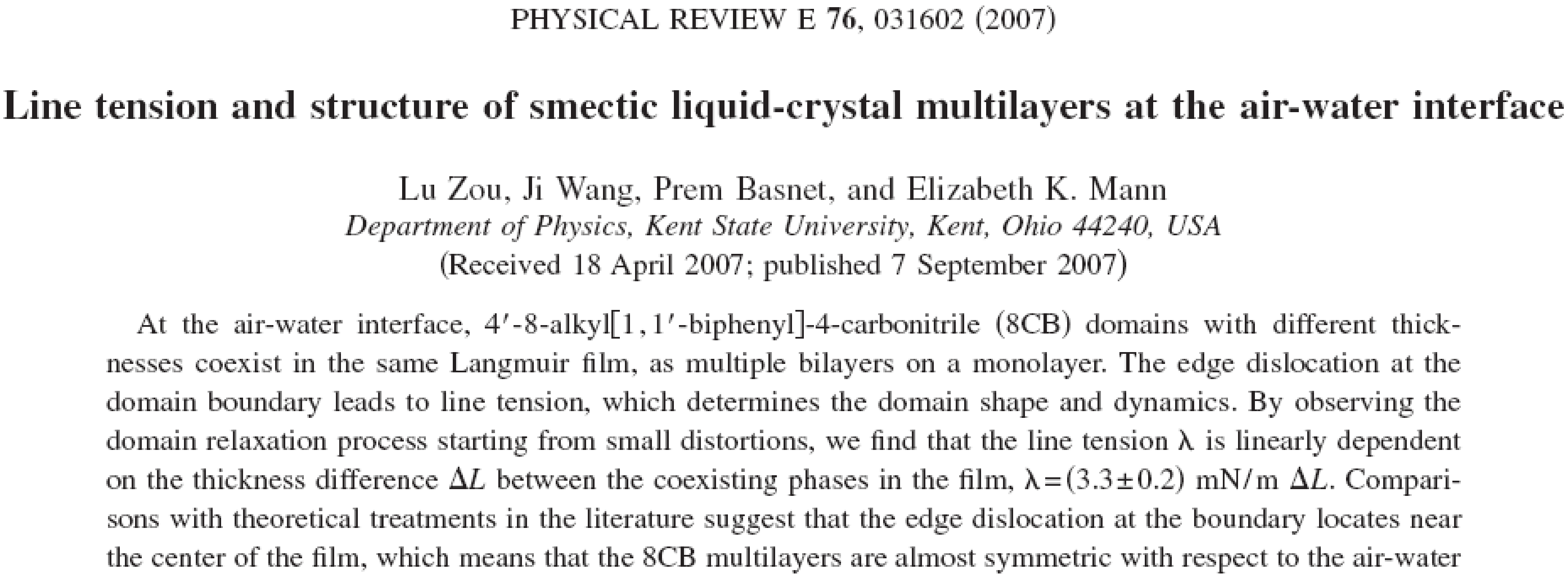

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Line tension and structure of smectic liquid-crystal multilayers at the air-water interface

Lu Zou, Ji Wang, Prem Basnet, and Elizabeth K. Mann
Department of Physics, Kent State University, Kent, Ohio 44240, USA

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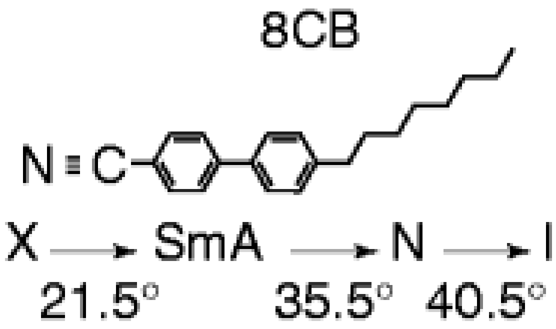
At the air-water interface, 4′-8-alkyl[1,1′-biphenyl]-4-carbonitrile (8CB) domains with different thicknesses coexist in the same Langmuir film, as multiple bilayers on a monolayer. The edge dislocation at the domain boundary leads to line tension, which determines the domain shape and dynamics. By observing the domain relaxation process starting from small distortions, we find that the line tension λ is linearly dependent on the thickness difference ΔL between the coexisting phases in the film, $\lambda = (3.3 \pm 0.2)$ mN/m ΔL. Comparisons with theoretical treatments in the literature suggest that the edge dislocation at the boundary locates near the center of the film, which means that the 8CB multilayers are almost symmetric with respect to the air-water

