10 nm lines with 14 nm half pitch grating written in HSQ by Electron Beam Direct Write at 5 keV

Fu-Min Wang[1], Susumu Ono[2], Hsin-Hung Su[1], Kuen-Yu Tsai[1], Chieh-Hsiung Kuan[1]
[1]Graduate Institute of Electronics Engineering, National Taiwan University, Taipei, Taiwan, 10617, R.O.C.
[2] Elionix Inc. 3-7-6 Motoyokoyamacho Hachioji, Tokyo 192-0063, Japan
E-mail: fumin@cc.ee.ntu.edu.tw

Electron Beam Direct Write (EBDW) has been in semiconductor industry since mid-1960s. Due to its relatively low throughput compared with optical lithography, EBDW has never been the mainstream lithography technology. Most commonly, high energy electrons are used for exposure because of high resolution. However, EBDW with a high accelerating voltage suffers from (a) causing damage to the underlying substrate, (b) low throughput (high exposure doses) due to a small fraction of energy dissipated in the resist layer rather than in the substrate, and (c) proximity effects, resulting from the electrons scattered within the resist and backscattered from the substrate, making the writing of dense patterns very challenging. These drawbacks can be rectified by using low energy EBDW[1-3]. Multiple-Electron-Beam Direct Write (MEBDW) is one of the possible lithographic solutions for 32-nm HP node and beyond[4]. The MEBDW using 5 keV can provide lower resist dosage and less heating effect onto substrate, which are better for enhancing throughput, CD, and overlay, comparing with that using 100 keV electron beam[5]. This motivates our study of ultimate resolution EBDW on HSQ at 5 keV.

Silicon substrates have been spin-coated with HSQ at 500 rpm for 1 sec and 2250 rpm for 45 sec. The resulting resist thickness is about 40 nm. The wafers with resist were either pre-baked on hotplate at 100°C for 120 sec or non-baked and exposed at 5 keV by a SEM based EBDW system developed by Elionix Inc. An Elionix CAD system ECA-6W (WecaS CAD format system) is installed to control the beam scanning and blanking of Elionix ESM-9000. After exposure, the wafer was developed in 2.38% TMAH at 21.5°C for 7 minutes.

The resolution capabilities for 40 nm thickness HSQ negative tone resist at low electron energy of 5 keV have been demonstrated in gratings and hole arrays. The main limitation for the resolution in dense pattern exposure is the electron scattering which makes the writing of dense patterns very challenging. We were able to achieve 20.8 nm lines with 15 nm half pitch grating in pre-baked HSQ (Fig. 1), 10 nm lines with 14 nm half pitch grating in non-baked HSQ (Fig. 2), and hole arrays of 17.5 nm in diameter with 37 nm pitch, 30 nm in diameter with 45 nm pitch, and 15 nm in diameter with 55 nm pith (Fig. 3). It is also found that pre-baked HSQ required less dosage, which can enhance the throughput, but sacrificed the resolution.

References

[1] Y.-H. Lee, R. Browning, N. Maluf, G. Owen, and R.F.W. Pease, J. Vac. Sci. Technol. B 10, 3094, 1992
[2] P.A. Peterson, E.J. Radzimski, S.A. Schwalm, and P.E. Russell, J. Vac. Sci. Technol. B 10, 3088, 1992
[3] M.A. McCord and T.H. Newman, J. Vac. Sci. Technol. B 10, 3083, 1992
[4] S.J. Lin, J.H. Chen, S.M. Chang, T.Y. Fang, B.R. Luo and Faruk Krecinic, Proc. SPIE 7271, 727154, 2009
[5] S.W.H.K. Steenbrink, B.J. Kampherbeek, M.J. Wieland, J.H. Chen, S.M. Chang, M.Pas, J. Kretz, C. Hohle, D. van Steenwinckel, S. Manakli, J. Le-Denmat, and L. Pain, Proc. SPIE Vol. **6921**, 69211T, 2008

Acknowledgements

This work was supported by National Science Council, Republic of China, under the contract number NSC 98-2622-E-002-003-CC1. The authors would like to thank Elionix Inc. for the effort on low energy electron beam lithography and S.J. Lin, J.H. Chen and S.M. Chang in TSMC, Taiwan for their helpful discussions. This work is performed in Electron Beam Lab of National Taiwan University.

