Nanofabrication of Super High-Aspect Ratio Structures in HSQ from Direct-Write E-beam Lithography and Hot Development

Leonidas E. Ocola
Center for Nanoscale Materials, Argonne National Laboratory, Argonne IL 60559.

Vijay R. Tirumala
Polymers Division, National Institute of Standards and Technology, Gaithersburg MD 20878.

Abstract

Hydrogen Silsequioxane (HSQ) is an inorganic precursor considered recently as an alternative for the deposition of SiO_2 in semiconductor processing applications [1]. The radiation crosslinking chemistry of HSQ also allows it to be used as a high-resolution negative resist in e-beam lithography. However, nanofabrication of high aspect-ratio features in HSQ has remained challenging since the nanopatterned features become susceptible for mechanical deformation when developed in conventional solvents. Recent advances suggest that nanopatterned HSQ features of sufficiently high aspect-ratio (~ 10) can be achieved by employing supercritical fluids for resist development.[2,3] The use of supercritical fluids in semiconductor fabrication, however, requires a change in the infrastructure. It is thus more desirable to optimize the conditions for resist development such that the high aspect-ratio nanopatterned resist features remain mechanically stable against capillary forces.

In this paper, we report on HSQ nanopatterned into super high aspect ratio structures (aspect ratio > 10) using 100 KV ebeam lithography, along with development in aqueous TMAH solution and rinse, both performed at elevated temperatures (60 ˚C). Hot development allows for the rapid removal of low molar mass uncrosslinked molecules from the exposed regions while preserving the mechanical integrity of the nanopatterned structures.[4, 5] Raising the water rinse temperature to 60 ^oC also has the benefit of reducing the surface tension of water by about 10%. Process concerns and initial mechanical implications of such high aspect ratio structures will be discussed.

The smallest resolved linewidth observed so far is 20 nm with an aspect-ratio of ~ 8 in 160nm thick HSQ (Fig. 1). Preliminary results of 90 nm structures using 1.2 μm thick HSQ, i.e. aspect ratios of 12, have been obtained as well (Fig. 2 and 3). Such structures have immediate application in MEMS, Fresnel zone plate fabrication, and nanophotonics among others.

References

1. C.W. Holzwarth, T. Barwicz, H. I. Smith, *J. Vac. Sci. Tech. B*, 25, 2658, (2007)
2. H. Namatsu, *J. Vac. Sci. Tech. B*, 19, 2709-2712, (2001)
3. T. Wahlbrink, D. Kupper, J. Bolten, M. Moller, M. C. Lemme, H. Kurz, *Microelectronic Eng.*, 84, 1045-1048, (2007)
4. M. Häffner, A. Haug, A. Heeren, M. Fleischer, H. Peisert and T. Chassé, D. P. Kern, *J. Vac. Sci. Technol. B*, 25, 2045, (2007)
5. S. Choi, N. Jin, V. Kumar, I. Adesida, Mark Shannon, *J. Vac. Sci. Technol. B*, 25, 2085, (2007)

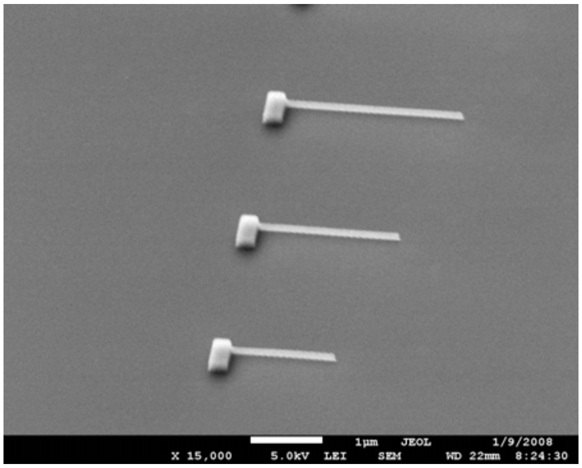

Figure 1. 20 nm lines (side, tilted, view) with aspect ratio of eight.

