Preliminary information of new product development

Positive e-beam resist for maximum resolution SX AR-P 6200 (CSAR 62)

1. General description

The electron beam resist SX AR-P 6200/2 is a positive-tone e-beam resist which provides, depending on the respective developer, high to very high sensitivity and allows to realise resolutions down to the sub-10-nm range. The resist is furthermore characterised by high process and plasma etch stability and in addition very suitable for lift-off processes up to structure sizes of 10 nm.

Due to the very high contrast of > 15, a resolution of 10 nm can be achieved at a film thickness of 180 nm. Realising an aspect ratio of 18 is thus possible.

Selecting an appropriate developer (X AR 600-54/8), the sensitivity of the resist can be increased to 10 µC/cm². An even higher resolution power is obtained with the developer X AR 600-54/6.

Main components of the resist are poly(α-methylstyrene-co-methyl chloroacrylate), an acid generator and the safer solvent anisole

2. Parameters

Properties / Resist	**SX AR-P**	**6200/2**
Solids content	%	9
Viscosity (25 °C)	mPa·s	6
Film thickness at 4000 rpm Semitec CPS 20, open chuck, 2“ Si-wafer	**µm**	**0.20**
Film thickness at 6000 - 1000 rpm Spin kurves ☞ S. 4	µm	0.17 – 0.39
Filtration	µm	0.1
Flash point	°C	43
Storage temperature Temporary temperature deviations have no effect on product properties.	°C	4-8
Guarantee from date of sale	Month	6

3. Prozess chemicals

Developer	X AR	600-54/6, 600-54/8
Thinner	AR	600-02
Stopper	AR	600-60
Remover	AR	600-71, 300-72
Adhesion promoter	AR	300-80

4. Process steps for SX AR-P 6200:

I.	• Spin coating (1000 – 6000 rpm)
II.	• Bake: 150 ± 1.0 °C, 30 min, convection oven or 150 ± 1.0 °C, 3 min, hot plate
III.	• Electron beam exposure
IV.	• Development: X AR 600-54/6, X AR 600-54/8 ; Stoppen: AR 600-60

(I) After adapting the resist to the temperature of the preferably air-conditioned working area (optimum conditions 20-25 °C at a relative air humidity of 30-50 %, no yellow light required), the resist is applied by spin coating.

(II.) It is recommended to perform the subsequent bake step on a hot plate at 150 °C for 3 min or in a convection oven at 150 °C for 30 min.

(III.) 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 of SX AR-P 6200/2 is 55 µC/cm² (dose to clear D_0, 30 kV, 170 nm layer, developer X AR 600-54/6, Si-wafer). The contrast was determined to be 14.2 (see Fig. 1):

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

An additional increase in sensitivity occurs already during exposure, due to the halogenated acidifiers. A post-exposure bake is thus not mandatory.

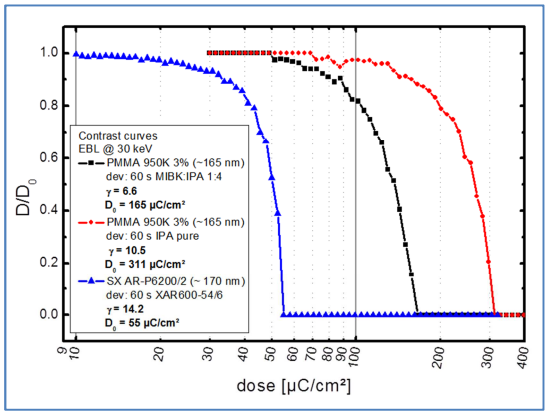

Fig. 1 Comparison D_0 and contrast of CSAR and PMMA

To generate trenches with a width of 10 nm (174 nm layer, 100 nm pitch, see Fig. 2), resist SX AR-P 6200/2 requires a dose of approx. pC/cm (30 kV, 180 nm, developer X AR 600-54/6).

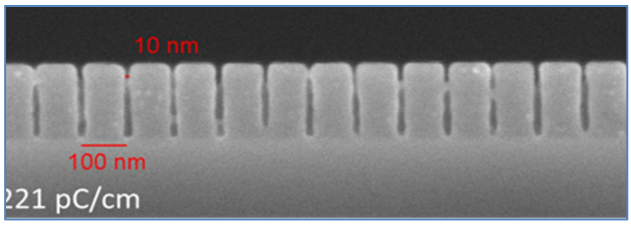

Fig. 2 Max. resolution of CSAR 62 of 10 nm at 180 nm

(IV.) For the development of exposed resist films, both **developer X AR 600-54/6** and **X AR 600-54/8** is recommended. As weaker developer, **X AR 600-54/6** provides a broader process window. If the stronger **developer X AR 600-54/8** is used, the sensitivity can be increased 6-fold to < 10 µC/cm².

