Positive E-Beam Resists AR-P 6200 (CSAR 62)

AR-P 6200 e-beam resists with highest resolution

High-contrast e-beam resists for the production of integrated circuits and masks

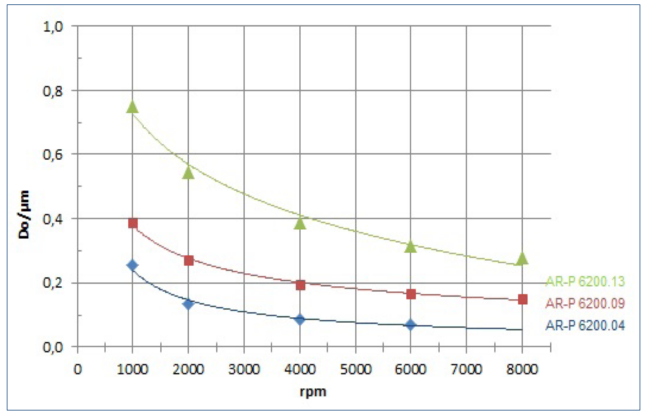
Characterisation

- e-beam
- high sensitivity which can be adjusted via the developer
- highest resolution (< 10 nm) and very high contrast
- highly process-stable, high plasma etching resistance
- easy fabrication of lift-off structures
- poly(α-methyl styrene-co-α-chloroacrylate methyl ester) and an enhancer of sensitivity
- safer solvent anisole

Properties I

Parameter / AR-P	6200.13	6200.09	6200.04
Solids content (%)	13	9	4
Viscosity 25 °C (mPas)	11	6	2
Film thickness/4000 rpm (µm)	0.40	0.20	0.08
Resolution best value (nm)	6		
Contrast	14		
Flash point (°C)	43		
Storage 6 month (°C)	8 - 12		

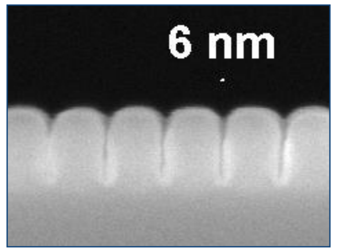
Spin curve



Properties II

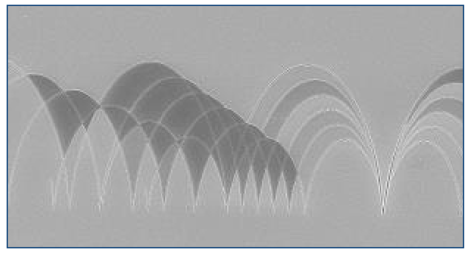
Glass trans. temperature (°C)	148	
Dielectric constant	2.8	
Cauchy coefficients	N_0	1.543
	N_1	71.4
	N_2	0
Plasma etching rates (nm/min)	Ar-sputtering	10
(5 Pa, 240-250 V Bias)	O_2	180
	CF_4	45
	80 CF_4 + 16 O_2	99

Structure resolution



AR-P 6200.04
Resolution of up to 6 nm at film thickness of 80 nm

Resist structures



AR-P 6200.09
25-nm structures, film thickness of 180 nm, artwork

Process parameters

Substrate	Si 4" waver
Tempering	150 °C, 60 s, hot plate
Exposure	Raith Pioneer, 30 kV
Development	AR 600-546, 60 s, 22 °C

Process chemicals

Adhesion promoter	AR 300-80
Developer	AR 600-546, 600-549
Thinner	AR 600-02
Stopper	AR 600-60
Remover	AR 600-71, 300-76

