Energy Spread Measurement of an Electron Impact Gas Ion Source Equipped with a Miniaturized Gas Chamber

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One of the many attractive features about the electron impact gas ion source currently under development is that it can provide a significantly lower energy spread than a Gallium liquid metal ion source (Ga LMIS). The Ga LMIS, presently the most widely used ion source for high resolution focused ion beam (FIB) applications, has an energy spread of $\geq 5\ eV_{FWHM}$ [1].

The low energy spread of our source arises from novel design features of the gas ionization chamber. The gas chamber is a MEMS fabricated structure consisting of two thin (~100 nm) conductive membranes separated by very small spacing (our target spacing is 100~200 nm). Ions are produced by electron impact (without forming a plasma) inside the gas chamber and can be sufficiently extracted by a small bias voltage (< 1 V) across the membranes. Due to a high restriction of gas flow through the sub-micron-sized electron-entrance and ion-exit apertures (the double-aperture) of the gas chamber, gas ionization is mostly contained between the membranes and the energy spread of the extracted ions is principally determined by the gas chamber bias voltage. By carefully optimizing the gas pressure and the extraction field inside the gas chamber any further increase of the energy spread from ion-ion and ion-neutral collisions can be avoided. [2]

Fig. 1 shows the experimental setup incorporating a retarding field energy analyzer inside a scanning electron microscope and Fig. 2 the measured energy spread spectra of an argon ion beam produced from a prototype gas chamber with 2 μm spacing and an 800 nm double-aperture diameter. The pressure inside the gas chamber was kept at approximately 50 mbar. As expected, the gas chamber bias voltage showed strong influence on the overall width of the ion energy spread. The fact the full width at zero bias voltage being only slightly smaller than the full width at 1 V can be explained by the electric-field (~0.8 V/um) created by the Ion Accelerator penetrating into the gas chamber through the ion exit aperture. It is also found the shape of the energy spread profile depends on the double-aperture/electron beam alignment as well as the gas pressure and the lensing effect created by the double-aperture when the applied bias voltage is relatively high.

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[1] J. Orloff, M. Utlaut, L. Swanson, *High Resolution Focused Ion Beams, FIB and Its Applications*. Kluwer Acadmic/Plenum Publishers, 2003.

[2] D. Jun, V. G. Kutchoukov, P. Kruit, J. Vac. Sci. Technol. B **29**, 06F603 (2011).

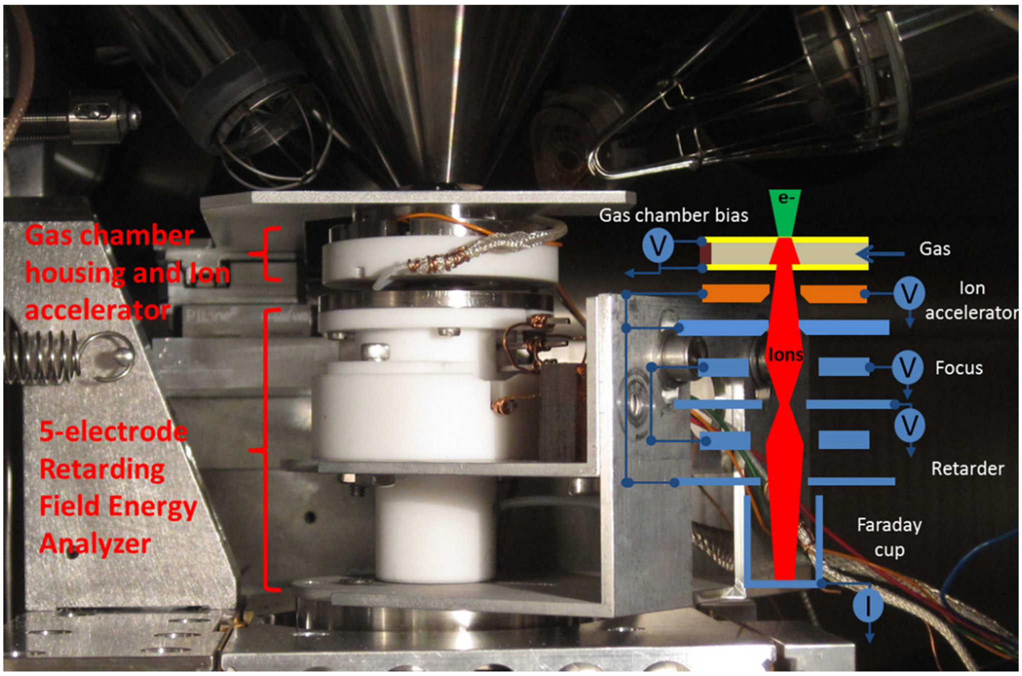

Fig. 1. Energy spread measurement setup inside a SEM (FEI Quanta3D FEG Dualbeam). Argon ions are produced by the SEM electron beam bombardment inside a prototype gas chamber filled with argon gas and accelerated towards the retarding energy analyzer by the Ion Accelerator. The analyzer is mounted on the SEM stage so it can be fully aligned to the ion beam.

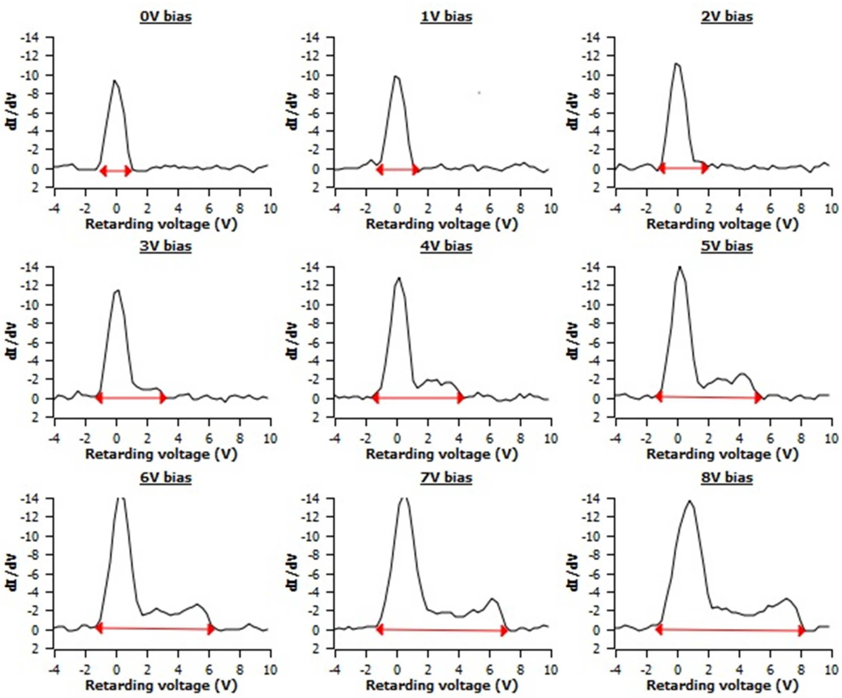

Fig. 2. The effect of the gas chamber bias voltage on the ion energy spread.