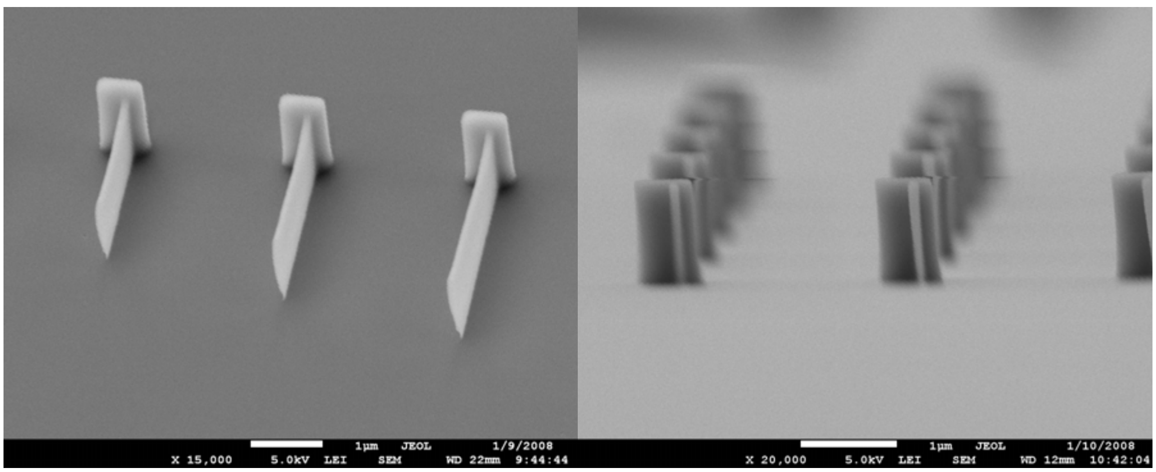

Figure 2. Tilted view (left) and front view (right) of 90 nm wide lines. Aspect ratio is 12.

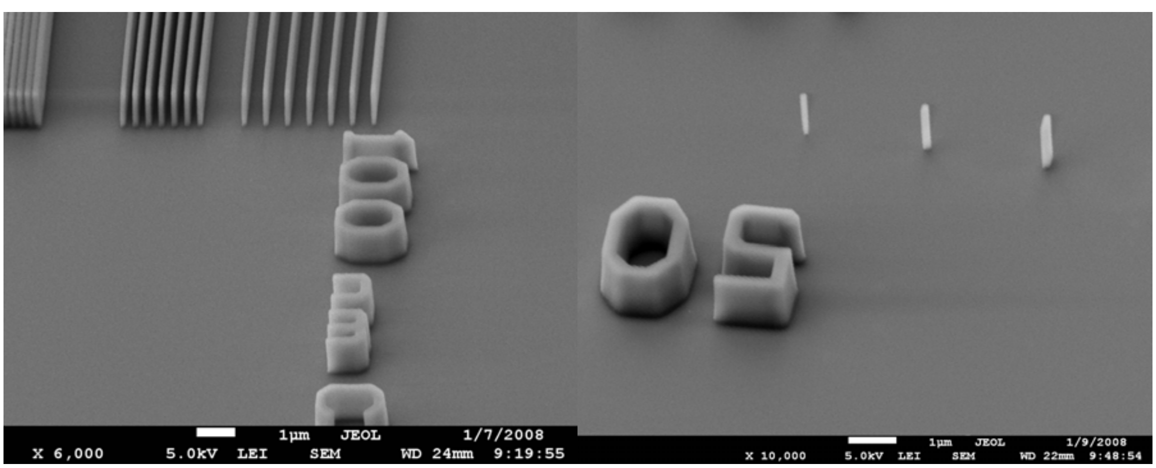

Figure 3. Sub-100 nm gratings. Fine structures are 1.2 μm tall with aspect ratios greater than 10.