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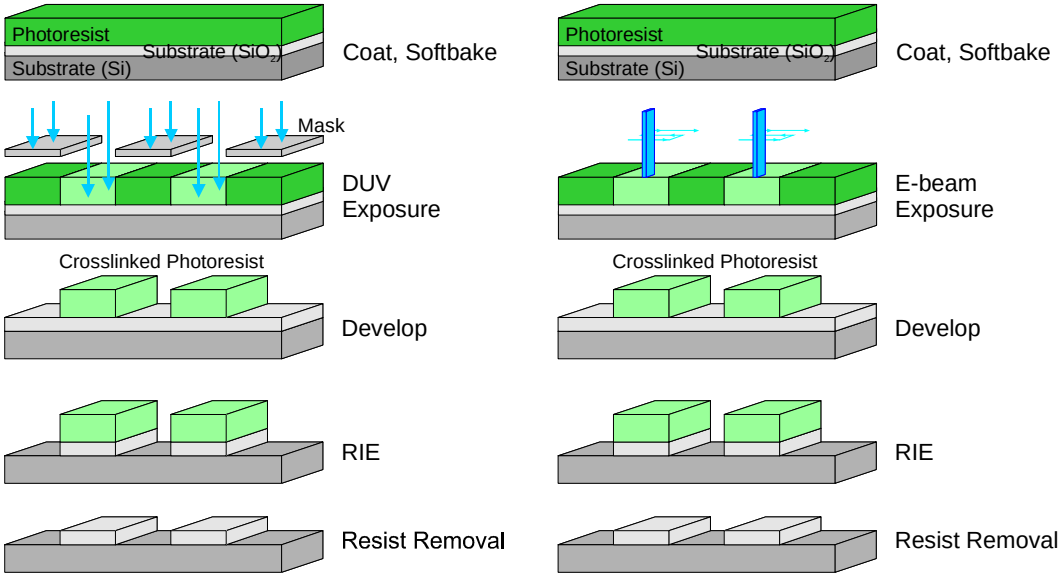
Negative Tone Resist Series ma-N 2400

Characteristics

ma-N 2400 is a negative tone photoresist series designed for the use in micro- and nanoelectronics. The resists are available in a variety of viscosities.

- Electron-beam and DUV-sensitive
- Well suitable as an etch mask exhibiting high dry and wet etch resistance
- Good thermal stability of the resist patterns
- High resolution capability
- Aqueous alkaline development

Process flow



Process flow for DUV and reactive ion etching (RIE)

Process flow for e-beam and RIE

Physical properties of the resist solution

Resist		ma-N 2401	ma-N 2403	ma-N 2405	ma-N 2410
Film Thickness[1]	[µm]	0.10 ± 0.02	0.30 ± 0.03	0.50 ± 0.05	1.0 ± 0.1
Dynamic Viscosity[2]	[mPa s]	1.5 ± 0.2	2.3 ± 0.2	3.3 ± 0.3	7.0 ± 0.3
Density [3]	[g cm^3]	0.985 ± 0.002	1.005 ± 0.002	1.018 ± 0.003	1.040 ± 0.003

[1] Spin coated at 3000 rpm for 30 s [2] 25°C, 1000 s^{-1} [3] 20°C

Processing

Best patterning results are obtained at temperatures of 20 – 25 °C and a relative humidity of 40 – 46 %. The guidelines relate to standard processing of resist films spin coated on silicon or silicon dioxide. The specific process parameters to be applied depend on substrate, application and equipment.

