All Cross References Refer to Sections in Our Book *Photolithography* Which You Can Request Via *Www.microchemicals.com/downloads/brochures.html*

STRANGE APPEARANCE OF THE PHOTO RESIST

Discolouring?

i) Storage Time

Positive and image reversal resists darken over months, accelerated at elevated storage temperatures. The photo active compound forms azo dyes, having a strong absorbance in the visible part of the spectrum without any impact on the UV sensitivity. The discolouration proceeds very slowly and therefore is often only noted when switching to a new resist lot.

ii) Contamination

The contact of the resist with water or unsuited solvents such as isopropyl alcohol, or a freezing of the resist may change its colour. In this case, a deterioration of the resist can not be excluded.

iii) Substrate and Resist Film Thickness

On different substrate materials, the resist film will show a different colour.

Especially in case of thin resist films, a change of the resist film thickness of only few 10 nm will cause an interference-based colour change of the resist film. Such a thickness change can be induced by solvent loss, resist ageing, changed temperature or air humidity, or modified coating equipment or –parameters.

iv) Chemical Attack

The attack of HNO_3-containing etchants or high baking temperatures can cause a brownish discolouring of the resist structures.

Uncoated Substrate Areas after Resist Coating?

i) Resist Wetting

An inferior resist wetting/adhesion (on noble metals or insufficiently cleaned substrates, on SiO_2-substrates treated with an HF-dip with incomplete SiO_2 removal, or at a high ambient air humidity) promotes the appearance of uncoated substrate areas.

ii) Dispensed Resist Volume

A too small resist volume can also be the reason for uncoated areas on the substrate. Depending 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 (section 10.4 on page 47).

iii) Spin Coating Profile and Textured Substrates

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 (Fig. 56 on page 48).

Textured substrates may require a two-step spin profile: After spreading 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 (section 10.4 on page 47).

iv) Particles and Bubbles

Bubbles and particles are often the starting point for defects in the coated resist film (section 10.5 on page 48), as detailed in the following section.

Bubbles and Comet-Like Structures after Spin Coating?

i) Air Bubbles

Air bubbles in the resist incorporated by transport, refilling or dispensing of the resist, often act as starting point of defects in the resist film. A delay before dispensing of – dependant on the resist viscosity – a few hours will help for outgassing the bubbles (section 10.5 on page 48).

Nitrogen Bubbles

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. A delay before dispensing of – dependant on the resist viscosity – a few hours or even 1 - 2 days for very high viscous resists will help for outgassing the bubbles. Another N_2 source is nitrogen used in the dispense system to transport the resist from the bottle to the substrate (section 10.5 on page 48).

ii) Particles

Particles impact on the resist film homogeneity in a similar way as air- or N_2-bubbles do. Beside insufficiently cleaned substrates or an inferior clean room class, particles often stem from an insufficient substrate cleaning or an expired resist (section 10.5 on page 48). A further resist dilution or elevated storage temperatures will accelerate resist ageing and thus particle formation (section 7.4 on page 33).

Bubbles in the Resist Film After the Softbake?

i) Volatile Resist Components

Some resists such as the AZ® 40XT contain volatile compounds of resin or solvents, which evaporate during typical softbake temperatures and hereby form bubbles in the resist film big enough to be visible with the naked eye. In this case, the heating to the final softbake temperature should be performed slowly enough to allow the volatile compounds to outgas without bubble formation. This can be realized via either a proximity hotplate; temperature ramps on a contact hotplate auch as 60 ... 80 ... 100°C; or a temperature ramp in a convection oven.

ii) Outgasing Substrates

Certain polymeric substrates can release volatile compounds during the softbake, which form bubbles in the resist film above. Heating the substrate before resist coating may help.

iii) Embedded Air Bubbles

Maybe bubbles too tiny to be visible are already incorporated in the resist film before softbake, and conglomerate to bigger and better visible bubbles during the softbake.

Rough or Bumpy Resist Surface after Coating?

i) Expired Resist

Expired resists or resists stored under the wrong (temperature) conditions (section 7.5 on page 34), as well as resists diluted too strongly or diluted with unsuitable solvents (section 7.4 on page 33), may form particles . In early stage averaging, the coated resist reveals a silky resist surface. Strongly deteriorated resist may also show bigger lumps and coating failures. Please contact us for recommended storage conditions and a suitable thinner!

ii) Strongly Diluted Resists

Besides particle formation, gelification is another irreversible ageing effect promoted by elevated storage temperatures, and high resist dilution ratios. The coated resist film shows a glossy, but bumpy surface.

RESIST COATING TECHNIQUES: COMMON PROBLEMS

Spin Coating: Edge Bead? (Further Details in Section 10.3 on Page 47)

i) Highly-viscous Resists

Spinning a highly-viscous resist (e. g. the AZ® 4562 or 9260 for 5 - 30 µm resist film thickness, or the ultra-thick resists AZ® 40 XT or 125 nXT for films > 30 µm) at high spin speed helps to suppress the edge bead.

ii) Circular Substrates

Circular substrates: If no automatic edge bead removal unit is installed, via 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, immediately followed by a spin-off of the solvent at an elevated spin speed.

iii) Rectangular 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 and solvent.

Alternatively, the installation of an assembly on the spin-coater substrate holder with a cut-out which tightly holds the substrate as close inlay which meanwhile is offered by some equipment manufacturers.

iv) Unusual High Resist Film Thicknesses

In the case of resist film thicknesses exceeding the standard thickness of a certain resist: An elevated spin-speed (e. g. 2000 - 4000 rpm) for few seconds with steep ramps up and down, instead of low spin speeds for a longer period of time.

v) Edge Bead Spin-off

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.

vi) Multiple Coating

A multiple coating with an elevated spin speed for each coating cycle requires a sufficiently high-viscous resist as well as a short softbake between two coating steps in order to prevent the dissolution of the already coated resist film by the next one.

vii) Delay between Coating and Softbake

For thick or solvent-rich resist films, a delay between coating and softbake (with the coated substrate hereby mounted horizontally) 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.

viii) Development of Edge Bead

In the case of positive or image reversal resists, an exposure and development of the edge bead is also possible but may cause T-topping of the resist profile due to the impact of the developer on the unexposed resist.

Spin Coating: Comet-Shaped Structures?

i) Air- or Nitrogen Bubbles

Radial resist inhomogeneities often stem from air or N_2-bubbles, more rarely from particles, both driven outwards during spin coating. Possible reasons and work-arounds are listed in section 36.2 and 36.3.

Spin Coating: Substrate Partially Uncoated after Spin-Coating?

i) Possible Reasons and Work-arounds Are Listed in Section 36.2 and 36.3.

Spray Coating: Inferior Edge Coverage?

i) Solvent Composition of the Resist

If the concentration of especially high-boiling solvents in the resist is too high, the growing resist film will flow and leave the edges of the texture uncoated. Please consult us for suited dilution recipes for spray coating resists!

ii) Equipment

Modifications in the equipment (e. g. an increased distance between nozzle and substrate) or the spray coating parameters (e. g. and increased rate or pressure) may increase the average solvent concentration of the resist droplets landing on the substrate. As a result, the growing resist film will flow and leave the edges of the texture uncoated.

Spray Coating: Rough Resist Film

i) Solvent Composition of the Resist

A concentration of especially high-boiling solvents in the resist being too low prevents the droplets landing on the substrate from flowing and thus smoothing the resist film (section 11.4 on page 54 and 11.5 on page 55). Please consult us for suited dilution recipes for spray coating resists!

ii) Equipment

Modifications in the equipment (e. g. a reduced distance between nozzle and substrate) or the spray coating parameters (e. g. a reduced rate or pressure) will decrease the average solvent concentration of the resist droplets landing on the substrate preventing a sufficient smoothing of the resist film. If realizable, an elevated substrate temperature of 40 - 60°C causes a faster solvent evaporation and shortens the time the resist film can flow (section 11.3 on page 53).

