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FAR-~~INFRARED~~ AND THERMAL STUDIES

ON LOW-~~TEMPERATURE~~ MATERIALS, ~~###~~

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ABSTRACT:

The progress report herein will deal with our major progress in setting up and testing the facility for the modulation far infrared spectroscopy with a He^3 -cooled bolometer system. The important result on the heat capacity measurement of liquid crystals will be included also.

REPORT:

In the past one and one-half years two major research activities are supported by the grant DE-AC02-79ER-10461.A000 from the Department of Energy. The first project is the far infrared spectroscopy. We have finished a complete stability test of our Michelson interferometer using a room temperature Golay cell. A simple and reliable method to attach a pair of electric leads (0.001 in. diam. constantan wire) to a gadolinium doped-Ge chip ($1 \times 0.5 \times 0.25 \text{ mm}^3$) has been developed successfully in our laboratory. Minimum amount of indium was used to reduce the extra heat capacity contribution to the bolometers. Preliminary test indicates that they are high quality detectors. The test run on the lead film in the transmission mode gives us great confidence in the overall performance of the entire system with the detector being cooled to 0.45 K.

The temperature derivative of the electric conductivity measurements near the martensitic structural phase transition of V_3Si has been tried several times with various contact materials and cleaning processes. Thus far the contact noise is still too high to allow a high resolution measurement.

The second project in which we have been involved heavily in the past one year is the heat capacity measurement between smectic A (SmA) and smectic B (SmB) phase transition. Because of high resolution and versatility of our calorimeter, I was invited to carry out some collaboration work in Bell Laboratories last summer.

It is well known that some liquid crystal materials exhibit a layered structure with hexagonal in-plane ordering. This phase is referred to as a smectic B (SmB) phase. Two microscopically distinct types of SmB phases in different materials have been identified experimentally. The first type has a crystalline structure. X-ray measurements showed that this SmB phase has long-range, three dimensional (3D) positional order. This crystalline nature was confirmed by mechanical measurements which showed that this phase supports a shear both within and between its layers. The second type of SmB phase was first noticed by its lack of interlayer correlations. A detailed X-ray study demonstrated that the second SmB phase has only short-range in-plane positional order but long-range 3D six-fold bond-orientational order. The mechanical measurements established that the second SmB phase does not support an in-plane shear.

The possibility of a phase characterized by bond-orientational order was first discussed in the context of two-dimensional (2D) melting by Halperin and Nelson. A bond-orientationally ordered phase (a hexatic phase) was predicted to occur between the 2D solid and liquid if 2D melting was a dislocation-mediated phase transition. Subsequently, Birgeneau and Litster proposed a 3D liquid crystal phase which consisted of stacked, interacting 2D hexatic layers. Both structural and mechanical properties

of the second SmB phase are those expected for this 3D stacked hexatic phase. We, therefore, refer to the first type of SmB phase as a crystalline B and the second as a hexatic B. Both B phases can melt into a higher temperature SmA phase with fluid-like layers.

While efforts have been made to determine the microscopic pictures of these two distinct SmB phases, little attention has been paid to the nature of the phase transition between SmA and SmB. Our results clearly indicated that the crystalline B-SmA phase transition (in 40.8) is first order. On the contrary, the hexatic B-SmA transition (in 650BC) is a continuous one, with critical exponents $\alpha = \alpha' = 0.64 \pm 0.04$. These large measured-critical-exponents are inexplicable in the context of the two dimensional melting theory. To our knowledge the only model system which predicts a heat capacity exponent consistent with our results is the 2D four-state Potts model in which $\alpha = 2/3$. However, X-ray results rule out the possibility of a four-state Potts structure in favor of a local herringbone molecular orientational ordering. Although the existing theories cannot explain the important phase transition between the hexatic B and SmA phases, our results definitely will stimulate a lot of theoretical interest in this quasi-two-dimensional system. In our renewal proposal, we have proposed two more experiments, i.e. heat capacity measurements of the mixture systems and freely-suspended-film. These experiments should provide further insight of this continuous phase transition.

PUBLICATIONS:

1. A specific heat study of the nematic-smectic A transition in octyloxycyanobiphenyl, (with J. M. Viner), accepted for publication in Solid State Commun.
2. A heat capacity study of the stacked hexatic B-smectic A phase transition, (with J. M. Viner, R. Pindak and J. W. Goodby), submitted to Phys. Rev. Lett. for publication.
3. A high resolution ac calorimeter for liquid crystals, (with J. M. Viner), in preparation.
4. A heat capacity study of phase transitions in 4-(2'-methylbutyl)phenyl 4'-n-nonyloxybiphenyl-4-carboxylate, (with J. M. Viner, R. Pindak and J. W. Goodby), in preparation.