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Processing conditions

Resist		ma-N 2401	ma-N 2403	ma-N 2405	ma-N 2410
Film thickness	[µm]	0.1	0.3	0.5	1.0
Substrate preparation		Oven: 200 °C, 30 min			
Spin coating	[rpm] [s]	3000 30			
Prebake					
Hotplate	[°C] [s]	90 60	90 60	90 90	90 150
Exposure dose					
e-beam					
20 keV [1]	[µC cm^{-2}]	120 - 200 (D_0 = 80)[3]	170 – 235 (D_0 = 80)[3]	170 – 250 (D_0 = 80)[3]	(D_0 = 80)[3]
50 keV [1]	[µC cm^{-2}]	120 – 260	120 – 300	150 – 350	
DeepUV [2]	[mJ cm^{-2}]	18 ± 5			
Development [4] **ma-D 525** (TMAH)	[s]	10 ± 3	30 ± 5	50 ± 10	120 ± 15
ma-D 331 (NaOH)	[s]	10 ± 3			
ma-D 332 (NaOH)	[s]		10 ± 3	15 ± 5	35 ± 10
Developer concentrate [5]	[s]	5 ± 2	10 ± 3	15 ± 5	30 ± 10

[1] exposure dose depends on the pattern size/ resolution, [2] Deep UV @ 266 nm, [3] D_0= clearing dose, [4] immersion development, [5] on critical substrates, such as Al containing

Substrate preparation:

The substrates have to be free of impurities and moisture. Oxygen or ozone plasma cleaning is recommended. After that the substrates should be baked at 200 °C and cooled to room temperature immediately before coating. For improving resist film adhesion to a variety of different substrates it is advisable to apply an adhesion promoter such as SurPass 4000.

Coating:

Uniform coatings are obtained by spin coating of ma-N 2400 solutions in the thickness range indicated in the spin curves. Please select the appropriate resist type and spin speed required for the desired film thickness and application. The information refers to an open spin-coating system. Film thicknesses in Fig. 1 are measured after the prebake process. It is recommended to use a filter when applying the resist to the wafer for spin-coating.

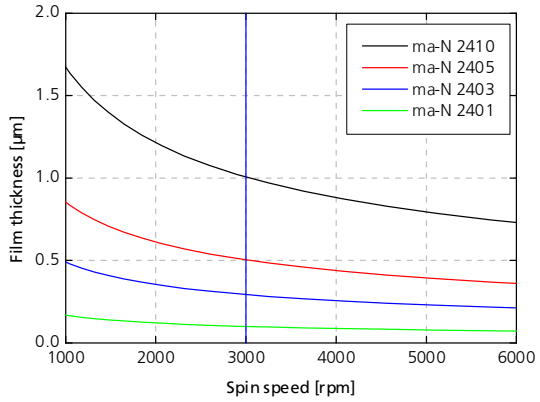

Fig. 1: Spin curves of ma-N 2400 series, 30 s spin time

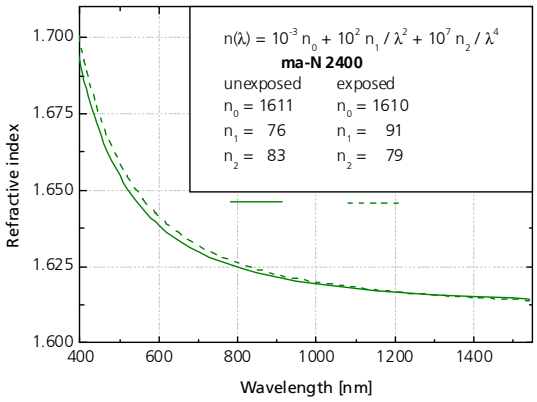

Fig. 2: Refractive index vs. wavelength, Cauchy coefficients of unexposed and exposed ma-N 2400

The refractive index of the resist film depending on the wavelength and the Cauchy equation are given in Fig. 2. This information is needed for ellipsometric or other optical thickness measurement.

Prebake:

Resist films are baked on a hotplate at 90 °C. If required, the etch resistance and thermal stability of the resist can be increased by applying a higher prebake temperature (max. 110 °C) or a longer prebake time. The developing time will increase in this case.

Exposure:

The resists are effective for e-beam exposure and Deep UV-exposure.

