Thick Resist Processing

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MicroChemicals

Fields of Application for Thick Resists

Electroplating often requires resist film thickness of 10 µm and beyond in order to realize high metal structures. Please consult the document Electroplating with Resist Masks for details on electroplating.

In **microoptics** or **microfluidics**, structures are often realized by transferring reflowed, spherical or cylindrical resist structures via dry-etching into the substrate. For this purpose, in many cases thick resist films are required.

Deep **dry etching** also requires resist films with a certain thickness.

Suited Resists for Thick Films

Realizing thick films with low-viscosity resists is problematic for two main reasons:

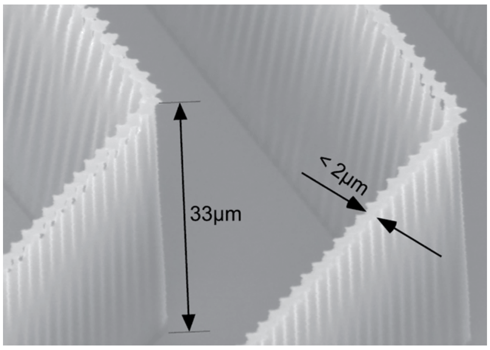
During **spin-coating**, the required low spin speed increases the edge bead. Multiple coating is not possible due to the high solvent concentration, which causes the dissolution of the resist film already coated.

During **exposure**, the typically high photo active compound concentration (= high absorption) in thin resist makes the through-exposure of thick films made with 'thin resists' difficult. In addition to high required exposure doses, the high N_2 release of DNQ-based resists may cause bubbles or cracks in the resist film.

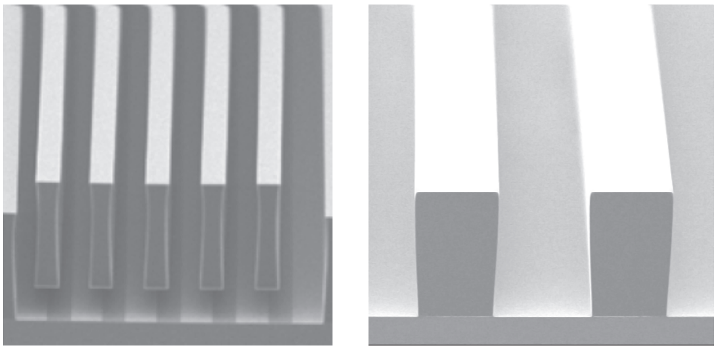
Suited thick resists are highly viscous as well as low absorbing in order to allow the formation as well as through exposure of thick films. For resist film thicknesses of 5-30 µm, we recommend the positive AZ® 4562 (g-, h-, and i-line sensitive), or the AZ® 9260 with enhanced resolution and aspect ratio (h-, and i-line sensitive).

If a negative resist is required, the AZ® nLOF 2000 series (only i-line sensitive) is a good choice for resist film thicknesses up to approx. 20 µm. For very high resist film thicknesses up to 150 µm, the positive AZ® 40 XT i-line resist, or the negative AZ® 15 nXT and AZ® 125 nXT i-line resists are recommended.

Please contact us for further technical information, technical data sheets, or samples!



AZ® 9260 lines with an aspect ratio > 16 (process and image by Mr. Roger Bischofberger, applied microSWISS GmbH)



Left: 10 µm lines with a 40 µm thick AZ® 40 XT; right: 80 µm lines with a 120 µm thick AZ® 125 nXT. Source: AZ® 40 XT and AZ® 125 nXT technical data sheet by AZ-EM.

Suited Spin Profiles for Thick Resist Films

The thick resists listed in the previous section allow film thicknesses of approx. 5-30 µm with standard spin profiles (2000-4000 rpm for 30 seconds). Generally, higher resist film thicknesses can be attained with lower spin speeds.

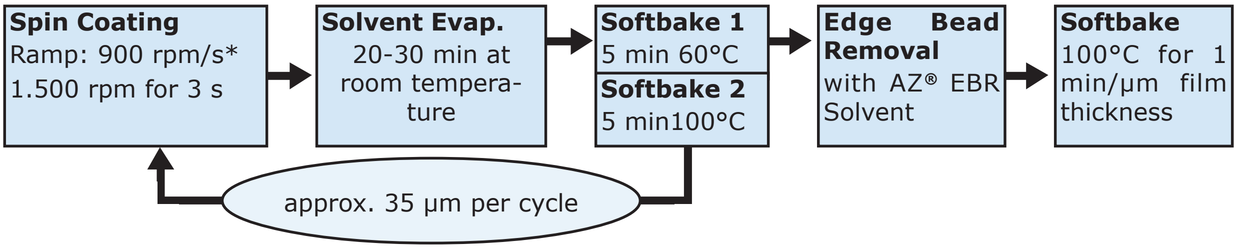
However, at low spin speed, the edge bead increases, and the resist film homogeneity decreases and becomes less reproducible. Therefore, a much better suited spin profile for thick resist films is a high spin speed of approx. 2.000 rpm (also requiring steep ramps up and down of approx. 1.000 rpm/s) for a short time (few seconds).

