Spin Coating of Photoresists

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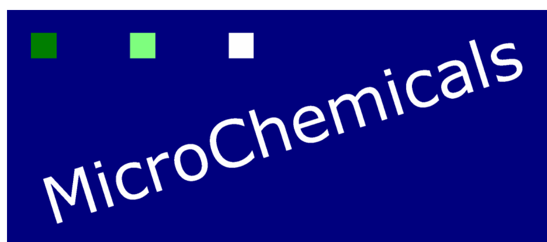


Basics of Spin Coating

During spincoating, the centrifugal force of the substrate spinning with several 1.000 rounds per minute (rpm) distributes few ml of resist over the substrate.

Advantages: The high resist film thickness homogeneity as well as the short coating times make spincoating the most-applied coating technique at least in microelectronics. The fact that the coated resist already lost a significant amount of its solvent after spin coating, no time-consuming delays have to be kept before further process steps (handling, softbake).

Limitations and disadvantages: In case of non-rotation-symmetric substrates, the resist forms a pronounced edge bead near the substrate edges due to the strong air turbulences. On textured substrate, the attained edge coverage of the textures is rather small, and parts of the topology might not be coated at all. With only few %, the resist yield is comparable low.

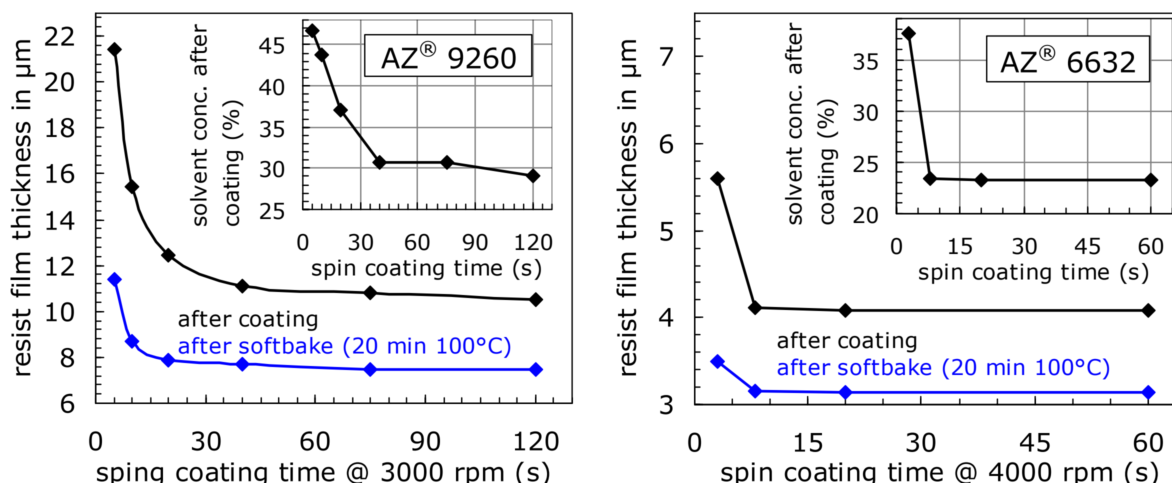
Nominal Resist Film Thickness

The resist film thickness attained by spin coating represents the equilibration between centrifugal force and solvent evaporation, both increasing with spin speed. Generally, the last two digits of the resist name (e. g. AZ® 6632) indicate the film thickness attained by spin coating (without gyrset) at v = 4.000 rpm in 100 nm units. Some US AZ®-resists such as the AZ® 9260, the 701 MiR, or nLOF 2000 refer to 3.000 rpm.

The resist film thickness approximately decreases with the reciprocal square-root of the spin speed (e. g. AZ® 4533: 4.0 µm ... 3.3 µm ... 2.3 µm at 2000 ... 4000 ... 6000 rpm). This allows to realize a certain range in the film thickness with one resist.

Influences on the Resist Film Thickness

The resist film thickness given for a certain spin speed holds for sufficiently long spin times, when the resist spin-off is completed. As the figure below shows, the spin times required to attain the final film thickness increases with the resist viscosity. Low spin speeds also increase the time for a constant resist film thickness.



Resist film thickness and remaining solvent concentration after different long spin coating for a thin (left) and thick resist (right) before (black) and after (blue) softbaking.

This time-dependency not only allows the film thickness to be adjusted for spin speed, but also the spin time. However, this is only a reasonable procedure for attaining thick and very thick films. For thin films (approx. < 10 µm), the spin times should always be 'sufficiently long' to make the result more reproducible.

