Exposure Strategy: Investigation Of The Relationship Between Exposure Speed And Ultra High Resolution In Electron Beam Lithography

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As the semiconductor industry begins to struggle to keep up with the demands of Moore's law, it has been found that as the dimensions of the MOSFET scales past the 22 nm node, certain lithography issues arise because the promise of EUV lithography has not come to fruition. Complementing optical lithography with electron beam lithography provides a route to produce the next generation microprocessors. The success of this approach depends on the resist system that is employed to produce sub – 10nm dimensions that directly writes fast enough over the entire wafer. This is dependent upon the clearing dose which is given by

$$Area\ Dose = \frac{I * t}{S^2} \tag{1}$$

Where I is the current, t is the dwell time and s is the step size. In order to reduce the dose, the dwell time must be reduced[1]. This can be achieved by either of two methods. The first is by increasing the step size, however, this will lead to large line edge roughness. The second method is by increasing the current. If this strategy is done, the overall resolution of the nanostructures will be decreased. This increases the current density that is confined in the beam spot where more point charges (i.e. electrons) will be present. The increased number of electrons will over expose the resist by generating secondary electrons (these electrons are scattered at angles larger than 80° in arbitrary trajectories at distances microns away from the primary beam[1, 2]), leading to large proximity effects, as they will expose the resist outside of the intended write area. Fabricating sub-10 nm structures cannot be achieved under these conditions[1].

The direct write strategy of exposing a resist called SML100 has been investigated using Monte Carlo Simulations. Figure 1 and 2 shows the scattering trajectories that were exposed with a current of 10 nA and 100 pA respectively. It was observed from Fig. 1 that the SML100 that was exposed with a current of 10 nA experiences increased electron scattering compared to the SML100 resist shown in Fig. 2 and this can be seen as the foot print is larger. From this, it was determined that the theoretical resolution of the SML100 polymer was 7.5 and 23 nm when the current was 100 pA and 10 nA respectively. This resulted with an aspect ratio of 13:1 and 4.3:1. Therefore, the proximity effects seen in electron beam lithography can be reduced. This would suggest that the approximately 32% smaller nano structures would be achieved using a current of 100 pA. The effect of this is that to obtain high resolution the writing speed must be reduced by an order of magnitude (50 and 0.5 μS when the current was 100 pA and 10 nA respectively).

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[1] S. Lewis, L. Piccirillo, 'Influence of nanocomposite materials for next generation nanolithography', Advances in diverse industrial applications of nanocomposite', Intech, pp 503 – 528, March 2011, ISBN: 978-953-307-202-9.

[2] K. W. Lee, S. M. Yoon, S. C. Lee, I. –M. Kim, C. E. Lee, D. H. Kim, 'Secondary electron generation in electron-beam-irradiated solids: Resolution limits to nanolithography', Journal of Korean physical society, Vol 55, No 4, Oct (2009), pp 1720 – 1723.