E-beam exposure

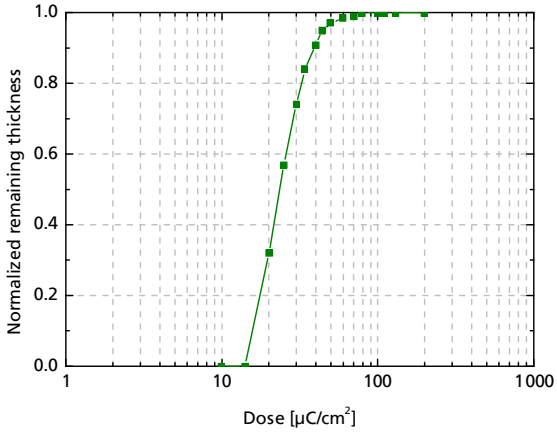

Fig. 3: Sensitivity curve at 20 keV electron energy

Deep UV exposure

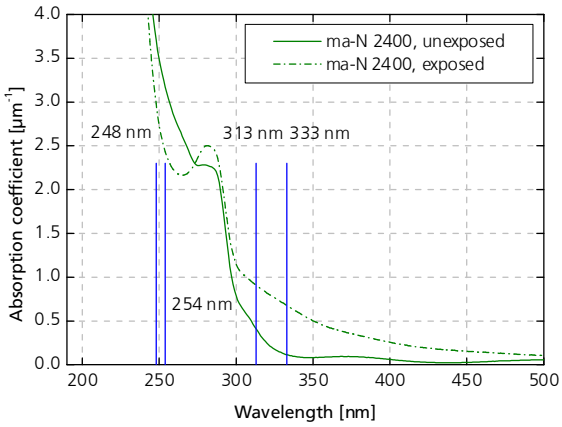

Fig. 4: UV/vis absorption of unexposed and exposed ma-N 2400

With higher electron energies the exposure dose shifts to higher doses. For a specific film thickness the generation of smaller features requires higher exposure doses (~1.5 x D_0) than larger features.

Development:

Ready-to-use developers **ma-D 525** (metal ion free) and **ma-D 332** or **ma-D 331** are recommended. On critical substrates, like aluminium containing substrates, the **Developer concentrate** is recommended. The temperature of the developer should be 20 – 25 °C. The developed resist films are thoroughly rinsed with deionized water for about 5 – 10 min and then dried. The developing time depends on film thickness, prebake parameters and pattern resolution.

Hardbake (optional):

If required, the etch resistance and the thermal stability of the resist can be further increased. Hardbaking of the developed resist patterns is suggested in an oven at 100 °C for approximately 5 – 15 min.

Removal:

Ready-to-use removers **mr-Rem 700** (NMP & NEP free), **mr-Rem 660** (NMP based), **mr-Rem 500** (NMP free) and **mr-Rem 400** (NMP free) and **ma-R 404/S** (strongly alkaline) are recommended. This also can be done at temperatures of 40 – 60 °C assisted by ultrasonics when solvent based removers are used. Acetone, N-methylpyrrolidone (NMP) or oxygen plasma is also suitable for the residue free removal of the resist. After resist removal the substrates are rinsed in water, then in isopropanol (IPA), and then dried.

Storage

Storage at temperatures of 18 – 25 °C is recommended. Keep the bottles closed when not in use.
Do not store ma-N 2400 resists in a refrigerator. Under these conditions a shelf life of 9 months from the date of manufacture is ensured.
A shelf life of 12 months is ensured for developers and removers.

Disposal

Unexposed resist & solvent based remover: dispose of as halogen free solvent
Exposed resist: dispose of as resist/ old resist
Developer: dispose of as weak alkaline aqueous solution

Environmental and health protection

ma-N 2400 resist series contains "safe solvents". Ensure that there is adequate ventilation while processing the resists. Avoid contact of the resists and process chemicals with skin and eyes and breathing solvent vapours. Wear suitable protective clothing, safety goggles and gloves.
Please, review the current product Material Safety Data Sheet before using the products.

