Engineering a pyro-electrohydrodynamic approach for a high-sensitive and efficient jet printing of biomolecules

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High-resolution biomolecule printing is crucial for many biomedical applications, including live cell patterning, high-density protein microarrays, targeted drug delivery systems, and biosensing. Electrohydrodynamic (EHD) printing uses electric fields to control droplet formation at the micrometer scale, enabling precise deposition of small volumes. Here, we present pyro-electrohydrodynamic jetting (p-jet), a novel EHD-based technique that leverages the pyroelectric effect of lithium niobate crystals. By applying controlled pulses to the crystal, we induce transient surface charges that extract small droplets (~1 pL or less) from a mother liquid drop. This method allows efficient and reproducible deposition of biomolecules into well-defined microscale spots with high spatial precision. Our p-jet system creates protein spots roughly 3–15 µm in diameter—over an order of magnitude smaller than spots produced by conventional pin-contact printing. This technique significantly reduces reagent and sample consumption. We engineered a compact, user-friendly p-jet device capable of continuous operation with precise control over jetting parameters. In biosensing applications, concentrating low-abundance proteins into these tiny spots enhances detection sensitivity and specificity. Preliminary results demonstrate that p-jet can effectively concentrate trace biomolecules, enabling ultrasensitive assays. Overall, the ability to pattern biomolecules at this resolution has broad implications for advanced diagnostic technologies, lab-on-a-chip platforms, and personalized medicine, where high-throughput analysis and minimal sample volumes are highly advantageous.

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