Seok, Sangjun

Line tension



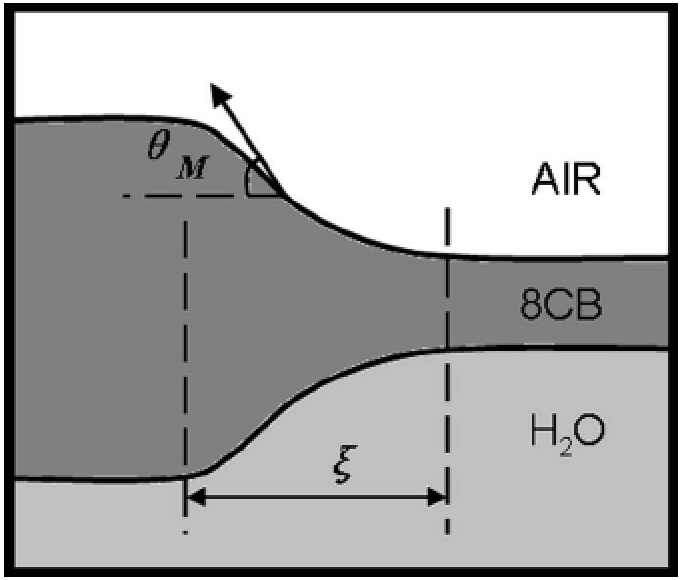


FIG. 5. Schematics of the profile of 8CB layer at the air-water interface. ξ is the dislocation width and θ_M is the maximum tilt angle on the boundary.

Line tension estimate

To estimate the line tension

the characteristic relaxation time of a deformation domain towards a circle

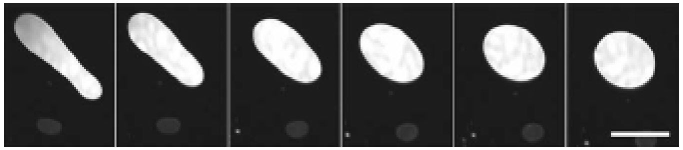


FIG. 1. Brewster angle microscope images of a relaxation process. The dark background is 8CB trilayer. The bright domains are 8CB multilayers with 12 bilayers on the top of the trilayer. The rippled variation in color within one domain is due to variations in illumination. The time interval between images is 1.0 s. The white bar corresponds to 1.0 mm. For the small distortion approximation, the first three images are not included in the data analysis.

Coexistence of domains with difference thickness

no sign of anisotropy

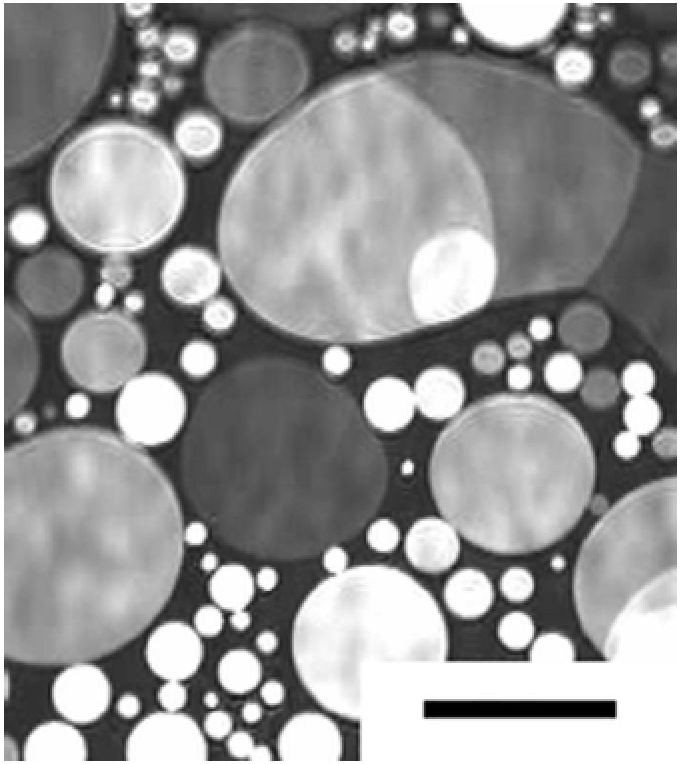


FIG. 2. Brewster angle microscope image of the coexistence of 8CB multilayers. The background is 8CB trilayer. The layer reflectivity increases with thickness, so that different grey levels correspond to different thicknesses. The rippled variation in color within one domain is due to variations in illumination. The black scale bar is 1.0 mm.

