Organization: Northwestern University

Title: Innovative On-Chip Biomolecules Transport & Transduction Systems: Integrated Simulations and Experiments

MTO **Simbiosys**

Start Date: July 2001 **End Date:** June 2004

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Project Goals

The goal of this project is to develop system level models and experimental processes for the design of an on-chip microdroplet-based transport used in DNA analysis system. Surface-tension and wettability is used to accomplish droplet moving, cutting, and enhanced mixing. The wettability is controlled by pure mechanical surface roughness, which is free from electrical or thermal interaction with bio-fluids. The System level goal is to demonstrate highly portable droplet-based PCR (Polymerase Chain Reaction). Component level goals are to develop droplet handling technology and enhance VOF methodology for wettability and thermo/flow simulation. Modeling and simulation, which provide the design parameters, are essential to achieve our goals.

Technical Approach

This project includes simulation, modeling and experiment. Modeling and simulation will provide design parameters for proper droplet handling, such as shape, dimension, and configuration of roughness structures. The controlled wettability-driven flow behavior is modeled. Thermofluid model is incorporated to simulate PCR process. For the experiment and demonstration, fundamental experiments are necessary to study the behavior of roughened surface. The dynamic surface roughness control mechanism is fabricated and tested. We will do experiments to observe the droplet moving, cutting and mixing, which will be used for PCR demonstration.

Recent Accomplishments

- Roughness induced contact angle variation simulation and measurement
- Droplet motion across different wettability (contact angle) region
- Solving major technical issues for dynamic roughness control hardware fabrication
- Completion of the dynamic contact angle coding (due to droplet motion)
- Work initiated on coding the anisotropic contact angle treatment

Six-Month Milestones

- Fundamental Analysis and Experiment
- Roughened surface with different shapes, sizes, and configurations
- Experiment matched to simulation
- Effective surface pattern designed by simulation
  - Hardware for dynamic control
- Contact angle measurement on actuated surface
- Provides realistic conditions for modeling
- Microdroplet motion experiments: separation and jointing demonstration
- Mixing experiment

Team Member Organizations

CFDRC Research Corporation

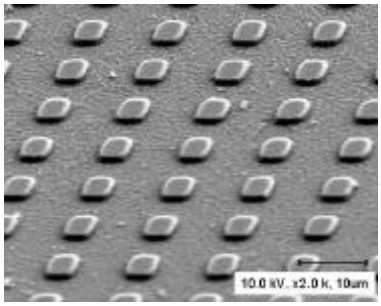


Fig. 1 Micromachined rough surface etching depth ~ 1μm

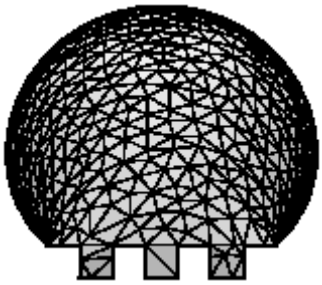
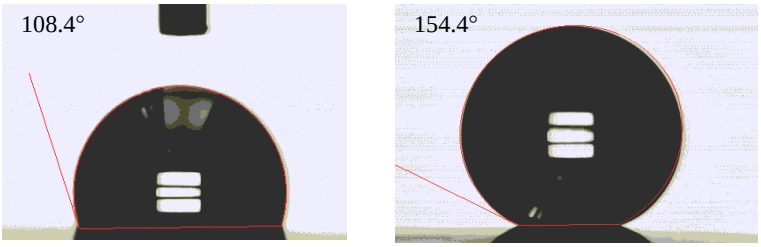


Fig. 2 Simulation of equilibrium droplet shape on roughened surface



Flat surface Roughened surface

Fig. 3 Hydrophobicity amplification due to surface roughness (Au –SAM coated surface)

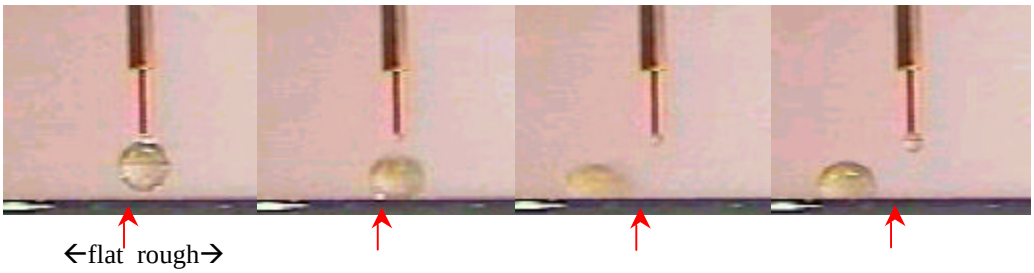


Fig. 4 Droplet motion due to wettability difference between flat and roughened surface

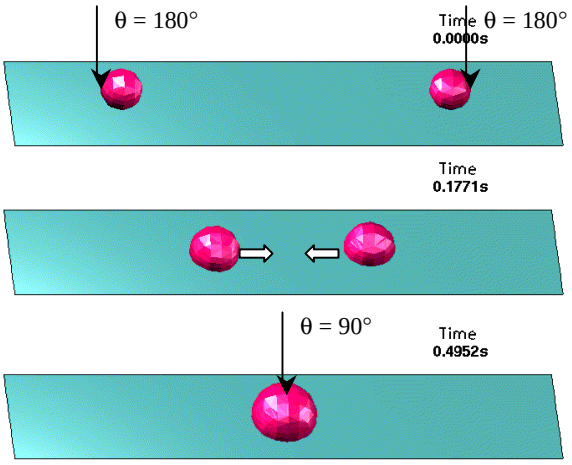


Fig. 5 Droplet motion simulation due to contact angle difference

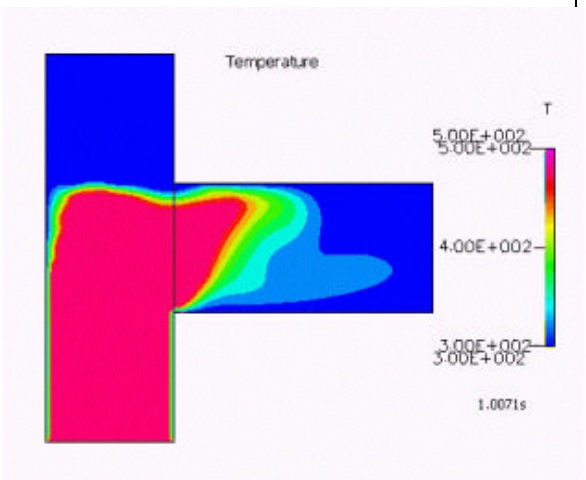


Fig. 6 Capability of VOF + mixing + heat transfer used in a simple demonstration solution