Determination of experimental spot sizes & acid diffusion lengths in CAR resist for e-beam lithography at 100 kV and 5 kV.

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Electron-beam lithography has been successfully used since decades for research and development activities even though it has never emerged as a rational option for manufacturing purposes yet. However, the high resolution targeted by the semiconductor industry raised new attention on e-beam lithography regarding the maskless approach. For this purpose, proofs of convenient throughput and high resolution with a stable process window are required. Throughput might be achieved by the multi-beam approach as proposed by MAPPER Lithography while resolution depends on resist process, proximity effects, beam spot sizes and vibrations. In this study we propose an experimental method to estimate the beam spot size and the acid diffusion length of an e-beam lithography chemically amplified resist (CAR) process. The impact of the beam spot size on the resolution capabilities was first investigated with a CAR reference process. Beam spot size estimations are based on the one line width measurement method previously proposed by D. Rio et al[1]. We applied this method to two specific dose ranges. In the first one, the chemistry mechanism in the exposed resist is dominated by the acid catalytic deprotection of a partially protected polymer [2] (standard process). In the second dose range, the chemistry is governed by the cross linking mechanism due a volunteer overdose in a positive tone CAR resist leading to a polarity inversion of the resist. This last range enables to remove the acid diffusion and to minimize vibrations effects. This strategy has been applied to a LETI reference CAR resist process with a Leica VB6 UHR at 100 kV and with a MAPPER tool at 5 kV. Experimental curves obtained at 5 kV are reported in figure 1. Moreover, the comparison of the beam spot size determined in each dose ranges enabled us to estimate the acid diffusion length of the resist process. By measuring the vibrations effects through monitoring stage vibrations during exposures, we were able to estimate an acid diffusion length of 6 nm for the LETI CAR resist process of reference, whatever accelerating voltage (100 or 5 kV). We were then able to measure a beam spot size of 14 nm and a reasonable exposure latitude on 18 nm half pitch dense pattern at 100 kV (cf. figure 2). The research leading to these results has been performed in the frame of the industrial collaborative consortium IMAGINE driven by CEA-LETI.

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[1] D. Rio, C. Constancias, M. Martin, B. Icard, J. van Nieuwstadt, J. Vijverberg, et L. Pain, « 5 kV multielectron beam lithography: MAPPER tool and resist process characterization », *J. Vac. Sci. Technol. B*, vol. 28, n° 6, p. C6C14‑C6C20, nov. 2010.

[2] T. Kozawa, « Theoretical Study on Acid Diffusion Length in Chemically Amplified Resists Used for Extreme Ultraviolet Lithography », *Jpn. J. Appl. Phys.*, vol. 52, n° 1R, p. 016501, janv. 2013.

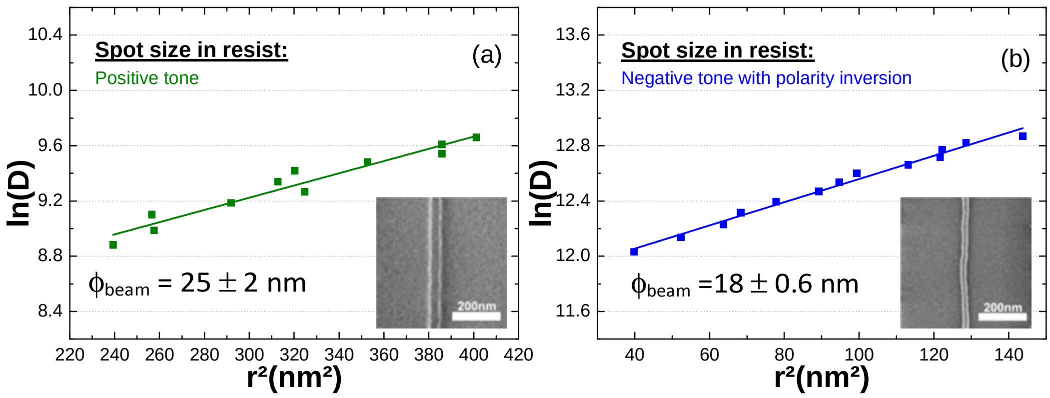

Figure 1: *Logarithm of the exposure dose (µC/cm²) as a function of line half width's squared value obtained with the MAPPER alpha tool at 5kV for (a) the standard process range and (b) for the polarity inversion range. Line width measurements were performed by means of a CD-SEM. The beam diameter is calculated from the slope of the straight line obtained by linear regression.*

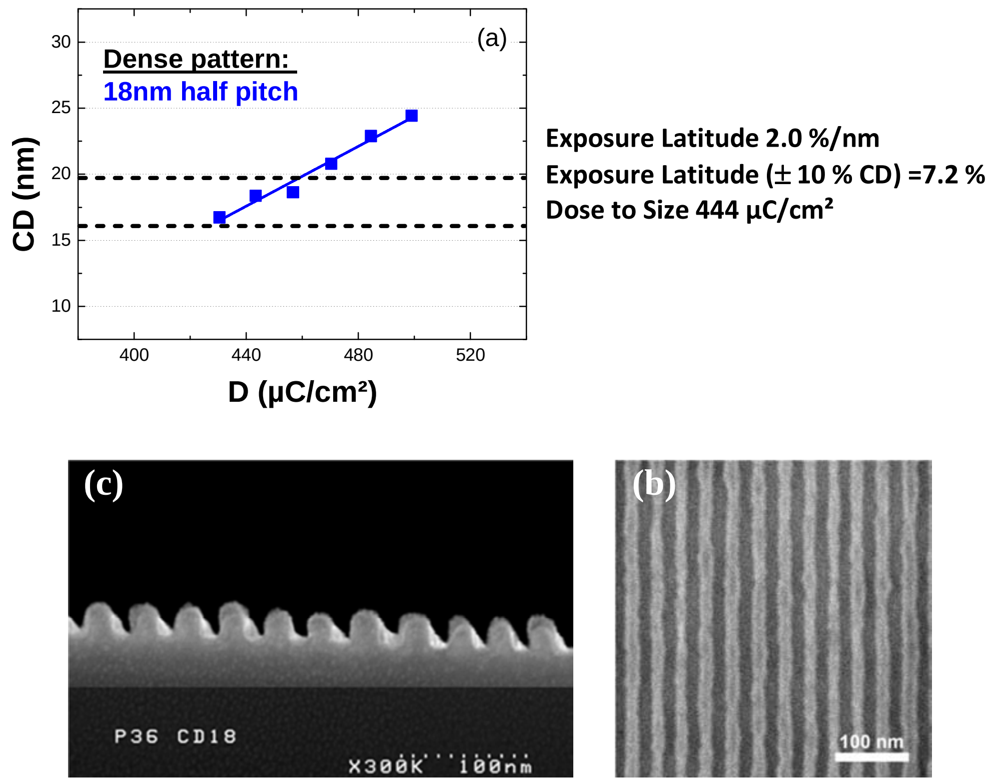

Figure 2: *(a) Process window with the CAR reference resist with a Leica VB6 UHR 100 kV, (b) CDSEM representative image of a18 nm half pitch dense pattern, (c) SEM cross-sectional view.*