Instabilities of Droplets Spreading on Gels

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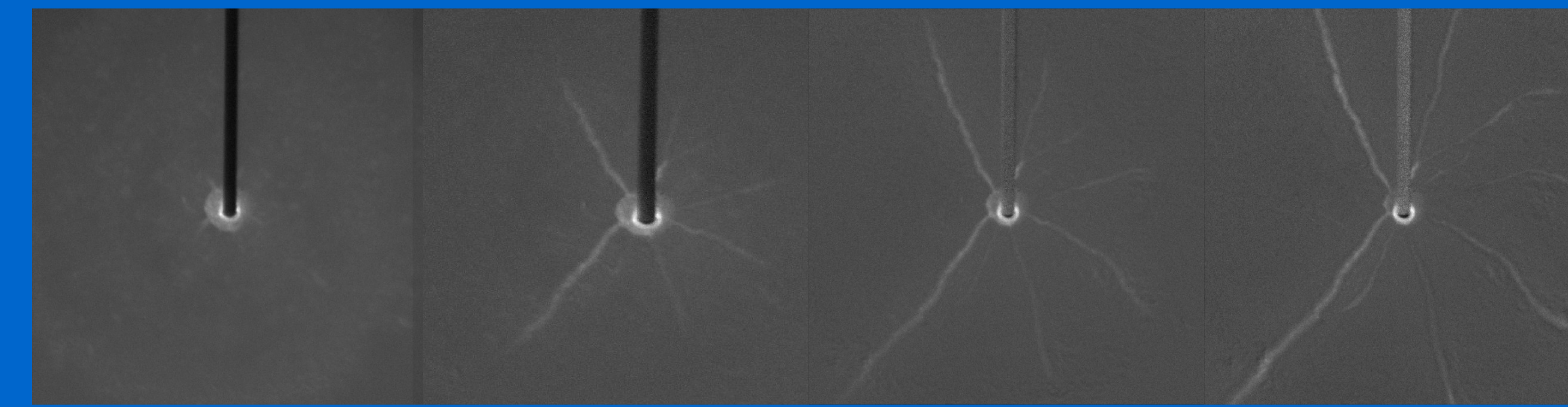