Dip Coating: Inhomogeneous Resist Film Thickness?

i) Solvent Composition of the Resist

A resist film thickness increasing from the upper (concerning the position during coating) towards the lower part of the substrate points towards the wrong solvent composition of the resist: If the resists need too much time to sufficiently increase its viscosity immediately after coating, the resist will drain off during dip coating. Optimized dip coating resists (section 12.3 on page 57) such as MC Dip Coating Resist (section 53.6 on page 182) have a solvent composition allowing very homogeneous resist film thicknesses.

ii) Expired Resist

Dip coating resists are usually highly diluted and therefore more susceptible for an accelerated ageing especially at room temperature (section 7.4 on page 33). As a consequence, particles or 'clots' form in the resist and cause inhomogeneities in the resist film. In this case, the entire resist bath needs to be exchanged.

iii) Equipment

Vibrations by the step motor or from the environment cause rather strong variations of the resist film thickness. If the substrate mounting comes into contact with the liquid resist, striations caused by resist draining off may deteriorate the coating homogeneity. A non-constant air flow around the cuvette is another possible reason for inhomogeneities in the resist film thickness (section 12.2 on page 56).

Roller Coating: Inhomogeneous Resist Film

i) Suited Resist for Roller Coating?

Resists optimized for roller coating often have thixotropic properties. The viscosity changes when mechanical stress is applied making the resist film thickness more homogeneous as compared to the usage of standard resists for roller coating application.

Screen Printing: Suited Resists

i) Suited Resist for Screen Printing?

The mechanical properties of photo resists make them less suited for screen printing. If nevertheless this coating technique should be applied, we recommend tests with resists with a high viscosity such as the positive resists AZ® 4562, AZ® 9260, or AZ® 40 XT, or the negative AZ® 15 nXT or AZ® 125 nXT.

EXPOSURE TECHNIQUES: OCCASIONAL PROBLEMS

Laser Scribing

i) Bubbles or Cracks in the Resist Film?

Bubbles or cracks after exposure in positive or image reversal resist films very probably stem from the high N_2-generation rate during the photoreaction. Using resists with a low photo active compound concentration such as AZ® 4562, AZ® 9260, or AZ® 40 XT without any N_2 release during exposure or lowering the total resist film thickness as well as increasing the softbake time/temperature and improving the resist adhesion might help (section 13.5 on page 62), as well as an optimized adhesion (chapter 8). If the bubbles or cracks still appear, the laser intensity should be decreased, or the whole laser scribing process split into several steps to allow the N_2 to outgas in time.

ii) Elevated Resist Film Temperature?

If the exposed resist cannot be developed despite a sufficient exposure dose, or neighboured resist parts finally not be removed, the resist film has probably become too hot during exposure. Hereby the resin of the resist thermally crosslinks thus becoming insoluble in solvents or alkaline removers. In this case, the laser intensity should be decreased, or the whole laser scribing process split into several steps.

iii) Focus of the Laser Beam

Especially in the case of thick DNQ-based positive resists, the resist film can inflate due to the N_2 formed in the exposed part of the resist, which brings the laser beam in the resist film out of focus. In this case, it helps to split the whole laser scribing process into several steps to allow the N_2 to outgas in time.

Laser Interference Lithography

i) Particles in Heavily Diluted Resists?

This technique generally requires very thin resist films, often realized via dilution of existing resists. While the AZ® 1500 or 6600 resists are known to form particles in the case of high dilution ratios (section 7.4 on page 33), AZ® 701 MiR and the AZ® ECI 3000 resists are capable for a strong dilution for resist films of 200 nm and less. As a thinner, we recommend the solvent PGMEA = AZ® EBR Solvent.

ii) Resists with the Required Resolution?

Laser Interference Lithography often requires resists with a high resolution potential in the sub-µm range. For this purpose, we recommend the thermally stable AZ® 701 MiR for applications such as dry etching or lift-off, or the AZ® ECI 3000 series for wet chemical processes requiring a superior resist adhesion.

Exposure Wavelengths Beyond/Below the Standard Resist Absorption

i) Wavelength Too High?

Wavelengths exceeding the absorption maxima of resists by several 10 nm (e. g. > 450 nm for broadband resists) are generally suited for exposure, since the resist absorption does not abruptly end at a certain wavelength (Fig. 41 on page 29). However, the low absorption with penetration depths much higher than the resist film thickness require high exposure doses. Additionally, the weak absorption promotes the lateral propagation of incident light in case of rough, textured, or transparent substrates thus lowering the attainable spatial resolution (section 16.9 on page 81).

ii) Wavelength Too Small?

Too small wavelengths (< 340 nm) only theoretically improve the resolution. Due to the low penetration depth of the incident light, and the parasitic absorption of the already exposed photo active compound, the exposure dose required strongly increases. In combination with the short-wavelength-promoted Rayleigh-scattering, the attained resolution often decreases as compared to i-line exposure.

Sticking Between Resist Film and Mask

i) Remaining Solvent Concentration Too High?

A softbake too cool/too short keeps the remaining solvent concentration in the resist film too high, which promotes sticking to the photo mask. We recommend a softbake at 100°C (hotplate) for one minute/µm resist film thickness (section 13.5 and 13.6 on page 63).

ii) Particles or Bubbles in the Resist Film?

Particles or bubbles in the resist film can transfer onto the photo mask and hereby promote the local sticking of the resist film. Cleaning the mask will help in this case.

iii) Hard-Contact?

A hard-contact during exposure promotes the sticking between resist film and mask. If applicable, switching to the soft-contact mode will help. This especially holds for resists such as AZ® 40 XT or AZ® 125 nXT which show a rather low viscosity even after the softbake.

iv) InferiorResist Adhesion (to the Substrate)?

An inferior resist adhesion promotes the resist peeling from the substrate by the photo mask. Chapter 41 on page 168 gives information on resist adhesion improvement.

v) ARC-Coating Als Solution

Coating the resist film with AZ® Aquatar (actually a top layer anti-reflective coating) makes the resist film lesss "adhesive". Due to its water solubility, AZ® Aquatar is automatically removed during development.

DEVELOPMENT: INSUFFICIENT DEVELOPMENT RATE

Sufficient Rehydration?

i) Rehydration Sufficiently Long?

DNQ-based positive resists (not AZ® 40 XT) and image reversal resists require a certain water content to allow a reasonable high development rate. After the softbake or image reversal bake, the now missing water has to diffuse back from the air into the resist film requiring a delay time between baking and exposure to rehydrate the entire photo resist film towards the substrate (chapter 14). The required rehydration time strongly depends on the resist film thickness and increases from approx. 1 min for 1 µm films to several hours for films exceeding 30 µm (Fig. 75 on page 66).

ii) Ambient Humidity Sufficiently High?

In case of a sufficiently long rehydration time, the ambient air humidity impacts on the later development rate which significantly drops if the humidity is below 40 %. We recommend to keep the humidity constant at approx. 40 - 50 %.

iii) Rehydration Reversed?

In case of a sufficiently long rehydration time, the ambient air humidity impacts on the later development rate which significantly drops if the humidity is below 40 %. We recommend to keep the humidity constant at approx. 40 - 50 % (section 14.2 on page 66).

Sufficient Exposure Dose in the Case of Positive Resists?

i) Optimized Exposure Dose?

Generally, the required exposure dose depends on the resist, the resist film thickness, and the emission spectrum of the light source with respect to the resist to be exposed (16.5 on page 75). We strongly recommend an exposure dose series and determine the development rate as a function of the exposure dose when starting with new resists or processes or after changes of the exposure equipment (Fig. 84 on page 77).

ii) Thin Resist Films?

In case of thin resist films (thickness < light penetration depth), an exposure dose being too low results in a constant but low development rate (section 16.6 on page 76). Since a large fraction of the light reaches the substrate, the optical properties (reflection and transmission coefficient) strongly impacts on the required exposure dose.

iii) Thick Resist Films

In case of thick resist films (thickness > light penetration depth), an exposure dose being too low results in a normal development rate until a certain depth where the development almost stops (section 16.6 on page 76).

