Abstract

There has been spectacular progress in the study on multiferroics, which is expected to make a realistic step toward an electrical control of magnetism or four state memories. We propose a tilted Heisenberg model of which the continuum limit is a gauge Landau-Lifshitz equation that provides a unified description for various exotic spin orders appeared. For certain gauge potential, we solved the magnetic skyrmion phase and also predicted the emergence of meron phase [1]. We also propose a mechanism to pin skyrmions in chiral magnet [2], and find that the position-dependent electric field can induce the Hall motion of the skyrmion [3]. Furthermore, we study spin-orbital driven ferroelectricity [4]; spin-orbital coupling and charge effect in Mott insulators showing that the tilted Heisenberg model can be derived from the Hubbard model in the presence of spin-orbital coupling as the large U limit [5]. The idea of tilted Heisenberg model has been extended to the SU(3) case by experts working on high-energy physics recently [6]. Moreover, we show that in the stationary regime the chirality of the domain wall can be efficiently reversed when the electric field is applied along the direction of the magnetic field. These characteristics suggest that the multiferroic domain

wall may provide a new prospective means to design faster and low-power-consumption domain wall devices [7,8]. These results are expected to motivate experimentalists to prepare new type of multiferroics material or design new spintronics device [9-11].

References

[1] Y. Q. Li, Y. H. Liu, and Y. Zhou, General spin order theory via gauge Landau- Lifshitz equation, Phys. Rev. B. 84, (2011) 205123;

[2] Y. H. Liu and Y. Q. Li, A mechanism to pin skyrmions in chiral magnets, J. Phys.: Condens. Matter 25 (2013) 076005;

[3] H. Liu, Y. Q. Li, and J. H. Han, Skyrmion dynamics in multiferroic insulators, Phys. Rev. B 87 (2013) 100402 (R);

[4] S. Zhu and Y. Q. Li, Spin-orbital driven ferroelectricity, J. Phys.: Condens. Matter 26 (2014) 395901;

[5] S. Zhu， Y. Q. Li, and C. D. Batista, Spin-orbit coupling and electronic charge effects in Mott insulators, Phys. Rev. B 90 (19), (2014) 195107;

[6] Y. Akagi, et al., Isolated skyrmions in the CP monlinear sigma model with DM type interaction, Phys. Rev. D 103 (2021) 065008;

[7] H. B. Chen, Y. H. Liu and Y. Q. Li, Electric field control of

multiferroic domain wall motion, J. Appl. Phys. 115 (2014) 133913;

[8] H. B. Chen and Y. Q. Li, Electric-field control of elective spin excitations in Neel-type skyrmions, Appl. Phys. Express 12 (2019) 093003;

[9] Y. H. Liu and Y. Q. Li, Dynamics of magnetic skyrmions, Chin. Phys. B 24 (2015) 017506;

[10] R. Wiesendanger, Nanoscale magnetic skyrmions in metallic films and multilayers: a new twist for spintronics, Nature Review Materials, 1 (2016) 1;

[11] C. Reichhardt and C. J. O. Reichhardt, Statics and dynamics of skyrmions interacting with pining: a review, arXiv:2102.10464v1. (2021).