A Novel Concept for Producing High Brightness, Low Energy Spread Ion Beams from a Miniaturized Gas Ionization Chamber

David S. Jun* and Pieter Kruit

Charged Particle Optics Group, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

We introduce a novel concept for producing a high brightness and low energy spread ion beam using a submicron sized gas ionization chamber. Our approach is to extract positively charged ions from a microfabricated gas chamber (Figure 1&2) once neutral gas atoms become ionized by energetic incoming electrons via electron impact. Our calculation suggests that using a high current density electron beam from a Schottky electron gun can produce up to 1-2nA of ion current in our gas chamber at an optimal gas pressure and gas chamber spacing.

The gas chamber consists of two thin membranes (~100nm) made of Silicon Nitride and Molybdenum coating, prepared through several lithographic fabrication steps. The membranes are separated by a thin film of insulator (PMMA or Silicon Oxide about 100-200nm thick) which determines the gas chamber spacing and provides electrical isolation when a bias voltage is applied between the membranes. The gas chamber includes a pair of small apertures (100-400nm) on the membranes for the electrons to enter and the ions to exit. These double apertures are easily made using a conventional FIB system and because these apertures are very small, hardly any neutral atoms are expected to escape [1].

Our source offers flexibility in which any type of gas can be used and the choice of a gas can be made depending on the type of application - a light gas specie such as Helium would be beneficial for imaging applications, a heavy gas specie such as Xenon for fast material removal, and a noble gas operation for the applications of which no sample contamination is desired.

The use of a very small gas chamber and a very narrow electron beam (<100nm) allows for a very small ionization volume, which, in turn, provides a small virtual source size and low energy spread. Our estimates indicate that the reduced brightness of this source can match or even exceed that of the current state-of-art Galium Liquid Metal Ion Source [2] and the energy spread can be well below 1eV (Figure 3).

[1] J. Peatross and D.D. Meyerhofer, Rev. Sci. Instrum., 64(11), 3066 (1993)
[2] V.N. Tondare, PhD thesis, Delft University of Technology, 2006

* Electronic address: d.s.jun@tudelft.nl

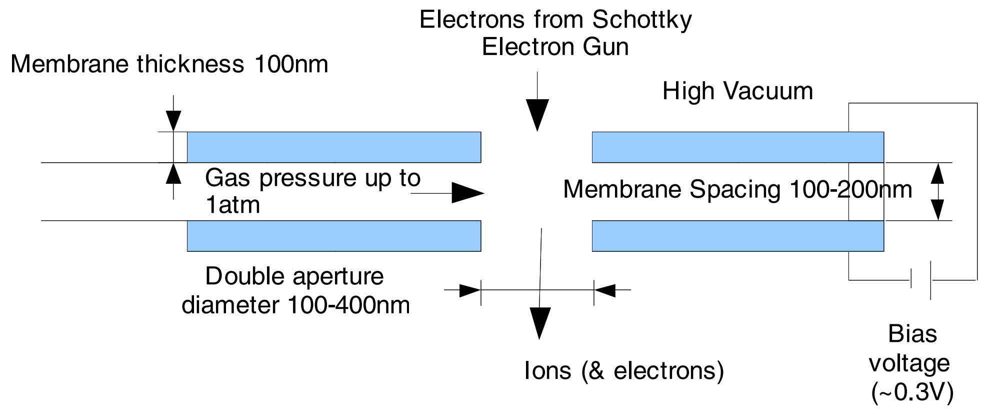

Figure 1. Basic operation of the source and gas chamber dimensions

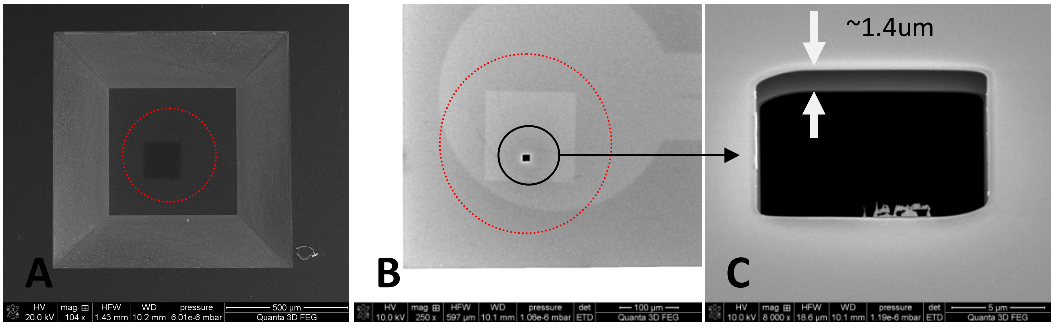

Figure 2. SEM micrographs of a prototype gas chamber - the smaller membrane showing through the larger membrane (A), a small area is FIB-milled for inspecting the membrane spacing (B), a tilted view of the FIB-milled area (C). Our target spacing is 100-200nm.

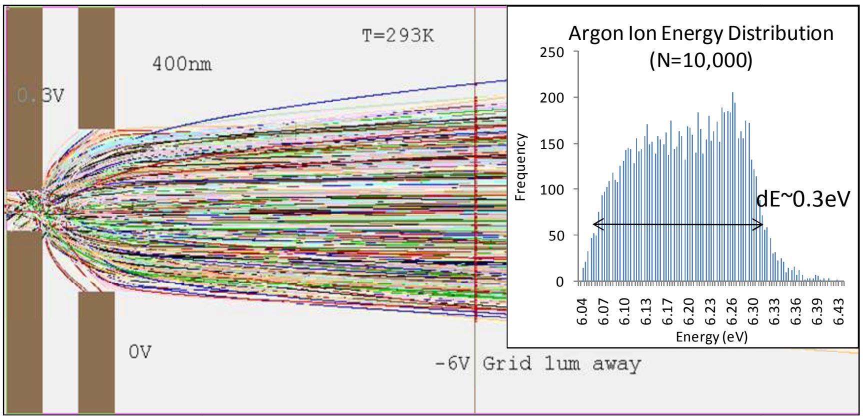

Figure 3. Simion 3D simulation showing the Argon ion trajectories out of the gas chamber and calculated ion energy distribution at room temperature operation. A uniform gas particle density distribution is assumed for the simulation.