In principle, also developer AR 600-56 and MIBK may be used for the development, but in this case sensitivity and contrast are substantially lower.

For immersion development, generally development times of 30 - 60 seconds are recommended. **Developer X AR 600-54/6** is well applicable at room temperatures, even after 10 minutes no erosion of unexposed areas is measurable. **Developer X AR 600-54/8** in contrast attacks resist surfaces already after two minutes visibly. If however the development process is carried out at temperatures around 0 °C, no erosion is observed even after 5 minutes (with loss of sensitivity).

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

Please note: Rigid rinsing procedures may lead to a collapse of smaller structures (see Fig. 3).

A post-bake at max. 130 °C for specific working steps results in improved etch stability during wet-chemical and plasma-chemical processes.

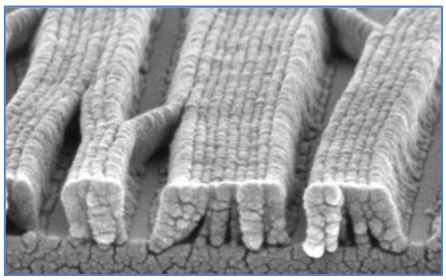

Fig. 3 Collapse of structures caused by too intense rinsing

Lift-off structures

Resist CSAR 62 is well suitable to produce lift-off structures with resolutions in a range down to 10 nm. If the dose is increased by a factor of 1.5-2, narrow trenches with defined undercut can be fabricated.

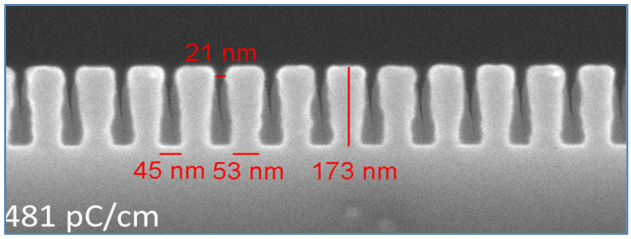

Fig. 4 Undercut structures due to increased dosage

After a vapour-deposition of metal and the subsequent easily performable lift-off, the metal structures remain.

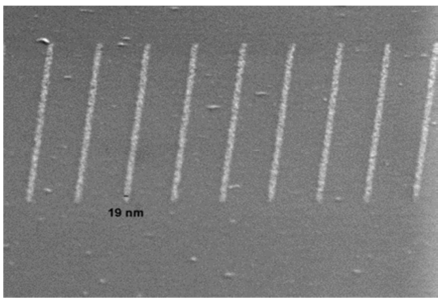

Fig. 5 19-nm metal lines after lift process

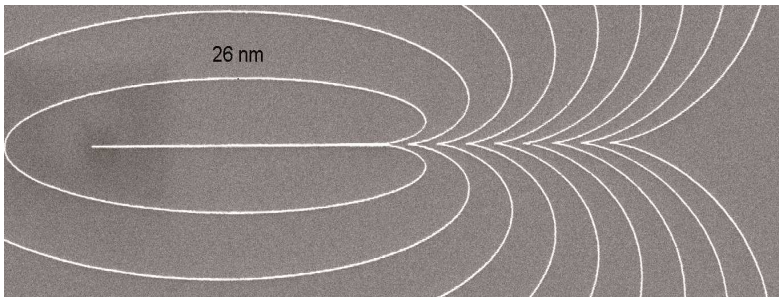

Fig. 6 CrAu test structures with a line width of 26 nm
(Dr. Büttner, MLU Halle)

Additional data for CSAR 62

Cauchy coefficients

The Cauchy coefficients are N_0 = 1.542 and N_1 = 72.

Plasma etch resistance

CSAR 62 is characterised by a high plasma etch resistance. Fig. 7 exemplarily shows the etch rates of SX AR-P 6200/2 in comparison to AR-P 3740 (positive photoresist), to AR-P 679.04 (PMMA e-beam resist), and to ZEP 520 in CF_4 + O_2 plasma.