The remaining solvent concentration in the resist film also impacts on its thickness. During coating, the solvent concentration drops and saturates at a value of approx. 15-25 % which depends on the film thickness and is higher for thicker films. The subsequent softbake reduces the remaining solvent concentration to values of typ. 5 %.

A high ambience solvent saturation in the spin coater reduces the attained resist film thickness due to a suppressed solvent evaporation from the resist. Therefore, the first few wafers of a coating series might reveal a slightly higher film thickness as compared to wafers subsequently coated with a certain amount of fresh resist in the spin-coater. In this case, coating some dummy wafers at the beginning of a coating series would be beneficial by means of constant resist film thicknesses.

The equipment also impacts on the attained resist film thickness: A gyr-set may reduce the film thickness by even a factor of two as compared to standard systems.

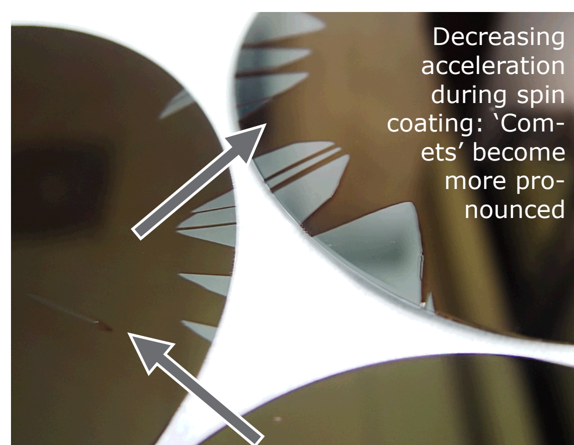
Edge Bead

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:

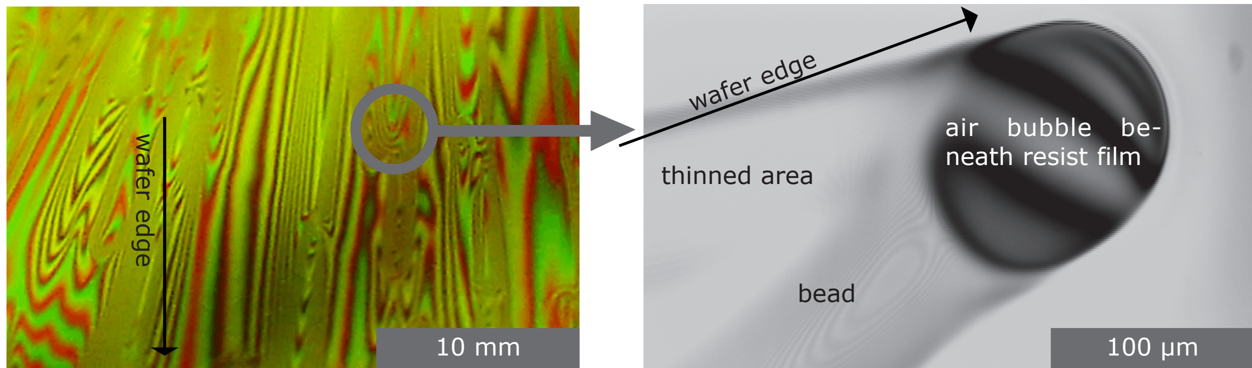
- Circular substrates: Manual edge bead removal at approx. 500 rpm with AZ® EBR Solvent (not acetone or other low-boiling solvents!) dispensed onto the edge of the rotating substrate
- An elevated spin-speed for a shorter time
- A 'spin-off' of the edge bead by abruptly increasing the spin speed at a 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.

Resist Striations and 'Comets'

The typical comet-shaped inhomogeneities in the resist film thickness often have their origin in either particles stemming from an insufficient substrate cleaning, or an expired resist. Bubbles (N_2 from bottles closed for a long time, or air bubbles from bottles moved before resist dispension) enclosed in the resist film will cause similar inhomogeneities. In this case, a certain delay before dispension to outgas the bubbles will help.



A too small resist volume can also be the reason for uncoated areas on the substrate. Depending



Inhomogeneities in the coated resist film (left) often misinterpreted as particles, mostly originate from air or N_2 bubbles (right).

on the resist viscosity, the desired resist film thickness, and the substrate size, 1-5 ml resist per substrate is recommended. Dispensing the resist as central as possible will improve the result.

In case of smooth substrates, a high acceleration (> 1000 rpm/s) towards the final spin speed suppresses the appearance of uncoated parts on the substrate. On the other hand, textured substrates may require a two-step spin profile: After distributing a comparable high resist volume at low spin speeds (e. g. 1000 rpm) for a few seconds, ramping upwards to the final spin speed adjusts the desired resist film thickness.

