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The 2D percolation transition in Fe/W(110) ultrathin films: Measurements of the phase transition line and critical exponent at finite temperature

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Percolation is a geometric condition that occurs naturally in the growth of two-dimensional (2D) films (and in many other contexts). Atoms that are deposited on a substrate aggregate to form isolated islands whose size bounds the range of correlated behavior, or correlation length, of the system. At greater deposition the islands coalesce, and at a critical fractional coverage of the substrate, p=p_c, at least one island forms a connected path throughout the entire sample. Then the correlation length has diverged and the system has "percolated". The percolation transition is a second order phase transition. When the deposited atoms normally support magnetic phases, the percolation transition is often accompanied by a second order magnetic transition, and can be studied using the magnetization M or susceptibility χ. Most experimental studies of percolation measure the properties of a series of samples, each with a fixed coverage, as a function of temperature or an applied field to determine whether or not it has percolated. This method cannot record and investigate percolation as it occurs. Our recent experiments on Fe/W(110) take the unusual approach of measuring χ(p) as the film grows at constant temperature and percolation occurs.

We have detected a sharp, narrow peak in χ(p) near a Fe coverage of one atomic layer on W(110) that is consistent with a second order phase transition. Using measurements at a series of constant temperatures, we have constructed the phase transition line in the (p,T) plane, and compared it quantitatively to the predictions of scaling theory as applied to the bicritical point (p_c , T=0). We have also made quantitative comparisons of measurements of χ(p≈p_c , T) and χ(p, T=255 K) to scaling theory and found that the phase transition is in agreement with the predictions for the 2D percolation of a 2D Ising system. In particular, we measure the percolation critical exponent of the susceptibility (or mean island size) to be γ_p=2.39±0.04, in excellent agreement with the theoretical value of 43/18.

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