Compatible Developer?

iv) Resist and Developer Interaction

Some photoresists require special developers for constant fast and residual-free development (section 53.7 on page 183). For example, the AZ® 4500 series (AZ® 4533 and 4562) require the KOH-based AZ® 400K or the TMAH-based AZ® 826 MIF. For the negative resists AZ® nLOF 2000, AZ® 15 nXT or AZ® 125 nXT we recommend the TMAH-based developers AZ® 326 MIF, 726 MIF or 826 MIF (the 826 MIF is specially suited for the removal of partially/accidentally crosslinked resist due to its built-in scum remover). The AZ® 111 XFS requires the developer AZ® 303.

Expired Developer?

i) Neutralization by CO_2

CO_2-absorption from air limits the lifetime of open developer baths depending on the surface/volume ratio of the developer bath. A nitrogen curtain reduces CO_2-absorption and thus decelerates the developer neutralisation. Even well-closed containments are permeable for CO_2, therefore the developer activity may decrease after the expiry date (section 7.6 on page 35).

ii) Exhaustion by Developed Resist

A developed resist concentration too high also exhausts the developer: As a rule of thumb, approx. one per mille resist dissolved in typical developers significantly reduces the development rate (section 18.6 on page 93).

Developer Dilution Too High?

i) Concentrates and Ready-to-Use Developers

The KOH-based AZ® 400K and NaOH-based AZ® 351B are typically applied in a 1 : 4 dilution with water. AZ® Developer can be applied as a concentrate (high development rate), or in a 1 : 1 dilution (improved selectivity). The TMAH-based ready-to-use developers AZ® 326 MIF, 726 MIF and 826 MIF are generally applied undiluted. The AZ® 303 is typically applied at a dilution ratio of 1 : 4 (for the AZ® 111 XFS) or 1 : 5 - 1 : 10 (for other resists). In case of very thin resist films or very small resist structures, increasing the dilution ratio by a factor of up to 1.5 above the ratios mentioned, sometimes make the process more stable but strongly lowers the development rate (Fig. 97 on page 91).

HMDS Applied Correctly; Contamination by Other Substances?

i) HMDS Applied Correctly?

In case of spin-coating of HMDS, a comparable thick HMDS film forms on the surface. Additionally, HMDS vapours from the spincoater will penetrate the resist film during resist coating. During the subsequent softbake, this excess of HMDS releases ammonia which diffuses into the resist and chemically modifies the resin near the substrate, and also may cause crosslinking of the resin. As a result, the development rate decreases, and through-development may become impossible (scumming) (Fig. 49 on page 39). We strongly recommend to apply HMDS from the vapour phase onto heated substrates, and keep resist and resist film away from HMDS vapour (section 8.2 on page 38). This recommendation especially holds for spin coaters: Never apply HMDS in a spin coater where also resist films are coated!

ii) Contamination from Air

Many substances often used in cleanrooms such as ammonia or chlorobenzene interact with the chemistry of the photoresist. Diffusing into the resist film via the gaseous phase, during a subsequent baking step (e. g. softbake) the resist will become photochemically inert or crosslink thus reducing the development rate.

Thermal Decomposition of Photo Active Compound?

i) During Storage

If the resist is stored beyond its expiry date, or at temperatures exceeding the recommended storage temperature, the photo active compound will gradually decompose thus reducing the attained development rate. Adjusting the exposure dose, developer concentration, or development time can compensate this effect to a certain extent. The dark erosion, however, hereby will increase.

ii) During the Softbake

The photosensitive compound of photoresists is partially decomposed during baking steps. If the softbake temperature and -time are higher than recommended, the development rate decreases (Fig. 105 on page 101). For standard positive resists, we recommend a softbake temperature of 100°C for 1 minute/µm resist film thickness. For certain negative resists (AZ® 15 nXT or AZ® 125 nXT) or special thick resists (AZ® 40 XT), the optimum softbake parameters deviate from this rule, and are detailed in the individual technical data sheets.

Resist Film Thickness Higher Than Expected?

i) Spincoaters Geometry

The airflow conditions in the spin-coater impact on the evaporation rate of the solvent from the resist film coated. Therefore, any changes in the equipment (covered chuck, flowbox, exhaustion ...) or substrate size and shape are a possible reason for changes in the attained resist film thickness.

ii) Ambient Solvent Saturation

The ambient solvent saturation in the spin coater depends on the number of substrates coated before, and the time span between the last cleaning of the spin coater and the last resist coating. Since the atmosphere solvent concentration impacts on the solvent evaporation rate from the resist film, it is recommended to coat some dummy wafers before starting with new coating series.

iii) Solvent Loss in the Resist

The resist viscosity and thus the attained film thickness depends on the temperature, and the solvent concentration which gradually drops over the months if the resist bottles are frequently opened.

Spray- and dip coating resists often contain also a low-boiling solvent such as acetone or MEK which evaporates much faster than the solvents used in standard resists. Thus, the solvent loss and therefore attained resist film thickness change is sometimes more pronounced.

iv) Expired Resist?

Depending on the storage temperature of the resist bottle, some resists show an increase in their visocity over months and years.

Changed Substrate Reflectivity?

i) Thin Resist Films

Especially in case of thin (e. g. < 2 µm) resist films, the effective exposure dose absorbed by the resist film depends on the substrate properties (reflection coefficient and scattering). For this reason, the exposure dose required for a certain resist film depends on the substrate material and surface. While metals such as Ag, Cr or Pt show a high reflectivity of short wavelength light, ITO absorbs most of the blue and UV part of the spectrum and quartz and glasses transmit the major part of these wavelengths.

Negative or Image Reversal Resists in Image Reversal Mode?

i) Post Exposure Bake or Reversal Bake Too Hot or Long?

An image reversal bake or post exposure bake too hot/too long as well as a significantly too hot softbake cause thermal crosslinking of the resin also in the unexposed resist which thereby show a slower development rate (Fig. 101 on page 96).

ii) Unintentional Exposure

If also the resist part to be developed is unintentionally exposed to short wavelength light, crosslinking or the image reversal reaction take place which lowers the development rate or makes through-development impossible. Possible reasons for an accidental exposure are insufficient yellow light conditions (section 7.3 on page 31), diffraction due to a gap between photomask and resist surface, light scattering in the resist film in combination with a high exposure dose, diffuse reflection from a rough substrate or a lateral guidance of the light by textured or UV-transparent substrates

iii) Critical Negative Resists

Some negative resists such as the AZ® 15 nXT are very sensitive to the time interval between exposure and post exposure bake, as well as between post exposure bake and development. For such senstive resists both intervals should be kept as short as possible (not more than few minutes) to prevent chemical reactions in the resist which crosslink also the unexposed part of the resist.

Chemically Amplified Resists?

i) Required Post Exposure Bake

The chemically amplified AZ® 40 XT requires a post exposure bake to perform the photoreaction, otherwise the development rate is almost zero.

DEVELOPMENT: DARK EROSION TOO HIGH

Proper Developer Dilution?

With increasing developer concentration, the dark erosion rate growths faster than the development rate (Fig. 97 on page 91). The KOH-based AZ® 400K and NaOH-based AZ® 351B are typically applied in a 1 : 4 dilution with water. AZ® Developer can be applied as a concentrate (high development rate), or in a 1 : 1 dilution (improved selectivity). The TMAH-based ready-to-use developers AZ® 326 MIF, 726 MIF and 826 MIF are generally applied undiluted. AZ® 303 is typically applied at a dilution ratio 1 : 4 (for AZ® 111 XFS) or 1 : 5 ... 1 : 10 (for other resists). For thick resist processing or the demand of very high throughput, the developer concentration can be increased by some 10 % which, however, reduces the selectivity.

Compatible Developer?

Certain developers such as AZ® Developer or AZ® 826 MIF reveal slightly higher dark erosion rates for photoresists. If these developers are not required by the applied resists, more selective developers are recommended (section 53.7 on page 183).

