Organization: SRI International

MTO Simbiosys

Title: Modeling and Experimental Study of Optical Microfluidics

Start Date: July 2001 **End Date:** July 2003

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Project Goals

A compelling need currently exists for rapid and inexpensive methods of detecting pathogens, diagnosing and prognosticating disease, developing new drugs, and performing genetic analysis. To meet these needs for processing large numbers of samples at high speed (high throughput), considerable interest has been placed on microfluidic devices. Current approaches to microfluidics have undesirable limitations, including challenges in scaling, difficulty in reconfiguring assays, poor efficiency in sample use, poor interface between the macro- and microenvironments, and considerable complexity of circuitry on the substrate. Our goal is to develop a new approach to microfluidics that uses optical control to significantly increase efficiency and flexibility while reducing costs.

Technical Approach

We are developing a new approach to microfluidics that is very powerful yet simple and robust—using light to control droplet motion. In this way, the complexity of fluid transport is removed from the substrate, allowing low cost substrates, random access, reconfiguration of assays on the fly, scalability, efficient use of samples and reagents, compact systems, high speed, and format flexibility between droplet dispensing and wells. The proposed work will involve synergistic and complementary interactions between modeling and experiment, with modeling helping guide potential experiments and experiments validating and enhancing the modeling. Both modeling and experimental efforts will increase our understanding of microfluidics based on optical control as well as the broader subject of the fundamentals of microfluidic transport phenomena.

Recent Accomplishments

- Assembled breadboard experimental apparatus based on an inverted microscope equipped with appropriate mirrors and filters for introducing the control laser beam.
- Assembled system for droplet preparation based on a medical nebulizer filled with the solution to be aerosolized and connected to a compressed gas supply.
- Prepared hydrophobic surfaces using a variety of silane and fluorosilane coatings.
- Prepared superhydrophobic surfaces based on low surface energy coatings on textured surfaces. The best performance was obtained using fluorosilane coating on a textured surface prepared by subliming aluminum acetylacetonate from a mixture of Boehmite and aluminum acetylacetonate.
- Moved droplets contained in liposomes surrounded by water using optical control.
- Selected Flow-3D software as starting point for simulation because of its capabilities for droplet modeling, heat transfer and phase change, and for inclusion of user-defined forces.
- Begun simulations of droplet motion on hydrophobic and hydrophilic surfaces.
- Developed a ray tracing model for describing optical forces on droplets including influence of refractive index, focusing cone angle, and relative positions of droplet center and beam focus.

Six-Month Milestones

- Improve superhydrophobic surfaces and minimize contact angle hysteresis.
- Demonstrate motion of droplets in air on a superhydrophobic surface.
- Complete modeling of basic droplet motion.
- Develop simple design correlations and phenomenological models for the droplet transport process.

Team Member Organizations

N/A

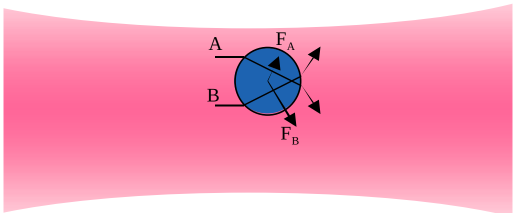

Fig. 1. Forces on droplet in focused laser beam.

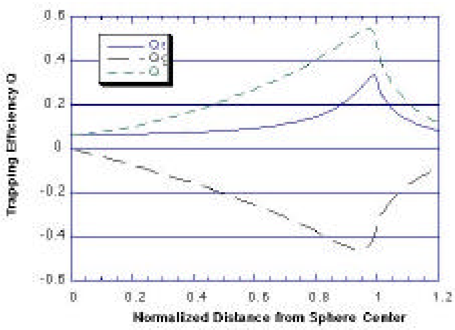

Fig. 2. Transverse force on a droplet in air exerted by a focused laser beam.

Fig. 3. Droplet on superhydrophobic surface.

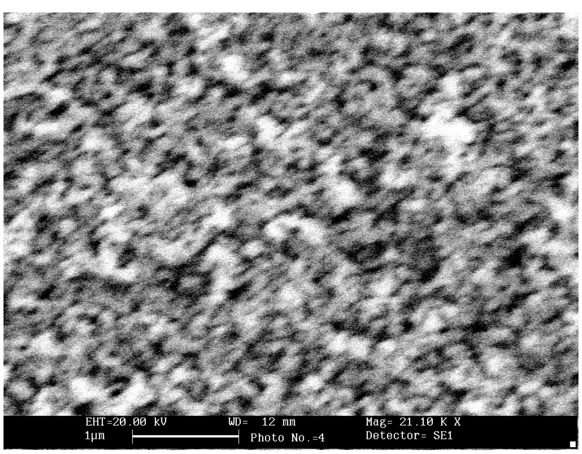

Fig. 4. Scanning electron micrograph of textured superhydrophobic surface. Bar is 1 µm.

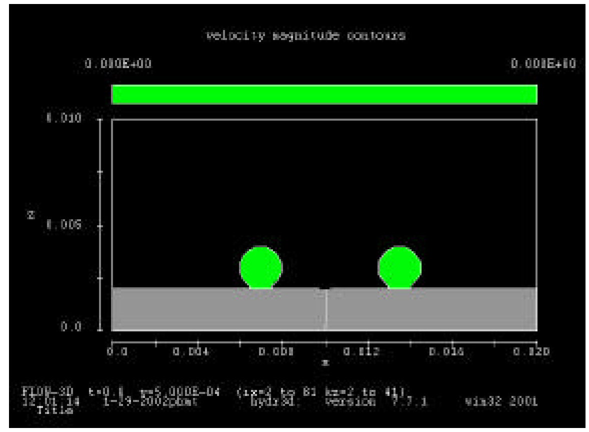

Fig. 5. Start of simulation: two droplets just touching surface.

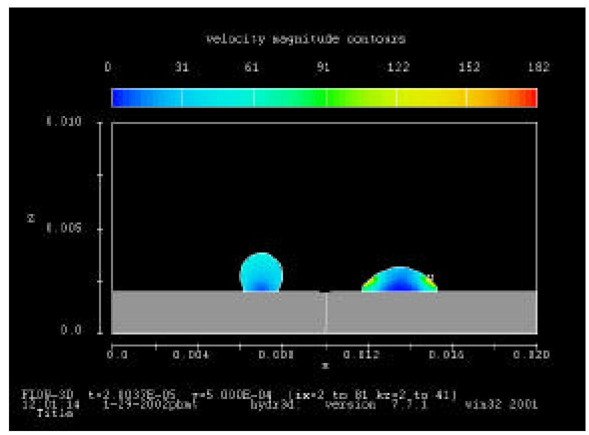

Fig. 6. Later in simulation: droplets now touching hydrophobic (left) and hydrophilic (right) surfaces.

Fig. 7. Breadboard system for optical microfluidics