High brightness source of energetic helium atoms for proximity nanolithography

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In ion beam proximity lithography a beam of light ions illuminates a stencil mask and transmitted beamlets transfer the mask pattern to a substrate. The charge of the lithography ions, however, makes them sensitive to the build up of charge on the mask and wafer and, also, to ambient magnetic fields. Our solution is atom beam lithography where the ions are converted to neutral atoms by charge transfer scattering[1] in a high pressure cell near the source. The dependence of PMMA exposure time on *charge transfer cell* pressure for 30 keV helium atoms is shown in figure 1. In these preliminary studies, the ions were produced by a duoplasmatron ion source and the ion exposure time would have been about 20 seconds. However, the large (1 mm) virtual source size of the duoplasmatron requires a very small (e.g. 5 μm) proximity gap to reduce penumbral blur to the nanometer range, even for a 10 meter long beam line. The goal of this work is to develop a high brightness atom source with a much smaller virtual source size.

In this paper, we present a neutral beam source design based on the multicusp ion source developed by McKenna et al. [2] at Hughes Research Laboratory (HRL). It has, figure 2a, a source chamber with an internal diameter of 2.5 cm and length of 7.0 cm. The filament is operated at a voltage of -100 V relative to the source body or anode. The *endplate* opposite the cathode is at -140 V. The maximum magnetic field intensity near the wall is about 1.5 kilogauss. Ions are extracted by applying a large (e.g. 0.85 kV) potential to the *extraction electrode.* We have found that the brightness at *11 kV* increases in proportion to the discharge current, figure 2b, up to at least 200 A/cm^2-sr (the experimental error is $\pm$5%.).

The concept of the neutral source, figure 3, is to inject 0.85 keV beam extracted from the multicusp source into a 3-electrode lens which accelerates the beam to a final voltage between 30-50 keV and focuses it into the charge transfer cell. The center electrode, with potential V_F, provides the flexibility required to keep the cross-over fixed as the beam energy is varied. Table 1, based on Simion modeling, shows the expected performance of the ion beam system. The cross-over size should be about 40 microns and the divergence semi-angle about 15 mradian, corresponding to a 7.5 cm beam, 3 meters from the crossover. The penumbral blur would be 1 nm for a mask-to-wafer distance of 75 μm; the lithography system would then be diffraction limited with a blur of about 4 nm. Experimental values of the brightness and virtual source size corresponding to the second cross-over will be presented at the conference for both the atom beam and the parent ion beam.

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1 Gao R S, Johnson L K, Schafer D A, Newman J H, Smith K A and Stebbings R F 1988 Phys. Rev. A 38 2789-93
2 C. M. McKenna, J. E. Wood, J. L. Bartelt, R. D . Olney, J. W. Ward and C. W. Slayman, “Masked ion beam lithography system and method,” US Patent #4,757,208 (1988).

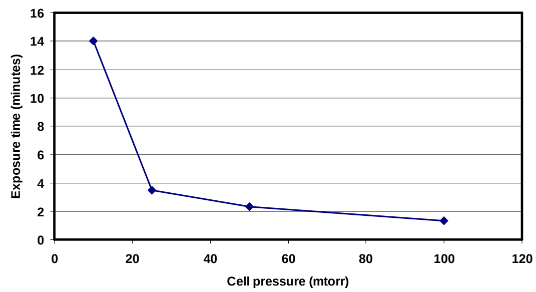
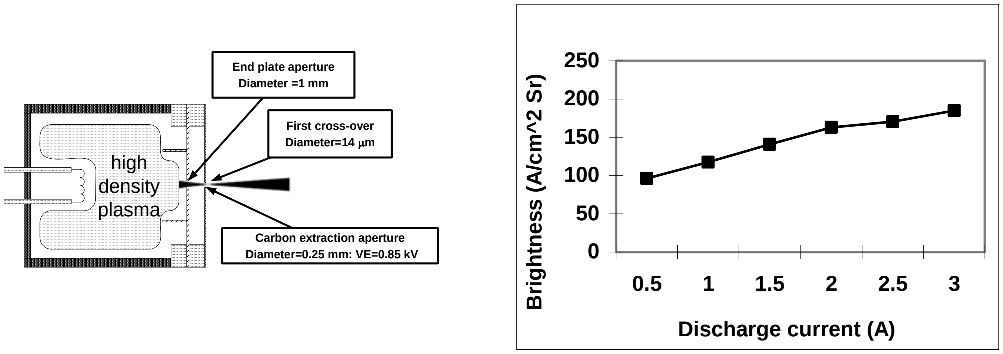


Figure 1: Helium atom exposure time for PMMA resist as a function of charge transfer cell pressure. For comparison, the ion beam exposure time was about 20 seconds.



a) b)

Figure 2: a) Diagram of the multicusp ion source developed by Hughes Research Laboratory; b) Brightness of the HRL source at 11 keV as a function of discharge current.

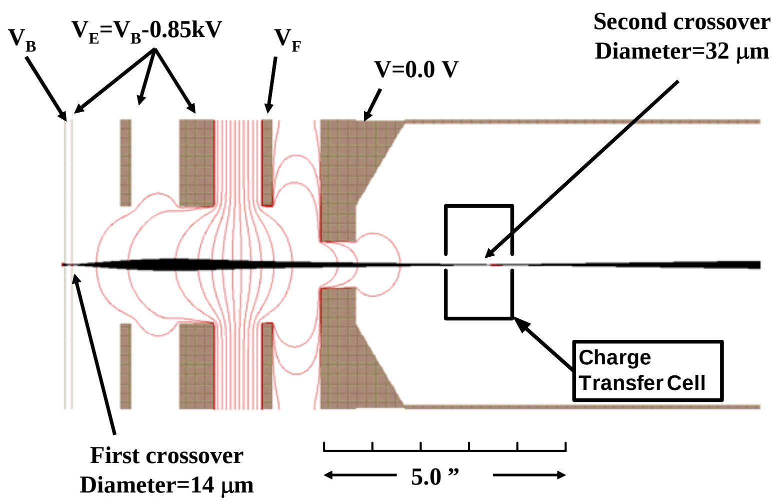


Figure 3: Neutral beam source concept: The ion beam extracted at 0.85 keV from the multicusp source is injected into a 3 electrode lens where it is accelerated and focused into a charge transfer cell. The focus voltage V_F keeps the second crossover within the cell as the beam energy is varied from 30-50 keV.

Table 1: Focus voltage values required to keep the second crossover at a fixed distance of 2.9” from the grounded electrode of the lens for beam energies of 30 keV and 50 keV. The expected cross-over diameter and beam semi-angles are also given (results based on a Simion model).

Beam Energy	30 keV	50 keV
Focus Voltage	-35 keV	0.0 keV
Crossover diameter	38 μm	32 μm
Beam divergence semi-angle	15.4 mradian	14.1 mradian