Supplementary Information for

# Metamagnetic transition and meta-stable magnetic state in Co-doped $Fe_3GaTe_2$

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**Note S1. Discussion on the energy levels of ferromagnetic and antiferromagnetic states in meta-stable magnetic region.**

Supplementary Fig. 2 shows schematic of energy levels and barrier of ferromagnetic (FM) and antiferromagnetic (AFM) states in isothermal magnetization (*M*-*H*) curve of 19% Co-doped $Fe_3GaTe_2$. Following the up-sweep procedure, the crystal is initially saturated to FM state with magnetic field -50 kOe. In this moment, the energy level of the FM state becomes global energy minima with significant difference compared to the energy level of AFM state. As the magnetic field is reduced and enters into meta-stable magnetic region in negative field, the energy level of FM state becomes higher and that of AFM state gets lower. Here, both FM and AFM states become global or local energy minima and energy barrier between them emerges. Due to this energy barrier, the state transition between two states is hindered and its initial FM state is preserved. When the magnetic field is further reduced to near zero, the energy level of FM state gets higher than energy barrier between two states and system undergoes state transition from FM to AFM state. As the up sweep continues, the energy level of FM state gets lower. Again, the energy barrier between two states recovers and the state transition is prohibited. The material initially favors the ground state energy of the AFM state. When a sufficiently large positive magnetic field is applied, now, the energy level of AFM state becomes higher than energy barrier and the system undergoes state transition from AFM to FM state. After magnetic field reaching 50 kOe and enters into the meta-stable magnetic region, which is remarked with dark-blue spot, the system again remains to be FM state in this region due to energy barrier between two states. Due to the energy barrier between FM and AFM states in meta-stable magnetic region, both FM and AFM states can be stable and multi-level magnetization can be maintained.

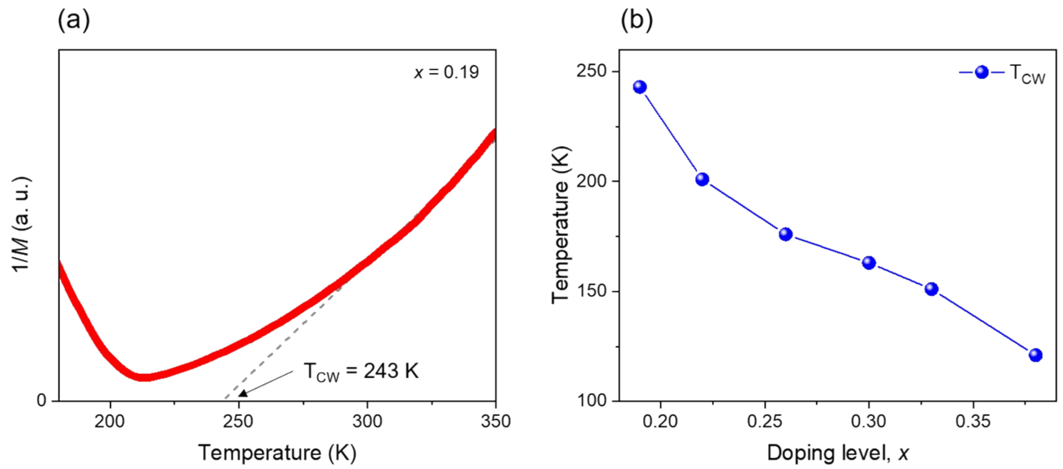


**Figure S1. Curie-Weiss temperature ($T_{CW}$) of antiferromagnetic Co-doped $Fe_3GaTe_2$ (FCGaT). a**, Inverse of the normalized temperature-dependent magnetization curve. $T_{CW}$ is obtained by *x*-axis intercept of extrapolate fitted curve. **b**, $T_{CW}$ of FCGaT with various doping level *x*.

