Study of hysteresis and dynamic phase transition in kinetic Ising ferromagnet on regular, disordered, and fractal lattices

Abstract

The Ising ferromagnet is a bistable system below the critical temperature (T_c) of ferromagnet to paramagnet transition and has two symmetry broken ordered phases. An external oscillating field can push the system to either of the equivalent ordered phases, and the other ordered phase remains metastable. There are two competing time scales present in the system, the time period (P) of the external field and the mean metastable lifetime $\langle\tau\rangle$ of the system. The average metastable lifetime ($\langle\tau\rangle$) of a system is the mean time spent in a metastable phase after a sudden reversal of the static field applied in the system. There exists a critical period P_c, at which the half period ($P_{1/2}$) of the field becomes comparable with $\langle\tau\rangle$, the Ising ferromagnet undergoes a dynamic phase transition (DPT) from dynamic ordered phase (DOP) to dynamic disordered phase (DDP). If the period of the oscillating field is small ($P < P_c$), the system will remain in one of the metastable wells over a full period, and the system is said to be in a DOP. Whereas for a higher period ($P > P_c$), the system will be able to move from one free energy well to the other and vice versa as the field changes sign and the system is said to be in a DDP. The dynamic order parameter or period average magnetization $Q = \frac{1}{P}\int_0^P m(t)dt$ changes from a finite value in DOP to zero in DDP. Also, the asymmetric hysteresis loop in DOP becomes symmetric in DDP. A spontaneous breaking of the symmetry of the hysteresis loop occurs at $P = P_c$.

Such a system is well studied applying pulse as well as sinusoidal fields varying period and keeping temperature fixed and vice verse. However, there exists controversy about the nature of DPT. Once it is claimed to be a discontinuous type phase transition due to stochastic resonance below a tricritical point. In another series of articles, it has been shown that the DPT is a continuous type phase transition and follows finite size scaling (FSS) with the same critical exponents of the 2d zero field equilibrium Ising model. Such an issue is taken afresh in this thesis and, a detailed analysis of DPT in Ising ferromagnet on 2d square lattice is performed on an extended system in the high field regime. A novel technique is developed to analyze hysteresis loop properties.

Apart from the above issues, the equilibrium Ising ferromagnet, as well as the kinetic Ising ferromagnet, are not well studied on disordered (or site diluted) lattices. The effect of site dilution on Ising ferromagnet is intriguing to explore. At different site dilution concentrations, the magnetic properties of Ising ferromagnet, hysteresis, and DPT are explored in this thesis.

The situation is going to more dramatic if the Ising ferromagnet is defined on a fractal lattice such as percolation cluster or percolation backbone. Both the equilibrium phase transition and DPT are rarely reported in the literature. A thorough investigation has been performed on the nature of phase transition and critical behaviour of the Ising ferromagnet defined on percolation cluster as well as on percolation backbone. Interesting novel results are obtained and reported in this thesis.

The thesis presents extensive Monte Carlo simulation results. Detailed FSS analysis is performed for the data obtained. Systems are studied with various concentrations of disorder, field amplitudes, periods, temperature, and system sizes. Far below the static equilibrium phase transition temperature T_c, DPT is studied either by varying temperature keeping the period fix or varying the period keeping the temperature fixed. A new methodology is developed to determine the hysteresis loop properties.