Formation isolated domains

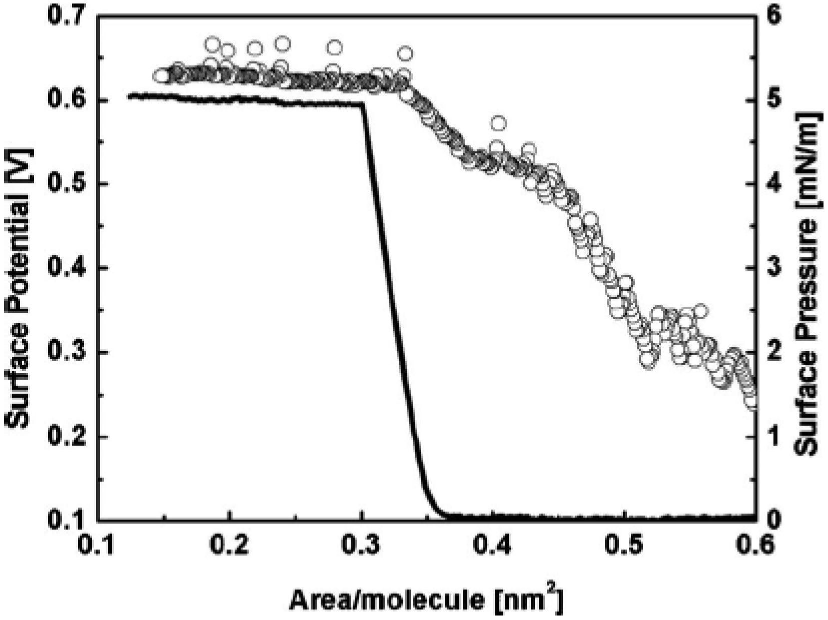


FIG. 3. Surface pressure and surface potential of 8CB area per molecule at the air-water interface. Solid line: surface sure; open circles: surface potential.

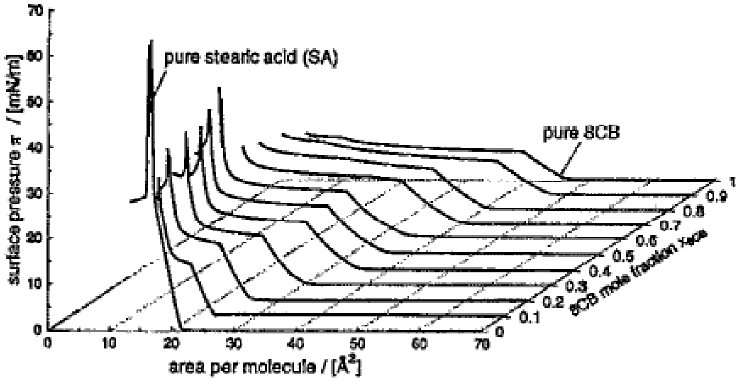


FIG. 3. Surface pressure isotherms at room temperature for pure and mixed Langmuir films of 8CB and stearic acid (SA) at different mole fractions.

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Formation isolated domains

(1) deposit the appropriate amount of 8CB-hexane solution on the water

(2) move the barriers at the compression rate ~ 100 mm/min (until the whole surface is covered by a trilayer)

(3) stop the barrier for ~ 5min and then move the back at ~10 mm/min (until the brighter domains disappear)

(4) stop the barrier when the trilayer is netlike on the top of monolayer (trilayer net relax)

(5) compress the 8CB film at ~ 10 min/min

Determining the line tension from the relaxation process

tip of a very thin, carefully cleaned, platinum wire (dia. = 1.3mm) to stir the film near the domain in order to stretch it.

whole relaxation process is recorded

to analyze the relaxation process, defines a distortion

$$\Theta = L/W - 1$$

where L and W are the length and the width of an elliptically deformed domain

Estimating the film thickness

$$R_m = \frac{I_m}{I_1} = \frac{G_0 - G_m}{G_0 - G_1}$$

monolayer and bilayer thickness as determined by X-ray reflectivity of 8CB on silicon wafer

$d_{\mathrm{mono}} = (1.2 \pm 0.1)$ nm, $d_{\mathrm{bi}} = (3.3 \pm 0.1)$ nm

Result

from small distortion, $\Theta \leq 1$

$$\Theta \propto \exp\left(-\frac{t}{T_c}\right)$$

The characteristic time T_c determined for the first order exponential decay fitting result of the plot Θ

dissipation in the surface can be neglected if $\eta_s \ll \eta_b R_c$

$$\eta_{8CB} = \eta_{water} < 10^2$$

The thickness D of the 8CB film is < 3×10^{-8} m

$$\eta_s = \eta_b \sim \eta_{8CB} D / \eta_{water} < 10^{-6} m$$

$$R_c \sim 10^{-4} m$$

$$\therefore T_c = \frac{5\pi}{16} \frac{\eta_b R^2}{\lambda}$$

where λ is the line tension of the domain and R is the radius of the round domain after relaxation