Multiple Coating for Very Thick Resist Films

If the required resist film thickness can not be attained with a highly viscous resist and an adjusted spin profile, multiple coating allows the formation of very thick films.

Multiple Coating requires thick resists such as AZ® 9260 or AZ® 4562 with a high viscosity (= low solvent concentration). Otherwise, a second coating step will partially or completely dissolve the resist film coated before, thus leading to strong inhomogeneities in the resist film thickness. A short softbake between two coating cycles also suppresses the dissolution of the already existing film by the next one.

The following flowchart shows recommended parameters for multiple coating of the thick resist AZ® 9260 in 35 µm steps:



Edge Bead Prevention and Removal

Especially in the case of coating thick resist films, a so-called edge bead forms which may cause sticking to the mask as well as an undesired proximity-gap during exposure (with a reduced lateral resolution as a consequence). If no automatic edge bead removal is possible, initial stages for solution to avoid/lower the edge bead are:

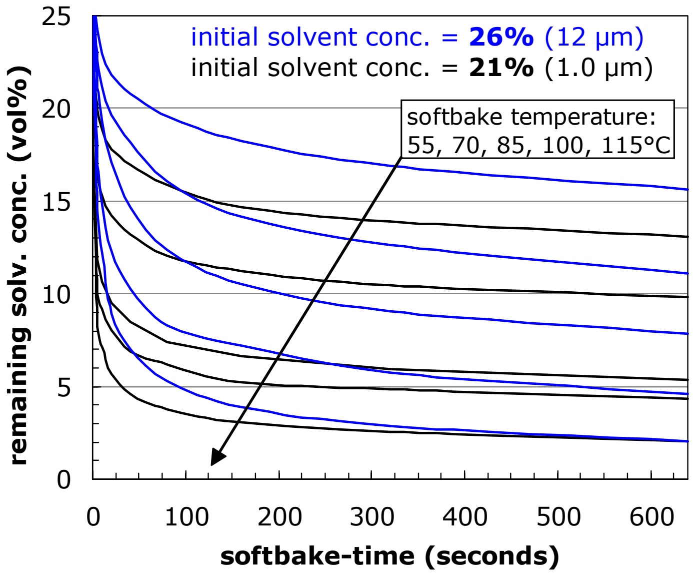
- Circular substrates: Manual edge bead removal with AZ® EBR Solvent (not acetone or other low-boiling solvents!) dispensed onto the edge of substrate spinning at 500 rpm.
- An elevated spin-speed for a shorter time
- A 'spin-off' of the edge bead by abruptly increasing the spin speed at a certain stage of spin coating: The resist film should be solvent-poor enough to prevent further thinning, while the edge bead needs a viscosity still low enough for proper spin-off. For this purpose, the optimum spin profile has to be found individually.
- A multiple coating with an elevated spin speed for each coating cycle
- For thick or solvent-rich resist films, a delay between coating and softbake prevents the edge bead from growing during softbake due to the thermally reduced viscosity. The delay time depends on the resist film thickness and can be shortened by applying moderate temperatures (e. g. stepwise: room temperature ... 50°C ... 95°C).
- A well-adjusted cavity in the substrate holder with the substrate as close inlay
- Edged substrates: If applicable, removing (breaking) the outer pieces of the substrate bearing the edge bead; alternatively manual cleaning of the substrate from the edge bead with cleanroom wipes. Exposure and development of the edge bead is also possible, but may cause T-topping.

Softbaking of Thick Resist Films

The thicker the resist film, the smaller the possible softbake parameter window formed by baking temperature and time:

A **softbake much too cool/short** may cause bubbling and foaming of the resist film due to the nitrogen generated during exposure. Additionally, the remaining solvent concentration causes a high dark erosion.

A **softbake too cool/short** may cause bubbles in the substrate-near resist by N_2 formed during exposure. These bubbles are sometimes not visible before 'free-developed'. Additionally, the dark erosion is increased.



A **softbake too hot/long** decomposes a fraction of the photo active compound thus decreasing the development rate. Additionally, the very low solvent concentration embrittles the resist film making it susceptible to the formation of crackles.

'Bubbles' in the resist film - despite a sufficient softbake - are in many cases cracks causes by mechanical stress due to the N_2 generated during exposure. If the N_2 cannot dissipate from the resist film fast enough due to the high resist film thickness, strong mechanical stress occurs expanding and cracking the resist.

As a rule of thumb, a compromise between sufficient solvent evaporation, and minimized DNQ-loss is a softbake at 100°C for 1 minute per µm resist film thickness on a hotplate. Detailed information on the softbake can be found in the document Softbake of Photoresists.