Equipment

ma-N 2400 resists are compatible with most commercially available photoresist processing equipment.
The data given in these guidelines were obtained using:
- SAWATEC spin coater or Suss Delta 6 spin coater
- Contact hotplate/ convection oven
- ZBA 23H and LION LV1 with 20 keV, Leica EBPG 5000plus with 20 and 50 keV
- EULITHA PhableR 100DUV, Deep UV @266 nm
- Immersion development

Patterning examples

E-beam: Courtesy of IPHT/ Jena and Fraunhofer HHI/ Berlin, DeepUV: Courtesy of EULITHA/Zurich

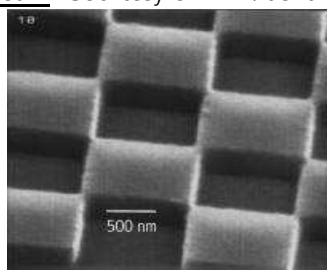

Fig.5: 0.3 µm thick ma-N 2400 chess pattern, e-beam exposed

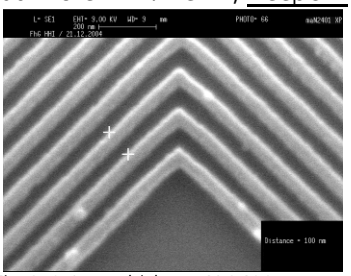
Fig.6: 0.1 µm thick ma-N 2400 pattern, 50 nm lines/ spaces, e-beam exposed

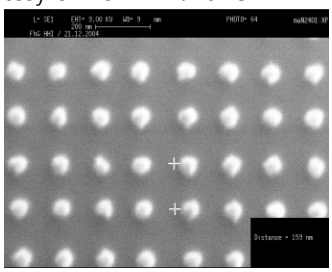
Fig.7: 0.1 µm thick ma-N 2400, 80 nm dots, e-beam exposed

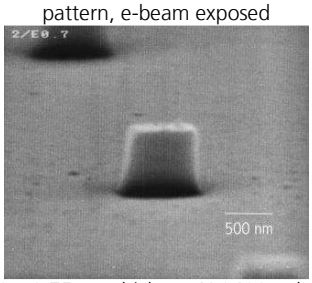

Fig.8a: 0.75 µm thick ma-N 2400, e-beam exposed, 0.8 µm wide dots

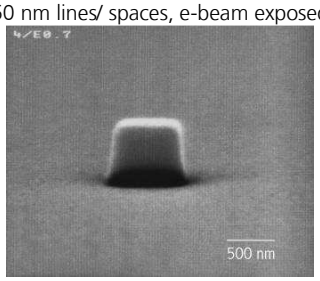

Fig.8b: Dot after a reactive ion etching with CF_4 ,(power: 60 W)

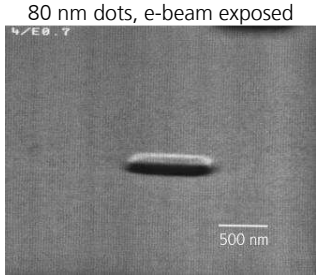

Fig.8c: 0.8 µm wide niobium dot after resist remove

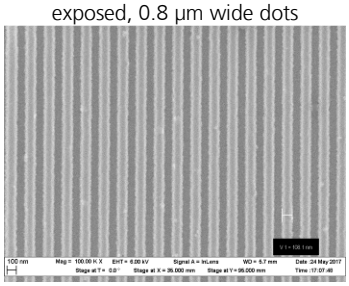
Fig. 9: 100 nm thick ma-N 2400, DUV@266 nm exposed, 200 nm period patterns

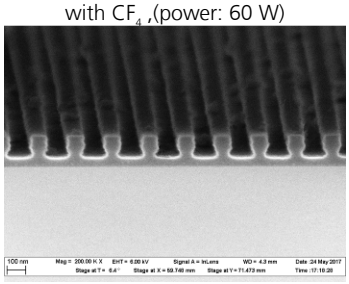
Fig. 10: 100 nm thick ma-N 2400, DUV@266 nm exposed, 94 nm CD

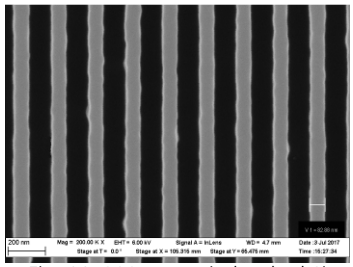
Fig. 11: 200 nm period etched Si patterns, etch depth: 100 nm, etch selectivity ~1:1