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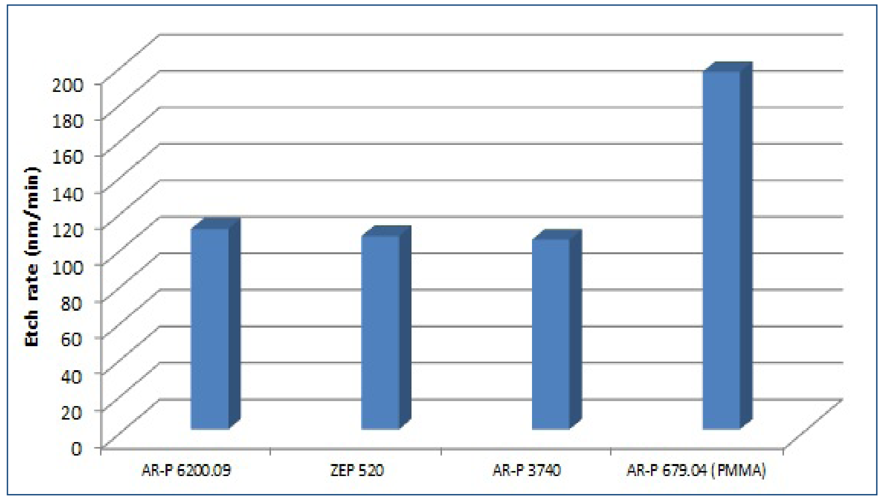
Process conditions

This diagram shows exemplary process steps for AR-P 6200 resists. All specifications are guideline values which have to be adapted to own specific conditions. For further information on processing, ☞ "Detailed instructions for optimum processing of e-beam resists". For recommendations on waste water treatment and general safety instructions, ☞ "General product information on Allresist e-beam resists".

	AR-P 6200.09
Coating	4000 rpm, 60 s 0.2 µm
Tempering (± 1 °C)	150 °C, 1 min hot plate or 150 °C, 30 min convection oven
E-beam exposure	Raith Pioneer, 30 kV Exposure dose (E_0): 65 µC/cm²
Development (21-23 °C ± 0,5 °C) puddle	AR 600-546 1 min
Stopping / Rinse	AR 600-60, 30 s / DI-H_2O, 30 s
Post-bake (optional)	130 °C, 1 min hot plate or 130 °C, 25 min convection oven for slightly enhanced plasma etching resistance
Customer-specific technologies	Generation of semiconductor properties
Removal	AR 600-71 or O_2 plasma ashing

Plasma etching resistance



CSAR 62 is characterized by a high plasma etching resistance. In this diagram, plasma etching rates of AR-P 6200.09 are compared with those of AR-P 3740 (photoresist), AR-P 679.04 (PMMA resist) and ZEP 520 in CF_4 + O_2 plasma.

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Processing instructions

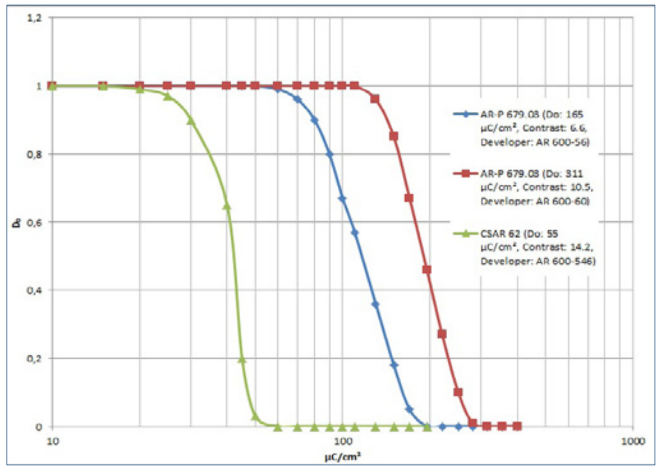
E-beam exposure: The required e-beam exposure dose for structural imaging mainly depends on the desired minimum structure size, the developer, the acceleration voltage (1 - 100 kV), and the film thickness.

The exposure dose for AR-P 6200.09 was in this experiment (☞ diagram comparison of CSAR 62 and PMMA) 55 µC/cm² (dose to clear D_0, 30 kV, 170 nm layer, developer AR 600-546, si wafer). The contrast was determined here to 14.2.

