The influences of the vacancies in the magnetic skyrmion lattice

Ricardo Lopes da Silva

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Abstract

Recently the real space measurements of the two dimension Skyrmion structure has been made a low temperature in films of $Fe_{0.5}Co_{0.5}Si$ and close to room temperature in $FeGe$. These compounds share the same $B20$ structure with chiral cubic symmetry, and commonly show the heli-magnetic ground state. When a magnetic field is applied normal to the plate, a $2D$ skyrmion lattice is observed. In this metallic compounds, the electric current can drag the skyrmion via a spin transfer torque, while the motion of the skyrmion generates a transverse electromotive force as the emergent electric field. Such electric controllability, as well as its particle-like nature with nanometric size, highlights skyrmion as a unique magnetic object with potential applications in spintronics and high-density magnetic storage devices. The skyrmion-like phase has been studied through the theoretical model and direct real-space observation as an excited state or spontaneous ground state. Even though these and many other issues should be investigated for a better comprehension of such configurations, it is noteworthy that even in the purest samples, structural defects are present, generally randomly distributed throughout the material. This defects can induce and control skyrmion motion, playing a crucial role in disrupting order in solids. The purpose of this work is to discuss the effects due to lattice defects such as nonmagnetic impurities in the formation of skyrmion lattice. In this work we are using the Monte Carlo method to investigate the formation of skyrmion in the presence of the impurities. Our system is modeled by the distribution of magnetic particles over a bi-dimensional lattice and represented by the Hamiltonian:

$$H = -J \sum_{<i,j>} \vec{\mu}_i \cdot \vec{\mu}_j - \vec{D} \cdot \sum_{<i,j>} (\vec{\mu}_i \times \vec{\mu}_j) - \sum_i \vec{h}_i \cdot \vec{\mu}_i. \qquad (1)$$

Here $\vec{\mu}_i = \mu_i^x \hat{x} + \mu_i^y \hat{y} + \mu_i^z \hat{z}$ is the unit spins vector at position i and the first sum $< i,j >$ is over nearest-neighbor spins with exchange interaction strength $J > 0$. The second term is the Dzyaloshinskii-Moriya (DM) interaction, where the vector product $(\vec{\mu}_i \times \vec{\mu}_j)$ favour canted spin structures and enforces a unique rotational sense such that the vector product is parallel to $\vec{D}$. From symmetry considerations the directions of $\vec{D}$ can be determined, and it is predominantly in plane surfaces, in this work we consider only DM interaction between nearest neighbours. The last term considers the effects of an external magnetic field $\vec{h}$.