Modulated phases in Monte Carlo simulations for ultrathin magnetic films

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Many ultrathin magnetic films (e.g. Co-Cu, Co-Au, Fe-Cu) are characterized by a strong uniaxial anisotropy and exhibit a reorientation transition in which the spins align perpendicularly to the film plane. Any realistic theoretical description of these systems must include both the short-range exchange interaction and the long-range dipolar interaction. This competition gives rise to stable modulated phases, such as the striped magnetic domain patterns observed in these materials. In spite of intense theoretical and experimental work on the behavior of ultrathin magnetic films, the precise nature of the phase transitions in these systems is still a matter of debate.

We study the two-dimensional Ising model with competing short-range ferromagnetic exchange and long-range dipolar interactions by means of Monte Carlo simulations. The long-range character of the dipolar interaction makes the problem computationally difficult and limits the system sizes that can be investigated in practice. We employ a Parallel Tempering method [1], which helps the system overcome energy barriers and thus equilibrate more efficiently.

Our results allowed the identification of three thermodynamic phases: the *stripe phase* at low temperatures, which presents both positional and orientational orders; the *nematic phase* at intermediate temperatures, which presents only orientational order; and the disordered phase called *tetragonal-liquid* at high temperatures. Using the energy and order parameter moments data, we were able to identify the range of temperatures in which the nematic phase is stable, in agreement with previous Monte Carlo results reported in the literature [2] and with the two-step disordering scenario predicted for these magnetic systems [3].

References

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