Optimum Softbake Conditions?

i) Too Short or Too Cool?

A softbake too cool/too short keeps the remaining solvent concentration at high values, thus increasing the dark erosion rate in developers. As a rule of thumb for most common resists, we recommend a softbake temperature of 100°C for 1 minute/µm resist film thickness (section 13.5 on page 62). For certain negative resists (AZ® 15 nXT or AZ® 125 nXT) or special thick resists (AZ® 40 XT), the optimum softbake parameters deviate from this rule, and are detailed in the individual technical data sheets. When using an oven, one has to consider the time the substrates need to heat up to the desired temperatures. When using a hotplate, thick substrates or substrates with minor heat conduction, as well as strained/curved substrates may reduce the effective temperature in the resist film (section 13.6 on page 63).

ii) Too Hot or Too Long?

A softbake too extended (too hot/too long) will thermally decompose a significant amount of the photo active compound. Since the unexposed photo active compound acts as inhibitor in alkaline solutions, its loss increases the erosion in developers (section 13.5 on page 62).

Decomposition of Photo Active Compound during Resist Storage?

If the resist is stored beyond its expiry date, or at temperatures exceeding the recommended storage temperature, the photo active compound will gradually decompose thus reducing the attained development rate. The unexposed photosensitive compound of photoresists is a solubility inhibitor in alkaline solutions, thus decreasing the dark erosion in developers (section 7.5 on page 34).

In Case of Image Reversal- or Negative Resists?

i) Parameters for the Image Reversal Bake

The reason of the image reversal bake after the first exposure of image reversal resists is to make the exposed resist insoluble in the developer. If the image reversal bake is too cool/too short, the solubility keeps at a rather high value leading to resist erosion of the exposed part during development. The recommended image reversal bake parameters depend on the image reversal resist (section 20.3 on page 101).

ii) Parameters for the Post Exposure Bake for Negative Resists

Negative resist such as the AZ® nLOF 2000 resists require a post exposure bake (PEB) to crosslink the exposed part of the resist. If the PEB temperature or –time are not sufficiently high, the degree of crosslinking keeps at low values, leading to a resist erosion during development. For the AZ® nLOF 2000 resists we recommend a PEB temperature of 110 - 120°C for 1 - 2 minutes if applied on a hotplate (section 21.2 on page 104).

Accidental Exposure of Positive Resists?

i) Light Scattering in the Resist Film

If the exposure dose is too high, light scattering (Rayleigh scattering) in the resist film may expose parts of the resist close to the exposed areas, which hereby become soluble in developers (section 16.5 on page 75).

ii) Proximity Gap during Exposure

A gap between the resist surface and mask (intended or accidental via bubbles or particles in the resist film or the photomask, or an edge bead of the resist) will cause an interference pattern on the resist and thus widen the exposed structures (section 16.8 on page 80). Additionally, reflections between resist surface and photomask laterally guide light.

iii) Textured Substrates

Textured or rough substrates reflect or scatter light to parts of the resist film which should keep unexposed. In transparent substrates, light can be guided laterally thus exposing resist from the rear side. In both cases, an adjustment of the exposure dose to values not higher than required can be reasonable

(section 16.5 on page 75). Additionally, a bottom-layer anti-reflective-coating such as the AZ® Barli can be beneficial

iv) No Perfect Yellow Light Conditions

Most positive tone resists are also sensitive to short-wavelength visible light as emitted by fluorescent tubes or electrical bulbs, or day light transmitted through windows. Therefore, all light sources should be filtered by e. g. yellow foils absorbing wavelengths < 520 nm (details on our yellow foil in section 7.3 on page 31).

Second Development Step?

During development, the alkaline developer also penetrates the unexposed resist to a certain depth. If the rinse after development is not sufficiently long, the developer residuals concentrate in the resist when the water evaporates and forms a strong base with the water from a second development step. Such as base acts as stripper and is able to remove a layer of the resist film. If a second development step cannot be waived, much care has to be taken to sufficiently rinse with water after the first development.

INFERIOR RESIST ADHESION

Optimum Substrate Pretreatment?

i) In Case of Clean Substrates

In the case of clean substrates, baking at 120 - 140°C for several minutes is sufficient for the desorption of H_2O. At 150°C, the OH-bonds apparent on oxidized surfaces (Si with native oxide, SiO_2, glass, many metals) decompose thus further increasing the resist adhesion (section 8.1 on page 37).

ii) Organic Contamination

Substrates contaminated with particles or organic impurities can be cleaned with a two-stage cleaning process: Acetone removes organic impurities, a subsequent rinse in isopropyl removes the contaminated acetone thus avoiding striations, s. section 8.1 on page 37.

iii) Wrong HMDS Application

The correct application of HMDS is very important in order not to further deteriorate the resist adhesion: HMDS should be applied from the gaseous state onto heated substrates, never from the liquid phase. This recommendation especially holds for spin coaters: Never apply HMDS in a spin coater where also resist films are coated (section 8.2 on page 38).

iv) Preceding HF Etching

After SiO_2-etching with HF (e. g. 'HF-dip'), the resist adhesion strongly depends on the thoroughness of SiO_2 removal: With SiO_2 completely removed, the now H-passivated Si-surface reveals a hydrophobic surface with a very good adhesion. Incomplete etching with remaining oxide results in a poor and non-reproducible adhesion, which can be restored with a bake at temperatures > 700°C. (section 8.3 on page 39).

Using HF-Containing Etchants?

HF diffuses into the resist film and may lead to a large scale resist peeling either during the etching, or after the subsequent rinsing by resist swelling and large-scale etching of the resist covered substrate material. Work-arounds are i) increasing the resist film thickness (= barrier against HF), and the usage of buffered HF (BOE), see section 24.7 on page 116.

On Noble Metals?

The resist wetting and adhesion on noble metals (e. g. silver, gold) is often worse. In this case, resists such as AZ® 111 XFS, AZ® 1514 H or the ECI 3000 series may improve the adhesion. While organic adhesion promoters such as HMDS are not able to significantly improve resist adhesion, a metallic adhesion layer (titanium or chromium) results in a very good adhesion to resists. If required, such few nm thick metal

films can easily be etched after development and/or after resist removal.

Optimum Softbake Parameters?

i) Too Short or Too Cool?

A softbake too cool/too short keeps the remaining solvent concentration too high with inferior resist adhesion as a consequence. In this case, especially thick resist films show N_2 bubble formation during exposure. We recommend a softbake temperature of 100°C for 1 minute/µm resist film thickness. For certain negative resists (AZ® 15 nXT or AZ® 125 nXT) or special thick resists (AZ® 40 XT), the optimum softbake parameters deviate from this rule, and are detailed in the individual technical data sheets. When using an oven, one has to consider the time the substrates need to heat up to the desired temperatures. When using an hotplate, thick substrates or substrates with minor heat conduction, as well as strained/curved substrates may reduce the effective temperature in the resist film. A work-around are a longer softbake time or higher softbake temperature

ii) Softbake Too Long or Too Hot?

A softbake too hot/too long embrittles the resist film and causes mechanical stress between resist and substrate. In this case - especially after abrupt cooling after the softbake - the resist film may loose adhesion to the substrate. In this case, a slow temperature ramp down might be beneficial.

Positive Tone Resists on Transparent Substrates?

Especially in case of too high exposure doses, light can be guided in transparent substrates and hereby expose the resist near the substrate. As a result, small resist structures may lift in the developer (section 16.5 on page 75).

Image Reversal- or Negative Tone Resists?

Too low exposure doses (section 20.2 on page 100 and 21.1 on page 104) or a post exposure bake (section 21.1 on page 104) being too cool/too short will keep the substrate-near resist soluble in the developer. This may cause lifting of especially small resist structures from the substrate during development

Double-Sided Metallized Substrates?

