Visualization of Ion Beams from Ionic Liquid Ion Sources for Focused Ion Beam Applications

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Ionic Liquid Ion Sources (ILIS) are point sources that have been recently proposed for Focused Ion Beam (FIB) applications[1]. ILIS operate similarly to Liquid Metal Ion Sources (LMIS), but in contrast to LMIS, they are based on room-temperature molten salts. The source consists of an electrochemically treated tungsten needle—the emitter—coated with ionic liquid (Fig.1). A voltage difference of 1-2 kV is applied between the emitter and a downstream metallic extractor in order to obtain ion emission. ILIS share qualities with LMIS necessary for FIB operation, such as pure ion emission and low energy spreads[2], and ILIS could bring many advantages in a FIB system. For instance, ILIS emit stably at currents below 1 μA, can operate in both positive and negative polarity, and have been used for fast etching without chemical assistance.[3] In addition, the variety of ionic liquids is immense, which could diversify FIB applications.

In this work, ion beam visualization is used to determine the beam distribution of ILIS under different conditions. The emitter is placed on a tri-axial stage with sub-micron resolution, while the extractor is held fixed, and so the emitter position with respect to the extractor can be modified *in situ*. The ion beam fires towards a beam viewing system (BVS), and images of the emitted particle distribution are obtained. The BVS has been used to verify that the beam emitted from ILIS has a parabolic profile (Fig. 2), and to confirm the stability of the beam when switching from negative to positive polarity[4]. In this paper, we study the change in the beam with varying emitter-extractor geometries, in order to optimize the operating conditions of the ILIS for FIB. We also study the neutral particle population contained in the ILIS beam.

The beams obtained from ILIS contain several species, including neutral clusters. An ionic liquid composed of anions (A-) and cations (C+) will produce an ion beam with species $(AC)_nA-$ or $(AC)_nC+$, depending on the extraction polarity (n is the degree of solvation, usually 0 and 1). These clusters of ions can break during flight, yielding a high-energy neutral and another ion. Neutrals could be detrimental for FIB performance since they cannot be manipulated by optics. Thus, it is desired to characterize the neutral population to determine its properties and devise strategies to mitigate its effects on ILIS beams. Sufficiently energetic neutrals can be imaged by manipulating the emitter and extractor's electric potential, so that normal emission is obtained, but all charged particles are stopped at the extractor, before they reach the BVS. Then, we can determine the fraction of the beam composed by neutrals and gain qualitative information on their spatial and energy distributions.

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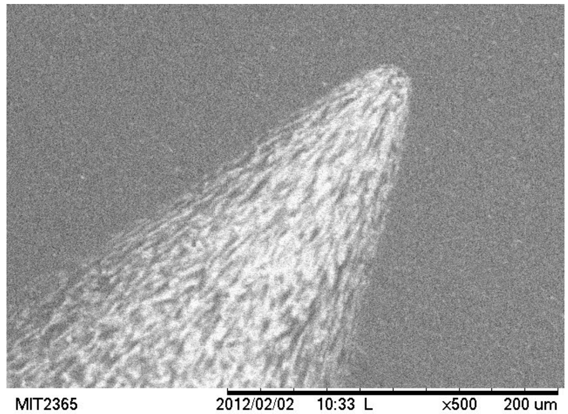

Figure 1. Scanning Electron Micrograph showing the ILIS emitter wetted by the ionic liquid EMI-BF_4.

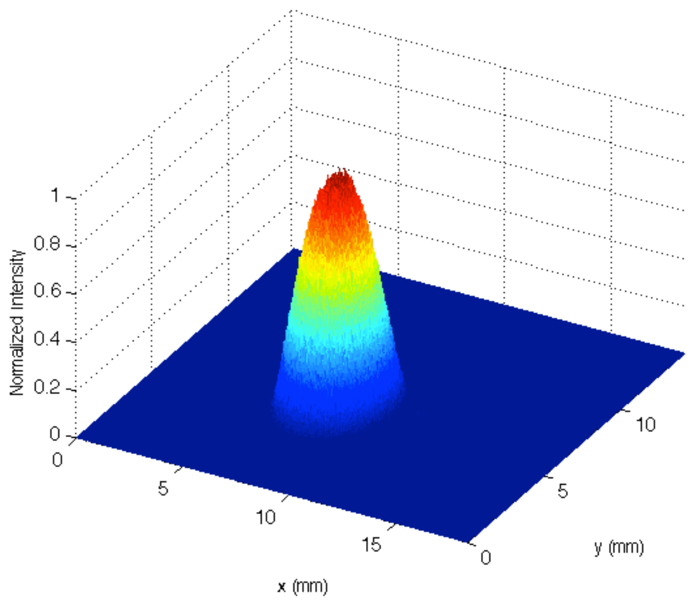

Figure 2: Spatial distribution of an ILIS ion beam using the ionic liquid EMI-BF_4, with the source operating at -2.75 kV.