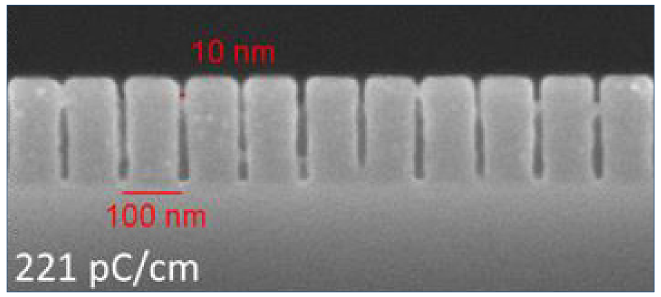
CSAR 62 is thus 3x more sensitive as compared to the standard PMMA resist AR-P 679.03 (developed in AR 600-56), or 6x more sensitive if developed in AR 600-60. Also the contrast is higher by a factor of 2 and 1.4, respectively.

An additional increase in sensitivity due to addition of sensitivity-enhancing components occurs already during exposure. A post-exposure bake is thus not required.

For the fabrication of 10-nm trenches (174 nm film, 100n pitch), AR 6200.09 requires a dose of approx. 220 pC/cm (30 kV, developer AR 600-546)



Comparison D_0 and contrast CSAR 62 and PMMA



Maximum resolution CSAR 62 of 10 nm (180 nm)

Development: For the development of exposed resist films, developers AR 600-546, 600-548 and 600-549 are recommended. As weaker developer, AR 600-546 provides a wider process window. If the stronger developer AR 600-548 is used, the sensitivity can be increased 6-fold to < 10 µC/cm². The intermediate developer AR 600-549 renders the CSAR 62 twice as sensitive as compared to AR 600-546, it shows also no dark erosion and has a contrast of 4.

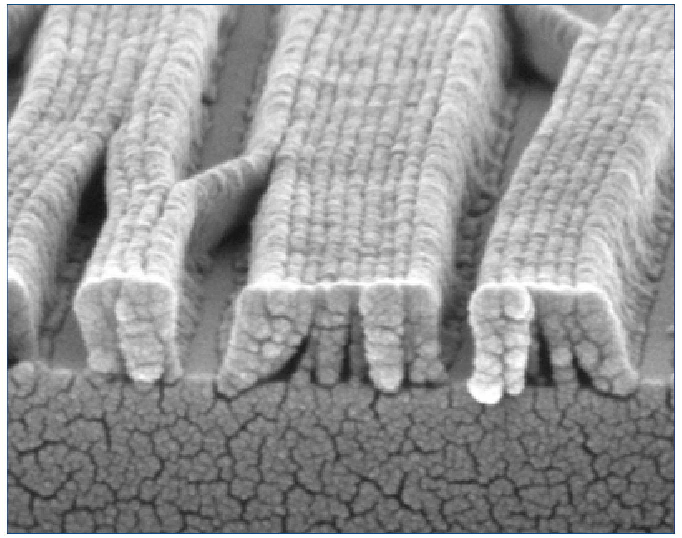
For immersion development, generally development times of 30 - 60 seconds are recommended. If developer AR 600-546 is used, even after 10 minutes at room temperature no erosion of unexposed areas is detected.

Developer AR 600-548 in contrast attacks resist surfaces already after two minutes visibly. If however the development process is carried out at temperatures of approx. 0 °C, no dark erosion is observed even after 5 minutes (which is however associated with a reduction of sensitivity).

The development procedure should be stopped quickly. For this purpose, the substrate is moved for 30 seconds in stopper AR 600-60. Optionally, the substrate may thereafter be rinsed for 30 seconds with DI water to remove all residual solvent.

Note: Please take into account that rigid rinsing procedures may lead to a collapse of smaller structures (☞ see image below).

A post-bake for special working steps at max. 130 °C results in a slightly improved etching stability during wet-chemical and plasma-chemical processes.



Danger of collapsed lines after too rigid rinsing

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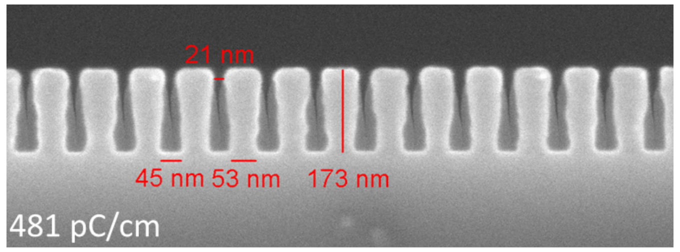
Processing instructions

