Serrating Nozzle Surfaces for Complete Transfer of Droplets

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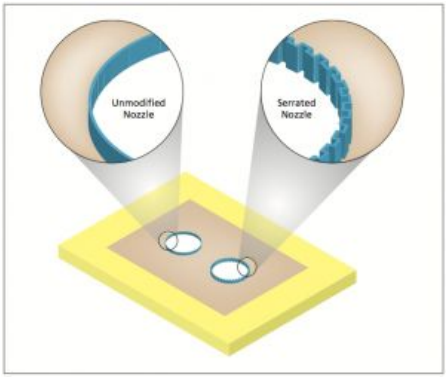
A method of ensuring the complete transfer of liquid droplets from nozzles in microfluidic devices to nearby surfaces involves relatively simple geometric modification of the nozzle surfaces. The method is especially applicable to nozzles in print heads and similar devices required to dispense liquid droplets having precise volumes. Examples of such devices include heads for soft printing of ink on paper and heads for depositing droplets of deoxyribonucleic acid (DNA) or protein solutions on glass plates to form microarrays of spots for analysis.



Micromachined Serrations on a nozzle surface reduce the liquid/solid contact area, thereby reducing the liquid/solid surface energy and thereby, further, reducing the liquid/nozzle attraction sufficiently to enable complete transfer of a liquid droplet from the nozzle to a nearby print surface." class="caption" align="left">The main purpose served by the present method is to ensure that droplets transferred from a nozzle have consistent volume, as needed to ensure accuracy in microarray analysis or consistent appearance of printed text and images. In soft printing, droplets having consistent volume are generated inside a print head, but in the absence of the present method, the consistency is lost in printing because after each printing action (in which a drop is ejected from a nozzle), a small residual volume of liquid remains attached to the nozzle.

By providing for complete transfer of droplets (and thus eliminating residual liquid attached to the nozzle) the method ensures consistency of volume of transferred droplets. An additional benefit of elimination of residue is prevention of cross-contamination among different liquids printed through the same nozzle — a major consideration in DNA microarray analysis. The method also accelerates the printing process by minimizing the need to clean a printing head to prevent cross-contamination.

Soft printing involves a hydrophobic nozzle surface and a hydrophilic print surface. When the two surfaces are brought into proximity such that a droplet in the nozzle makes contact with the print surface, a substantial portion of the droplet becomes transferred to the print surface. Then as the nozzle and the print surface are pulled apart, the droplet is pulled apart and most of the droplet remains on the print surface. The basic principle of the present method is to reduce the liquid-solid surface energy of the nozzle to a level sufficiently below the intrinsic solid-liquid surface energy of the nozzle material so that the droplet is not pulled apart and, instead, the entire droplet volume becomes transferred to the print surface. In this method, the liquid-solid surface energy is reduced by introducing artificial surface roughness in the form of micromachined serrations on the inner nozzle surface (see figure).

The method was tested in experiments on soft printing of DNA solutions and of deionized water through 0.5-mm-diameter nozzles, of which some were not serrated, some were partially serrated, and some were fully serrated. In the nozzles without serrations, transfer was incomplete; that is, residual liquids remained in the nozzles after printing. However, in every nozzle in which at least half the inner surface was serrated, complete transfer of droplets to the print surface was achieved.

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