THEORY OF CURVATURE-DEPENDENT DISJOINING PRESSURE AND ITS APPLICATION TO LIQUID FILMS

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ABSTRACT

When a liquid film thickness is less than 100nm, thin-film forces become prominent. These forces are collectively called disjoining pressure $\Pi$ at the continuum level. Since $\Pi$ becomes dominant at small film thickness, it governs the stability and wettability of thin films. Because of the important role of thin films in many biological and industrial processes, it is crucial to model $\Pi$ accurately. Current theories suggest that $\Pi = \Pi(h)$ [1] or $\Pi = \Pi(h, h_x, h_{xx})$ [2,3], where $h$ is the film height, $h_x$ and $h_{xx}$ are the slope and curvature of the film. The limitation of $\Pi = \Pi(h)$ is that $\Pi$ is unbounded when $h \to 0$, which makes it inapplicable to contact line problems. The second theory [2][3] only considered the slope effect even though the resulting $\Pi$ also depends on $h_{xx}$. Therefore, it is unclear whether all the curvature effects have been captured. We present a new theory of $\Pi$ that includes the curvature effect. We find that the curvature terms are different from the previous expression. However, the slope and height dependent terms remain the same. We apply the new theory to Lennard-Jones liquid films. The new $\Pi$ is bounded near the contact line as $h \to 0$, showing that the original singularity is artificial. We incorporate the new $\Pi$ to solve equilibrium drop and film profiles. We find a set of equilibrium shapes (parabola, periodic, and pancake), depending on the dimensionless parameters $C$ and $R_\xi^{10}$, as shown in Fig. 1. Some of the shapes are plotted in Fig. 2-5. We also study the linear stability of these shapes.
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REFERENCES