Substrates coated with different metals on both sides may cause a galvanic cell in aqueous solutions (24.7 on page 116), accompanied by gas (H_2-) formation under the resist peeling it from the substrate. A protective coating with e. g. AZ® 520 D on the "rear side" of the substrate will help

MINOR RESIST RESOLUTION

Suitable Photoresist?

Positive resists such as AZ® 1505 or AZ® 1512 HS allow structure sizes below 1 µm, AZ® 701 MiR and the AZ® ECI 3007 even below 0.5 µm. If high-resolution negative tone resists are required, thin films of the AZ® nLOF 2000 series allow sub-µm features for e. g. lift-off application. High aspect ratios with (very) thick resist films recommend the positive resists AZ® 9260 and 40 XT, or the negative resists AZ® 15 nXT and 125 nXT.

Gap between Photomask and Resist Surface?

iii) Light Diffraction

Particles, bubbles in the resist film, an resist edge bead, or curved substrates may cause a gap between mask and resist which degrades the theoretical and achieved resolution by diffraction and light scattering. (section 16.8 on page 80).

Suited Softbake Parameters?

i) Too Hot or Too Long?

A softbake too hot/too long thermally decomposes a significant part of the photoactive compound DNQ of positive and image reversal resists. If not exposed, the DNQ acts as a solubility inhibitor in alkaline solutions, thus decreasing the dark erosion in developers. Since the development rate decreases at the same time, the contrast of the resist and hereby its resolution performance deteriorates. We recommend a softbake temperature of 100°C for 1 minute/µm resist film thickness. When using an oven, one has to consider the time the substrates need to heat up to the desired temperatures. When using an hotplate, thick substrates or substrates with minor heat conduction, as well as strained/curved substrates may reduce the effective temperature in the resist film (section 13.6 on page 63).

ii) Too Hot or Too Cool?

A softbake too cool/too short keeps the remaining solvent concentration too high with increased dark erosion as a consequence (section 13.5 on page 62), which deteriorates the possible resolution of the resist film. The previous section informs about recommended softbake parameters.

Compatible and Sufficiently Diluted Developers?

i) Resist-compatible Developer?

Certain developers such as AZ® Developer or AZ® 826 MIF have higher dark erosion rates for photoresists than other developers, making them less suited for high-resolution demands. The AZ® 4500 series require the KOH-based AZ® 400K or the TMAH-based AZ® 826 MIF. For the negative resists AZ® nLOF 2000, we recommend the TMAH-based developers AZ® 326 MIF, 726 MIF or – better – 826 MIF. AZ® 111 XFS requires the developer AZ® 303.

ii) Developer Sufficiently Diluted?

→ section 40.1 on page 166

Optimum Exposure Dose?

i) Positive Resists

Positive resists exposed with a too small exposure dose (section 16.5 on page 75) require for through-development either a prolonged development time, or a stronger developer concentration. In both cases the dark erosion increases thus deteriorating the possible contrast and, respectively, resolution.

ii) Negative or Image Reversal Resists

Negative or image reversal resists exposed with a too small exposure dose (section 20.2 on page 100 and 21.1 on page 104) show an increased erosion of the exposed resist during development, which also reduces the attainable resolution of the resist

iii) Exposure Dose Too High?

If the exposure dose is too high, light scattering in the resist film also exposes 'dark' parts of the resist, which hereby become soluble (in case of positive resists), or insoluble (in case of image reversal or negative resists) in developers thus preventing the realization of very small structures. Section 40.6 on page 167 gives some more details on the possible reasons for accidental overexposure.

BUBBLES OR PARTICLES IN RESIST FILM AFTER COATING

Resist Bottles Moved?

Carrying or shaking resist bottles or moving them may inject small air bubbles into the resist. In this case, a delay before coating allows the bubbles to raise to the resist surface. The waiting time depends on the resist viscosity, 1 - 2 hours should be sufficient in most cases.

Resist Bottles Closed for A While?

Over months, the photo active compound of many resists releases N_2 which dissolves in the resist. When the resist bottle is opened, N_2 bubbles may form which - more or less slowly - raise to the surface. For this reason, shaking the closed bottle followed by a delay with the screw cap set loosely (pressure balance!) on the bottleneck is required to outgas the N_2. The waiting time depends on the resist viscosity, 1 - 2 hours should be sufficient in most cases.

Manual Resist Dispensing?

Dispensing the resist with pipettes often leads to air bubbles in the resist. As a work-around, give the resist-filled pipette some time allowing the air bubbles to raise away from the outlet.

Spray Coating?

If the fraction of a low-boiling solvent such as MEK or acetone is too high, the resist droplet may dry during flight and subsequently hit the substrate as a resist pellet (section 11.3 on page 53).

Expired Resist?

Expired resist or resist stored under wrong conditions may form particles. This effect especially concerns low-viscosity thin resists with a high concentration of the photo active compound (section 7.5 on page 34).

Diluted Photoresist?

If a dilution is required, only suitable solvents (such as PGMEA or MEK) should be used, and a resist-specific maximum dilution should not be exceeded. Otherwise, the resist may rapidly form particles. Please contact us for suited solvents and dilution recipes (section 7.4 on page 33).

Bumps in the Resist Film after Spin-Coating?

i) Resist ‚Clots'?

One or few mm-sized scattered resist structures on the resist-coated substrate often origin from a solidified resist in the dispenser nozzle. Especially in the case of a long delay after a previous dispensing step or a strong air flow (exhaustion), a resist skin forms in the nozzle and is scattered onto the substrate during the subsequent dispensing. Possible methods to inhibit the formation of such a resist skin between two dispensing steps are a shorter delay, a minimized or paused exhaustion or the pre-dispensing of a small resist volume beside the substrate.

ii) Central Superelevation?

A cm-sized resist bump in the centre of the substrate (the location where the resist has been dispensed) often results from a too long delay between resist dispensing and the spin start. Hereby, the evaporation of the solvent from the resist solidifies especially high-viscous resists which no longer homogeneously thin out during spin-coating.

BUBBLES IN RESIST FILM AFTER EXPOSURE

Softbake Sufficient?

A softbake too cool/too short keeps the remaining solvent concentration too high allowing the N_2 formed during exposure to form bubbles in the resist film. For many common resists, we recommend a softbake temperature of 100°C for 1 minute/µm resist film thickness (section 13.5 on page 62) or the parameters recommneded in the individual data sheets. When using an oven, one has to consider the time the substrates need to heat up to the desired temperatures (section 13.6 on page 63).

Sufficient Resist Adhesion?

The N_2 generated during exposure of positive tone and image reversal resists may form bubbles at locations of minor resist adhesion to the substrate. Detailed information on substrate cleaning and adhesion

promotion are listed in chapter 41 on page 168.

Exposure Intensity Too High?

The N_2 generated during exposure of positive tone and image reversal resists needs to dissipate from the resist film before its concentration becomes too high. If the exposure intensity is too high, the N_2 cannot timely outgas and therefore forms bubbles or resist cracks due to mechanical stress. Lowering the exposure intensity (= extending the exposure time), or splitting the exposure into several steps with delays in-between (especially reasonable in case of laser scribing) will help in this case.

Resist Film Thickness Too High?

Towards thicker resist films, it becomes more difficult for the N_2 formed during exposure to diffuse towards the resist film surface. Thus, bubble formation is much more pronounced during thick resist processing. For this reason, we recommend suited thick resists such as AZ® 4562 or 9260 with a lower photo active compound concentration causing less N_2 during exposure, or chemically amplified resists such as the AZ® 40 XT which don't release N_2 during exposure.

BUBBLES IN RESIST FILM AFTER THERMAL PROCESSES

After Baking Steps of Exposed Photoresist?

The N_2 generated during exposure of positive tone- and image reversal resists may form thermally activated bubbles in the softening resist during baking steps (post exposure bake or image reversal bake) or during any other process steps performed at elevated temperatures, such as electroplating. In this case, a delay between exposure and baking step will help to sufficiently outgas N_2 from the resist film (section 16.14 on page 86).