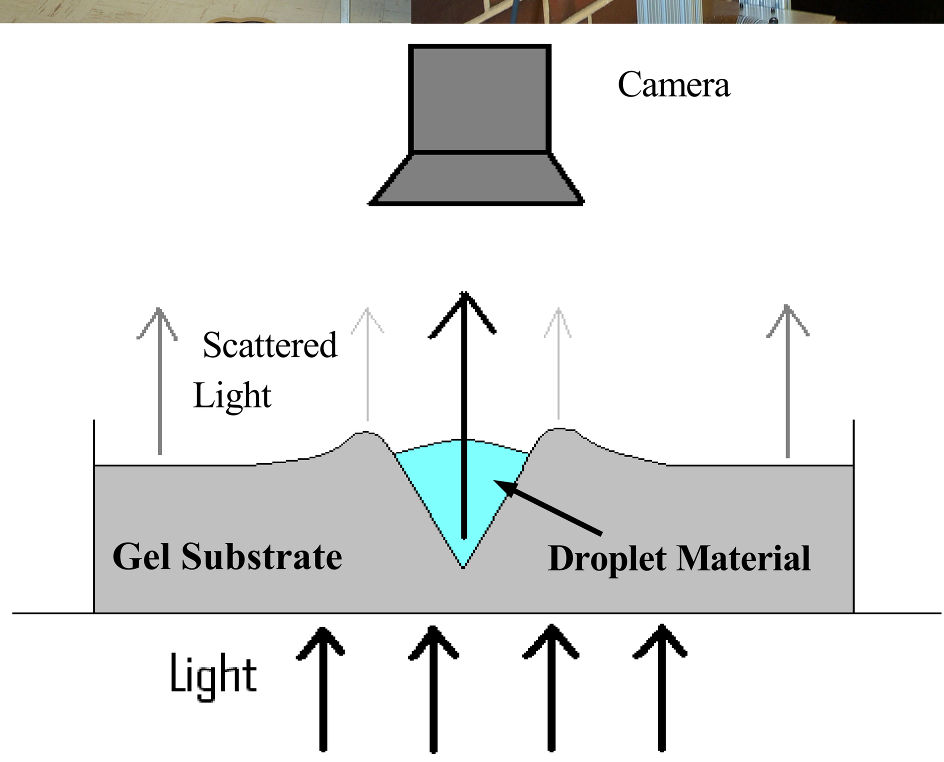
Abstract

The spreading of a droplet of one simple fluid over another is well understood. For example, a drop of oil on water will spread in a circular pattern. Alternatively, when the substrate is a complex fluid, like a gel, a droplet of another fluid spreading along the gel's surface will instead form arms, provided that the surface tension of the drop is significantly larger than that of the gel. We show this pattern to be a result of fracturing of the gel's macromolecular network at the surface. By utilizing light scattering through gels containing one micron polystyrene beads, we can quantitatively determine the cross sectional shape of the arms. We investigate how the depth and width of these arms change, both over time and for different strength gels. This data will be used to form mathematical models of these interactions.

Objectives

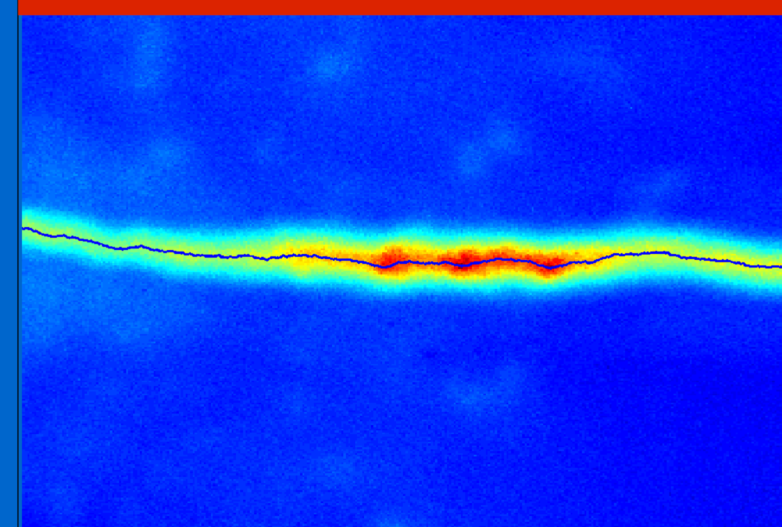
- Research intended to develop methods for determining depths and widths for the arm growth instabilities
- Using these methods, investigations performed to determine how arm depths and widths change over time, as well as how gel strength influences these depths and widths
- Results will be used to provide a better understanding of ongoing problems in several industrial and biomedical fields

Experimental Set-up



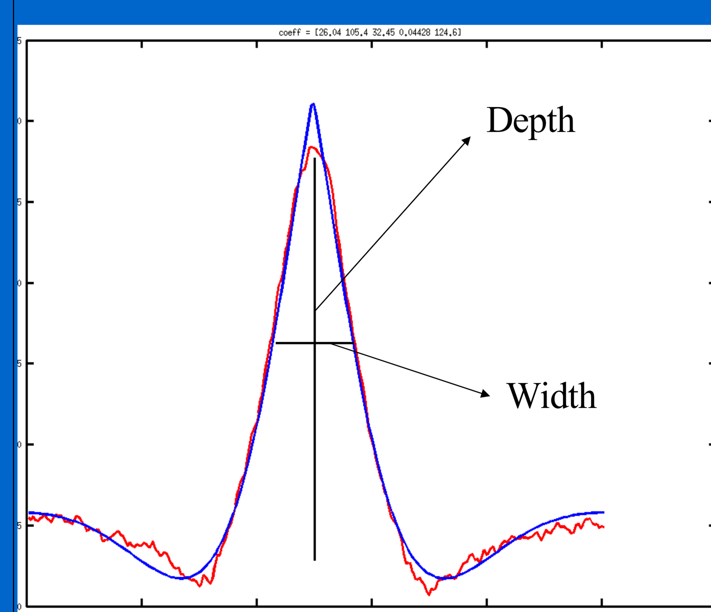
- Gels of varying concentrations of Agar, water, and 0.04% by weight one micron polystyrene beads are allowed to set.
- The set-up consists of (from bottom to top) a light source, a collimating lens, a smoked glass diffusion plate, the gel being imaged, a dropper apparatus, and a computer-operated digital camera.
- Both image processing and calculations are done within MATLAB 7.0.