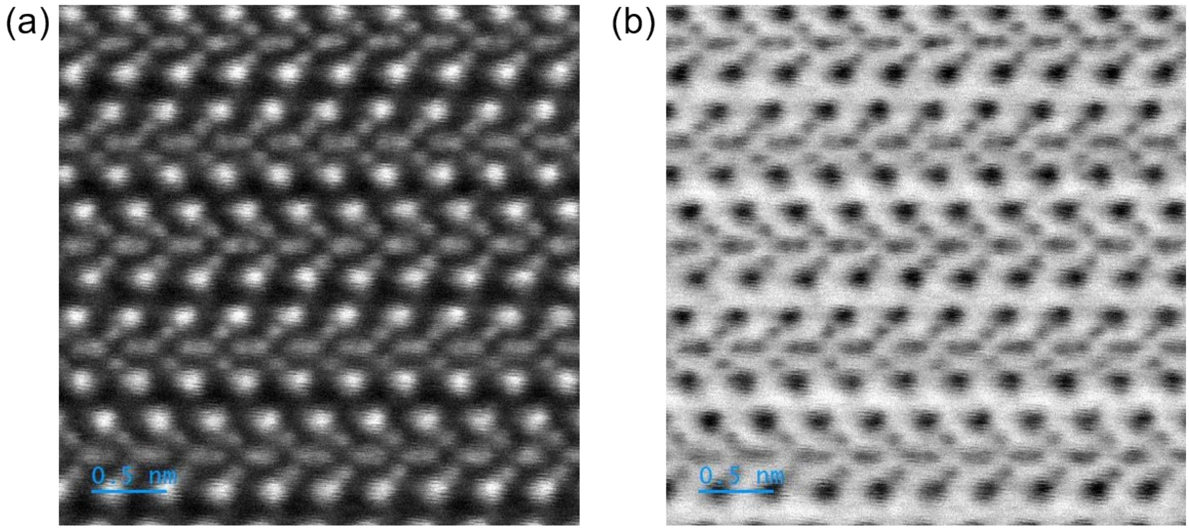


**Figure S2. Scanning Transmission electron microscope (STEM) images of 19% Co-doped $Fe_3GaTe_2$ (FCGaT).** Cross-sectional high-angle annular dark-field (HAADF)-STEM image (**a**) and corresponding annular bright-field (ABF)-STEM image (**b**) (scale bar: 0.5 nm).

