Two-Photon Polymerization Direct Printing of Porous Silica Electrospray Emitters

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Electrospray atomization utilizes strong electric fields to generate a plume of charged droplets or ions from a conductive liquid. This technique possesses many applications across various disciplines, ranging from micro/nano manufacturing to pharmaceuticals and biotechnology. Among the aerospace industry, electrospray thrusters have gained in popularity as a form of propulsion technology which generates thrust via droplet/ion emission. These thruster systems are particularly advantageous for small satellite spacecraft, where minimal mass, power consumption, and fuel requirements are critical. The performance of electrospray thrusters is closely tied to the design and efficiency of the emitters. However, achieving the required precision in emitter design and fabrication at small scales remains a challenge, as existing techniques often require highly sophisticated manufacturing equipment and processes which do not allow precise control over the internal structure of the emitter.

This work explores a novel approach for fabricating electrospray emitters, utilizing the two-photon polymerization (TPP) technique for direct printing of the emitter geometry. TPP printing is a form of photolithography that uses a precisely focused beam of light to build a rigid body in 3D space within a pool of photosensitive resin, enabling fabrication of intricate microstructures with micron and sub-micron resolution. The efficiency of electrospray emitters is strongly dependent on their porosity and permeability, which are crucial for ensuring adequate transport of propellent to the tip. In this work, we leverage the high-precision capabilities of TPP in combination with silica-containing photosensitive resins to fabricate silica electrospray emitters with micron-scale pores formulated using triple-periodic minimal surface (TPMS) lattices. TPMS lattices provide the electrospray emitters with high porosity near or exceeding 50%, which would be difficult or impossible to achieve with other fabrication techniques. Additionally, the geometry of the TPMS structure can be modified to tune the transport properties of the printed emitter. Here, we investigate the effects of TPMS geometry on emitter fabrication and performance, evaluating the geometrical limits of pore size and pore-size-graded lattices, and optimizing emitter porosity for efficient emission.

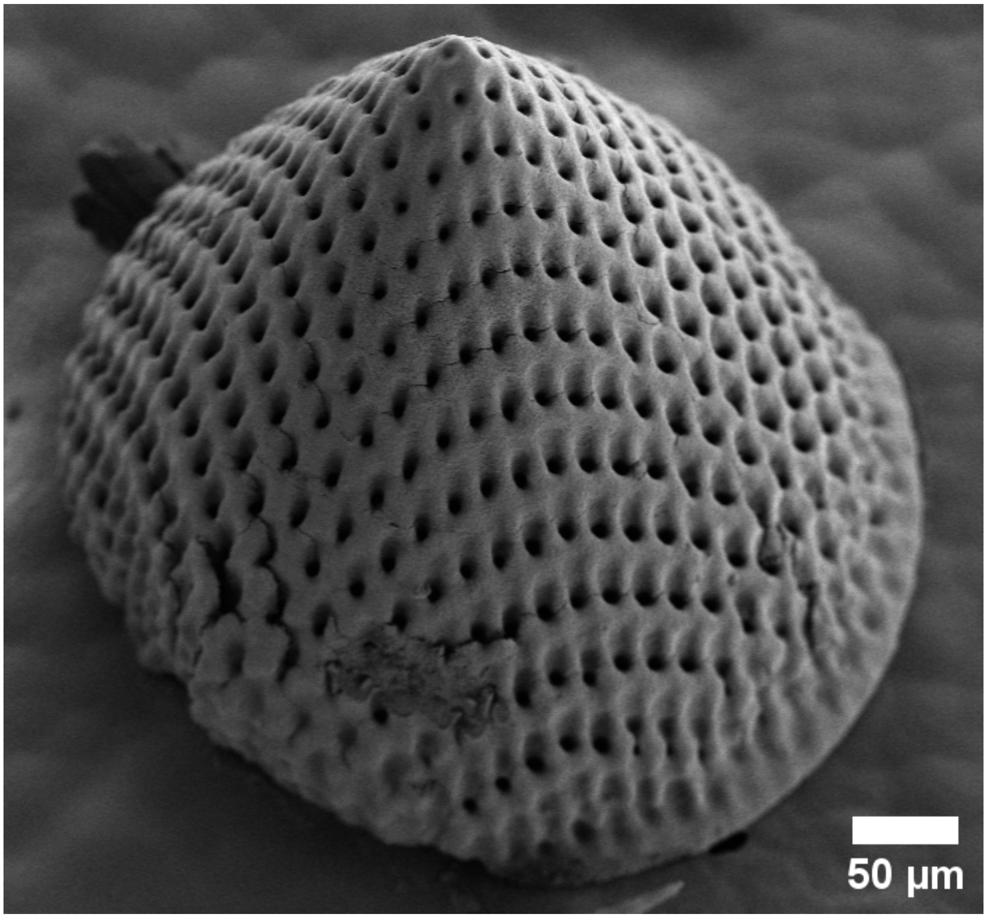

Figure 1: TPMS porous silica electrospray emitter fabricated using TPP printing.