After Coating (Sputtering, Evaporation) or Dry Etching?

i) Remaining Solvent or Water?

Elevated temperatures may evaporate remaining solvent or water (from development) in the resist. In combination with the low ambient pressure, bubbles may occur. Increasing the softbake time or temperature (section 13.6 on page 63) will reduce the remaining solvent concentration, while a baking step after development below the softening point of the resist (section 6.5 on page 27) reduces the water content.

ii) Nitrogen?

The N_2 generated during exposure of positive tone- and image reversal resists may form thermally activated bubbles in the softening resist during baking steps (post exposure bake or image reversal bake) or during any other process steps performed at elevated temperatures, such as electroplating. In this case, a delay between exposure and baking step will help to sufficiently outgas N_2 from the resist film.

WET ETCHING: COMMON PROBLEMS

Resist Adhesion Problems?

Possible reasons and work-arounds with respect to inferior resist adhesion are listed in chapter 41 on page 168.

Underetching?

Isotropic etchants generally underetch the resist to an extent comparable to the etched depth. A more pronounced underetching points towards an inferior resist adhesion (s. section 41 on page 168) which - for the purpose of wet etching - often can be improved by a hardbake after development at approx. 140°C for 5 - 10 minutes (section 19.1 on page 96).

Inhomogeneous Etch Start?

i) Resist Residuals?

Even a few nm resist residuals on the substrate can act as a barrier against many etchants. Possible reasons for resist residuals are incompatible developers (section 39.3 on page 164), incorrect HMDS treatment (section 8.2 on page 38), or insufficient rinsing after development

ii) Resist Film on Aluminium?

Alkaline developers preferentially dissolve the (native) Al_2O_3 where the resist is primarily through-developed (at regions with lower resist film thickness, near the edges of cleared structures, or below cleared structures with larger features, s. Fig. 118 on page 118). Dependant on the extent of (desired or undesired) overdeveloping as well as delay between development and Al-etching, the process parameters may cause spatial inhomogeneous Al etching start

Inhomogeneous Etch Depth during Al-Etching?

H_2 bubbles formed during Al-etching tend to stick to the substrate and hereby locally inhibit etching. These bubbles can be released either via ultrasonic treatment, or by repeatedly dipping the substrate into DI-water for 1 - 2 seconds between a certain number of etch cycles (section 25.1 on page 118).

Resist Attack in HNO_3-Containing Etchants?

Strong oxidizing etchants attack the resist. A hardbake after development at 140 - 150°C improves the chemical stability of the resist (section 19.1 on page 96).

Inferior Resistance Against Alkaline (KOH, NaOH, TMAH ...) Solutions?

While a hardbake at 150°C or higher improves the alkaline stability of resists, cresol-based resists will never be stable enough to be suitable as an etch mask for KOH- or TMAH-based anisotropically silicon etching. For this purpose, we recommend the use of e. g. SiO_2 or Si_3N_4 hard masks.

DRY ETCHING: COMMON PROBLEMS

Resist Rounding/Flowing?

If, during dry etching, the resist it heated above its softening point (110 - 130°C for most positive tone and image reversal AZ® resists), the resist profile starts rounding. Work-arounds are listed in section 28.3 on page 131.

Bubbling of Resist?

Unexposed positive resists may be exposed with UV radiation present during dry etching. Thus, N_2 is released which can form bubbles in the thermally softened resist. Work-arounds are listed in section 28.3 on page 131.

Resist Can Not Be Removed After Dry Etching?

High temperatures, DUV-radiation, and the ion bombardment may strongly crosslink the resist making its removal problematic. Work-arounds are listed in chapters 22 on page 107 and 22.4 on page 107 describes possible solutions. Material redeposited onto the resist can also hinder resist removal, in this case the combination of removers and ultrasonic treatment can help.

ELECTRO-PLATING: COMMON PROBLEMS

Inferior Resist Stability

i) Acidic Electroplating Baths?

AZ® and TI photoresists are stable in common acidic electroplating baths, as long as no organic solvents are added.

ii) Alkaline Solutions?

Aqueous alkaline solutions, however, attack the resist mask when the pH-value exceeds 10 (depending on the time and temperature of the bath). Moreover, one has to consider that the local pH-value near the metal deposition can be quite different from the value measured in the bath. Crosslinking resists such as AZ® 15 nXT, AZ® 125 nXT or the AZ® nLOF 2000 series are more stable in alkaline media as compared to positive and image reversal resists.

Bath Contamination by Remaining Solvent?

i) Insufficient Softbake?

Typical softbake parameters keep the remaining solvent concentration at approx. 2 - 4 %. If released to the electroplating bath, the solvent may impact the metal deposition chemistry with a reduced deposition rate or other problems as a consequence. In this case, a longer softbake and/or elevated softbake temperatures are recommended.

ii) Thick Resist Films?

Thick resist films will have a comparable high solvent concentration especially near the substrate even after a prolonged softbake. In this case, a baking step after development at temperatures of approx. 10°C below the resist softening point would be beneficial.

Undesired Resist Profile

i) Steep Resist Profiles Desired?

→ section 34.4 on page 154

ii) Undercut (Negative Resist Profile) Required?

A positive profile of the deposited metal structures requires a negative resist profile. This can easily be obtained with the AZ® nLOF 2000 negative tone resist allowing an adjustment of the undercut via the process parameters exposure dose and post exposure bake temperature (section 34.4 on page 154)

iii) Positive Resist Profile Desired?

If the metal structures shall widen upwards, a positive resist profile is required. This can either be attained via a proximity gap of the photo mask during exposure, or a thermal reflow after development beyond the softening point of the photo resist used.

Bad Adhesion of the Metal Structures?

i) Resist Residuals After Development?

Some resists require special developers for residual-free development. If unsuitable developers are used, a few nm resist may stay on the substrate preventing a proper contact between substrate and deposited metal (section 39.3 on page 164).

ii) Resist Residuals by Incorrectly Applied HMDS?

Incorrectly applied adhesion promoter may also deteriorate the contact between seed layer and deposited metal: HMDS applied form the liquid phase or on unheated substrates may crosslink the substrate-near resist which can not be developed (section 8.2 on page 38).

iii) Negative Resist Residuals?

Crosslinking negative resists processed on certain metals (e. g. Cu is critical) crosslink under certain process conditions of the metallization and/or lithography, which stops the development some 10 or 100 nm before the substrate is reached. The negative resists AZ® 15 nXT and AZ® 125 nXT are Cu-compatible.

iv) Underplating?

Due to the swelling of Resist in aqueous solutions, the adhesion to the substrate during plating can be reduced. Chapter 8 on page 37 gives hints for optimizing the resist adhesion. The negative resists AZ® 15 nXT and AZ® 125 nXT show an optimized adhesion for electroplating on most common substrate materials. On noble metals such as gold, a few nm thin titanium film (alternatively chromium or aluminum) significantly improves the adhesion of the resist. Such a thin metal film can be removed, if necessary, after development in the developed areas in appropriate media. In this case, care must be taken to ensure that the etching process is not etched too far below the resist film.

LIFT-OFF DOES NOT WORK (WELL)

Optimum Coating Technique?

The more or less isotropic sputtering will also coat the resist sidewalls, while evaporation is much more directed and therefore generally gives better lift-off results, especially in case of thick (> several 100 nm) films (section 28.3 on page 131).

Suitable Photoresist for the Required Resist Profile?

A pronounced undercut of the resist sidewalls makes the lift-off much easier as compared to vertical or even positive sidewalls. Therefore, negative tone resists such as the AZ® nLOF 2000 series, or image reversal resists such as AZ® 5214E or TI 35ESX are a good choice. If nevertheless positive tone resists have to be used for lift-off application, e. g. the AZ® ECI 3000 series or the AZ® 9260 thick resist allow almost vertical sidewalls. Developer soaking of positive resists may be an alternative - please ask us for details.

Resist Softening and Rounding during Coating?

