A Wien filter to separate beams of ionic liquid ions

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Ionic Liquid Ion Sources (ILIS) are a novel ion source that could be used in material treatment applications, including focused ion beams. Ionic Liquids (ILs) are a type of salt, normally defined as having melting points below 100°C. Ionic liquids are normally synthesized by combining an organic cation with delocalized charge with a smaller anion, preventing the formation of an ordered crystal lattice due to poorly coordinated ions and low symmetry.

Ion emission in ILIS is achieved by wetting a needle emitter with ionic liquid and biasing the liquid to a high enough electric potential relative to an extractor close to the needle tip, illustrated in Figure 1. The surface of the liquid forms into an electric meniscus, due to the balance of surface tension and electrical pressure. The electric field intensifies at the tip of the meniscus becoming large enough to induce evaporation of the ions.

The large variety of ionic liquid chemistries available make ILIS a versatile tool for materials processing. ILIS produce ions ranging from monoatomic species such as I^- or Cl^-, or kilodalton organic molecules. ILIS are also bright point sources with properties that could make them amenable to operation in a focused ion beam (FIB) column[1]. which could be used for patterning and lithography applications. ILIS have already been used for reactive etching of silicon[2]. Some ionic liquids contain halogenated ions; the halogen species in the beam react with sputtered material from the target and prevent the redeposition of dislocated atoms. In addition, ILIS can provide both positive and negatively charged ion beams, by simply reversing the polarity of the field between the emitter and the extractor. Negative ions can be used when treating dielectric substrates to mitigate charging[3]. ILIS produce ion beams containing a variety of component particle species, and it is desirable to filter these species for materials processing with specific chemistries.

This work will present the design, simulation and implementation of a Wien filter to separate the different ion species found in the ion beam. COMSOL Multiphysics has been used to calculate electromagnetic fields, trace particle trajectories, and evaluate the effectiveness of the design in selecting the desired ion species, the geometry used and the results of ray tracing through this geometry are presented in Figure 2. The filter has been built and the talk will present experimental results from retarding potential analysis (RPA) comparing the full beam and the filtered beam. An example RPA of our source is shown in Figure 3.

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[1] A. Zorzos and P. C. Lozano, J. Vac. Sci. Technol. B 26, 2097 (2008)

[2] C. Perez-Martinez, S. Guilet, N. Gogneau, P. Gegou, J. Gierak, and P. C. Lozano, J. Vac. Sci. Technol. B 28, L25 (2010).

[3] Xu, T., Tao, Z., & Lozano, P. C, *J. Vac. Sci. Technol. B 36*, 052601 (2018)

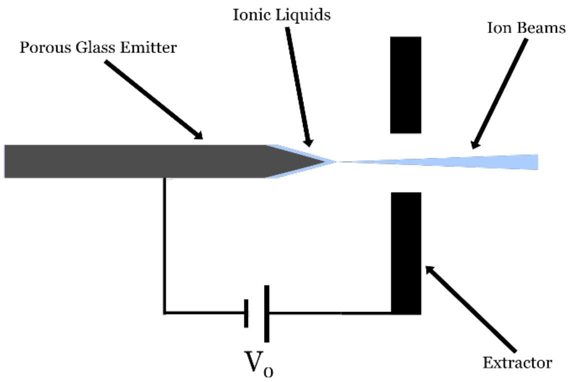

Figure 1. Diagram of an ILIS setup incorporating a porous emitter, in the negative emission polarity.

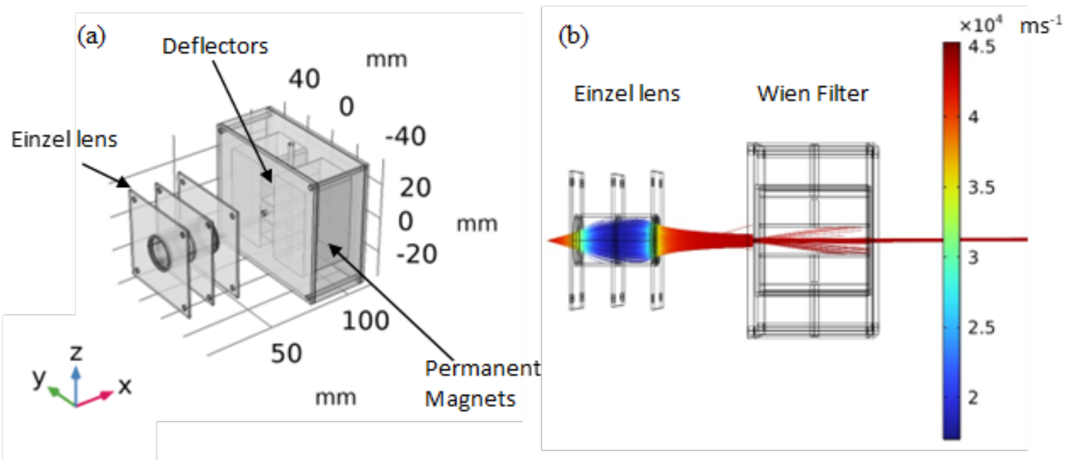

Figure 2. a) Depiction of the Einzel lens and Wien filter geometry constructed in COMSOL, through which ions are simulated to pass through in the x-direction. The lens is a three electrode configuration with the outer electrodes grounded and inner electrode biased. The Wien filter uses orthogonal electric and magnetic fields generated by the deflectors and permanent magnets respectively, to select ions to pass through an aperture based on velocity. b) Example of the raytracing of the monomeric species 1-Ethyl-3-methylimidazolioum (EMI^+) progressing through the lens and filter. The colour scale indicates the velocities of the ions as they traverse the device. The highest obtainable yield from the simulations was around 35%, when tracing 10000 directly emitted monomers.

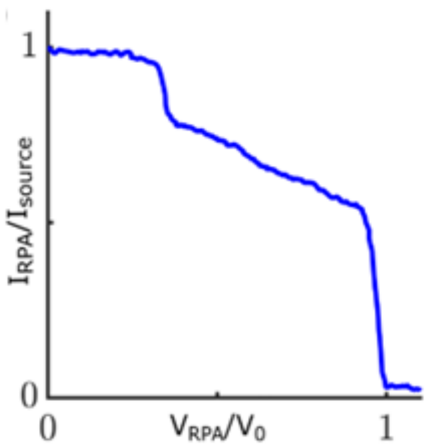

Figure 3. Sample retarding potential analyser curve for the full beam operating in the negative mode. The beam, with energy V_0 (-1540 eV in this example), is passed through a set of grids at potential V_{RP} and the current that makes it past the retarding grids is measured by a collector. For a monoenergetic beam, the full beam current should drop to zero only once V_{RP} exceeds V_0. However, ILIS beams have solvated ions that break up during flight, and these fragmented ions have energies lower than the unfragmented ions. The fragmented ions account for the current drops for $V_{RP} < V_0$.