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Hard ferromagnetic van-der-Waals metal $(Fe,Co)_3GeTe_2$: a new platform for the study of low-dimensional magnetic quantum criticality

Abstract

Magnetic van-der-Waals (vdW) materials have recently been attracting a great deal of attention worldwide and yielding a plethora of exciting results. An interesting future direction for the study of magnetic vdW materials is to study the physics of quantum criticality in a truly two-dimensional system. A quantum critical point is achieved by tuning a second order quantum phase transition of a long-range ordered state to zero temperature, through controls such as doping and pressure. The only ferromagnetic vdW metal currently available, Fe_3GeTe_2, while widely studied in recent years for potential technological applications, has great promise in this area, but a relatively high Curie temperature in excess of 200 K. To help render the quantum critical point achievable in such a system, we have discovered a variant of $(Fe,Co)_3GeTe_2$ with ideal physical properties for both this purpose and the wider study of low-dimensional magnetism and spin transport. It has a sharp Curie temperature at a value below 40 K and a coercive field 10 times larger than that of Fe_3GeTe_2. This unprecedented hard metallic vdW ferromagnet is then attractive for the study of 2D magnetism with an expected even larger Ising anisotropy.

Figures

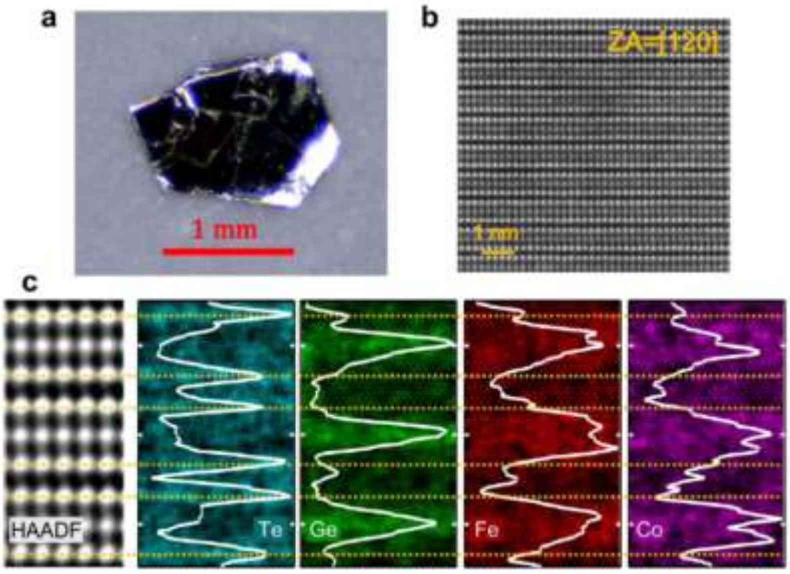

Figure 1: a) Photograph of a $Fe_2Co_{0.7}GeTe_2$ crystal. b) HAADF STEM image of $Fe_2Co_{0.7}GeTe_2$. Van der Waals layers lie between the Te columns, the black-striped areas between the brightest spots in the image. c) Energy dispersive X-ray

spectroscopy normalized intensity maps in the HAADF image. The inset graphs show the normalized intensity line profile of corresponding atoms along the crystal planes. The intensities of the EDX signals from Fe and Co indicate that Co atoms occupy the Fe sites I and II randomly

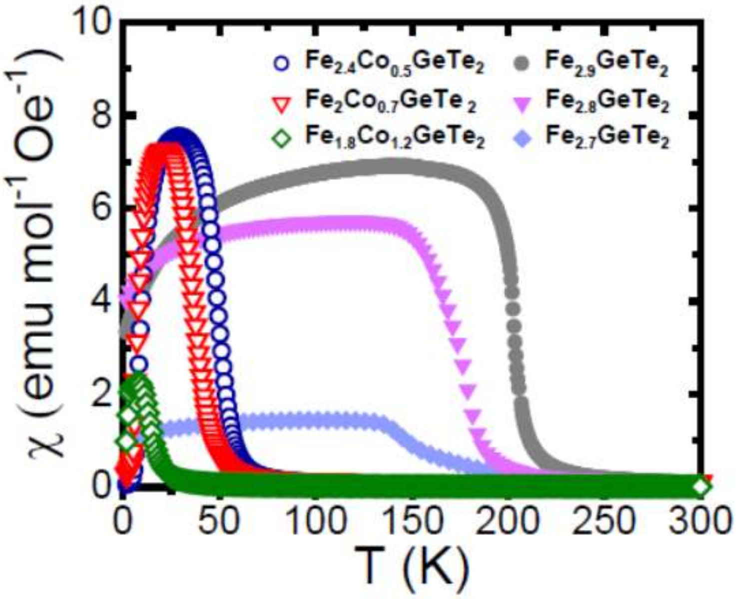

Figure 2: Zero-field cooling curve of temperature-dependent molar susceptibility for $Fe_{3-x}GeTe_2$ and $(Fe,Co)_{3-x}GeTe_2$ with 500 Oe of magnetic field applied along the c-axis. For $(Fe,Co)_{3-x}GeTe_2$, the transition temperatures are suppressed as compared to $Fe_{3-x}GeTe_2$, but it still shows a clean transition below 51 K ($Fe_{2.4}Co_{0.5}GeTe_2$), 37 K ($Fe_2Co_{0.7}GeTe_2$), and 14 K ($Fe_{1.8}Co_{1.2}GeTe_2$).