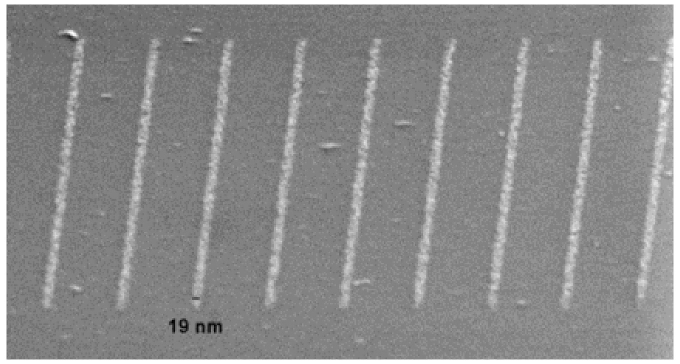
Lift-off structures:

Resist CSAR 62 is well suited to generate lift-off structures with a resolution of up to 10 nm. If the dose is increased by a factor of 1.5 - 2, narrow trenches with defined undercut can be fabricated with AR-P 6200.09.

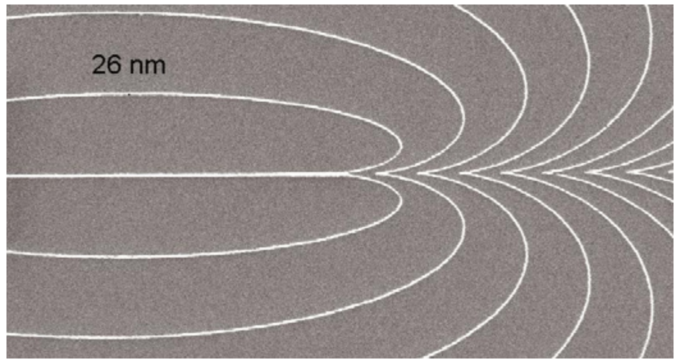


Undercut structures obtained with increased exposure dose

After vapour-deposition of metal and subsequent easy lift-off, metal structures remain



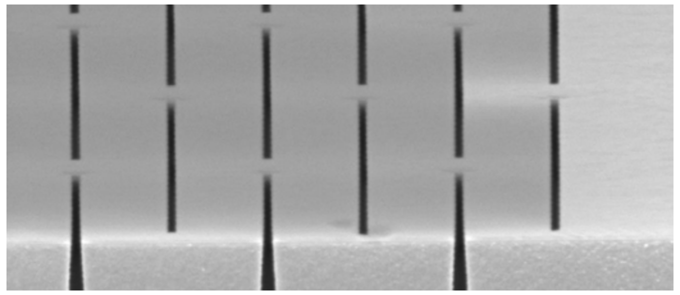
19-nm metal lines after lift-off process with AR-P 6200.09



CrAu test structures with a line width of 26 nm

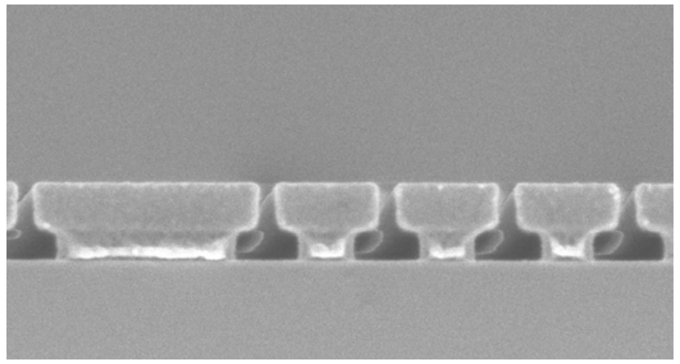
High layers for special applications:

Films with a thickness of up to 800 nm can be produced With AR-P 6200.13, and even 1.5-µm films are possible with experimental sample SX AR-P 6200/10.