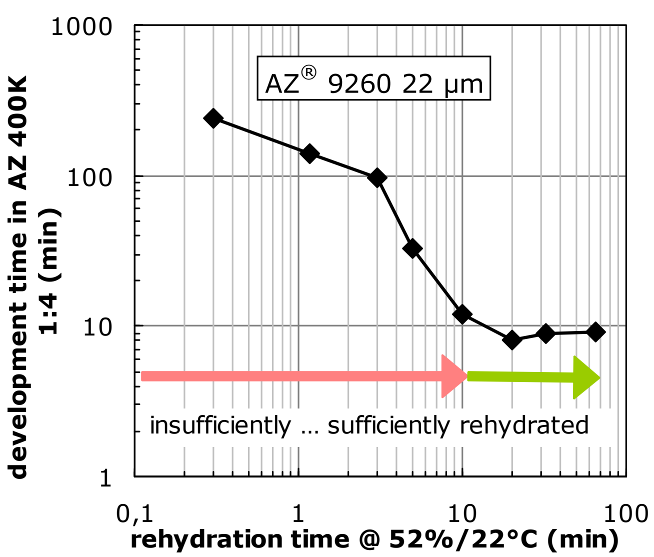
Rehydration

During the softbake, the bulk water concentration of photoresist films drops. However, a certain water content in the resist is required to allow a reasonable high development rate and a high contrast of DNQ-based positive resists (details see Exposure of Photo Resists) such as the AZ® 1500, 4500, 6600 or 9200 series - but NOT the AZ® 40 XT.

This missing water has to diffuse from the air into the resist film. Therefore, a delay time between baking and exposure is necessary to rehydrate the complete photo resist film towards the substrate. Beside the resist film thickness, the required rehydration time also depends on the temperature (water diffusion in the resist bulk is thermal activated) and the air humidity itself.

If the air humidity is too low, even a long rehydration cannot provide a sufficient water content, since the equilibrium (adsorbtion and evaporation) H_2O concentration in the resist film keeps below a required value.

Dependant on the resist film thickness, a rehydration time of approx. 10 min (10 µm resist film thickness), one hour (30-40 µm) up to 10 hours (100 µm) are required. The document Rehydration of Photoresists gives more details on this topic.



Bubbling and Cracks in the Resist Film after Exposure

During exposure of DNQ-based resists (such as the AZ® 4562 or 9260 series - but NOT the AZ® 40 XT), the photo active compound diazonaphtoquinone (DNQ) is converted into indene carboxylic acid with a nitrogen molecule (N_2) as a side product. Completely exposed photoresist releases a N_2-volume significantly exceeding the resist volume which, thermally activated, diffuses to the resist surface and dissipates.

Especially thick resists generate a comparable high N_2-volume with respect to the resist surface. As a consequence, during or after exposure, bubbles or cracks may appear in the resist film. In some cases even a milky, styrofoam-like appearance becomes visible (pictures see overleaf). Possible reasons are:

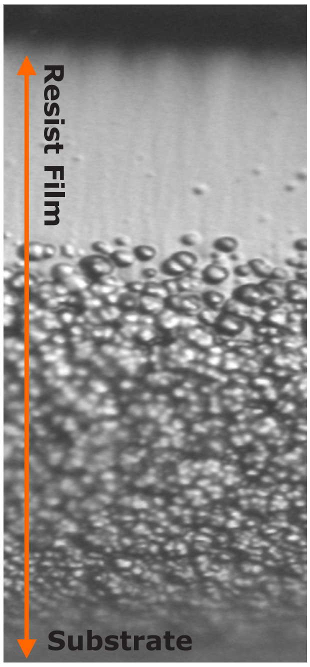
- A softbake too cool/too short (details see Softbake of Photoresists)
- Inferior resist adhesion by insufficient substrate pretreatment (see document Substrate Cleaning and Adhesion Promotion), or a substrate surface modified by previous process steps
- An exposure intensity too high, with a N_2 generation rate too high as a consequence. In this case, try multiple exposure with delays in between.
- An exposure dose too high. It is generally recommended to evaluate the optimum exposure dose for each process.
- A photoresist not suitable (photo active compound concentration too high, N_2 permeability too low) for the required resist film thickness. For recommended thick resists, please consult the first section of this document.

Disclaimer of Warranty

All information, process guides, recipes etc. given in this brochure have been added to the best of our knowledge. However, we cannot issue any guarantee concerning the accuracy of the information.

We assume no liability for any hazard for staff and equipment which might stem from the information given in this brochure.

Generally speaking, it is in the responsibility of every staff member to inform herself/himself about the processes to be performed in the appropriate (technical) literature, in order to minimize any risk to man or machine.



Too much remaining solvent due to a softbake too short/too cool causes bubbles especially near the substrate (top, right-hand). Resist films softbaked very long/hot tend to embrittle causing cracks by the expanding nitrogen (bottom: onsight view left-hand, cross-section right-hand).