Chemical semi amplified positive e-beam resist (CSAR 62) for highest resolution

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Motivation

PMMA e-beam resists are characterised by a high process stability, but sensitivity, contrast and plasma etch stability are low [1]. A significant improvement of sensitivity and plasma etch stability can be achieved with the e-beam resist ZEP [2]. Chemically amplified resist (CAR) systems are known to show higher sensitivity in comparison to conventional e-beam resists, but the resolution of these resists is limited due to diffusion processes inherent to the chemical amplification [3 - 5].

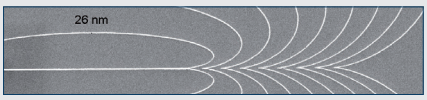
Idea: Utilisation of resists based on different styrene and chloroacrylate copolymers in combination with components of CAR systems which provide both high resolution and increased sensitivity. These resists are the so-called Chemical Semi Amplified Resist, CSAR.

Purpose & sample

Purpose of work:

E-beam exposure with 30-100 kV to explore

- area and line dose
- narrowest trenches
- narrowest lift-off-structures
- different resist thickness up to 2 µm
- different developer for different sensitivities
- plasma etch stability
- application in multi layer systems for t-gates / lift-off
- shelf life



Cr-structures after removing of the CSAR resist (Artwork)

Sample preparation

Spin coating:
AR-P 6200.09
60´´4.000 rpm, resist thickness 200 nm

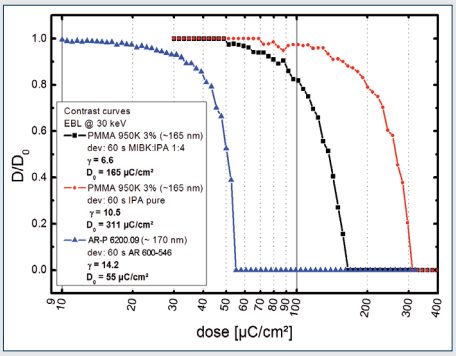
Soft bake:
1 min, 150 °C hot plate

E-Beam lithography:
Raith Pioneer, 30 kV
exposure dose: 65 µC/cm²

Development:
60 sec, AR 600-546
temperature: 23 °C

Stopping/Rinse:
30 sec, AR 600-60

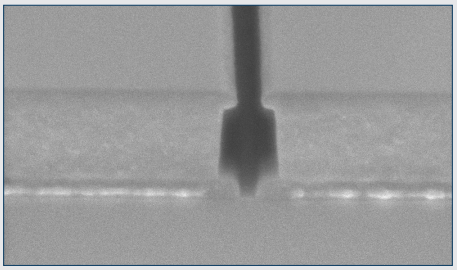
Comparison CSAR 62 - PMMA 950k



Comparison of the sensitivity of resist AR-P 679.03 (PMMA-based) and new CSAR resist AR-P 6200.09

The sensitivity of CSAR is 3-times higher as compared to PMMA (black line). Using the advanced PMMA-process (red line, developer IPA) for maximum contrast, sensitivity differs by a factor of 6. With a value of 14.2, the contrast is excellent.

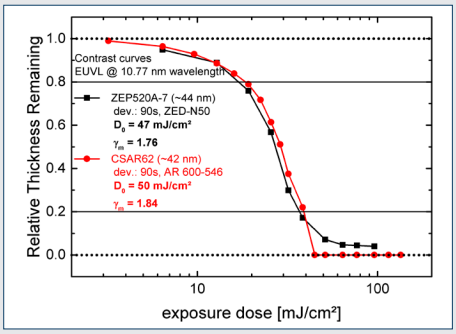
T-gates



T-gate structures produced with a triple-layer system

T-gates of high quality can be produced with the triple-layer system PMMA/AR-P 617/PMMA. However the use of CSAR 62 in triple-layer coatings allows an even more accurate adjustment of the T-gate geometry. In this case, the differing sensitivities of resists AR-P 617 > CSAR 62 > PMMA are exploited. The picture shows resist CSAR 62 on top, followed by AR-P 617 in the middle and PMMA as bottom resist. Each layer was developed with a selective developer.

