Ion Beams in SEM: An Experiment towards a High Brightness Low Energy Spread Electron Impact Gas Ionization Source

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We are currently developing a next generation ion source suitable for both high resolution focused ion beam milling and imaging applications. Our source relies on electron impact gas ionization inside a sub-micron sized gas chamber and can provide reliable production of a variety of ion species from a single source. The gas chamber consists of two very thin membranes (~100nm) separated by a small distance (100 to 1000nm) as shown in Figure 1. A small aperture (100 to several hundred nm in diameter) on each membrane allows electrons to enter and ions to exit while keeping a high gas pressure inside the gas chamber. Due to a high ionization rate resulting from a high input current density electron beam from a Schottky electron gun and a very small ionization volume, our source is expected to produce a reduced brightness matching or even exceeding that of typical Gallium LMIS[1].

As a proof-of-concept study, we attempted to produce ion beams of several different gas species from a prototype gas chamber using an electron beam inside a SEM. Using micro-channel plates and a phosphor screen, we first successfully acquired ion beam patterns proving that our source indeed outputs a beam of ions. We then measured up to several 100's of pico-amperes of ion current in a faraday cup using an input electron beam current of ~14nA with 1keV incident energy. Measured exit ion current as a function of gas pressure for Helium, Argon, Xenon, and air is shown in Figure 2. The differences in the measured ion currents among the gases reflect the fact that each gas has a different electron impact ionization cross section for a given incident electron beam energy. The graph also clearly shows the deteriorating ion current at higher pressures indicating ion transmission rate dependence on the mean free path of gas particles inside the gas chamber.

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[1] V.N. Tondare, PhD thesis, Delft University of Technology, 2006

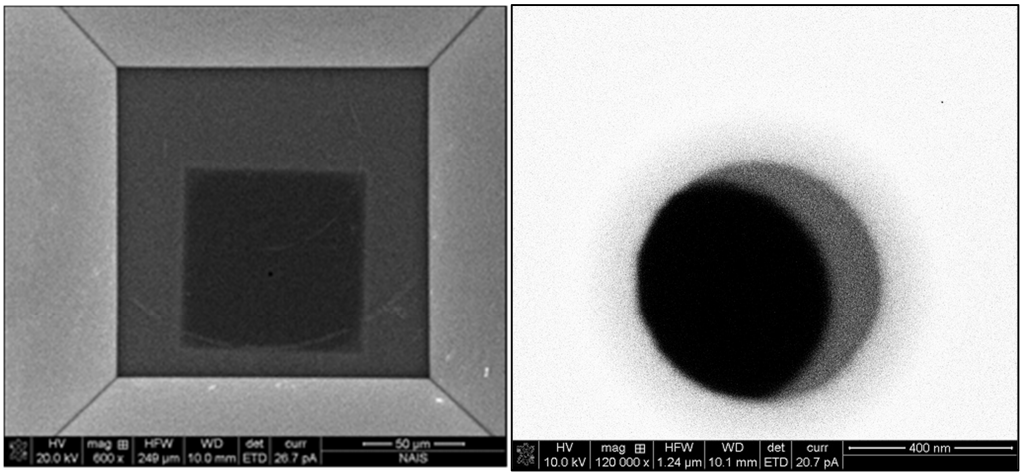

Figure 1. SEM micrographs of a prototype gas chamber – (A) the smaller membrane showing through the larger membrane, (B) a tilted view of the FIB-milled double aperture. The tilted view clearly shows a small separation between the two membranes.

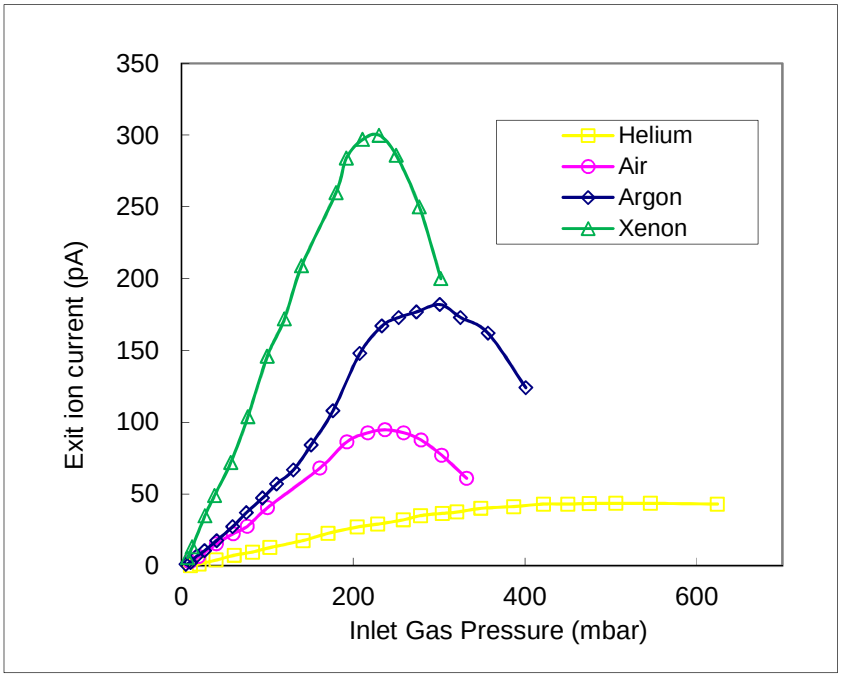

Figure 2. Measured ion current for Argon, Helium, Xenon, and air. Input electron current was ~14nA at 1keV.