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Wafer-scale Two-dimensional Ferromagnetic Fe_3GeTe_2 Thin Films Grown by Molecular Beam Epitaxy

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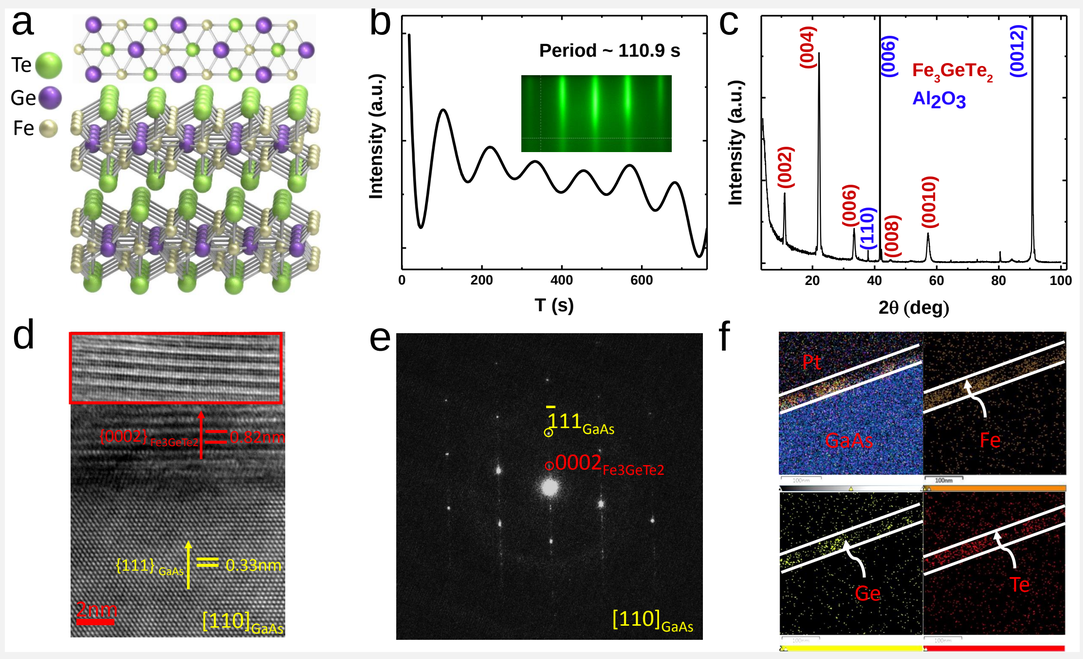
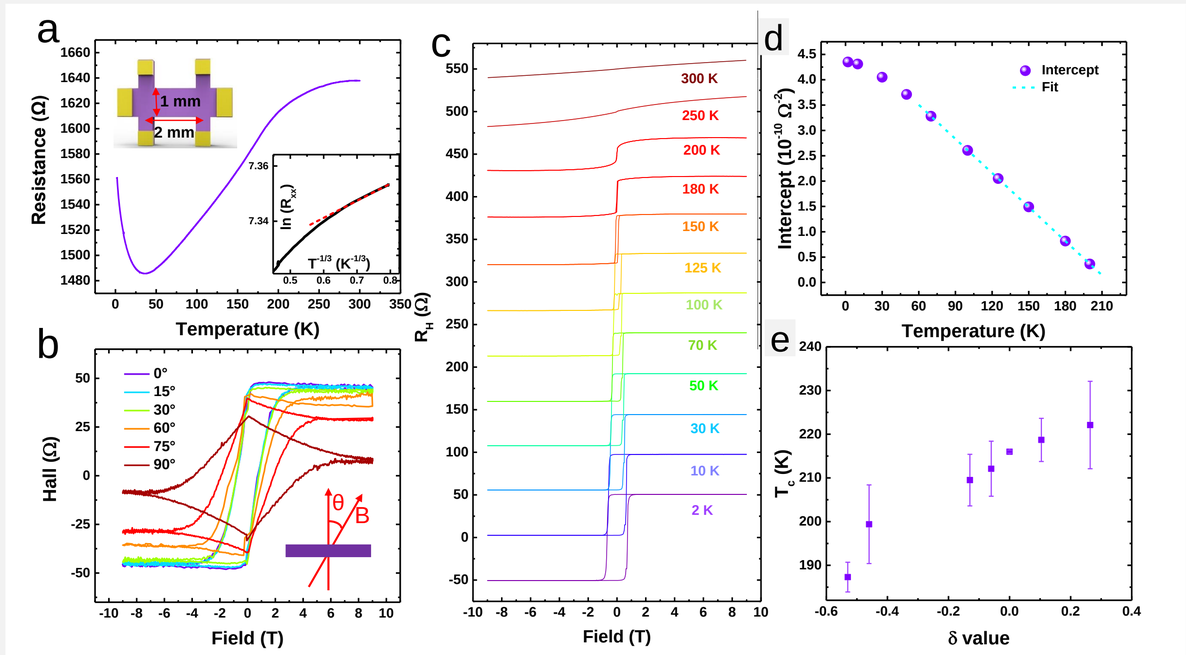
we report the first wafer-scale growth of 2D ferromagnetic thin films of Fe_3GeTe_2 via molecular-beam epitaxy, and their exotic magnetic properties can be manipulated via the Fe composition and the interface coupling with antiferromagnetic MnTe. A 2D layer-by-layer growth mode has been achieved by *in-situ* Reflection-High-Energy-Electron-Diffraction oscillations, yielding a well-defined interlayer distance of 0.82 nm along {002} surface. The magnetic easy axis is oriented along *c*-axis with a Curie temperature of 216.4 K. Remarkably, the Curie temperature can be enhanced when raising the Fe composition. Upon coupling with MnTe, the coercive field dramatically increases 50 % from 0.65 to 0.94 Tesla.

