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NUMERICAL SIMULATION OF IONIC LIQUID ION SOURCES FOR ELECTROSPRAY PROPULSION DURING STEADY ION EVAPORATION

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 and ionic liquids. The emission characteristics and physics of liquid metal ion sources theory is well established from the eighties and nineties. 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 limited effect 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 electrospray meniscus sizes (3 to 5 microns).

Electrohydrodynamic numerical modeling has been very helpful in understanding the operational physical conditions of these ionic liquid ion sources, although any model built so far has not been capable to reproduce actual experimental conditions. The main contribution of this work is the development of an electrohydrodynamic model of ionic liquid electrosprays in the pure-ion mode amenable to experimental validation. Complementary experimental efforts are provided. The implementations of this model 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 presence of space charge, 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, rather than any factor referring to the emission region. 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.