Above room temperature ferromagnetism in epitaxially grown films of the 2D magnets Fe_5GeTe_2 and Fe_3GaTe_2

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2D magnetic materials and van der Waals (vdW) heterostructures are promising building blocks for the realization of novel devices with integrated electronic, optical, and magnetic functionalities [1]. However, most of the studies on these materials have so far been performed using bulk crystals and flakes, both not suitable for integration in device processing. Hence, it is crucial to develop their scalable growth in order to realize highly uniform films and heterostructures with well-defined interfaces. It also requires that each material component of the heterostructure remains functional, which ideally includes magnetic order above room temperature for the 2D magnets. Among different candidates, the 2D ferromagnetic metals Fe_5GeTe_2 (FGeT) and Fe_3GaTe_2 (FGaT) show a great potential due to their relatively high Curie temperature and perpendicular magnetic anisotropy [2,3]. In this contribution, we will report on scalable growth of FGeT and FGaT films on epigraphene/SiC(0001) via molecular beam epitaxy. Structural characterization using different methods reveals the formation of continuous and crystalline FGeT and FGaT films (e.g., Fig 1a). Moreover, magneto-transport and magnetometry measurements reveal ferromagnetic order persisting above 350 K with an out-of-plane anisotropy (see Fig. 1b,c). We will discuss in detail the correlation between structure and magnetism, showing the effects of thickness, Fe composition, and the formation of metastable phases on the magneto-transport properties of the materials. These results represent an important advance beyond non-scalable bulk crystals and flakes, thus marking a crucial step towards future applications.

[1] J. F. Sierra *et al.*, Nat Nanotech. **16**, 856 (2021).
[2] S.N. Kajale *et al.,* Nat Commun. **15**, 1485 (2024).
[3] H. Lv et al., Small **19**, 2302387 (2023); IEEE Trans. Magnetics **60**, 4100505 (2024).

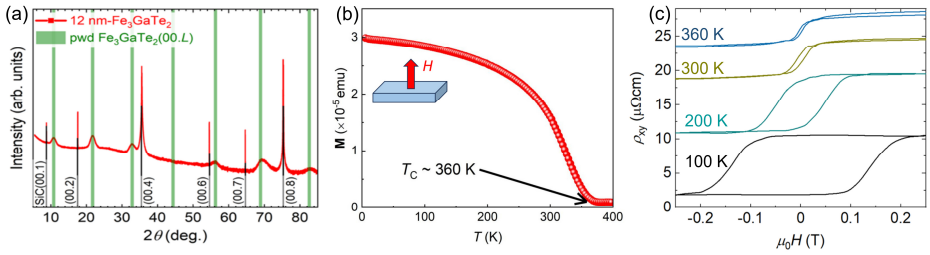

Fig. 1.: (a) X-ray diffraction pattern for a 12 nm thick FGaT film on epigraphene/SiC(0001), plotted together with results for FGaT powder pattern (green bars). (b) Out-of-plane remanent magnetization curve for the same sample. (c) Anomalous Hall effect measured at different temperatures for a 10 nm thick FGeT on epigraphene/SiC(0001).

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