During coating (evaporation, sputtering, CVD), the resist film may be heated by the evaporation source radiation, the condensing heat of the growing film, or the kinetic energy of the ions, above its softening point (110 - 130°C for most positive tone and image reversal AZ® resists). The resist profile starts rounding allowing the coating material to also cover the resist profile sidewalls. As a result, subsequent lift-off will work worse or become impossible. Possible work-arounds are listed in section 28.3 on page 131.

Suitable Lift-Off Medium?

i) Using Organic Solvents

Using solvents with a high vapour pressure, such as acetone as a lift-off medium, sometimes promotes the re-adsorption of material already lifted onto the substrate. We recommend high boiling solvents such as DMSO as a lift-off medium, which can be heated up to 80°C if required. If necessary, ultrasonic treatment assists the lift-off process.

ii) Special Strippers

For thermally crosslinked positive resists or negative resists such as AZ® nLOF 2000 or AZ® 15 nXT / 125 nXT, we recommend the high-performance strippers TechniStrip P1316 (positive resists and AZ® 125 nXT), or NI555 (AZ® nLOF 2000, AZ® 15 nXT) (chapter 22 on page 107).

SUBSTRATE ATTACK BY PHOTOCHEMICALS

Discolouring/Attack by the Photoresist?

i) Dyed Resists?

Under certain circumstances, additionally dyed resists such as PL 177 or AZ® 520D may stain especially porous substrates. In this case, the use of undyed resists should be considered.

ii) Solvent Stability?

Resists usually contain rather strong organic solvents such as PGMEA which attack many polymers. A swift coating immediately after dispensing resist as well as a softbake immediately after the coating may help a little bit. Alternatively, a thin metal film protects the polymeric substrate from the solvent to a certain extent. The metal film can be etched after resist development and resist removal.

iii) Impact of Products from the Photoreaction?

Many resists form organic acids during exposure which might attack acidic sensitive substrates.

Attack by the Developer?

i) Aqueous Alkaline Developers?

Aqueous alkaline (KOH-, NaOH or TMAH based) developers attack alkaline sensitive materials such as Al or conductive oxides such as ITO. AZ® Developer is optimized for low Al attack and, in an adjusted dilution, suited for almost all resists and processes.

ii) Alternatives for Negative Resists

Crosslinking negative resists such as the AZ® nLOF 2000 series, AZ® 15 nXT and 125 nXT can alternatively be developed in certain organic solvents. We recommend PGMEA = AZ® EBR Solvent. However, there is always the danger of resist peeling caused by the solvent

Attack by the Remover?

i) Alkaline Removers?

AZ® 100 Remover is uncritical on alkaline sensitive materials as long as applied absolutely water-free. Even traces of water increase the pH-value, so the remover will attack e. g. Al.

ii) NMP?

Undiluted NMP is pH-neutral, while the pH-value increase to approx. 10.5 when diluted with water in a 1 : 1 ratio.

PHOTORESIST REMOVAL DOES NOT WORK (WELL)

Organic Solvents as Remover?

Acetone, sometimes used as a stripper, promotes resist residuals on the substrate due to the fast evaporation. Heating acetone for faster stripping is absolutely not recommended due to the low flash point and high risk of fire. NMP (N-methyl-2-pyrrolidone) or the nontoxic DMSO (dimethyl sulphoxide) are much better removers due to their low vapour pressure. In case of cross-linked resists, heating the NMP or DMSO up to 80°C may be required for resist removal. We also recommend NMP-free and pH-neutral high-performance strippers such as TechniStrip® P1316, P1331 and NI555 (section 22.4 on page 107).

Alkaline Remover?

As an alternative to organic solvents, AZ® 100 Remover is optimized for stripping photoresists residual-free and striation-free. In the case of Al (-containing) substrates, even traces of water have to be avoided in order to prevent Al attack. NaOH or KOH (> 2 %) can also be used as stripper (on sufficiently alkaline stable substrates), a higher cross-linking degree may require higher concentrations and elevated temperatures.

Hardbake at Elevated Temperatures?

Negative tone resists, such as the AZ® nLOF 2000 series already crosslink during the post exposure bake (PEB) and crosslink more strongly at moderate hardbake temperatures. All cresol-resin-based AZ® resists thermally crosslink from approx. 150°C on. If applicable, lowering the hardbake temperature will improve the solubility of the resist in the remover. For heavily cross-linked positive resist films, we recommend the high-performance stripper TechniStrip® P1316 or – in the case of very thick resist films or Novolak-

based negative resists – TechniStrip® NI555 (section 22.4 on page 107).

After Coating (Evaporation, Sputtering, CVD)?

If the resist film is strongly heated by the evaporation source radiation, the condensing heat of the growing film, or the kinetic energy of the ions, crosslinking of the resist may decrease its removability. For heavily cross-linked positive resist films, we recommend the high-performance stripper TechniStrip® P1316 or – in the case of very thick resist films or Novolak-based negative resists – TechniStrip® NI555 (section 22.4 on page 107).

After Dry Etching?

Generally consider what is mentioned in the previous subsection. Additionally, re-deposition of material already etched onto the resist may prevent resist removal. In this case, the re-deposited material first has to be wet-chemically etched which can be assisted by ultrasonic treatment.

Crosslinked Negative Resists?

In the case of heavily cross-linking (e. g. by high process temperatures), Novolak-based negative resists such as AZ® nLOF 2000 or AZ® 15 nXT can be dissolved with TechniStrip® NI555, while for the AZ® 125 nXT, epoxy-based resists, polyimides as well as dry films we recommend TechniStrip® P1316 (section 22.4 on page 107).

Our Photoresists: Application Areas and Compatibilities

	Recommended Applications [1]	Resist Family	Photoresists	Resist Film Thickness [2]	Recommended Developers [3]	Recommended Removers [4]
Positive	Improved adhesion for wet etching, no focus on steep resist sidewalls	AZ® 1500	AZ® 1505 AZ® 1512 HS AZ® 1514 H AZ® 1518	≈ 0.5 µm ≈ 1.0 - 1.5 µm ≈ 1.2 - 2.0 µm ≈ 1.5 - 2.5 µm	AZ® 351B, AZ® 326 MIF, AZ® 726 MIF, AZ® Developer	AZ® 100 Remover, TechniStrip® P1316 TechniStrip® P1331
		AZ® 4500	AZ® 4533 AZ® 4562	≈ 3 - 5 µm ≈ 5 - 10 µm	AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	
		AZ® P4000	AZ® P4110 AZ® P4330 AZ® P4620 AZ® P4903	≈ 1 - 2 µm ≈ 3 - 5 µm ≈ 6 - 20 µm ≈ 10 - 30 µm	AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	
		AZ® PL 177	AZ® PL 177	≈ 3 - 8 µm	AZ® 351B, AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	
	Spray coating	AZ® 4999		≈ 1 - 15 µm	AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	
	Dip coating	MC Dip Coating Resist		≈ 2 - 15 µm	AZ® 351B, AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	
	Steep resist sidewalls, high resolution and aspect ratio for e. g. dry etching or plating	AZ® ECI 3000	AZ® ECI 3007 AZ® ECI 3012 AZ® ECI 3027	≈ 0.7 µm ≈ 1.0 - 1.5 µm ≈ 2 - 4 µm	AZ® 351B, AZ® 326 MIF, AZ® 726 MIF, AZ® Developer	
		AZ® 9200	AZ® 9245 AZ® 9260	≈ 3 - 6 µm ≈ 5 - 20 µm	AZ® 400K, AZ® 326 MIF, AZ® 726 MIF	
	Elevated thermal softening point and high resolution for e. g. dry etching	AZ® 701 MiR	AZ® 701 MiR (14 cPs) AZ® 701 MiR (29 cPs)	≈ 0.8 µm ≈ 2 - 3 µm	AZ® 351B, AZ® 326 MIF, AZ® 726 MIF, AZ® Developer	
Positive (chem. amplified)	Steep resist sidewalls, high resolution and aspect ratio for e. g. dry etching or plating	AZ® XT	AZ® 12 XT-20PL-05 AZ® 12 XT-20PL-10 AZ® 12 XT-20PL-20 AZ® 40 XT	≈ 3 - 5 µm ≈ 6 - 10 µm ≈ 10 - 30 µm ≈ 15 - 50 µm	AZ® 400K, AZ® 326 MIF, AZ® 726 MIF	AZ® 100 Remover, TechniStrip® P1316 TechniStrip® P1331
		AZ® IPS 6050		≈ 20 - 100 µm		
Image Re-versal	Elevated thermal softening point and undercut for lift-off applications	AZ® 5200	AZ® 5209 AZ® 5214	≈ 1 µm ≈ 1 - 2 µm	AZ® 351B, AZ® 326 MIF, AZ® 726 MIF	TechniStrip® Micro D2 TechniStrip® P1316 TechniStrip® P1331
		TI	TI 35ESX TI xLift-X	≈ 3 - 4 µm ≈ 4 - 8 µm		
Negative (Cross-linking)	Negative resist sidewalls in combination with no thermal softening for lift-off application	AZ® nLOF 2000	AZ® nLOF 2020 AZ® nLOF 2035 AZ® nLOF 2070	≈ 1.5 - 3 µm ≈ 3 - 5 µm ≈ 6 - 15 µm	AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	TechniStrip® NI555 TechniStrip® NF52 TechniStrip® MLO 07
		AZ® nLOF 5500	AZ® nLOF 5510	≈ 0.7 - 1.5 µm		
	Improved adhesion, steep resist side-walls and high aspect ratios for e. g. dry etching or plating	AZ® nXT	AZ® 15 nXT (115 cPs) AZ® 15 nXT (450 cPs)	≈ 2 - 3 µm ≈ 5 - 20 µm	AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	
			AZ® 125 nXT	≈ 20 - 100 µm	AZ® 326 MIF, AZ® 726 MIF, AZ® 826 MIF	TechniStrip® P1316 TechniStrip® P1331 TechniStrip® NF52 TechniStrip® MLO 07