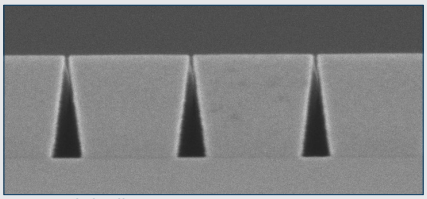
Resist characterization at EUV wavelengths



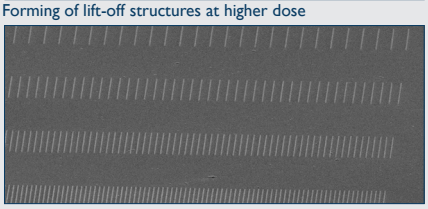
Characteristic curve plots for CSAR 62 and ZEP 520A-7 positive tone resists

Two state-of-the-art electron beam resists are characterized at extreme ultraviolet (EUV) wavelengths with the EUV laboratory exposure tool (EUV-LET) [6]. Both resists show comparable sensitivity and contrast in this wavelength range, offering a reasonable alternative to the not yet commercially available EUV-CARs.

Lift-off application



Forming of lift-off structures at higher dose

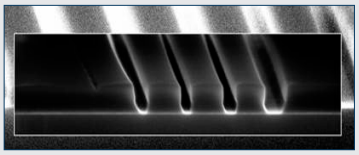


Metal structures after removing

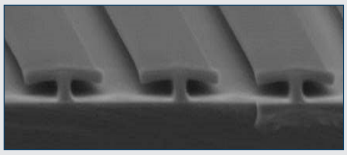
The CSAR is especially suitable for lift-off processes. At an aspect ratio of 18, structures show completely vertical walls. If the dose is increased, undercut structures form due to the proximity effect. It is usable for excellent metal vaporisation.

The smallest lines which could be generated by lift-off with CSAR were 10 nm wide. The removing (lift-off) is easy. With a 2-layer system CSAR 62 / AR-P 617 it is possible to generate complicated lift-off structures.

New developer for two-layer system CSAR 62 / AR-P 617



Development with a standard developer



Development with X AR 600-50/3

For the optimal use of the CSAR 62 as a single layer or in multilayer systems, various developers were designed which allow to specifically influence sensitivity, gradation and edge roughness. Since strong developers make CSAR 62 more sensitive, a certain amount of dark erosion (DL) has to be accepted. Selective developers were also sought for other multilayer systems, for example the two-layer system CSAR 62 (top) / AR-P 617 (bottom). For the structure depicted in the left figure, developers AR 600-546 for CSAR 62 and AR 600-50 were used. A slight modification of AR 600-50 resulted in an easily adjustable, larger undercut during development.

(Pictures from DTU Danship, Tine Greibe)

Conclusion & outlook

The synthesis of the copolymers was optimised and allows a simple and environmentally friendly production of the resists. Similarly, almost no differences could be observed for a bake of films between 150 – 180 °C, while the contrast decreases at a temperature of 95 °C. Depending on the respective samples, the Cauchy coefficients were determined in a range of 1.541 – 1.544. Sensitivity, gradation and resolution can be influenced to a great extent if different developers are utilised. Plasma etch stability is similar to the commercial photoresist and two times better to the PMMA. In summary, our investigations demonstrated that the CSAR shows a high sensitivity, high resolution and good plasma etch stability and can be used to generate excellent lift-off structures. The optimization of non-CAR samples produced such excellent results with almost identical sensitivity which eliminates the need to add CAR components.

Literature: [1] Shazia Yasin, D.G. Hasko, H. Ahmed; Microelectronic Engineering 61–62 (2002) 745–753, [2] Mohammad Ali Mohammad, Kirill Koshelev; Jap. Journal of Applied Physics 51 (2012) 06FC05, [3] T. H. P. Chang, D. P. Kern, and L. P. Murray, J.Vac. Sci.Technol. B 10, 2743, 1992., [4] E. Kratschmer, H. S. Kim, M. G. R. Thomson, K.Y. Lee, J.Vac. Sci.Technol. B 13, 2498, 1995., [5] M. Böttcher, L. Bauch, and I. Stolberg, J.Vac. Sci.Technol. B 12, 3473, 1994, [6] S. Brose, S. Danylyuk, J. Tempeler, H. Kim, P. Loosen, L. Juschkin; Proc. of SPIE 9776, Extreme Ultraviolet (EUV) Lithography VII, 97760R, (2016) As of: Sept. 2016