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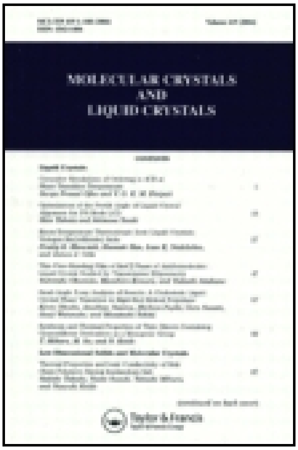

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Research Note: Measurement of the Interfacial Tension Between Nematic and Isotropic Phases of MBBA

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Research Note

Measurement of the Interfacial Tension Between Nematic and Isotropic Phases of MBBA

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The interfacial tension between nematic and isotropic phases of the liquid crystal material, MBBA, has been measured, using the sessile drop method. A value of 1.6×10^{-2} erg/cm^2 is obtained. This agrees well with a value that has been calculated theoretically by Sheng and Priestley.

When the isotropic phase of a thermotropic liquid crystal material is cooled through the nematic-isotropic transition temperature, T_c, the nematic liquid appears in the form of spherical droplets. This observation clearly shows the existence of a positive interfacial free energy or interfacial tension, γ_{N-I}. This is an important quantity in the Landau–de Gennes theory of the phase transition and in the theory of phase nucleation.[1,2] From data on elastic constants, Sheng and Priestley[2] calculated a value of 0.02 erg/cm^2 for γ_{N-I} in MBBA (*p*-methoxy-benzylidine, *p*-*n*-butyl-aniline). Two experimental values are available. Kahlweit and Oster[3] estimated a minimum value of γ_{N-I} of 5×10^{-4} erg/cm^2 for *p*-azoxyphenetole, based on observations of the oscillation of coagulating drops. The value for MBBA would not be identical but should be of the same order of magnitude. Langevin and Bouchiat,[4] working with MBBA, deduced, from the linewidth of laser light scattered from the interface, a value, $\gamma_{N-I} = 2.3 \times 10^{-2}$ erg/cm^2. Even though these results refer to two different materials they are probably too far apart for both to be correct. To clarify the experimental picture we measured γ_{N-I} for MBBA, using a different method that is more direct and has the advantage of relating more closely to the usual concept of interfacial tension.

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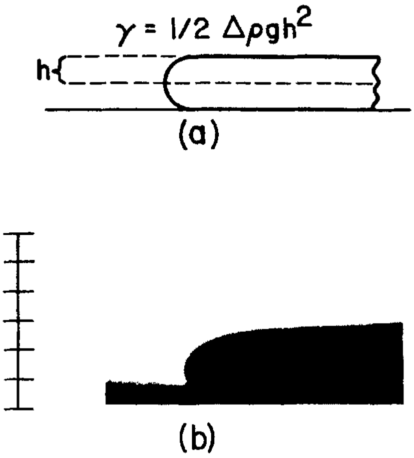

FIGURE 1 (a) Side view of a sessile drop showing the definition of h. (b) Photograph of the profile of one edge of a drop of nematic MBBA resting on a teflon surface and surrounded by isotropic liquid. The scale divisions are in mm.

The sessile drop method was used,[5] as illustrated in Figure 1(a). A drop, large enough to be flat on top, is placed on a horizontal surface of a material that it does not wet. The drop may be either in air or in another liquid with which it is immiscible. The surface or interfacial tension, γ, is related to the height, h, of the drop above the equatorial plane, the density difference, $\Delta\rho$, between the drop and the surrounding fluid, and the gravitational acceleration, g, by the expression:

$$\gamma = \Delta\rho(gh^2/2) \tag{1}$$

The magnitude of $\Delta\rho$ at T_c has been measured for MBBA by Press and Arrott.[6] They find $\Delta\rho = 1.9 \times 10^{-3}$ gm/cm^3. A measurement of h then will give us γ.

Photographs were made of large drops of nematic liquid resting on a smooth horizontal teflon surface under isotropic liquid. The teflon was in the form of a disk 2.5 cm in diameter. To contain the drop in the center of the disk a shallow depression was machined into the surface at the center. This was smaller than the drop size which was about 2 cm in diameter. The validity of the sessile drop method with this apparatus was verified by measuring interfacial tensions for the interfaces: benzene–water, ethyl acetate–water, and butyl alcohol–water. In all cases there was good agreement with previously reported values.[5] For the measurements with MBBA the teflon disk, in a small glass beaker, was covered with the liquid to a depth of about 2 cm. The beaker was mounted in a mineral-oil temperature bath and brought to a temperature such that the liquid just turned isotropic.

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The material used was from Eastman Kodak. Its N-L point was at 43° and its electrical resistivity was 1.5×10^{10} ohm-cm, indicating that there is no gross contamination from either ionic or non-ionic impurities. Because the interfacial free energy being measured is very low, one would not expect any serious effect due to the possible presence of trace contaminants. Effects due to trace contaminants are found mainly in liquids with high surface tensions, such as water or mercury. According to the Gibbs equation when an impurity lowers the surface tension the free energy gained serves to concentrate the impurity in the surface so that a trace contaminant has a large effect. When the interfacial free energy is very small to begin with, the free energy to be gained per particle by moving from the volume to the surface is small compared to kT. There is no driving force to concentrate molecules of a trace contaminant in the surface and it requires substantial contamination to alter the interfacial tension. With a fine-tipped medicine dropper a volume of liquid somewhat larger than that needed to form a drop was drawn up above the rest of the liquid, where it cooled slightly and turned nematic. The nematic liquid was then ejected slowly onto the top of the teflon disk to form a drop about 2 cm in diameter. The drop assumed its final shape within one second and then remained stable in shape. It would remain for about one minute, gradually disappearing as it melted into isotropic liquid. It was in stable mechanical equilibrium as required for the use of the sessile drop method. It was not, of course, in thermal equilibrium since it was slowly melting. Photographs of the drops were taken from the side, with back lighting, through a low power microscope. In this lighting the drop appears dark against the bright background of the surrounding isotropic liquid. Figure 1(b) shows the profile of one edge of a typical drop. The magnitude of h is measured directly from the photograph. For ten different drops, the mean value obtained was $h = 1.3 \pm 0.1$ mm. From this and equation (1) we get $\gamma_{N-I} = 1.6 \times 10^{-2}$ erg/cm^2. This confirms the theoretical value of Sheng and Priestley and the experimental value of Langevin and Bouchiat to within the expected limits of accuracy.

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