Influence of Fermi surface on magnetization processes and the magnetocaloric effect in the two-dimensional Ising model with RKKY interaction

L. Regeciová[1] and P. Farkašovský[1]

[1] *Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, 040 01 Košice, Slovakia*

The long-range Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction provides an important mechanism of indirect coupling between localized magnetic moments in metallic systems and naturally leads to competing ferromagnetic/antiferromagnetic interactions and nontrivial magnetization processes. In this paper, we perform an extensive Monte Carlo study of the Ising model with long-range RKKY interaction on a square lattice. In low-dimensional materials, the Fermi surface is often closer to a two-dimensional geometry than to a three-dimensional spherical one. Motivated by this fact, we consider two limiting cases of the RKKY interaction corresponding to two- and three-dimensional Fermi surfaces. In addition to the half-filled case, we study the effect of electron/hole doping, which is simulated by varying the Fermi wave vector k_F. We show that both the dimensionality of the Fermi surface and the value of k_F have a significant impact on the strength of the RKKY interaction and, consequently, on magnetization processes. In particular, for the three-dimensional Fermi surface, the magnetization curves have only one dominant 1/2 fractional magnetization plateau which width depends on k_F. In contrast, the two-dimensional Fermi surface gives rise to various sequences of fractional magnetization plateaus with magnetizations 1/2, 1/3, 2/3, 1/4, 1/6, 4/9, 5/9, 1/12, 5/12, 7/12... We show that deviations from the half-filled case, induced by the electron or hole doping, can lead to a pronounced enhancement of the magnetocaloric cooling. This suggests that tuning the electron filling can be used to control magnetocaloric properties in low-dimensional magnetic systems with RKKY interaction.

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