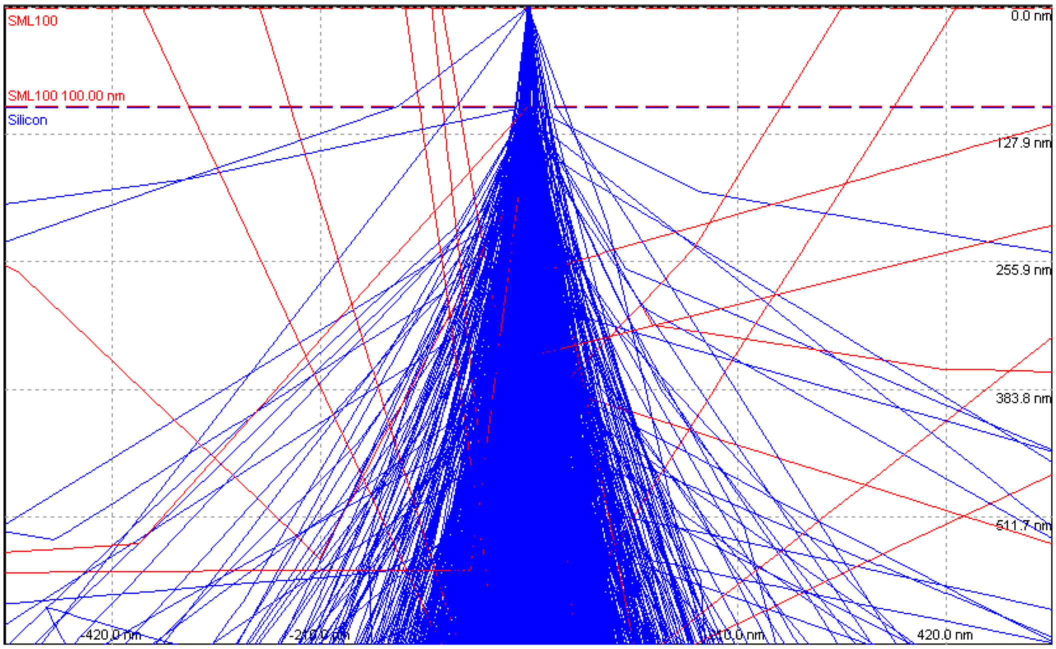

Figure 1: The internal electron scattering interactions inside the SML100 resist film that was exposed using a current of 10 nA and an acceleration voltage of 100 KeV. The red lines represent secondary electrons.

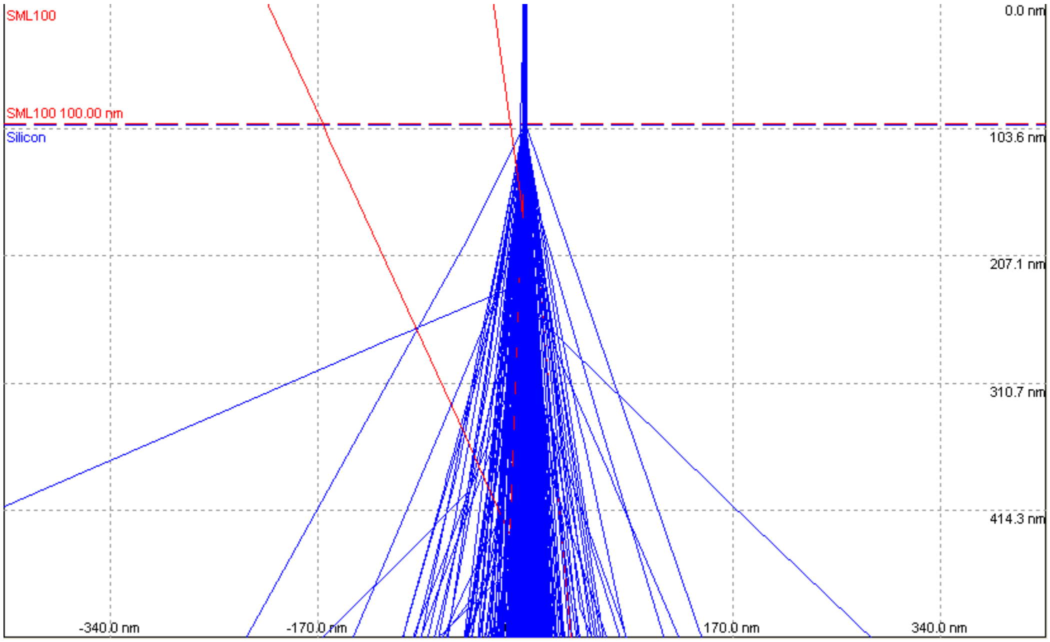

Figure 2: The internal electron scattering interactions inside the SML100 resist film that was exposed using a current of 100 pA and an acceleration voltage of 100 KeV. The red lines represent secondary electrons. Reducing the current density decreases the number of secondary electrons created inside the SML100 resist.