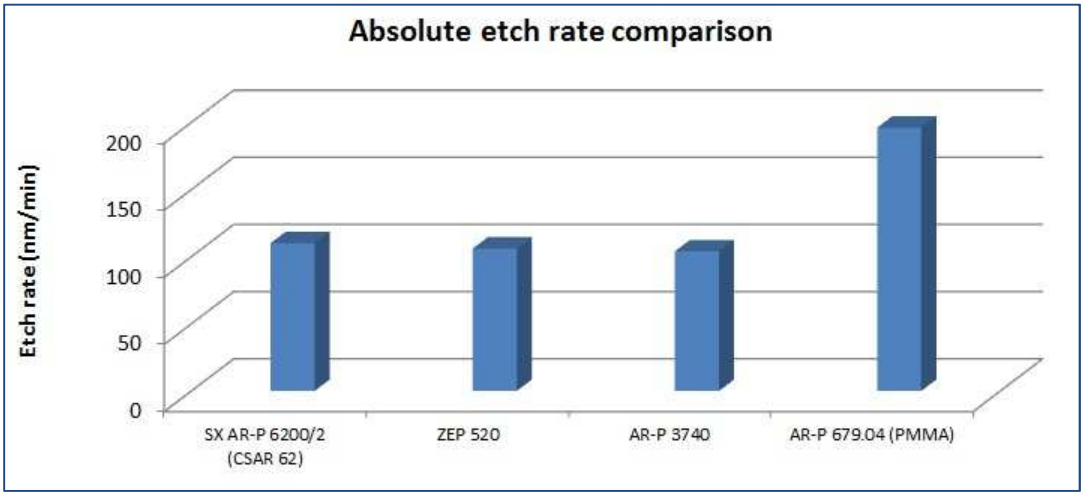

Fig. 7 Comparison of etch rates in CF_4 + O_2 plasma

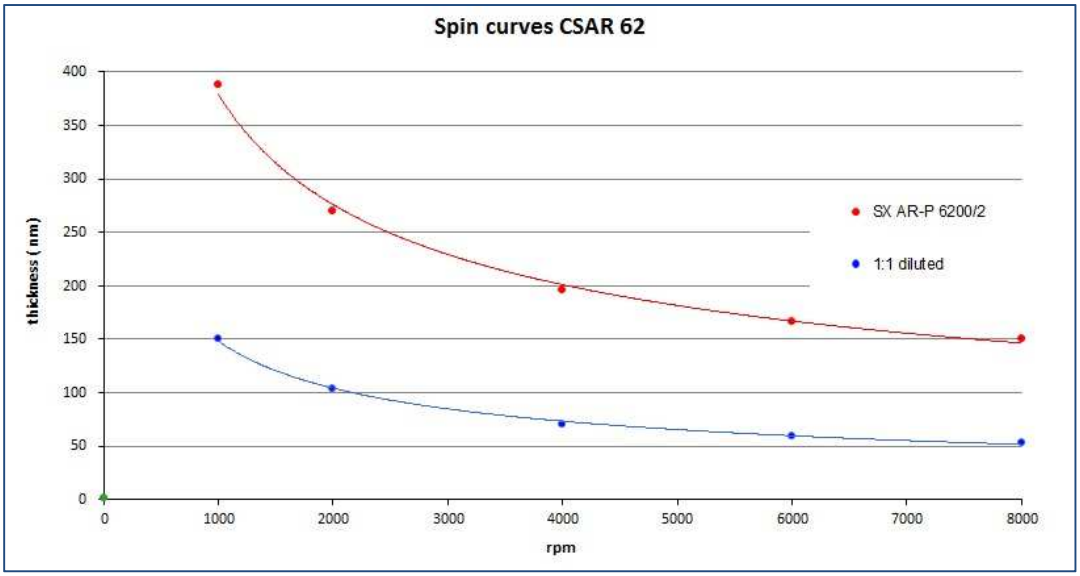

Fig. 8: Spin curves SX AR-P 6200/2 (9 % solid matter) and 1: 1 diluted (4,5 % solid matter)

5. Cleaning and Removal

For the cleaning and removal of soft-baked substrates, polar solvent mixtures such as **remover AR 600-71** and **thinner AR 600-02** can be used. To remove hard-baked layers it is recommended to use the **remover AR 600-71** and **AR 300-72.** Very hard-baked layers (plasma processing or UV-stabilization) need a treatment with oxydizing acids or O_2 plasma.

6. Waste Water Disposal

Liquid or solid wastes have to be disposed at proper deposit places or by controlled combustion in officially authorized plants.

7. Safety References

Resists and thinner contain organic solvents. Adequate ventilation in the working area is demanded. Avoid direct contact with products and their vapours. Wear safety goggles and rubber gloves!

Further information is provided in our EC material safety data sheets. As of: May 2013