VII. X-RAY DIFFUSE SCATTERING

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We have now completed construction of a two-spectrometer x-ray diffuse-scattering system based on a Rigaku 12-kW rotating-anode x-ray generator. The system is designed in such a way that one may easily tailor the instrumental resolution function to optimize studies of structure and fluctuations in a vast range of physical systems. Angular resolution of 1.8 seconds of arc and sample temperature control of 2 mK between 10 K and 500 K are available. We are currently implementing a position-sensitive detection system to allow rapid scans over a wide range of scattering angles, again with continuously variable resolution. Our current research program emphasizes structure and melting transitions both for monolayer physiadsorbed films on graphite and for layered liquid crystals. The surface experiments involve in situ high-precision vapor-pressure and surface-coverage measurements. We now discuss our individual projects.

1. MELTING AND COMMENSURATE-INCOMMENSURATE TRANSITION OF KRYPTON ON GRAPHITE

It has traditionally been assumed that only surface-sensitive probes such as low-energy electron diffraction (LEED) could be used to study monolayer surface films. However, for a variety of experimental reasons LEED is extremely limited in the information which it can provide. Accordingly, we have initiated a study of monolayer surface overlayers using x-ray scattering techniques. Our first experiments were performed on krypton physiadsorbed onto exfoliated ZYX graphite. This system is particularly interesting because the ideal krypton-krypton interatomic separation is quite close to, albeit slightly less than, a natural superlattice ($\sqrt{3} \times \sqrt{3}$) spacing provided by

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the (0001) graphite-plane substrate. We find that for less than monolayer coverage the krypton forms a commensurate $\sqrt{3} \times \sqrt{3}$ structure at all temperatures. Furthermore, for coverages greater than 0.9, the melting transition is second-order with the critical behavior of the 3-component Potts lattice gas model as predicted by theory.[1] With increasing coverage the krypton undergoes a two-step commensurate-incommensurate transition. The details of this transition are still being investigated.

2. STRUCTURE OF XENON-ON-GRAPHITE

Xenon provides an interesting contrast with krypton-on-graphite in that the solid xenon-interatomic spacing lies intermediate between the graphite (0001) $\sqrt{3} \times \sqrt{3}$ and 2×2 superlattices. We find that xenon for nearly all coverages and temperatures forms an incommensurate, floating solid hexagonal overlayer. We have carried out a detailed study of the two-dimensional solid-liquid-gas coexistence near the triple point at 99 K. Our experiments confirm that a triple point may indeed exist in two dimensions, in contrast to much theoretical speculation to the contrary. However, the 2D solid exhibits anomalous properties; in particular, the solid-structure factor varies drastically as the relative amounts of 2D solid and vapor are varied. This may reflect a fundamental instability of line interfaces in two dimensions. Work on this most interesting system is continuing.

3. NEMATIC-SMECTIC A TRANSMISSION IN BILAYER SMECTIC-LIQUID CRYSTALS

De Gennes has proposed an elegant model which establishes an isomorphism between the nematic-smectic A transition in liquid crystals and the normal metal-superconductor transition in metals. However, because the liquid-crystal interactions are short-range, one should observe true critical behavior rather than mean-field behavior as in a superconductor. We have carried out a detailed study of the mass-density critical fluctuations in three bilayer smectic-liquid crystals CBOOA, 8OCB, and 8CB.[2] In all cases both the smectic susceptibility and the longitudinal correlation length exhibit helium($d = 3$, $n = 2$)-like critical behavior as predicted by de Gennes. However, the transverse correlation length appears to diverge more weakly, probably due to the highly anisotropic elastic forces in the liquid crystal.

4. THE NATURE OF SMECTIC B LIQUID CRYSTALS

Smectic B liquid crystals constitute one of the most mysterious phases of condensed matter. These systems exhibit considerable positional order in all three dimensions, yet they have a number of liquidlike properties which distinguish them from conventional solids. No rigorous model for this phase has yet been proposed. However, an important clue may have been provided by Halperin and Nelson who show that in <u>two</u> dimensions melting may occur in two stages with the solid first losing its positional long-range order at T_1 and its orientational order at a higher temperature T_2. The intermediate phase has been labelled "hexatic." We have proposed a model[3] in which the smectic B essentially corresponds to stacked hexatic films. We have shown that this model appears to be consistent with all available data. High-resolution x-ray experiments are now under way to test a number of the predictions of our model.

References

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