The phase diagram of a bilayer Ising model.

M. Gitterman and E. Sloutskin
Department of Physics, Bar Ilan University, Israel.

The rapid progress of surface-specific experimental techniques in the last decade resulted in the discovery of numerous new phenomena which occur at interfaces. In addition to the well-known “surface freezing” phenomenon, the surface-induced ordering phenomena, forming, in some cases bilayers, were observed in liquid metals, liquid crystals, molten salts, membranes of biological cells, etc. Therefore, the theoretical study of the phase diagram and dynamic behavior of the bilayers is of great importance. For the analysis of the phase diagram of a bilayer, we use the two-dimensional Ising model with different in-plane and inter-layer interactions [1]. The simple method of an estimate of the critical temperature of the Ising model [2] has been used. The critical behavior is discussed and the problem is shown to belong to the two-dimensional Ising universality class for any given values of the inter-layer interaction. Indeed, the addition of the second layer changes the local environment of a spin in the first layer, and thus the critical temperature will be altered. On the other hand, the critical exponents, which determine the asymptotic behavior of the thermodynamic quantities, cannot be influenced by the changes at distances shorter than the correlation length. Far from criticality, the correlation length can be of order of the thickness of the n-layer system or smaller, and thus the behavior of the system may differ from that of the two-dimensional Ising lattice. However, upon approaching criticality the correlation length diverges to values much larger than the thickness of the n-layer system. The system’s finite thickness ceases to matter, and the universal two-dimensional Ising behavior is recovered.

We study also the phase diagrams of bond-diluted bilayers. In the absence of short-range spatial correlations between the diluted bonds, the phase diagram is the same as that of the non-diluted model, while in presence of these correlations the critical temperature is obtained by means of Bethe approximation.

Results are compared with those obtained by mean-field and renormalization group approaches, and verified by comparison to earlier results obtained by computer simulations, perturbation series expansion, Bethe-tree approximations and other methods. The model describes a “surface phase” produced by a crystalline monolayer at the free surface of alkane [3] and some other surface-induced ordering phenomena. The possible applications include a molecular junction.