Invited Submission

Ionic Liquid Ion Sources as a unique and versatile option in Focused Ion Beam Applications

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This work discusses the potential application of Ionic Liquid Ion Sources (ILIS) in Focused Ion Beam (FIB) technology. ILIS work in a similar fashion as Liquid Metal Ion Sources (LMIS), but use ionic liquids, which are mostly organic room-temperature molten salts, capable of being electrostatically stressed to trigger ion emission under vacuum. The source consists of an electrochemically sharpened tungsten needle mounted on a loop structure (Fig.1). A voltage difference of 1-2 kV is applied between the tip and a downstream electrode aperture to extract the ions, which could be directed towards a FIB column.

ILIS share characteristics with LMIS that make them suitable for FIB applications, such as the emission of ions with no intervening droplets[1], and low energy spreads[2]. In addition, ILIS bring potential advantages for a FIB system, such as stable emission at currents below 1 μA, the ability to extract either negative or positive ions, and the reactive nature of some of the ions, that makes ILIS apt for fast etching with no chemical assistance[3]. Also, a large variety of liquids is available, suggesting a myriad of ions that could be tailored for different applications.

In this work, we present an overview of ILIS characteristics, including studies on the beam's profile and energy distribution. A beam visualization system is used to study the emission of an ILIS based on the liquid EMI-BF_4 (1-ethyl 3-methylimidazolium tetrafluoroborate). The shape of the beam has been established as a parabolic function of the divergence angle (Fig. 2). In addition, the stability of the source when alternating from the positive to the negative polarity is confirmed.

ILIS beams, in contrast to LMIS, contain several ion species. An ionic liquid composed of anions A+ and cations C- will produce beams with composition $(AC)_nA+$ or $(AC)_nC-$, depending on the extraction polarity, where n, the degree of solvation, is the number of neutrals attached to the ion, and is usually zero or one. A potential advantage of ILIS is using the heavier ions for patterning, while reserving the lighter species for imaging. Furthermore, individual degrees of solvation could have sharper energy distributions than the full beam and hence improved resolution, because their extraction energies must defer from each other when field-evaporated, and some ions with $n > 0$ break up into lighter fragments during flight. The magnetic filter design is discussed in this work. In addition, stable emission from ILIS using the liquid BMI-Im (1-butyl 3-methylimidazolium imide) was obtained, and the energy characteristics of the full beam are presented (Fig. 3). These results will help build on the merit of ILIS as a new tool in FIB.

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Figure 1. ILIS configuration showing the sharpened tip and loop reservoir

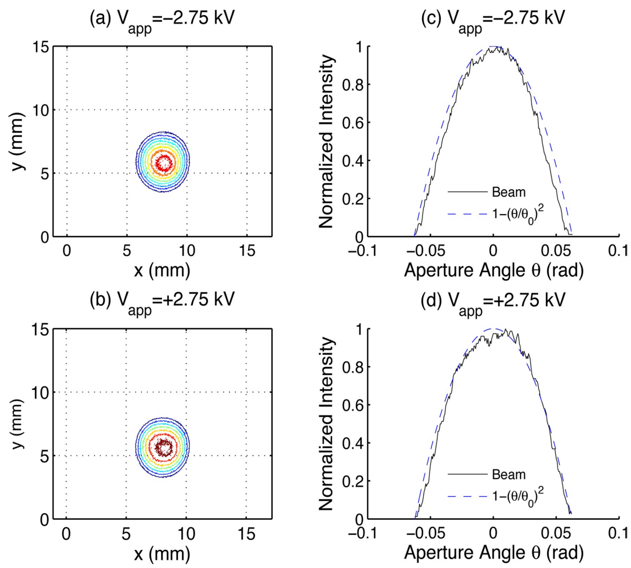

Figure 2. (a,b) Contour plot of positive and negative mode beam profiles, respectively and (c,d) cross-section of the beam profile and comparison to parabolic distribution

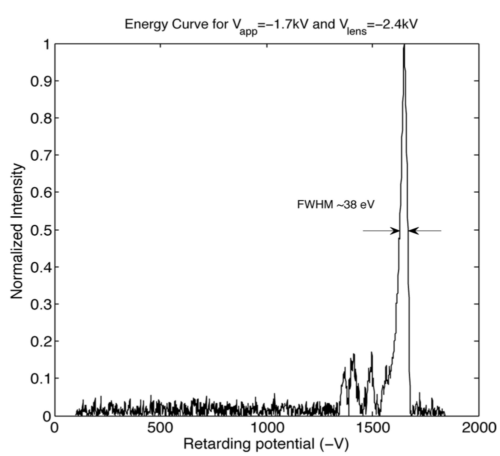

Figure 3. Retarding Potential Energy Analyzer energy distribution for full BMI-Im beam.