Electron impact gas ion source development: a miniaturized gas ionization chamber using polymer PMMA

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An electron impact gas ion source is being developed to improve the brightness for MeV proton beam writing applications. Proton beam writing has the advantage of proximity free fabrication of high aspect-ratio nanostructures in photo-resist. Proton beam size of 13×30 nm^2, has been achieved at a current of about 4 fA. The reduced brightness was measured to be about 10 A/m^{2}SrV [1]. For proton beam writing, the exposure dosage for photo-resist is typically 10-100 nC/mm^2. The beam resolution and writing time are limited by the low brightness Radio frequency (RF) ion source. The electron impact gas ion source designed in Delft is expected to give much higher reduced brightness, about 10^7 A/m^{2}SrV [2]. Prototypes have been fabricated and tested using a Schottky electron source as injector in Delft. The idea is to introduce an electron beam to a gas chamber confined by two thin membranes with small spacing (100-1000 nm), where gas particles are ionized.

A miniaturized ionization chamber using polymer PMMA has been developed in NUS (Fig. 1). The polymer based ionization chamber has a 2 µm deep channel imprinted onto a bulk PMMA substrate and a sealed channel is obtained by thermal bonding another 2 µm thick PMMA layer. The accesses for gas and electron beam delivery are obtained by laser drilling, with a resolution of 10-20 µm (Fig. 2). The exit for ions can then be achieved by FIB milling to nm size. The experimental ion source test setup has been established inside a Schottky SEM in NUS. The SEM provides electron beam with 300eV to 1keV beam energy and an injecting electron beam current of 300-450 pA. Different gases are introduced into the source (e.g. Helium Argon and Hydrogen). The extracted ion currents for different gases will be studied as functions of gas inlet pressure and electron beam energy (Fig. 3). The reduced brightness of the electron impact gas ion source will be measured using two sets of apertures. The experimental reduced brightness will be examined and compared with the theoretical calculations.

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References

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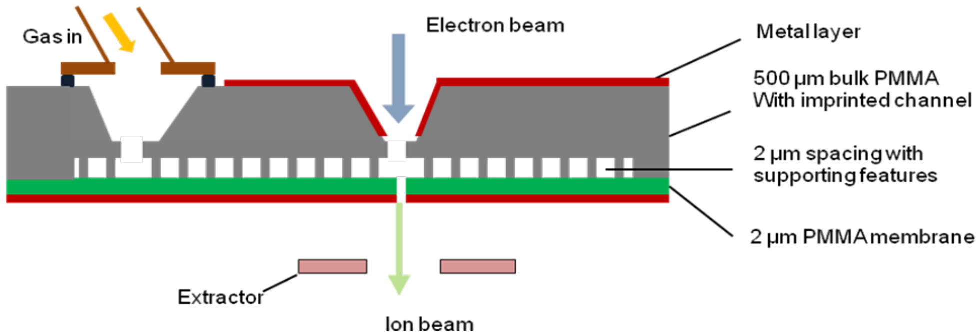

Figure 1: Electron impact gas ion source fabricated from a miniaturized PMMA ionization chamber. A 2-µm deep channel path for gas is created by imprinting onto the bulk PMMA substrate. Two openings for beam transport and gas inlet are created by laser drilling respectively, with sizes chosen from 5 µm to 500 µm. The exit for ions are created with FIB, as small as few tens of nm.

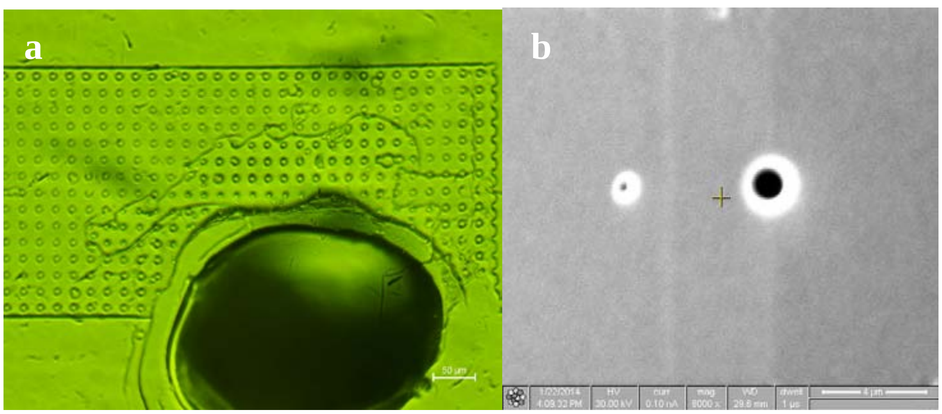

Figure 2: The sealed channel in PMMA. a) The channel imprinted in PMMA with supporting pillars and with gas/electron access created by laser drilling. b) The ion exits on the thermal bonded PMMA layer, created by FIB milling, with size of ~300 nm and ~1 µm.

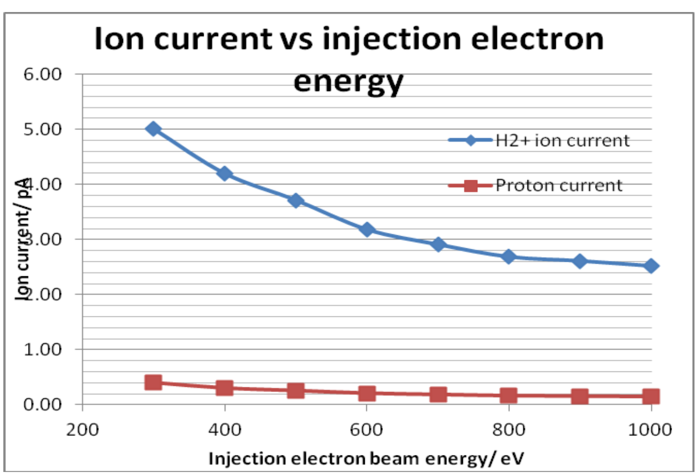

Figure 3: Estimated ion output from the miniaturized ion source by impact with different electron beam energy from the ESEM in NUS. The electron impact path length is 2 µm and Hydrogen gas inlet pressure is 60 mbar.