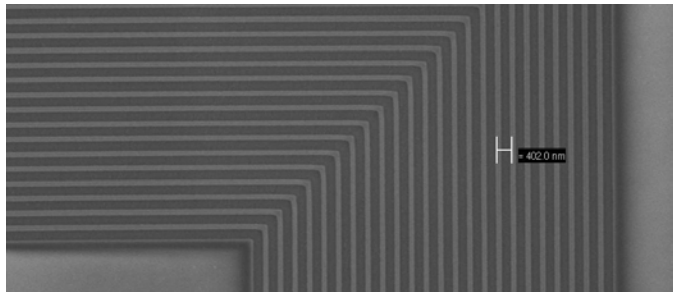
AR-P 6200.13: 100-nm trenches in 830-nm thick layer

CSAR 62 is also applied in various two-layer systems and can be used both as bottom and as top resist.



AR-P 6200.09 as top resist for extreme lift-off applications

Another field of application for CSAR 62 is the production of mask blanks which are coated with our resist and offered by our partners:



At a film thickness of 380 nm, 100-nm lines and spaces can be obtained on a chrome mask with AR-P 6200.13. The sensitivity is 12 µC/cm² (20 kV, AR 600-548).

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Application examples for CSAR 62

Circuits for the 5 GHz range which are primarily needed for wireless Bluetooth or Wi-Fi technologies can in future be produced with CSAR 62. E-beam lithography is also required for the research on nanomaterials like graphene, for three-dimensional integrated circuits as well as for optical and quan-tum computers. The computing power or memory density is constantly increased in each of these technologies. Applications with the highest demands on computing power (supercomputers), e.g. in computational fluid dynamics or in space applications, thus also demand microchips with highest inte-gration density.

CSAR 62 on mask blanks

Experts at the HHI Berlin have already tested CSAR 62 on mask blanks (☞ Fig. 1). They immediately achieved a resolution of 50 nm which is an excellent value for masks. To date, 100 nm lines and above are used on masks. Currently test coatings of mask blanks with CSAR 62 are conducted, and samples will be offered by our partners to all customers in the near future.

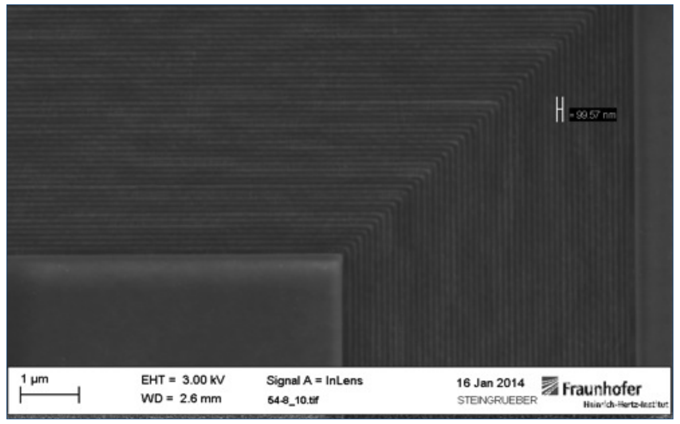

Fig. 1 CSAR 62 test structure on a mask blank with 50 nm lines and 50 nm trenches, pitch line & space 99.57 nm

Fabrication of plasmonic nanomaterials

The work group for quantum detection has for already many years successfully promoted electron beam projects for nanostructuring. This group in particular emphasised the high process stability of CSAR 62 as compared to ZEP 520 (☞ Fig. 2). CSAR 62 is able to balance out small process fluc-tuations and still reliably provides the desired high resolution. The new Allresist product furthermore showed 1.5-fold higher contrast values than ZEP in comparative measurements.

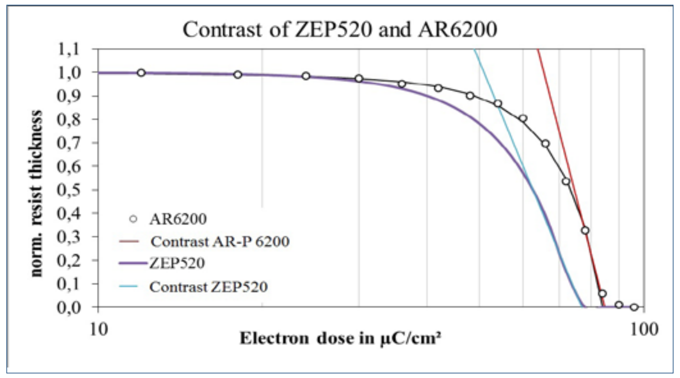

Fig. 2 Contrast curves AR-P 6200 and ZEP 520, 50kV, substrate: Si; ZEP 520, film thickness 220 nm, 60 s ZED N-50, contrast 6; AR-P 6200, film thickness 260 nm, 60 s AR 600-546, contrast 9

