Computational Modeling of Medical Device Coating Processes

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Drug-polymer and hydrophilic coatings have been widely used for medical devices, such as drug-eluting stents, as well as other miniature devices such as balloons, catheters and guide-wires. In order to provide high quality physical characteristics without defect, the specific coating processes must be able to contend with challenging geometries that can scale to micrometer dimensions. Final coatings must have good integrity, be durable and have good consistency (i.e. uniform thickness) for design requirements such as drug release or deliverability.

In this presentation, the computational modeling of coating medical implantables will be highlighted as it relates to processes such as drop-on-demand inkjet (DOD) and electrostatic-assist spray. In DOD processes, the high-precision and repeatability of drop generation can enable very accurate placement on challenging geometries such as stents. In order to better understand the jetting and deposition properties of the dispensed material, computational modeling including Fluent's VOF model was used to evaluate various aspects of the process technology. The presentation will give an overview of how droplet spreading is impacted by the

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dimensionless Reynolds and Weber numbers as well as the product geometry of the medical device. Validation cases will also be shown to highlight the accuracy of the models by comparing the results to experimental and numerical data available in the literature which confirm the physical attributes of contact angle and surface energy as it relates to wetting and spreading on the substrate.

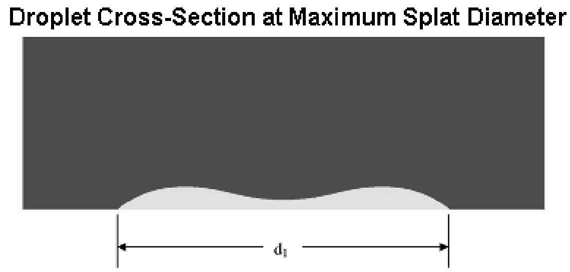

Figure 1: Droplet deposition in regime of inertial impaction and surface tension leveling

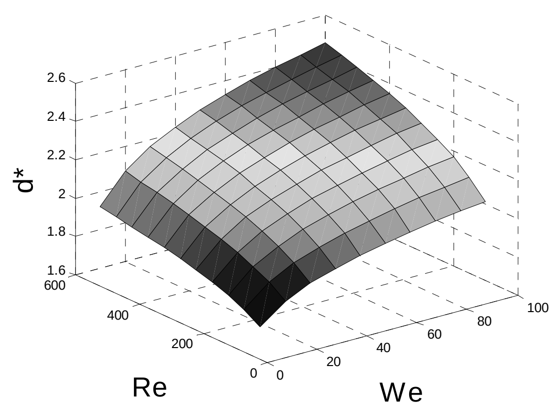

Figure 2: Reynolds' and Weber range where droplet sticks and spreads without splashing

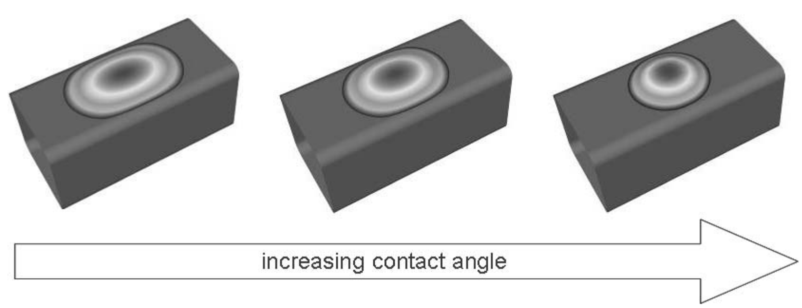

Figure 3: Variation of droplet spreading along substrate geometry with contact angle

Using an alternative coating process such as electrostatic-assist spray coating, both inertial and electrical-field deposition models will be shown to illustrate the relevant capture efficiency of high-speed charged droplets on various stent geometries. For instance, the manipulation of the electric field lines using biasing voltages can manipulate droplet pathways for a variety of coating designs where sharp boundary profiles are required between coated and uncoated areas. Likewise, computational modeling can aid in describing the tracking of injected particles to provide accretion rates and parametric relationships to other process factors, including attractive and repulsive electrical fields for charged particle steering.

