Utilizing single species ionic liquid ion source beams for material irradiation

Alexander Storey, Shaun Boodram, Aydin Sabouri, and Carla Perez-Martinez

London Centre for Nanotechnology, University College London, WC1H 0AH, London, United Kingdom

E-Mail: alexander.storey.15@ucl.ac.uk

Ionic Liquid Ion Sources (ILIS) are a developing ion source that could be used in a variety of applications, including in focused ion beams to both pattern and implant material. Ionic Liquids (ILs) are comprised purely of ions and are traditionally defined as having melting points below 100°C. Ionic liquids are typically made up of an organic cation with delocalized charge and a smaller inorganic anion. This combination of ions is poorly coordinated and has low symmetry and does not form an ordered crystal lattice.

An ILIS produces a beam of ions by wetting a needle emitter with an IL and biasing it to a high potential relative to a grounded extractor positioned close to the emission tip. The surface of the liquid forms into an electric meniscus whose shape is dictated by the balance of surface tension and electrical pressure. The electric field strength intensifies at the emitter tip and becomes large enough to separate ions from the liquid.

The wide range of ion species available make ILIS a flexible tool for material processing applications. Potential ion sources range from monoatomic species such as halides to 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]. ILIS have already been used for reactive etching of silicon[2]. ILIS containing halides produce free radical species on impact with a substrate which have been seen to react with sputtered material and prevent redeposition. ILIS can provide access to both the positive and negative ion, by altering the polarity of the field between the emitter and the extractor. Negative ions can be used when treating dielectric substrates to mitigate charging[3]. The beams emitted by ILIS contain various particle species, and it is desirable to filter these species for materials processing with specific chemistries.

This work will present the results of irradiation experiments using filtered ILIS beams containing only monomeric species. The beam is filtered via an Einzel lens and Wien filter setup, a schematic of which is presented in Figure 1 (a) and the experimentl setup shown in Figure 1 (b). The filtered beam has been previously characterised[4]. An 1-ethyl-3-methylimidazolium tris(pentafluoroethyl)trifluorophosphate (EMI-FAP) beam has been utilised to irradiate an Si substrate overlain by a copper grid, a microscope image of the results can be seen in Figure 2 (a). Irradiation at -4.2 keV landing energy for a duration of 30 minutes resulted in a trench depth of roughly 15 nm when analysed with AFM. A 50 µm x 50 µm portion of the irradiated substrate was probed by AFM and the trench visualised in Figure 2 (b). Figure 2 (c) presents a cross section of this trench. The ion dose is estimated to be 2.1 x 10^{13} ions. In this work, we will report on the results of irradiations on both the positive and negative polarities at a range of energies up to 20 keV, and compare the effects of irradiating with the full and filtered ion beams.

[1] A. Zorzos and P. C. Lozano, J. Vac. Sci. Technol. B 26, 2097 (2008)
[2] C. Perez-Martinez er al., J. Vac. Sci. Technol. B 28, L25 (2010).
[3] Xu, T., Tao, Z., & Lozano, P. C, *J. Vac. Sci. Technol. B 36*, 052601 (2018)
[4] Storey, A.C.G et al.,J. *Vac. Sci. Technol. 42,* 064201 (2024)

(a) (b)

