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MEMS technology all-photopolymer electrospray emitters for highly scalable nano- and micropropulsion

Torsten Henning, Katharina Huhn, and Peter J. Klar
Institute of Experimental Physics I *and* Centre for Materials Research ZfM/LaMa
Justus Liebig University, Giessen, Germany

Electrospray emitters or colloid emitters are promising candidates for truly miniaturised electric thrusters since they scale favourably upon miniaturisation; namely, the voltage required to extract ions from the ionic liquid propellant is reduced with shrinking diameter of the fuel transport capillary and nozzle orifice. This implies that it should be possible to switch such miniaturised emitters on and off using relatively simple (low voltage) electronics. Calculations have shown that single emitters fabricated using technologies routinely employed in the field of micro electro mechanical systems (MEMS) should be able to deliver specific impulses in excess of 1000 s [1]. Individual emitters are expected to deliver a thrust in the micronewton or even submicronewton range, which may be useful for very high precision manoeuvres needed in scientific and/or deep space missions. However, arranging such minaturised emitters in large or even very large arrays should allow one to create thrusters in the millinewton thrust range while retaining the high specific impulse of the individual emitters. This concept of "scaling-up by numbering-up" requires the high areal integration density that only MEMS technologies can provide today.

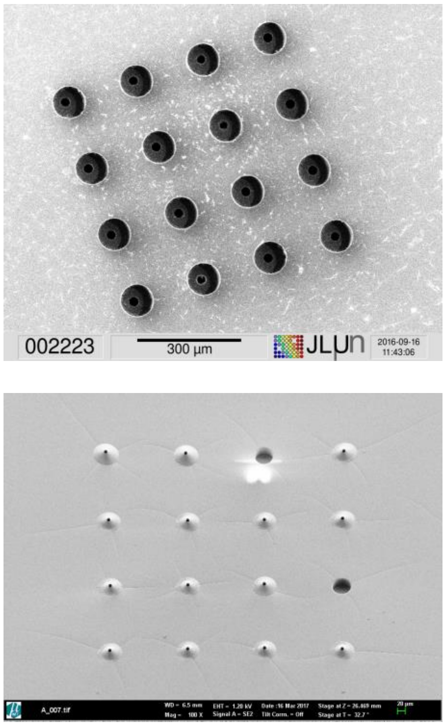

Figure 1. Array of sixteen emitters made by 2D photolithography of SU-8, with integrated extraction electrode (top); tapered emitter nozzles ("volcano emitters") aligned to pre-patterned vias in an SU-8 membrane, made by 3D microlithography (bottom, image courtesy of Karlsruhe Institute of Technology).

MEMS approaches have hitherto mostly concentrated on realising emitters in silicon based technologies [2]. Silicon as a well-understood material has its advantages, but also its limitations, such as the need to carefully insulate the conducting silicon from the ionic liquid, and certain limitations in the freedom of design. We pursue an alternative approach, fabricating all essential parts of the fuel transport system and the extraction electrode support from photostructurable polymers like the SU-8 epoxy resin [3]. With the recent advent of 3D microlithography equipment, most prominently the Nanoscribe two photon lithography system, the very high degree of design freedom allows one e.g. to design tapered emitter orifices, to mitigate the problem of surface wetting, or to integrate more complex extraction electrode support geometries. We present results on the time-resolved measurement of emission from individual emitters and small arrays of emitters, made both by 2D and 3D lithography.

[1] Dandavino S. *et al.*, *J. Micromech. Microeng.* 24 (2014), doi: 10.1088/0960-1317/24/7/075011

[2] Dandavino S. *et al.*, 33rd Intern. Electric Propulsion Conf. (Washington DC, 2015), paper IEPC-2013-127

[3] Henning T. *et al.*, Space Propulsion 2016 (Rome, 2016), paper SP2016_3124766.