LadHyX/LMS Seminar -- March 23rd, 10:45 -- Room Jean Mandel (LMS)

Electrohydrodynamics in Additive Manufacturing, Coating and Painting: Experiments and Theory

A. L. Yarin

University of Illinois at Chicago

The talk will cover the following six inter-related topics:

(i) *Drop manipulation by electrowetting for 3D printing.* The feasibility and effectiveness of electrowetting in motion control of drops of different liquids in 3D printing processes is demonstrated and explored. To control the movement of ink drops on dielectric substrates, the electrodes are embedded in the substrate. It is demonstrated that drops of different liquids can be moved on horizontal, vertical and even inverted substrates.

(ii) *Electrostatic forces: elucidation and advancements for 3D printing application*. The employment of Coulomb force acting on the ionic-conductor drops, which results from a strategically applied electric field holds a great promise to enhance 3D printing systems. This reveals novel solutions to problematic printing applications, namely, 3D printing within confinements.

(iii) *Electrostatically-assisted Direct Ink Writing for additive manufacturing*. While nozzle-based printing is already arguably versatile, such sub-categories as Direct Ink Writing (DIW) find difficultly when printing material on rough surfaces, increasing the writing speed and improving resolution Here, we introduce an additional electrode added to the printhead generating an electric field between this electrode and printing nozzle. The resulting Coulomb force pulls the extruded ink jet in the direction of printing allowing for a 100X faster translational speed, thinner trace widths, and a dramatically improved deposition on rough surfaces. An electrohydrodynamic theory of the proposed DIW processes is developed and compared to the experimental results.

(iv) *Coalescence of sessile droplets driven by electric field in the jetting-based 3D printing*. Here we investigate the effectiveness of a Coulomb force created by charged electrodes placed either below the substrate or on the printhead. From the physical point of view, the phenomenon of dynamic electrowetting-on-dielectric (DEWOD) is used. It is demonstrated that sessile droplets, placed initially separately with little chance of natural coalescence, can be selectively coerced by the added electric field into the electrically-enhanced forced coalescence. Reduction in raw material use, droplet-into-line coalescence, the first-approximation potential to merge 2D droplet arrays into films are demonstrated.

(v) *Evolution and shape of two-dimensional Stokesian drops under the action of surface tension and electric field: linear and nonlinear theory and experiment*. An analytical linearized creeping-flow theory describing evolution and steady-state shape of two-dimensional ionic-conductor drops under the action of surface tension and the sub-critical (in terms of the electric Bond number) electric field imposed in the substrate plane is developed. In steady-state the drop shape is determined by a pointwise balance of the Maxwell stresses and surface tension. The range of validity of the linearized theory is established by comparison with the nonlinear numerical results and the acquired experimental data.

(vi) *Metamorphosis of trilobite-like drops on a surface: electrically-driven fingering.* The experimental evidence in super-critical electric field (in terms of the electric Bond number) reveals that the Maxwell stresses become dominant and not only stretch the drop as a whole, but also trigger growth of multiple fingers crawling towards electrodes on both sides of the drop. This makes the drops with fingers stretched along the electric field lines similar to some trilobites known from their imprints in petrified sediments studied in paleontology. It is shown experimentally and theoretically that fingers are triggered during the encounters of the spreading drop outlines with minor surface imperfections.