Particles, Air or Nitrogen Bubbles?

The appearance of air bubbles or particles in the coated resist film is very similar to each other (figure above).

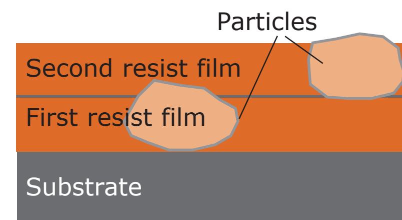
Particles often stem from an insufficient substrate cleaning, or an expired resist.

Air bubbles in the resist are often caused by transport, refilling or dispensing of the resist. N_2-bubbles originate from the gradual decomposition of the photo active compound in the liquid resist. If - after storage for a certain time - the resist bottle is opened, the N_2 dissolved in the resist may form bubbles.

In case of either air or N_2 bubbles, a delay before dispensing of - dependant on the resist viscosity - a few hours will help for outgasing the bubbles.

A locally reduced resist wetting can stem from previous processes or insufficient substrate cleaning, or incorrect HMDS application.

Particles and Bubbles in Etching Masks



Particles or bubbles in the resist film may act as channel for wet etches or during electroplating. If such defects cannot be avoided, double coating is a good work-around, since two particles or bubbles on top of each other are very improbable.

Double coating can only be realized with high-viscosity resists, since a high solvent concentration will cause a dissolution of the existing resist film. The lower the resist viscosity is, the more important is i) a softbake between the two coating steps, and ii) spin-coating immediately after the second resist dispension in combination with a high acceleration in order to suppress the dissolution of the first resist film.

Measuring the Film Thickness

The resist film thickness can be determined via optical methods such as transmission or reflection spectroscopy. The required optical properties of many resist families are listed in the document Optical Properties of Photoresists.

Another simple way to determine the film thickness is to scratch the softbaked resist on a dummy wafer with e. g. a scalpel or tweezers, and measure the depth of the scratch with a surface profilometer.

Thick Resist Films: Suited Spin Profiles

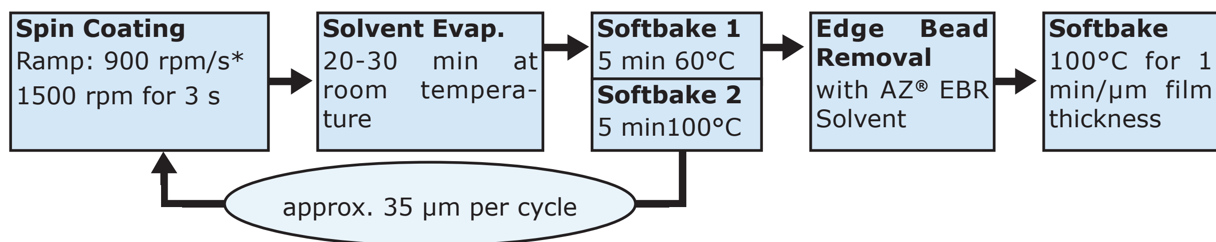
Generally, there are two ways to attain resist film thicknesses of several 10 µm via spin coating: Either by reducing the spin speed, or by reducing the spin time.

Low spin speeds, however, cause a pronounced edge bead and sometimes even prevent the resist from tearing off the substrate with a non reproducible resist film thickness as a consequence.

Therefore, a much better suited spin profile for thick resist films is a high spin speed of approx. 2000 rpm in combination with a high acceleration of approx. 1000 rpm/s for a short time, such as few seconds.

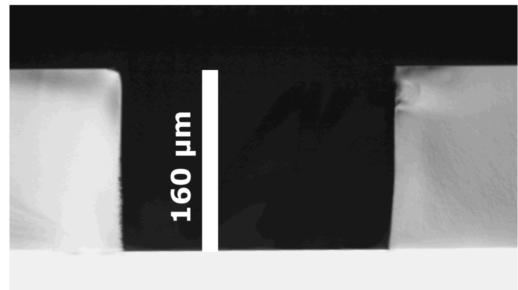
Multiple Coating for Thick Resist Films

In case of thick resist films, the rather high remaining solvent concentration after spin coating promotes softening (causing an pronounced edge bead, and reduced edge coverage) during softbake. For a homogeneous drying of the resist without significant loss in thickness homogeneity, we recommend a double- or multiple coating as follows:



Example: 160 µm with AZ® 9260

Parameters (attained cross-section right-hand):



Coating: 5-fold spin coating

Exposure: 4.9 J/cm2 (i-line dose)

Development: AZ® 400K, 10 : 38, 75 min

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.

Thick (Highly Viscous) Photo Resists for Thick Film Single-Coating

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!