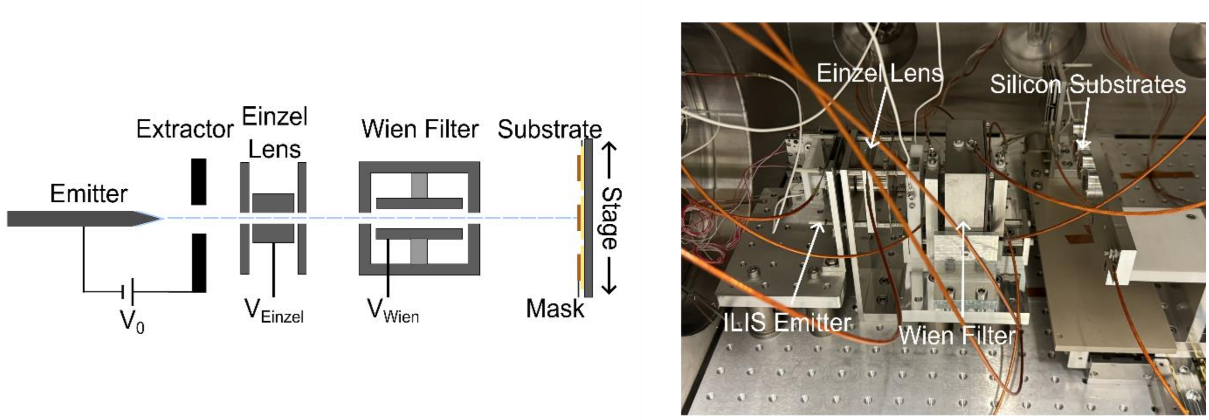

Figure 1. (a) Schematic of experimental ILIS set up, depicting components from left to right of the needle emitter and extractor, Einzel lens, Wien filter and finally Si substrates mounted on stage. (b) Photograph of these experimental components in vacuum chamber.

(a)

(b)

(c)

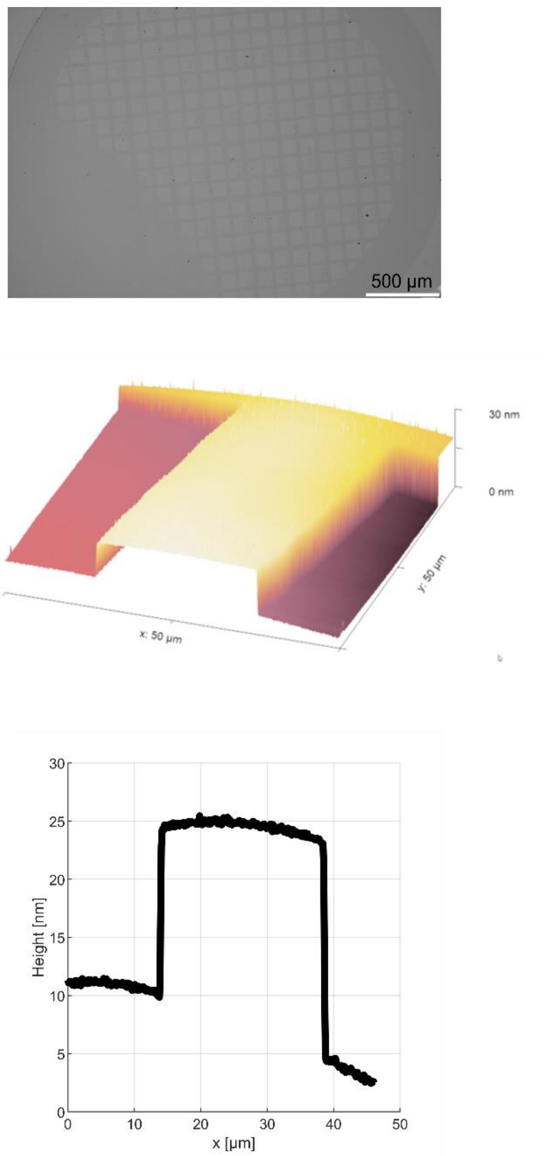

Figure 2. (a) Microscope image of silicon substrate (with mask removed) after being exposed to irradiation of filtered FAP⁻ beam. (b) AFM profilometry of 50 x 50 µm area of Si substrate. The Si was irradiated for 30 mins with a filtered FAP⁻ beam. A trench depth of around 15 nm was observed. (c) *Cross section of trench observed during AFM profilometry of Si substrate irradiated for 30 mins with filtered FAP⁻ beam. A trench depth of around 15 nm was observed.*