

Fabrication of high density, high-aspect-ratio polyimide nanofilters



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MOTIVATION

Nanofilters have a wide range of applications in many fields, including medical diagnostics, drug delivery, separation technology, size screening, nano-stamps, etc. Common commercial nanofilters are in the form of glass fibers and cellulose membranes, but they have non-uniform pore size and not straight pores. Nuclear track etched nanopores and anodically oxidized alumina can have uniform and straight pores, but nuclear track etched nanopores have low pore density and anodically oxidized alumina is not biocompatible. Here we report a novel method for fabricating very high porosity polymer nanofilters that have smooth, uniform and straight pores with high aspect ratios. Pore size, density, and shape can be predetermined with a high degree of precision.

Energetic Neutral Atom Beam Lithography/Epitaxy (ENABLE) utilizes a proprietary source to produce a collimated beam of neutral oxygen and nitrogen atoms with kinetic energies of a few electron volts and simultaneously delivers a very large flux of these energetic atoms to a substrate (flux $\sim 10^5$ larger than other energetic neutral O- or N-atom sources). Due to the inherent properties of the oxygen atom beam (charge neutrality, directionality, and $\sim 98\%$ atomic content) and the very direct chemistry involving the interaction of the oxygen atoms with polymer surfaces, reproduction of mask features into polymeric films takes place without significant undercutting or tapering effects. Suitable polymer materials must contain no metal (e.g., PMMA, polyimide, polycarbonate, polyethylene). The surface is first patterned with a mask material, such as metal or SiO_2 , that does not react with energetic oxygen atoms to form volatile products.

METHOD

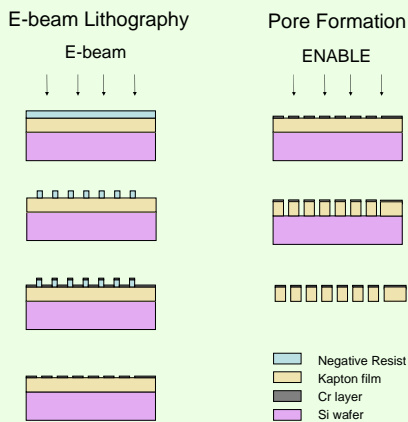


Figure 1. Fabrication method combines e-beam lithography with ENABLE etching.

25- μm - and 7.5- μm -thick Kapton® films (DuPont) were coated with 500 nm layer of ma-N 2405 negative resist. E-beam patterning was performed in a Raith 150 system, with accelerating voltage of 30 keV and beam current 340 pA. The pore patterns represent arrays of holes of 100 - 200 nm in diameter and pitch distance of 400 nm. A 40-nm-thick layer of Cr was sputtered onto the developed sample. Lift-off was done at 70°C in Remover 1165. Etching by ENABLE at LANL using 2.8 eV O-atoms and substrate temperature of $\sim 100^\circ\text{C}$. The etch rate was about 50 - 150 nm/min.

RESULTS

E-beam lithography

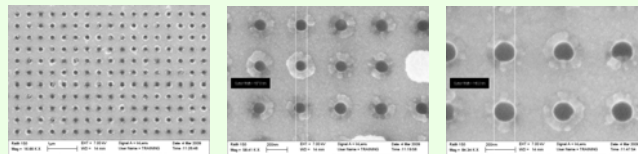


Figure 2. Chromium coated Kapton® films after e-beam lithography and lift-off.

Filter fabrication

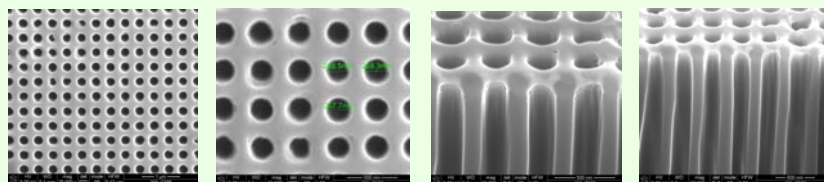


Figure 3. Chromium coated Kapton® films after ENABLE (cross section performed with FIB (FEI Nova NanoLab)).

CONCLUSIONS

We have demonstrated the method for fabrication of nanopores in a biocompatible polyimide material. High density, high-aspect-ratio uniform channels were produced.

A reusable etching mask can eliminate the costly and laborious e-beam writing for each filter and to allow large scale, rapid production of polymer nanofilters. We plan to use 7.5- μm -thick Cr coated Kapton® filter as a mask for etching holes in polymer material.