MODELING SURFACE TENSION UNDER APPLIED FIELDS: ENERGY METHODS, STOKES FLOW, AND LEVEL SETS

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Surface tension is one of the dominant forces on the micro scale. Moreover, surface tension can be exploited to precisely control flows in MEMS devices. For instance, one can shape micro fluidic components in such a way that surface tension will cause a micro fluidic network to fill in a desired order. This enables passive (no moving parts) control of flow in micro fluidic networks (as demonstrated by Nanostream Inc.). Conversely, applying varying electric fields can change surface tension properties locally causing droplets to move, split, merge, and mix. (This type of active electrowetting control has been demonstrated by CJ Kim at UCLA and by Fair at Duke.)

In this talk I will discuss our efforts to model surface tension effects, and especially will show how these efforts are aimed at system design, optimization, and control. Energy methods will be used to solve the quasi-steady passive filling problem efficiently. Instead of simulations that takes hours *per component*, we can now simulate networks with thousands of components in seconds. Likewise, the equilibrium electro-wetting problem can be phrased as a minimal energy problem. By precisely solving for the electric fields inside the liquid, and by including loss-mechanisms such as liquid resistance, we have been able to accurately predict the electrowetting data we see in the UCLA devices, including contact angle saturation. To address droplet dynamics, including droplet motion, splitting, and merging, it is necessary to include fluid viscous forces. Our current models combine the low Reynolds Stokes fluid equations together with a level set formulation which tracks the liquid/gas interfaces. We will present results for this family of models, will show some current limitations (such as the dependence of the split time on the mesh density), and will suggest future research needs.

I will close the talk by discussing what kind of models are necessary for effective design, optimization, and control; and I will outline our efforts in that direction.