Abstract

The work explores new strategies for enhancing micro-flows through the application of thermal and electrical effects and also the effects of the presence of nanoparticles. The work is broadly divided into three major parts namely, i) thermally enhanced self-propelled droplet motion on gradient surfaces, ii) electrically induced droplet oscillation for microcooling and, iii) enhanced spreading of nanoparticle laden electrowetted thin liquid films. The first part investigates the effect of temperature on enhancing the movement of water droplet on chemical energy induced gradient surfaces; both experimentally and using molecular dynamic simulations. The solution of the proposed model for droplet motion clearly indicates the dominance of the three-phase contact line friction force and a decrease in the contact line friction co-efficient with temperature leading to faster droplet movement. As the contact line friction is molecular in nature, a molecular dynamic simulation is performed. Investigations of the molecular movement near the three phase contact line clearly corroborate the experimentally observed trends with additional physical insights to the process. The second part of the study demonstrates the augmented heat removal capability of an oscillating (induced by a pulsating DC field) droplet from a hot-spot. Rapid and reversible periodic change in the shape of the droplet is observed due to the cyclic electrowetting and dewetting of a droplet in an electrowetting on dielectric (EWOD) setup. The final part of the study deals with the effect of nanoparticles during the eletrowetting of ultrathin, extended, curved liquid menisci. Significant increase in the electric field induced spreading and the contact line velocity is observed with the addition of negatively charged nanoparticles. The effect of polarity, particle size and concentration on the contact line dynamics are reported. The solution of a proposed model based on the augmented Young-Laplace equation provides additional insights to the physics of the process and the model predicted results are successfully compared with the experiments.

Keywords: Gradient surfaces, Contact line friction, Molecular dynamic simulation, Electrowetting on dielectric, Droplet oscillation, Micro-cooling, Extended meniscus, Contact line dynamics, Nanoparticles.