Chemical Semi Amplified Positive-E-Beam Resist (CSAR 62) for Highest Resolution

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Positive PMMA based e-beam resists are already used for decades in electron beam lithography. These resists are characterised by a high process stability, but sensitivity, contrast and plasma etch stability must be regarded as comparatively low [1]. A significant improvement of sensitivity and plasma etch stability can be achieved with e-beam resists on the basis of methyl styrene/methyl α-chloracrylate copolymers (e.g. ZEP) [2]. Disadvantage of these resists is however their low commercial availability. On the other hand, chemically amplified resist (CAR) systems are known to show an order of magnitude higher sensitivity in comparison to conventional e-beam resists [3 - 5]. However, the resolution of these resists is limited due to the diffusion processes inherent to the chemical amplification.

We have successfully developed and systematically tested resists based on different copolymers of methyl styrene and chloracrylate in combination with components of CAR systems which provide both high resolution and increased sensitivity (see Fig. 1).

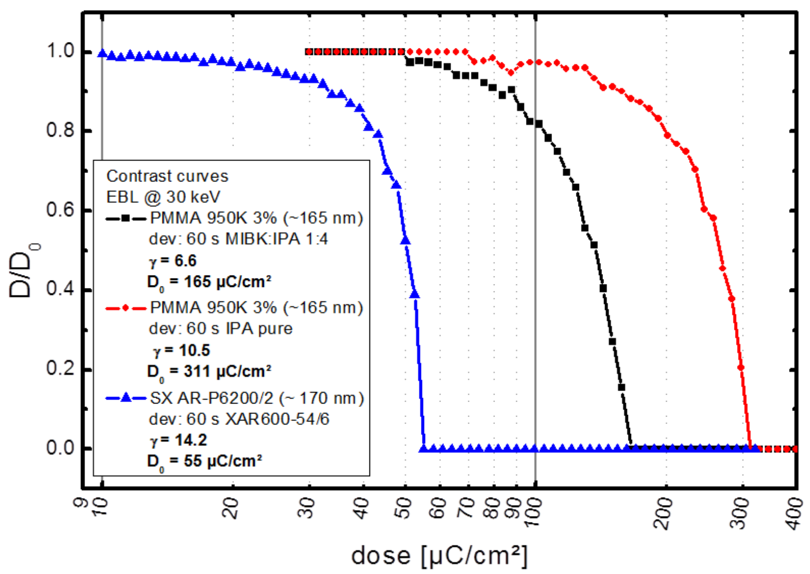

Figure 1: Comparison the sensitivities of resist AR-P 679.03 (PMMA-based) and new CSAR resist SX AR-P 6200/2

In initial experiments, the starting material for the positive e-beam resists was assessed. Various resists with a film thickness of 180 nm were prepared from methyl styrene/methyl halogen acrylate copolymers synthesized in different ways. In a second series of tests, halogenated acid generators were added in different concentrations to enhance both sensitivity and etch stability (so-called **C**hemical **S**emi **A**mplified **R**esist, CSAR). Furthermore, copolymers were substituted with higher aromatics (naphthalene, anthracene) to improve the etch resistance.

The different resists were tested under the following conditions:

Resists are spin-coated onto silicon substrates and dried for 5 minutes at different temperatures (150 – 180 °C). Electron beam lithography is performed at an acceleration voltage of 30 kV using a Schottky field-emission system. For resists with addition of CAR, a post exposure bake of 2 minutes at 100 °C is performed on a hot plate prior to development. The samples were developed in different organic solvent developers and rinsed in IPA and DI-water. Test structures were used to determine the area dose and the resolution. The best resolution of the 180-nm-layers is about 13 nm with a pitch of 100 nm (see Fig. 2). First results with lift-off-applications generate 10-nm-lines (see Fig. 3).

With the new developer X AR 600-54/6 a sensitivity of approximately 55 µC/cm² is obtained. Utilizing the optimised developers which were designed with particular regard to highest occupational safety (flash point) a contrast of up to 14 could be observed. As first results indicate the sensitivity (D_o) reaches up to 10 µC/cm² at 30 kV (still in progress).

The plasma etch resistance is considerably higher as known for PMMA resists (CF_4 and $CF_4 + O_2$) and comparable with ZEP. By introducing higher conjugated aromatic monomer units in polystyrenes (naphthalene, anthracene), the plasma etch resistance can be expected to considerable increase (still in progress).

In summary, our investigations demonstrated that the CSAR shows a high sensitivity, high resolution and good plasma etch stability. Final results will be presented at the HARMNST 2013.

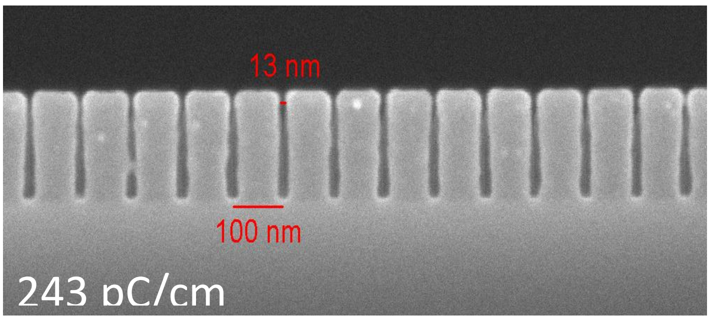

Figure 2: Resolution of the 180-nm-CSAR-layers

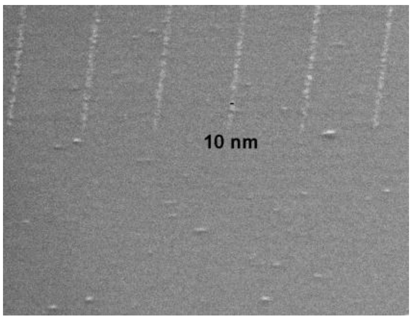

Figure 3: Prepared 10-nm-lift-off-lines

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