Method for improvement of aspect ratio of ultra high resolution structures in negative electron beam resist.

V. Sidorkin[a], E. van der Drift[a], R. Schmits[b], and H. Salemink[a]

[a]*Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, Delft 2628 CJ, Netherlands*
[b]*TNO, Stieltjesweg 1, Delft 2600 AD, Netherlands*

A method for improvement of aspect ratio of ultra high resolution structures in negative electron beam resist is provided. The key point of the proposed method is the formation of a protecting cap by electron beam induced deposition (EBID) on the top of the resist structure in a self-aligned approach (Fig. 1). It is implemented by a combination of electron beam lithography (EBL) and EBID during exposure of resist material in the presence of the precursor gas[1]. The cap prevents material losses during development in the top of the formed structure while unexposed resist material being removed from the structure's sidewalls, especially in the case of a longer development time. It enhances the aspect ratio and improves the resolution of the formed structures. Depending on the uniformity of the cap formation and resist development properties the method could improve uniformity and roughness of the resulting structures. Additionally the EBID deposit could serve as a supplementary mask for the pattern transfer process. Stronger plasma resistance of the EBID deposit compared to the resist material could be an additional benefit in this matter.

E-beam pattering experiments were done on 10 nm thick HSQ resist with and without simultaneous exposure to Pt precursor. Structures exposed at 15 mC/cm^2 dose using the EBL + EBID method and developed for 5 min manifest 40% linewidth decrease compared to structures obtained by EBL only and developed for 1 min (See Fig. 2a and 2d). Moreover, this 5 min development with the EBL + EBID method gives 20% higher structures with same linewidth compared to EBL structures developed for 5 min (See Fig. 3c and 3d). The height uniformity and line edge roughness of the formed structures stayed more or less similar for both cases, even so EBID deposits obtained on HSQ surface possessed inherent irregularities due to HSQ surface roughness compared to deposits on Si wafer coated with natural SiO_2. Further improvement of the method could be achieved by: 1) Using gas precursors with higher yield and uniformity of deposits resistant against developer 2) Making exposure at lower temperatures to enhance EBID deposition 3) Making exposures on more thick and less rough resist layers. The results on further improvement of the method would be presented in a due course.

---

1 Y. Guan et al., Nanotechnology. **19**, 505302 (2008).

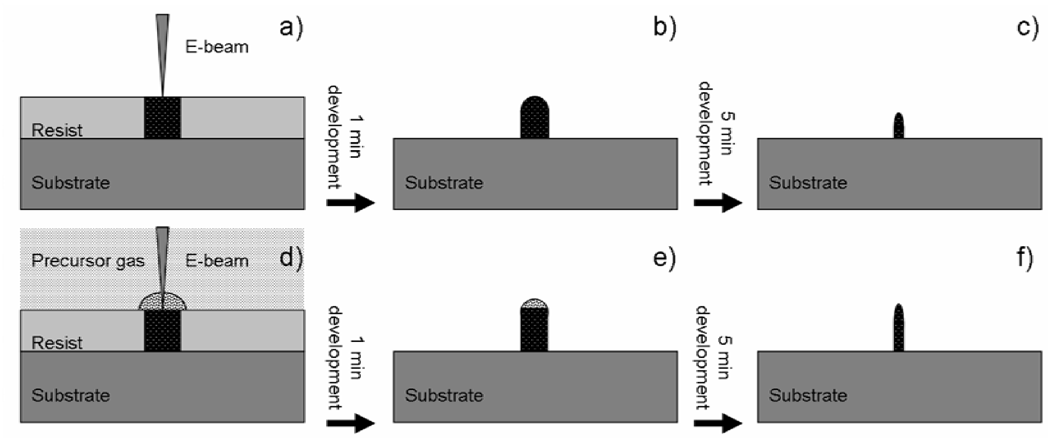

Fig 1: a) Conventional EBL process; b) Pattern after development using EBL for 1min and c) for 5 min; d) Combination of EBID and EBL; e) Pattern after development using EBID + EBL for 1min and f) for 5 min.

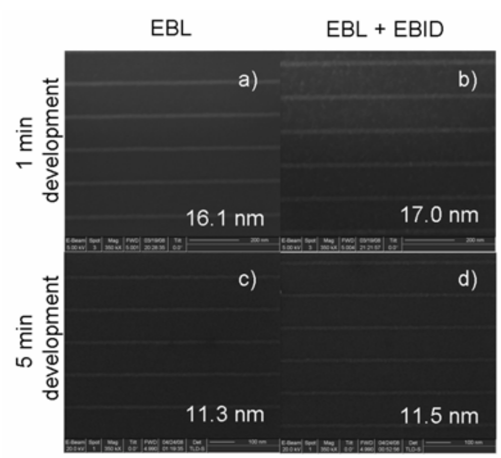

Fig 2: a) SEM image of line structures obtained by conventional EBL process; and b) by combination of EBID and EBL. c) SEM image of line structures obtained by conventional EBL process (1 min development) and d) by combination of EBID and EBL (5 min development). Dose: 15 mC/cm^2. Average structures linewidth is shown for each case.

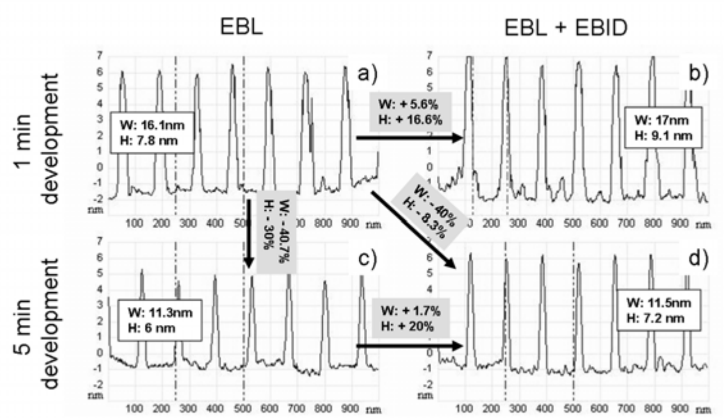

Fig 3: a) Cross sections of line structures obtained by conventional EBL process (1 min development) and b) by combination of EBID and EBL (5 min development). c) Cross sections of line structures obtained by conventional EBL process (1 min development) and d) by combination of EBID and EBL (5 min development). Dose: ~15 mC/cm2. Average structures width (W) and height (H) is shown for each case.