CSAR 62 for highest-resolution lithography

In the work group for nanostructured materials, CSAR 62 is mainly used in highest-resolution lithography for the lift-off and as etching mask for dry chemical etching processes. The new resist offers several specific advantages. It achieves the high resolution of PMMA, but at a much lower dose, which is favourable for the following reason: CSAR 62 however counterbalances this effect due to its higher sensitivity, and in combination with the more favourable contrast curve can slight undercuts be achieved even in thin layers. This allows a uniform lift-off in the sub-100 nm range.

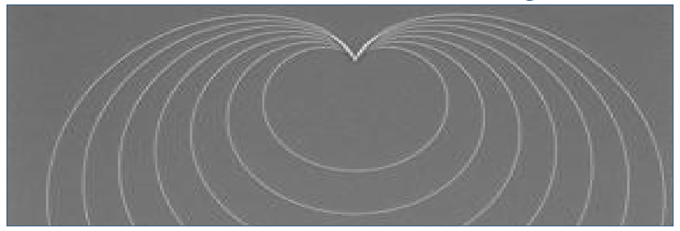

Fig. 3 Chrome structures with 20 nm lines after lift-off

The goal in the lift-off of metal structures is however not always to go beyond the limits of resolution. Typical applications for example in the contacting of nanowires rather require dimensions in a range of 30-50 nm, which can also be realised with other resists. The „resolution reserve" of CSAR 62 however allows for significantly improved structure accuracy and faster design with less iteration:

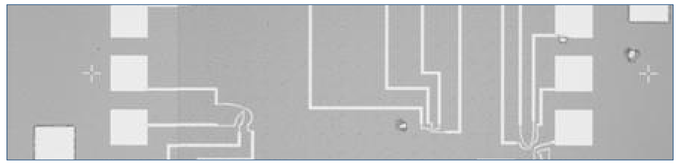

Fig. 4 Typical structure for contacting nanowires. Large areas are mixed with small details

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Application examples for CSAR 62

During dry chemical etching, for example in the structuring of silicon nitride, CSAR combines the best of two worlds: It not only allows the use as a high resolution positive resist similar to PMMA, but also offers a stability which is comparable to novolacs. This facilitates the production of masks with sharp edges that provide the required etch stability without the otherwise frequently occurring disturbing faceted edges. In addition, a new variant of CSAR 62 with an extremely high layer thickness (1 µm) was assessed. The thick layer allows producing a strong undercut with only one layer, which is perfectly suitable for lift-off (☞ Fig. 5). The process is designed for larger surface areas in the micrometer range which should however clearly be defined since the pronounced undercut (as obvious from the figures) restricts the minimum distance between different structures.

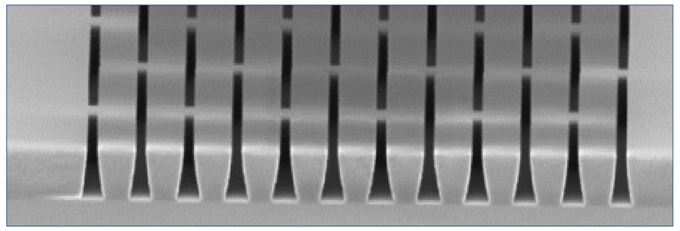

Fig. 5 Particularly thick CSAR with pronounced undercut for extreme lift-off applications

Comparison of CSAR 62 and ZEP 520A

A leading company for electron-beam devices conducted a comparison of CSAR 62 and ZEP 520A. Using the current e-beam system SB 250, three comparative studies of CSAR 62 (AR-P 6200.09) and ZEP 520A were carried out which focused on the parameters structural resolution, contrast and sensitivity in the respective native developers:

