Harvey Mudd College
Mathematics

Senior Thesis
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Research Proposal: Inter-Phase Line Tension in Langmuir Films

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1 Introduction

A Langmuir film is a molecularly thin film on the surface of a fluid. The study of the evolution of a Langmuir fluid with two co-existing fluid phases is of particular interest because it allows us to extract physical parameters from experimental data that would otherwise not be observable. Relaxation in the Langmuir layers is driven by the inter-phase line tension and in some cases by electrostatic forces in the Langmuir layer. For many Langmuir fluids the molecules can be modelled as dipoles where the negatively charged end is hydrophilic and sticks to the surface of the subfluid and the positive end is hydrophobic which attempts to get as far from the subfluid as possible. These intermolecular forces can be deduced by integrating over all the dipole-dipole interactions in the Langmuir layer.

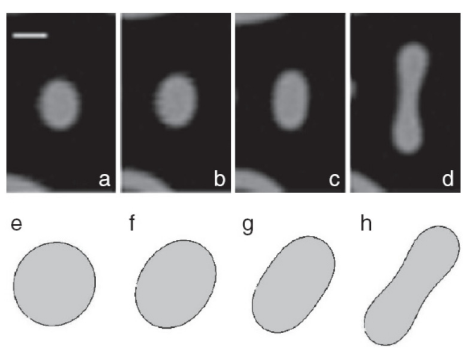

Figure 1: The electrostatic forces due to the dipoles favor distorted shapes, whereas the line tension between the two phases favors a circular domain. When the long-range dipole forces exceed the line tension force the circular domain deforms into a dogbone shape. These images from experiments and simulations preformed by Heinig [3] illustrate this circle-to-dogbone transition.

Experimentally, these dipole-dipole interactions are associated with interesting dynamics. For example, a circular patch may elongate into a dogbone shape or even deform further into a labyrinthine pattern consisting of many long finger-like domains. Our goal is to model these transitions theoretically and numerically.

2 Proposed Research

In [1, 4], Wintersmith et. al studied the evolution of a Langmuir fluid driven by an inter-phase line tension and damped by the viscous drag of the underlying subfluid. They used a boundary-integral method where the domain boundary was represented pseudospectrally as a Fourier series and the evolution could be described in terms of the evolution of the Fourier amplitudes. Wintersmith et. al worked in the case where the electrostatic effects were negligible. I propose to extend their work by taking into consideration electrostatic forces. Heinig et al. [3] have developed an explicit model for this problem. They ran simulations and observed the dogbone and labyrinth patterns, but their numerics experienced significant area loss. Using the methods developed in [1, 4], I hope to achieve much higher precision.

3 Prior Research

I have taken Applied Analysis (M180), and I will be working on the problem during the spring semester.

References

[1] Alexander, J. C., A. J. Bernoff, E. K. Mann, J. A. Mann Jr., J. R. Wintersmith, and L. Zou. *Domain relaxation in Langmuir films*, Journal of Fluid Mechanics, 571 (2007) pp. 191-219.

[2] de Koker, R. and H. M. McConnell. *Circle to Dogbone: Shapes and Shape Transitions of Lipid Monolayer Domains*, Journal of Physical Chemistry 97 (1993) pp. 13419-13424.

[3] Heinig, P., L. E. Helseth, and T. M. Fisher. *Relaxation of patterns in 2D mdoulated phases*, New Journal of Physics, 6 (2004) pp. 189.

[4] Wintersmith, J. R., L. Zuo, A. Bernoff, J. C. Alexander, J. A. Mann, Jr., E. E. Kooijman, and E K. Mann. *Determination of Inter-Phase Line Tension in Langmuir Films*, Preprint. 19 Feb. 2007.