Atom sieve for nanometer resolution neutral helium microscopy

M.M Greve, R. Flatabø, and B. Holst
University of Bergen, Department of Physics and Technology, Allegaten 55, 5007 Bergen, martin.greve@uib.no

K.K Berggren
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA 02139

Neutral helium microscopy is a new tool for imaging fragile and/or insulating structures as well as structures with large aspect ratios. In one configuration of the microscope, the neutral helium beam is focused using a Fresnel zone plate. The resolution is determined by the width of the outermost zone [1]. Because the helium beam does not penetrate solid materials, the focusing element must be a free standing membrane structure, which gives a particular fabrication challenge. Recently a photon sieve structure [2] was used for the first time to focus helium atoms down to 3 µm [3]. The hole size distribution was 1840 ± 5 nm to 150 ± 5 nm.

Here we present work on a new atom sieve, which can be used to make a helium atom microscope with a resolution of around 20 nm. The atom sieve is fabricated on a 50 nm free-standing silicon nitride membrane. An etch mask consisting of antireflective coating (ARC), a SiO_2 layer and poly(methyl methacrylate) PMMA was used, and pattern transfer to the silicon nitride membrane is achieved with reactive ion etching.

The atom sieve hole size distribution is 376 nm to 20 nm, with a minimum hole-edge distance of 20 nm. The design is shown in Figure 2(a). Work has been done using both electron beam lithography and helium ion beam lithography. SEM images of an atom sieve fabricated using electron beam lithography are shown in Figure 3. The large hole size variation and small hole-edge distances present fabrication challenges to both techniques. Electron beam lithography suffers from proximity effects, while helium ion beam lithography has a low throughput and limited source lifetime.

[1] Palau A.S, Bracco G, and Holst B, *Theoretical model of the helium zone plate microscope*, accepted Physical Review A.
[2] Kipp L, Skibowski M, Johnson R.L, Berndt R, Adelung R, Harm S, and Seeman R, *Sharper images by focusing soft X-rays with photon sieves*, Nature, 414; 184 - 188, 2001.
[3] Eder S.D, Guo X, Kaltenbacher T, Greve M.M, Kalläne M, Kipp L, and Holst B, *Focusing a netrual helium beam with a photon-sieve structure*, Physical Review A, 91, 043608, 2015.

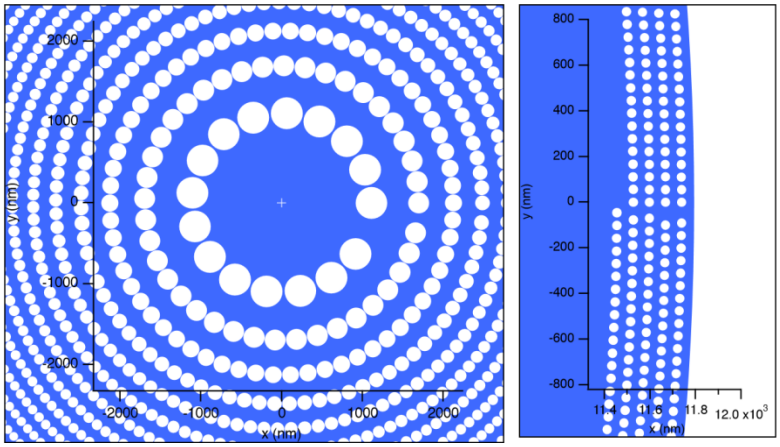

Figure 1 Atom sieve design. The atom sieve hole size distribution is 376 nm to 20 nm, with a minimum hole-edge distance of 20 nm. The radius of the sieve is 11791 nm.

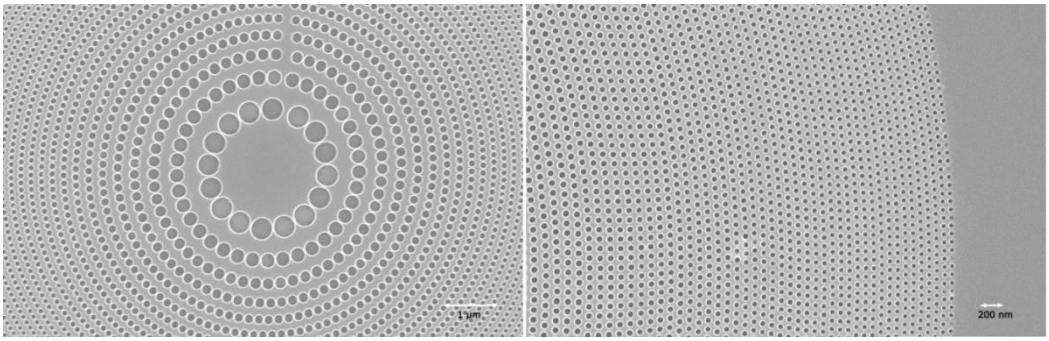

Figure 2 SEM image of atom sieve fabricated using electron beam lithography: SEM image of atom sieve prior to etching.