1. Structural resolution: The comparison of 90 nm lines of both resists (☞ Fig. 6 and 7) in the centre of a silicon wafer with a film thickness of 200 nm shows that both CSAR and ZEP are characterised by an excellent structural resolution (trench width of 91 nm, pitch 202 nm) and comparable broad process windows:

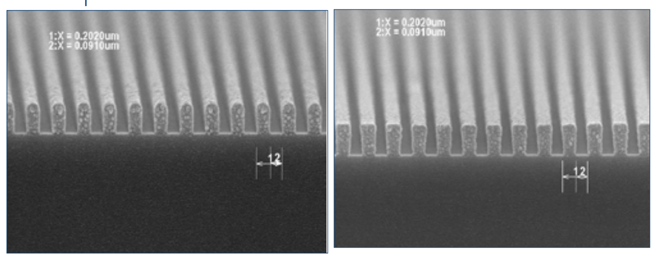

Fig. 6 ZEP 520A, 200 nm, ZED N50, 50kV, 80 µC/cm²
Fig. 7 AR-P 6200.09, 200 nm, AR 600-546, 50 kV, 85 µC/cm²

2. Contrast: The diagram (Fig. 8) illustrates the comparison of contrast values: ZEP 520 in the corresponding developer ZED-N50 and CSAR in developers AR 600-546 and 600-549. While systems ZEP-ZED-N50 and CSAR-AR 600-549 provide almost equally good contrast values, the contrast of CSAR in developer AR 600-546 (which was specifically optimised for this purpose) is almost twice as high. This system is therefore ideally suited for high-resolution applications:

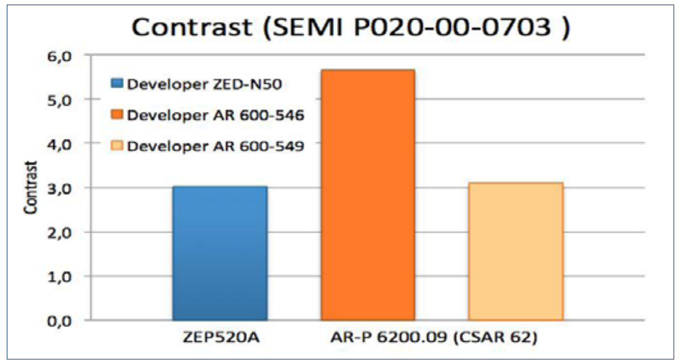

Fig. 8 Contrast ZEP 520A, 200 nm, ZED N50 as well as AR-P 6200.09, 200 nm, AR 600-546 and AR 600-549

3. Sensitivity (dose to clear): The diagram (Fig. 9) demonstrates a good range for the required dose of both resists. Again however, the CSAR resist-developer system with AR 600-546 is twice as sensitive in comparison to the ZEP resist-developer system:

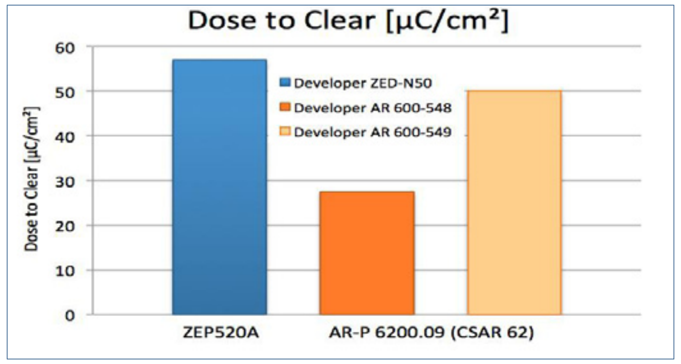

Fig. 9 Sensitivity ZEP 520 A, 200 nm, ZED-N50 as well as AR-P 6200.09, 200 nm, AR 600-548 and 600-549

All three studies come to the conclusion that ZEP 520A and CSAR 62 are both characterised by very good properties. CSAR 62 is thus an attractive alternative - with partly even more favourable application parameters. Advantages of CSAR 62 also arise from the variety of developers offered by Allresist, i.e. AR 600-546, 600-548 and 600-549.