., *Small* 21, 2408044 (2025).

[2] Safeer et al., *Adv. Funct. Mater.* 35, e00907 (2025).