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Author: Mr. Ximo Gallud Cidoncha
Massachusetts Institute of Technology (MIT), United States, ximogc@mit.edu

THE OPERATIONAL RANGE OF LIQUID METAL AND IONIC LIQUID ION SOURCES IN THE PURE IONIC REGIME.

Abstract

Electrosprays in the pure-ion mode are very appealing for micropropulsion for its ability to reach very high specific impulses at high attainable efficiency. The most established types of electrospray sources that operate in the pure-ion mode are made of liquid metals or ionic liquids. The emission characteristics and physics of liquid metal ion sources theory is well established from the eighties and nineties, yet computational limitations precluded any full understanding of the geometrical aspects and current dependence on operational parameters of these sources. The understanding of the emission physics of limited conductivity liquids such as ionic liquids has become more elusive due to the particular differences from liquid metals, which are believed to restrict the stability and current throughput of these sources. The most apparent is the absence of space charge, the lower surface tension coefficient and limited conductivity. These factors have been thought to condition the very small operational range of these sources to a limited set of extracting potentials, the need for sufficient hydraulic impedance and a very small range of meniscus sizes ($\sim 3 - 5\ \mu$m). The latter especially restricts their experimental study, since it difficults any non-invasive observation of ionic liquid menisci emitting *in situ* in the pure-ion mode.

Electrohydrodynamic numerical modeling has been very helpful in understanding the operational physical conditions of these sources, although any model built so far. We present preliminary implementations of this model that account for the specific geometry of the sources, and unveils a presumably universal range of electric fields local to the meniscus that can sustain the pure-ion mode. The range starts at the extinction voltage, where a Taylor-resembling conical geometry is postulated; and ends when the electric field local to the electrode that holds the meniscus exhibits an electric pressure equal to two times the surface tension of a sphere of equal radius as the meniscus.

Further preliminary observations of the model regard the emitted current emitted as counter-intuitively independent from the electric conductivity, dielectric permittivity, the temperature of the liquid or the free energy of solvation of the ions. The modeling suggests that the current is a byproduct of the upstream conditions of the flow and space charge effects. These upstream conditions include the local pressure (affected solely by hydraulic impedance, viscosity of the liquid and reservoir pressure), and local electric field near the meniscus anchoring point to the electrode.