
High Precision Electrohydrodynamic Printing and Application to 2D Materials

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Abstract

Printing techniques, particularly inkjet methods, offer promising solutions for high-resolution manufacturing due to their additive nature, design flexibility, compatibility with large-area substrates, and cost-effectiveness. However, conventional inkjet printing, which relies on thermal or acoustic droplet ejection, is limited to a resolution of $\sim 20\text{--}30\ \mu\text{m}$, constrained by droplet size and placement errors. While lithographic-based techniques can assist in creating high-resolution features, they require additional processing steps.

In contrast, electrohydrodynamic (EHD) printing uses electric fields to drive fluid flow, enabling sub-micron precision and patterning at scales below $1\ \mu\text{m}$. This technique allows for intricate geometries and is particularly well-suited for high-resolution electronics applications, such as the printing of electrodes and complex circuits. EHD printing surpasses the resolution limitations of conventional techniques without necessitating additional patterning steps, representing a new frontier in advanced manufacturing.

EHD printing is currently used to create high-precision patterns from 2D materials and metals, including silver, graphene, transition metal dichalcogenides (TMDs), MXenes, and van der Waals heterostructures. By optimizing key parameters such as applied voltage, nozzle geometry, substrate interaction, and ink rheology, nanoscale features with high uniformity and minimal defects can be achieved. Ongoing research demonstrates its potential for next-generation flexible electronics, sensors, and energy storage devices.

Moreover, the performance of EHD-printed 2D material-based devices—such as field-effect transistors (FETs), photodetectors, and supercapacitors—has been demonstrated, highlighting the superior device performance achievable through precise material deposition. This positions EHD printing as a versatile and scalable method for advanced 2D material systems, driving innovation in nanotechnology and flexible electronics.