Arm Tracking and Width Determination



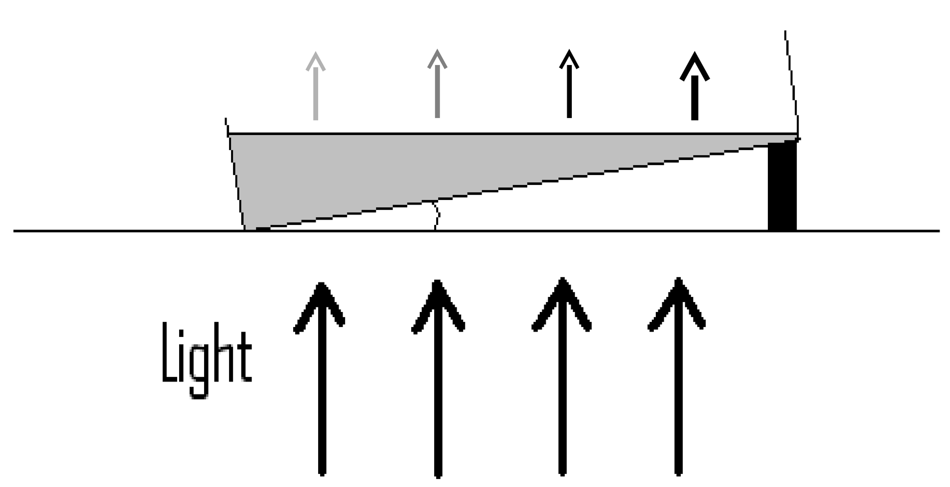
- Images of arms created using 30 microliter drops of 300 parts per million Triton X-305 in distilled water.
- Images cropped to show a single arm (shown at left).
- A program written to process these images performs a division of the single arm image and an image of the same region of gel prior to the arm's formation, leaving only the differences between these images.
- Arm tracked by finding the location with maximum intensity in each column of the pixel matrix.
- These position values are used as the initial estimate for *a* in the function below.

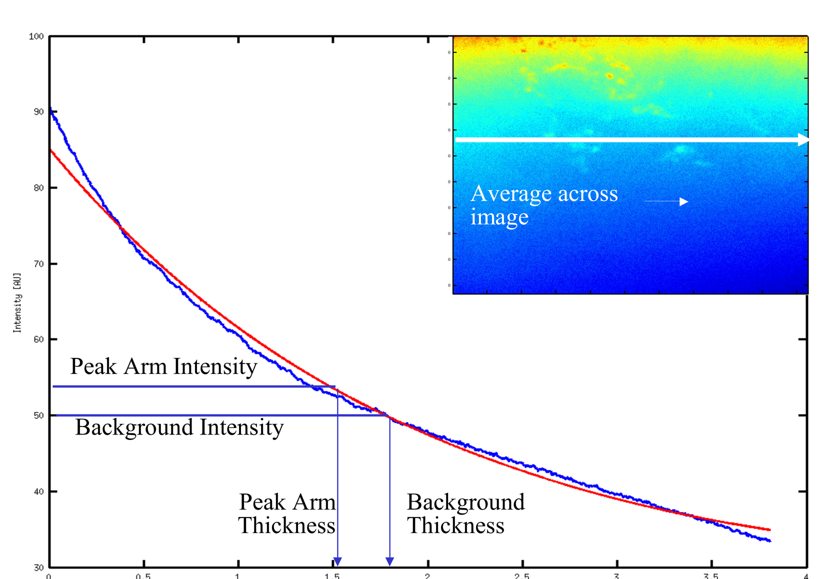
$$Intensity = Ae^{|(x-a)/x_o|}\cos(k|x-a|)+B$$



- Arm width determined using full width-half height method.
- Function shown above is fit to a five column average of the intensities as shown. This is done to prevent the inclusion of noise away from the arm during the determination.
- The processing program then counts the number of values within the fitted function that are greater than the average of the background and peak intensities.
- These values equate to pixels directly, and are easily converted to millimeters using an image of a metric ruler taken previously.

