

13. Graphoepitaxy of Colloidal Crystals

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13.1 Studies of Micellar Liquid Crystals

Joint Services Electronics Program (Contract DAAL03-86-K-0002)

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In these experiments, we used precision birefringence measurements in combination with quasielastic light scattering to study the orientational order of the micelles, the normal modes which arise because of this order, and the effect of the lamellar order on these modes. The latter is closely analogous to the Meissner effect in which magnetic fields are expelled from a superconductor. The physical effect is, of course, quite different, since it consists of certain optic axis alignment distortions being expelled from the lamellar phase. A quantitative mathematical description of these effects confirmed the applicability of the Ginsberg-Landau model to describe the main features of the process by which lamellar order is established.

Our studies also established that the micellar orientational order in these systems has much in common with that in thermotropic nematic liquid crystals; the order-disorder transition is required to be discontinuous by symmetry, but we found it to be very nearly continuous in one system (cesium perfluoro-octanoate in water) we studied. This system thus offers the possibility to learn more about the nematic-isotropic transition. It also has Goldstone modes (the director modes of the nematic phase) which are truly hydrodynamic with zero energy at long wavelengths. This material should then show behavior analogous to that predicted theoretically for an isotropic Heisenberg ferromagnet, which includes an infinite zero field susceptibility.

The scientific questions raised by this research are important and currently interesting ones in the field of statistical mechanics, but are not closely related to problems in the area of electronic materials. This research therefore is no longer being carried out with support of the Joint Services Electronics Program. It will be continued with support from the National Science Foundation under grant DMR83-19985.

13.2 Growth of Colloidal Crystals

Ronald Francis, J.David Litster

In recent years there has been much interest in crystalline order formed by aqueous suspensions of polystyrene latex spheres. These have lattice parameters several hundred nm and have been studied as model systems for conventional crystals, for the preparation of ceramics, and to elucidate the properties of colloids. In previous, unpublished work, we had studied "thermal diffuse" scattering of light by such crystals and determined the Lindeman ratio at the melting point to be 0.007, smaller than the typical value 0.2 in most conventional solids. We have recently followed up on that work, learning to prepare samples in water deionised by reverse osmosis as that promises to provide better control over sample properties. Our goal is to study the epitaxial growth of these crystals on carefully controlled surface relief structures prepared using submicron fabrication facilities.

Our recent activity efforts have been to learn how to control conditions so we can reproducibly and reliably grow the colloidal crystals. We started with commercially available synthetic colloids of polystyrene latex spheres. These come with electrical conductivity in the range of 50–100 micro Siemens (uS). The volume fraction of suspended solids is in the 8–10 percent range. We have found that crystallization generally requires conductivity to be less than 20 uS. Carbonic ions formed from carbon dioxide in the air causes difficulty only in the region below 3 uS. Ion exchange resins filling from 25 to 50 percent of the total volume are capable of lowering the conductivity enough to cause crystallization, given several days equilibration time. One must minimize concentration gradients in salt and ions to have a uniform crystal.

A cell to grow thin samples of colloidal crystals on a 300 nm period substrate is being constructed. This cell will permit the crystals grown to be studied either by light scattering or by observation under an optical microscope.