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2D Ferromagnetism in Van der Waals Bonded Fe_3GeTe_2

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Abstract : For many years, researchers have been fascinated by the subject of how properties evolve as dimensionality is lowered. Early on, it was shown that the presence of a significant magnetic anisotropy might compensate for the lack of long-range (LR) magnetic order in a low-dimensional system ($d < 3$) with continuous symmetry, as proposed by Hohenberg-Mermin and Wagner (HMW). Strong magnetic anisotropy allows an LR magnetic order to stabilize in two dimensions (2D) even in the presence of stronger thermal fluctuations which is responsible for the absence of Heisenberg ferromagnetism in 2D. Van der Waals (vdW) ferromagnets, including CrI_3, $CrTe_2$, $Cr_2X_2Te_6$ (X = Si and Ge) and Fe_3GeTe_2, offer a nearly ideal platform for studying ferromagnetism in 2D. Fe_3GeTe_2 is the subject of extensive investigation due to its tunable magnetic properties, high Curie temperature ($T_c \sim 220K$), and perpendicular magnetic anisotropy. Many applications in the field of spintronics device development have been quite active due to these appealing features of Fe_3GeTe_2. Although it is known that LR-driven ferromagnetism is necessary to get around the HMW theorem in 2D experimental realization, Heisenberg 2D ferromagnetism remains elusive in condensed matter systems. Here, we show that Fe_3GeTe_2 hosts both localized and delocalized spins, resulting in itinerant and local-moment ferromagnetism. The presence of LR itinerant interaction facilitates to stabilize Heisenberg ferromagnet in 2D. With the help of Rhodes-Wohlfarth (RW) and generalized RW-based analysis, Fe_3GeTe_2 has been shown to be a 2D ferromagnet with itinerant magnetism that can be modulated by an external magnetic field. Hence, the presence of both local moment and itinerant magnetism has made this system interesting in terms of research in low dimensions. We have also rigorously performed critical analysis using an improvised method. We show that the variable critical exponents are typical signatures of 2D ferromagnetism in Fe_3GeTe_2. The spontaneous magnetization exponent β changes the universality class from mean-field to 2D Heisenberg with field. We have also confirmed the range of interaction via the renormalization group (RG) theory. According to RG theory, Fe_3GeTe_2 is a 2D ferromagnet with LR interactions.

Keywords : Van der Waal ferromagnet, 2D ferromagnetism, phase transition, itinerant ferromagnetism, long range order
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