First focused ion beam images using a novel electron impact gas ion source

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Over the past several years we have been making steady progress in developing a high performance gas ion source suitable for high resolution focused ion beam (HR FIB) applications. This source, based on electron impact ionization, is expected to provide very high source brightness (> $1x10^6$ A/m^2srV) by utilizing a miniaturized gas chamber and a high current density electron beam from a Schottky electron gun[1]. The miniaturized gas chamber design allows a small ionization volume (hence a small virtual source size) while the high current density electron beam maximizes the ionization rate. Due to room temperature operation, the extracted ions have a small emission angle. Previously we reported our progress in fabricating miniaturized gas chambers[2] and measured ion currents of a variety of inert ion species produced from prototype gas chambers[3]. Experimental work also has shown that the energy spread of this source can be much smaller than that of the typical gallium liquid metal ion sources[4].

This time, we present our recent results acquired from a mini-FIB setup incorporating the new ion source concept. The FIB setup is a simple two-lens focusing column with a set of scan octupoles and a thru-the-lens secondary electron detector built inside a SEM (Fig. 1). An electron probe from the SEM (~10nA/1keV) serves as impact electrons for inducing ionization inside a gas chamber. Due to design constraints in the SEM specimen chamber, the operation of this FIB is limited to a relatively low energy of 5keV but sufficient for demonstrating ion imaging and milling using an ion beam emerging from a minaturized gas chamber (Fig. 2). In addition to the details of the experimentation, we also present our progress towards building a full-scale, high resolution FIB system utilizing the new source.

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[1] V.N. Tondare, PhD dissertation, Delft University of Technology, 2006.
[2] D. Jun, V. G. Kutchoukov, C.T.H. Heerkens, P. Kruit, Microelectron. Eng, **97**, 134-137 (2012).
[3] D. Jun, V. G. Kutchoukov, P. Kruit, J. Vac. Sci. Technol. B **29**, 06F603 (2011).
[4] D. Jun, P. Kruit, Conference abstract, Electron or Ion Sources and Systems 8C-3, EIPBN (2012).

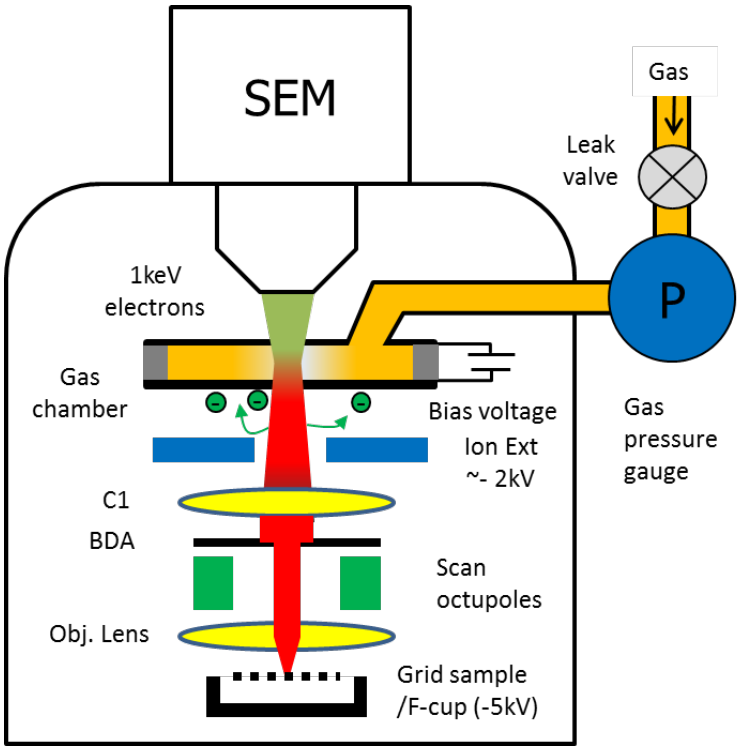

Fig. 1. Schematic of a focused ion beam system built inside a SEM. Ions are generated inside a gas-filled miniaturized gas chamber by a SEM electron probe and extracted by a small bias voltage across the gas chamber. The ions are then focused by electrostatic lenses and raster-scanned on sample. A thru-the-lens secondary electron detector (not shown) is used for imaging.

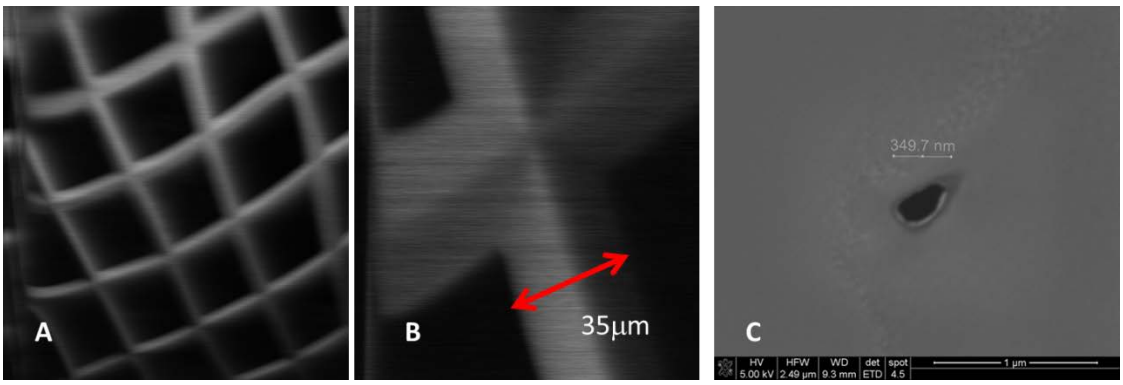

Fig. 2. FIB images of a silicon grid using a 5keV/70pA argon ion beam (A and B) and a SEM image of an argon ion spot-burn (5keV/250pA) on a thin metal membrane (C).