Depth – Intensity Calibration

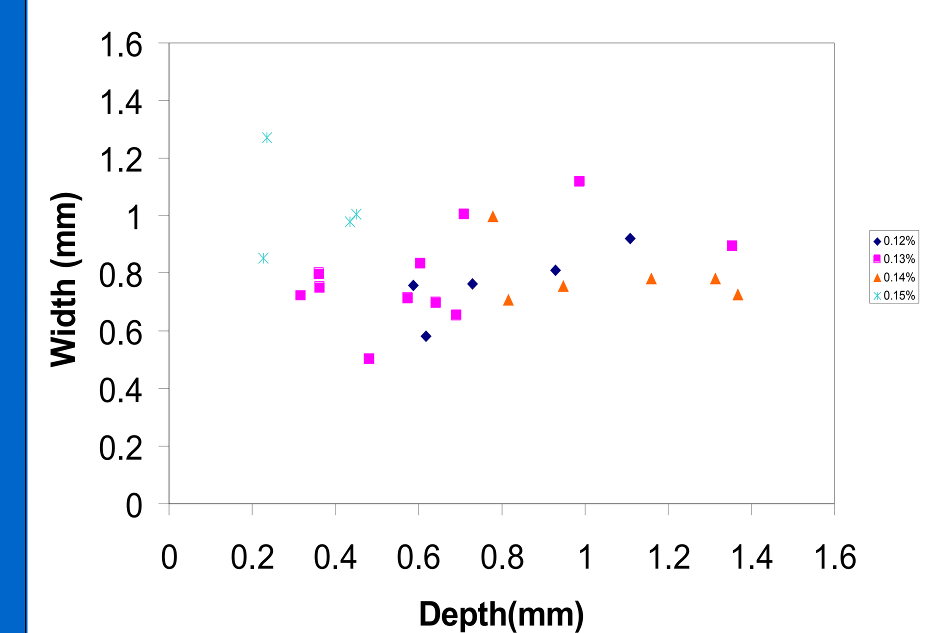


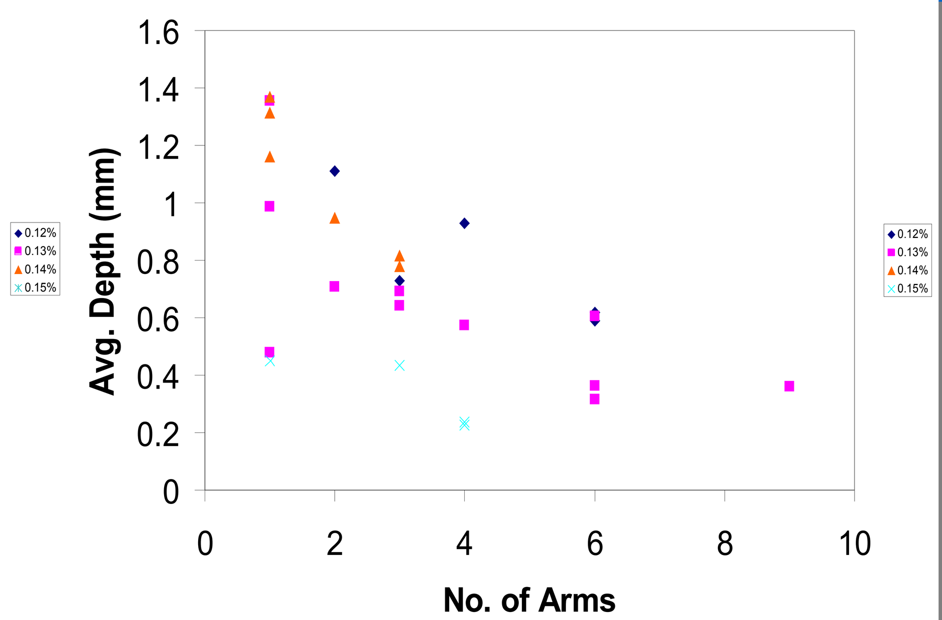


Background Thickness – Peak Arm Thickness = Actual Arm Depth (mm)

- Comparing the peak arm intensity and the intensity from the background image determines depth of an arm
- A gel is set in a square dish angled to a known degree as shown to create intensity gradient
- Light intensity gradient averaged as shown in insert
- A second order exponential function fit to data and resulting equation solved solved for independent variable (thickness)
- Intensities from the locations determined on the arm and the background image used as inputs to the solved equation resulting in two thicknesses of gel
- These thicknesses can then be subtracted to reveal the total depth of the arm