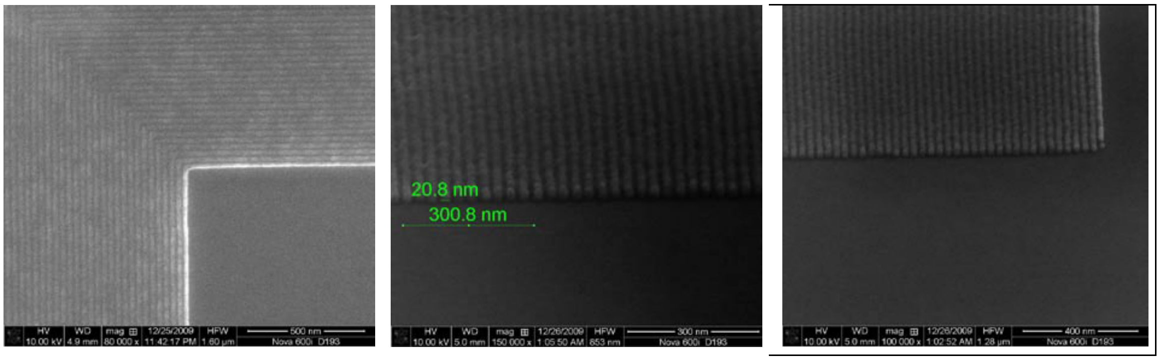

Fig. 1 20.8 nm lines with 15 nm half pitch written in prebaked HSQ at 5keV with line dose of 0.2178 nQ/cm
(a) L shape patterns shown the writings in X and Y directions are connected (b) SEM photo shown the middle of grating structures at magnification of 150,000 and tilt angle of 52° (c) SEM photo shown the edge of grating structures at magnification of 100,000 and tilt angle of 52°

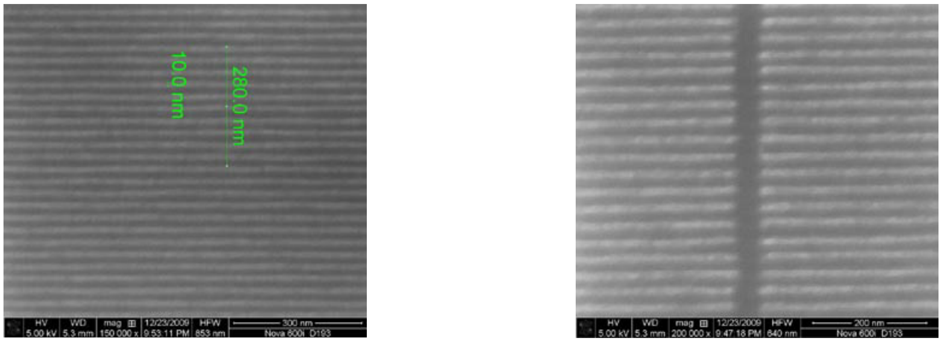

Fig. 2 10 nm lines with 14 nm half pitch written in non-baked HSQ at 5 keV with line dose of 0.2376 nQ/cm
(a) SEM photo at magnification of 150,000 (b) SEM photo at magnification of 200,000 shown the designed 40 nm gaps

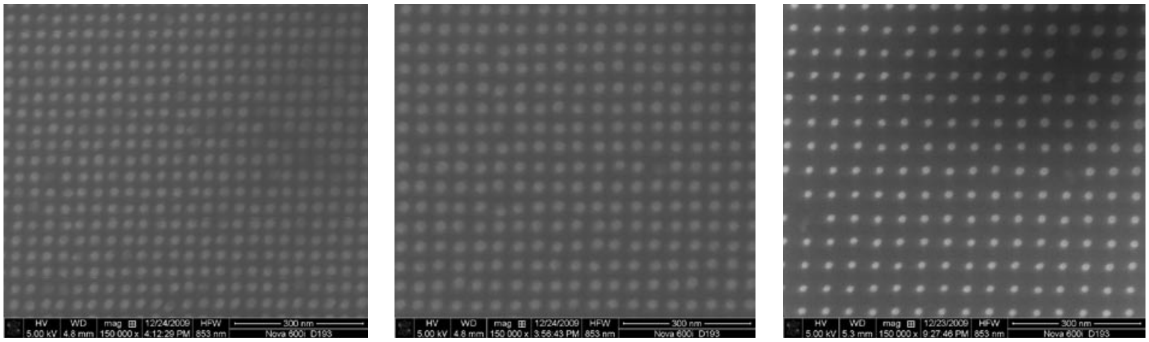

Fig. 3 Hole arrays written in HSQ at 5 keV (a) 37 nm pitch hole array with diameter of 17.5 nm (b) 45 nm pitch hole array with diameter of 30 nm (c) 55 nm pitch hole array with diameter of 15 nm