Result

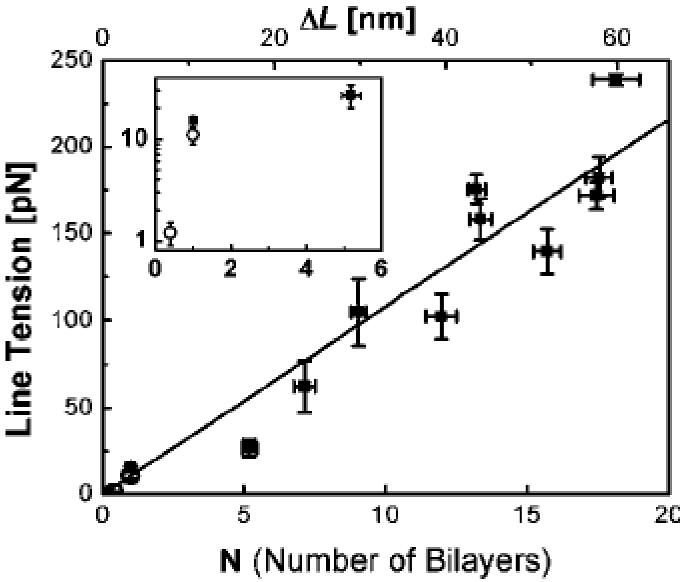


FIG. 4. Plot of line tension vs thickness jump in number of bilayers and nanometers. Empty circles are from Lauger *et al.* [11].

the 8CB monolayer and the 8CB bilayer on the top of the monolayer as λ =(1.2±0.3)x10^{-12} N and λ = (1.1±0.2)x10^{-11} N, respectively

λ/ΔL = (3.3±0.2) mN at fig.4

Discussion and Conclusion

the equilibrium position of the edge dislocation inside a general film with two different system

$$t = z_0 / D = \frac{1}{1+Q} \quad \text{with} \quad Q = \left(\frac{A_1}{A_2} \right)^{2/3}$$

D is the thickness of the film and $z_0 = 0$ is at the film-water interface.

$$A = \left(\frac{\gamma - \sqrt{\kappa B}}{\gamma + \sqrt{\kappa B}} \right)$$

γ is surface tension, κ is the curvature constant, and B is the elastic modulus of the layers. The subscripts 1 and 2 correspond to the air-film and the film-water interface

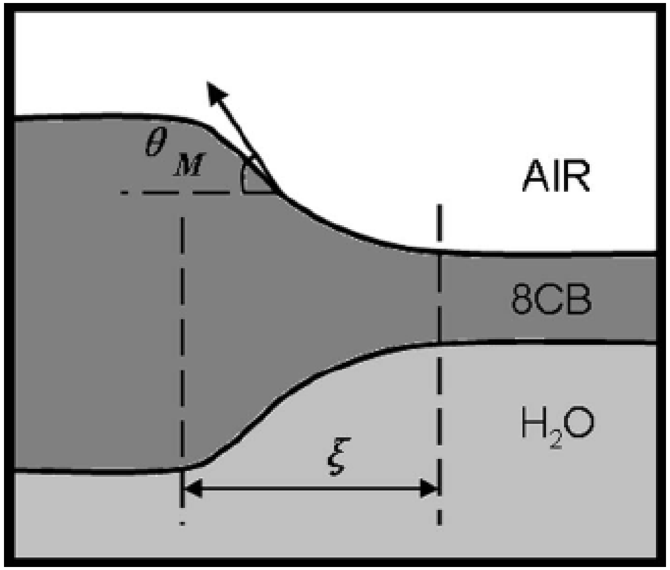
Discussion and Conclusion

For 8CB layers, $\kappa=(5.2\pm0.3)\text{x}10^{-12}$ N, B = $1.63\text{x}10^{7}$ N/m^2 at 18 °C, and γ_1 = 28.46 mN/m

considering the surface energy per unit area, $\gamma = \gamma_1 + \gamma_2 + U$

$\gamma = \gamma_{\text{water}} - \pi \sim 66$ mN/m, ignoring U, $\gamma_2 \sim 38$ mN/m

$A_1 = 0.51$ and $A_2 = 0.61$, $t = 0.53$



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