Arms In Varying Gel Concentrations

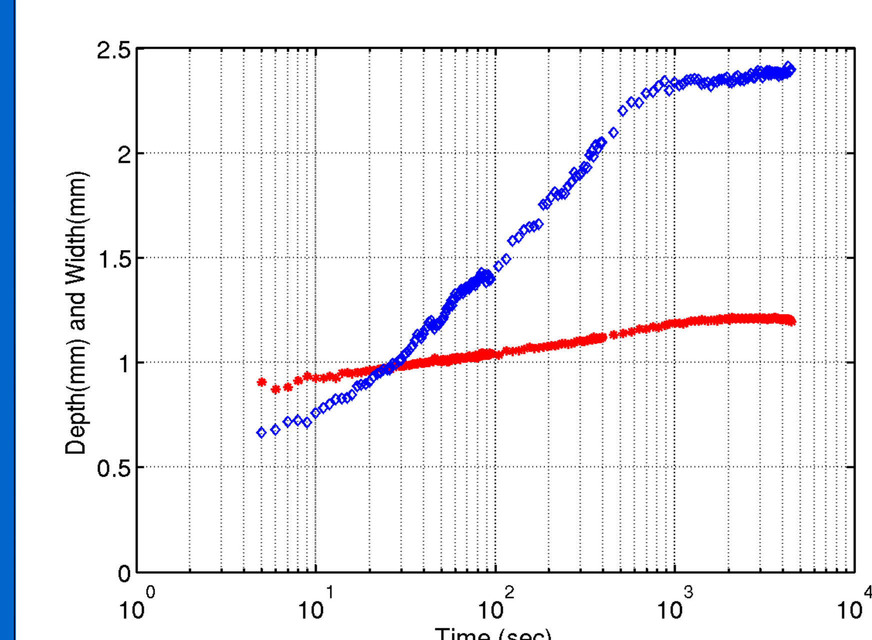




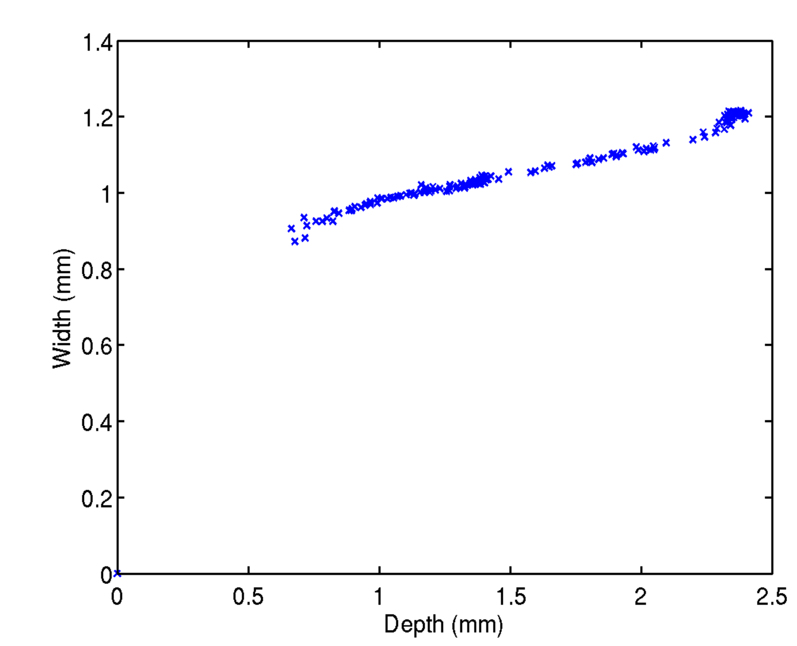
Percentages are concentrations of Agar by weight within the gel and correspond to gel strength directly.

Each data point represents the average for all arms formed by one drop of Triton.

Arms In Time



Plot of Depth (blue diamonds) and Width (red stars) over time



Plot of Width as a function of Depth

Graphs represent the average depth and width of one arm imaged between five and 4500 seconds after formation.

Conclusions

- For a single droplet, average arm depth and number of arms formed are inversely related (conservation of mass)
- Arm depths and gel strengths are negatively correlated
- For both individual arm growths and drop averaged arms, arm depth and width are correlated
- Individual arms grow in depth (and, to a lesser extent, in width) as they age

Acknowledgments

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Department of Physics at North Carolina State University

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