Characterization of a Saddle-Field Ion Source for Proximity Lithography

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Saddle field ion sources[1] generate a high-density plasma at very low operating pressures by trapping electrons in an oscillating path in the saddle-region of an electrostatic field. These cold-cathode sources are extremely compact, simple in design, and require only a single high voltage power supply and one needle valve for controlling the gas flow. Such sources also possess a significant energy spread and a large atom fraction that makes them unsuitable for use in ion-optical systems and have mostly been used for TEM sample thinning and mass spectrometry. However, in proximity lithography, where the images in a stencil mask (a thin membrane with etched openings) are copied when illuminated by a broad beam, modest energy spread can be tolerated if the virtual source size remains small. Hence, for this work, we are interested in determining the lithographic performance of spherical saddle field sources for proximity lithography for the purpose of developing a simple, low-cost lithography tool.

We have constructed a saddle field ion source based on an existing design[2], as shown in Figure 1, that uses an annular ring anode, held in place by alumina spheres, and two cup-shaped cathodes. A feedthrough on the side of the source connects the anode to a high-voltage supply, typically operated between 6-10 kV and 0.25-2 mA. A 1.5 mm diameter opening at the base of the lower cathode cup allows ions from the source to escape and drift through a 1.3 m beamline to an exposure chamber. The system pressure during operation ranges from $0.5\text{-}2\times10^{-5}$ Torr.

We have placed a cup connected to a picoammeter onto an *x-y* stage in the exposure chamber with a 1 mm diameter opening to measure the current density in the beam. Figure 2 is a graph of the normalized beam profile, which shows that the beam is about 5 and 9 mm in diameter for a ±2.5% and ±5% uniformity, respectively. Through a dose series, we estimate the virtual source size to be about 325 μm at 6 keV. Figure 3 shows an SEM of 200 nm diameter structures in PMMA printed with a mask-to-wafer gap of 250 μm. For this work, we will continue to measure the beam uniformity and virtual source size as well as the ion/atom content and mean particle energy as a function of power supply settings.

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[1] McIlraith, *Nature*, **212**, 1422-1424 (1966); J. Franks and A. M. Ghander, *Vacuum*, **24**, 489-491 (1974).

[2] A. Hogg, *International Journal of Mass Spectrometry and Ion Physics* **49**, 25 (1983)

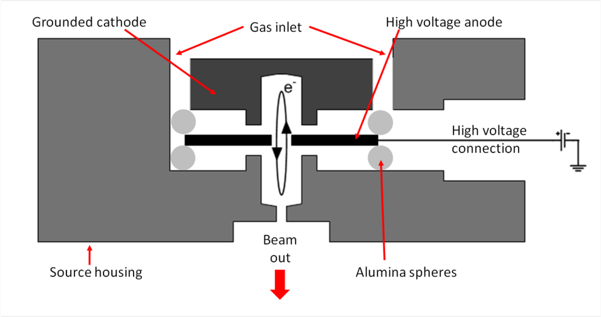

Figure 1: Schematic of the Saddle Field Ion Source.

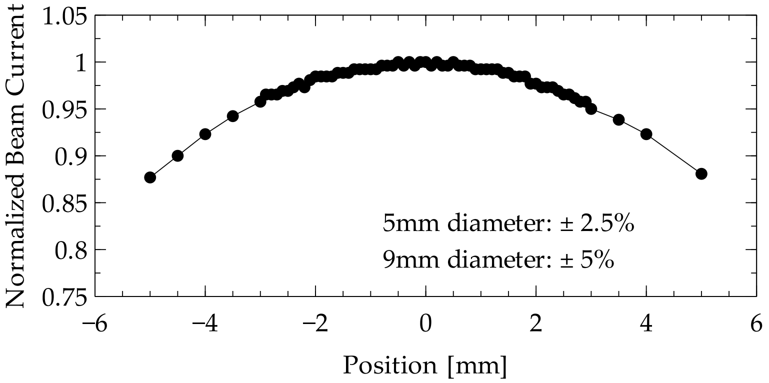

Figure 2: A plot of normalized ion beam current density versus cup position with an anode voltage of 7 kV and source current of 1 mA.

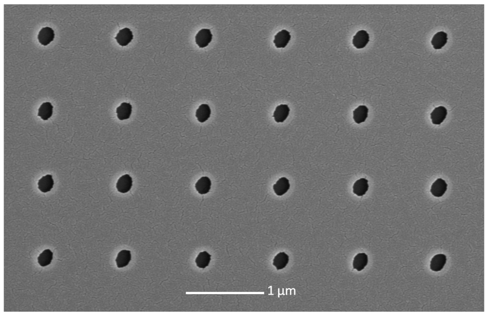

Figure 3: Scanning electron micrograph of an array of 200 nm diameter structures printed in PMMA with a mask-to-wafer gap of 250 µm, then coated with a 5 nm layer of gold. For this print, the anode voltage was 6 kV and the source current was 1 mA.