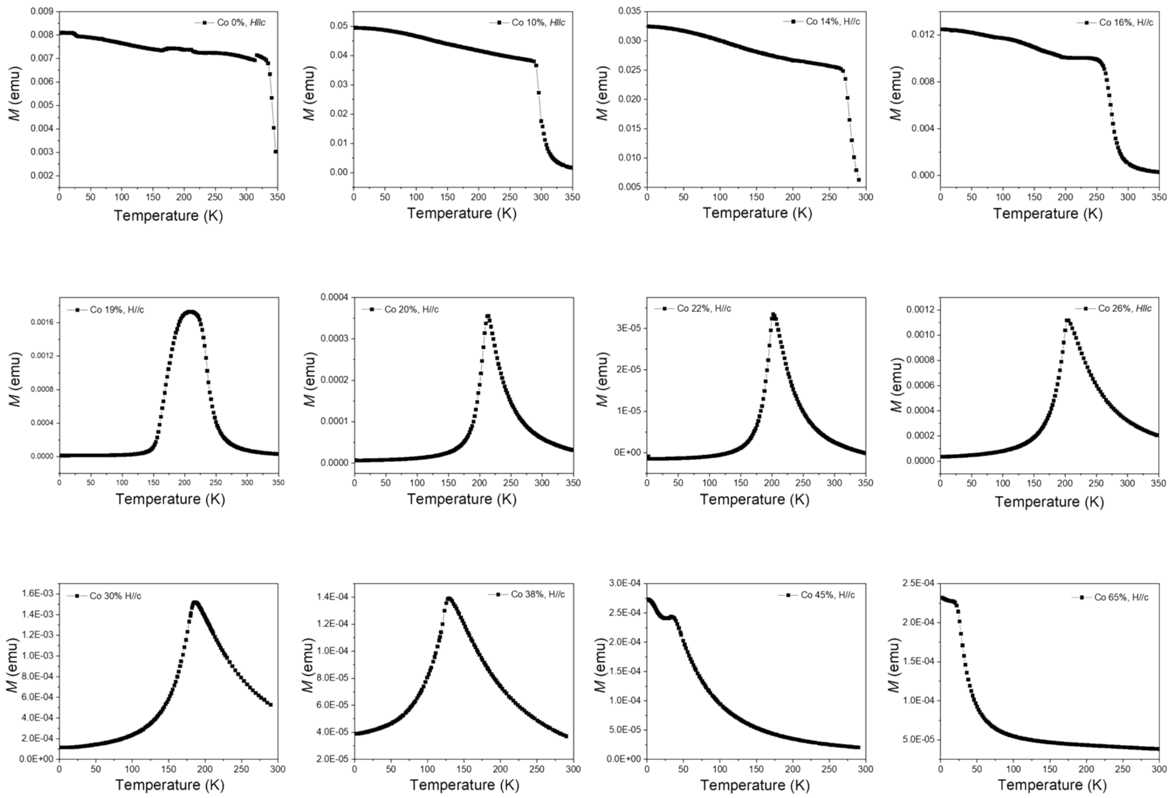


**Figure S3. Field-cooling temperature-dependent magnetization curves of Co-doped $Fe_3GaTe_2$ bulk crystals with various doping level *x*, with *H* = 1 kOe and perpendicular to plane.**

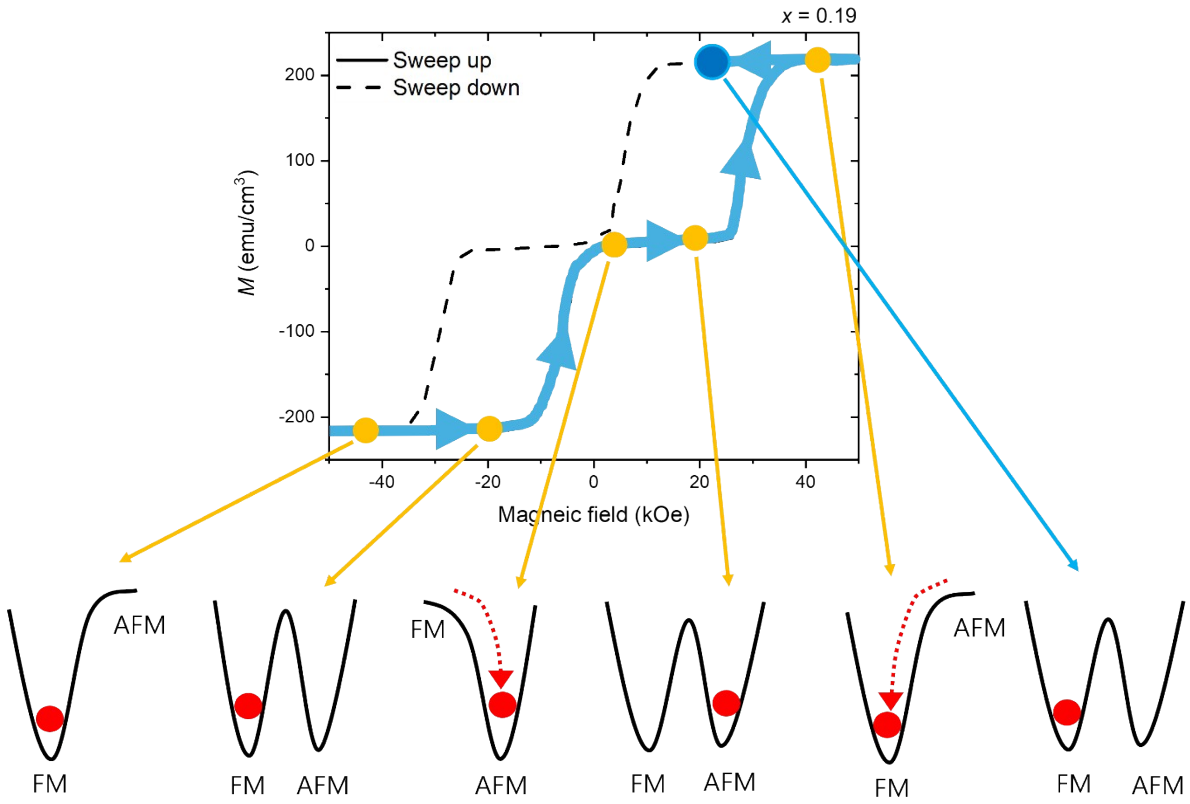


**Figure S4. Schematic of energy levels of ferromagnetic and antiferromagnetic states in isothermal magnetization curve of 19% Co-doped $Fe_3GaTe_2$.**