Electrostatic Enhancement of Magnetic Order in Two-Dimensional $Cr_2Ge_2Te_6$

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Electrostatic manipulation of magnetism in semiconductors has been attracting a great deal of interest due to its prospects in future spintronics [1,2]. Recent discovery of gate-tunable ferromagnetism in two-dimensional metallic Fe_3GeTe_2 [3] highlight the unique potential of ferromagnetic van der Waals compounds as an ideal platform to study the interplay between charge and magnetic ordering. A related compound $Cr_2Ge_2Te_6$ (CGT) is a ferromagnetic semiconductor with a van der Waals layer structure. Recent experimental work suggests that electrostatic field could alter the spin-polarized band structure of CGT thus allowing control over its magnetic properties [4]. On the other hand, theoretical studies suggest that the long-range order of CGT, which persist down to 2D limit due to magneto-crystalline anisotropy [5,6], can be effectively tuned by electric field [7], thus hinting the prospects for electric tuning the magnetic order and stabilization against thermal fluctuations.

Here we report observation of ferromagnet-like hysteresis in the magnetoresistance of heavily electron-doped CGT. We utilized ion-gating to study naturally *p*-doped CGT in the *n*-type regime. In contrast to weakly hole-doped CGT, which exhibits insulating behaviour with divergent *R-T* curve, strong electron-doped CGT exhibit metallic behaviour, allowing accurate transport measurements in few-layered flakes (Figure 1). We show that heavily doped CGT devices exhibit pronounced hysteretic asymmetry with clear ferromagnet-like switching features in its magnetoresistance curves. Surprisingly, this hysteresis, which indicates presence of magnetic order, persists at the temperatures higher than 150 K, well above the bulk T_c of ~61 K. Furthermore, our magnetoresistance curves at various magnetic field orientations show that the easy axis responsible for the observed magnetic hysteresis is oriented in-plane, in stark contrast with the out-of-plane easy axis in pristine undoped CGT [5]. We further discuss the role of charge carrier density and changes of magneto-crystalline energy with electrostatic doping.

References

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Figures

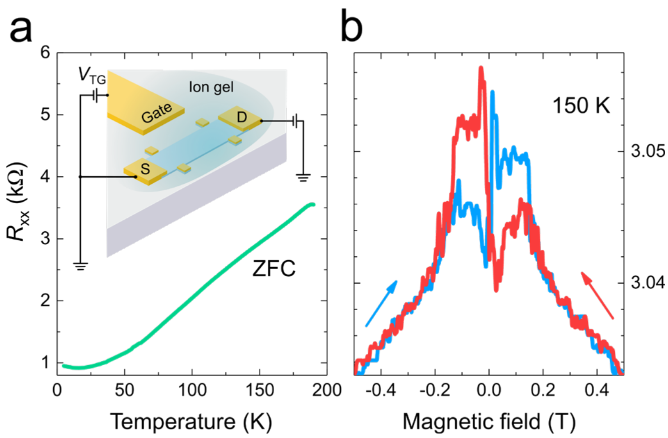

Figure 1: (a) *R-T* curve of the heavily *n*-doped CGT device shows metal-like behaviour. Inset outlines the device geometry. (b) Magnetic loop at 150K with pronounced hysteresis around zero field. Magnetic field was oriented perpendicular to the CGT plane.