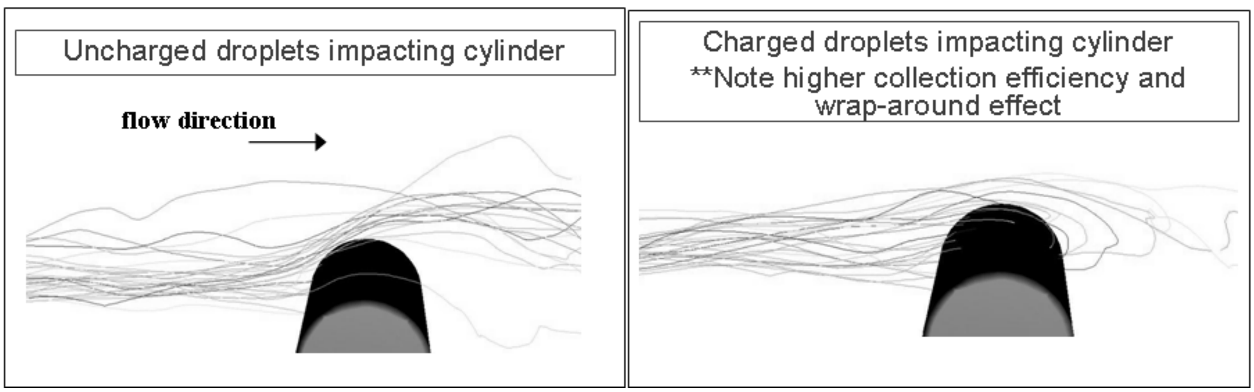

Figure 4: Particle trajectories on cylindrical geometry using charged and uncharged droplets

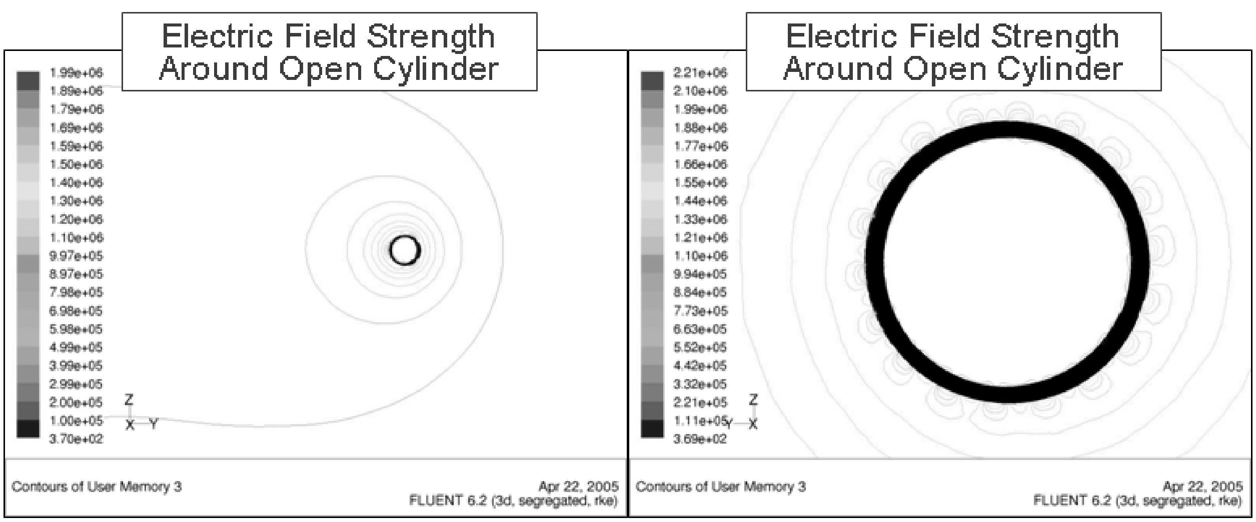

Figure 5: Electrical field strength around unique cylindrical geometries