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Finite Size Kosterlitz-Thouless Transition in Fe/W(001) Ultrathin Films

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Idealized two-dimensional ferromagnetic films are predicted to undergo a Kosterlitz-Thouless (KT) transition that involves topological excitations termed vortices. Whereas the idealized system is isotropic within the plane (2DXY symmetry), real ferromagnetic films grown on single crystal substrates display anisotropy and finite-size effects that can lead to more complicated behaviour. In this work, magnetic susceptibility measurements of 3-4ML Fe/W(001) films with four-fold in-plane anisotropy were compared to theoretical predictions for a finite-size KT transition, and found to be in excellent quantitative agreement. Susceptibility measurements on many films grown independently in ultrahigh vacuum were made *in situ* using the magneto-optic Kerr effect (MOKE). Since the susceptibility signal can become complicated by dissipation caused by domain walls at low temperatures, the analysis concentrated on the high temperature, paramagnetic tail of the signal where quantitative theoretical predictions apply. The paramagnetic tail was fit to the distinctive form predicted by KT theory for a gas of unbound vortex/antivortex pairs: χ(T)=χ₀ exp(B/(T/T_{KT}-1)^a), using a four-parameter fit. An analysis of 16 susceptibility signals from 12 independently grown films gave fitted parameters of a=0.50±0.03 and B=3.48±0.16, in excellent agreement with the predicted values of a=1/2 and 3.2 < B < 3.8. In about one-third of the films, the dissipative signal Im(χ) was very small, so that the peak of Re(χ) occurred close to the finite size transition temperature, T_C(L). In these cases, the fitted values of the KT transition temperature, T_{KT}, were tens of K below T_C(L), which is quantitative agreement with finite size KT theory. In contrast, fitting to a power law typical of a second order phase transition, χ(T)=χ₀(T/T_γ -1)^γ, gives an effective critical exponent of γ=3.7±0.7 and places the transition temperature T_γ ˜10K below the peak temperature. Both of these results are unphysical.

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