I. Material Synthesis and Characterization



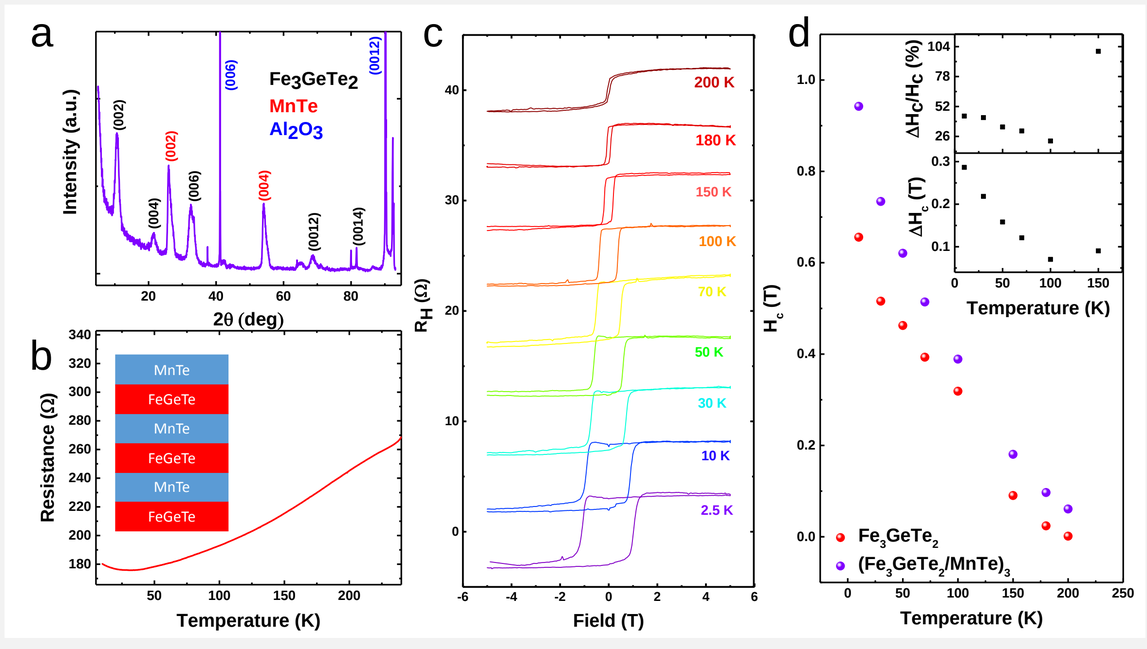
1, Through RHEED oscillation, the growth time is around 111 seconds
2, From cross section HRTEM, layer distance is determined to be 0.82 nm

II. Transport results on $Fe_{3+\delta}GeTe_2$ (-0.52<δ<0.28)



1, Metallic *R-T* behavior, small jump at low temperature is due to variable range hopping effect.
2, Easy axis is out-of-plane, with T_c of 216.4±0.4 K.
3, with increasing Fe composition, T_c increases.

III. Heterostructure of Fe_3GeTe2 and antiferromagnetic (AFM) MnTe



(1) At T_{mea}=2.5 K, coercive field (H_c) increased from 0.65 to 0.94 Tesla.
(2) At all the temperature, enhanced H_c is over 50%.

IV. Conclusion

- **For the first time, we produce the wafer-scale 2D FM via MBE on arbitrary substrates, (0001) sapphire, (111) GaAs, and mica;**
- **The ferromagnetic properties of 2D Fe_3GeTe_2 have a tunability with variable Fe composition and coupled with AFM.**

V. Reference

arxiv.1604.08833; 10.1038/nature22060;

arXiv:1703.05892;

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