[1] In general, almost all resists can be used for almost any application. However, the special properties of each resist family makes them specially suited for certain fields of application.

[2] Resist film thickness achievable and processable with standard equipment under standard conditions. Some resists can be diluted for lower film thicknesses; with additional effort also thicker resist films can be achieved and processed.

[3] Metal ion free (MIF) developers are significantly more expensive, and reasonable if metal ion free development is re-quired.

Our Developers: Application Areas and Compatibilities

Inorganic Developers

(typical demand under standard conditions approx. 20 L developer per L photoresist)

AZ® Developer is based on sodium phosphate and –metasilicate, is optimized for minimal aluminum attack and is typically used diluted 1 : 1 in DI water for high contrast or undiluted for high development rates. The dark erosion of this developer is slightly higher compared to other developers.

AZ® 351B is based on buffered NaOH and typically used diluted 1 : 4 with water, for thick resists up to 1 : 3 if a lower contrast can be tolerated.

AZ® 400K is based on buffered KOH and typically used diluted 1 : 4 with water, for thick resists up to 1 : 3 if a lower contrast can be tolerated.

AZ® 303 specifically for the AZ® 111 XFS photoresist based on KOH / NaOH is typically diluted 1 : 3 - 1 : 7 with water, depending on whether a high development rate, or a high contrast is required

Metal Ion Free (TMAH-based) Developers

(typical demand under standard conditions approx. 5 - 10 L developer concentrate per L photoresist)

AZ® 326 MIF is 2.38 % TMAH- (TetraMethylAmmoniumHydroxide) in water.

AZ® 726 MIF is 2.38 % TMAH- (TetraMethylAmmoniumHydroxide) in water, with additional surfactants for rapid and uniform wetting of the substrate (e. g. for puddle development)

AZ® 826 MIF is 2.38 % TMAH- (TetraMethylAmmoniumHydroxide) in water, with additional surfactants for rapid and uniform wetting of the substrate (e. g. for puddle development) and other additives for the removal of poorly soluble resist components (residues with specific resist families), however at the expense of a slightly higher dark erosion.

Our Removers: Application Areas and Compatibilities

AZ® 100 Remover is an amine solvent mixture and standard remover for AZ® and TI photoresists. To improve its performance, AZ® 100 remover can be heated to 60 - 80°C. Because the AZ® 100 Remover reacts highly alkaline with water, it is suitable for this with respect to sensitive substrate materials such as Cu, Al or ITO only if contamination with water can be ruled out..

TechniStrip® P1316 is a remover with very strong stripping power for Novolak-based resists (including all AZ® positive resists), epoxy-based coatings, polyimides and dry films. At typical application temperatures around 75°C, TechniStrip® P1316 may dissolve cross-linked resists without residue also, e.g. through dry etching or ion implantation. TechniStrip® P1316 can also be used in spraying processes. For alkaline sensitive materials, TechniStrip® P1331 would be an alternative to the P1316. Nicht kompatibel mit Au oder GaAs.

TechniStrip® P1331 can be an alternative for TechniStrip® P1316 in case of alkaline sensitive materials. TechniStrip® P1331 is not compatible with Au or GaAs.

TechniStrip® NI555 is a stripper with very strong dissolving power for Novolak-based negative resists such as the AZ® 15 nXT and AZ® nLOF 2000 series and very thick positive resists such as the AZ® 40 XT. TechniStrip® NI555 was developed not only to peel cross-linked resists, but also to dissolve them without residues. This prevents contamination of the basin and filter by resist particles and skins, as can occur with standard strippers. TechniStrip® NI555 is not compatible with GaAs.

TechniClean™ CA25 is a semi-aqueous proprietary blend formulated to address post etch residue (PER) removal for all interconnect and technology nodes. Extremely efficient at quickly and selectively removing organo-metal oxides from Al, Cu, Ti, TiN, W and Ni.

TechniStrip™ NF52 is a highly effective remover for negative resists (liquid resists as well as dry films). The intrinsic nature of the additives and solvent make the blend totally compatible with metals used throughout the BEOL interconnects to WLP bumping applications.

TechniStrip™ Micro D2 is a versatile stripper dedicated to address resin lift-off and dissolution on negative and positive tone resist. The organic mixture blend has the particularity to offer high metal and material compatibility allowing to be used on all stacks and particularly on fragile III/V substrates for instance.

TechniStrip™ MLO 07 is a highly efficient positive and negative tone photoresist remover used for IR, III/V, MEMS, Photonic, TSV mask, solder bumping and hard disk stripping applications. Developed to address high dissolution performance and high material compatibility on Cu, Al, Sn/Ag, Alumina and common organic substrates.

Our Wafers and their Specifications

Silicon-, Quartz-, Fused Silica and Glass Wafers

Silicon wafers are either produced via the Czochralski- (CZ-) or Float zone- (FZ-) method. The more expensive FZ wafers are primarily reasonable if very high-ohmic wafers (> 100 Ohm cm) are required.

Quartz wafers are made of monocrystalline SiO_2, main criterion is the crystal orientation (e. g. X-, Y-, Z-, AT- or ST-cut)

Fused silica wafers consist of amorphous SiO_2. The so-called JGS2 wafers have a high transmission in the range of ≈ 280 - 2000 nm wavelength, the more expensive JGS1 wafers at ≈ 220 - 1100 nm.

Our glass wafers, if not otherwise specified, are made of borosilicate glass.

Specifications

Common parameters for all wafers are diameter, thickness and surface (1- or 2-side polished). Fused silica wafers are made either of JGS1 or JGS2 material, for quartz wafers the crystal orientation needs to be defined. For silicon wafers, beside the crystal orientation (<100> or <111>) the doping (n- or p-type) as well as the resistivity (Ohm cm) are selection criteria.

Prime- ,Test-, and Dummy Wafers

Silicon wafers usually come as „Prime-grade“ or „Test-grade“, latter mainly have a slightly broader particle specification. „Dummy-Wafers“ neither fulfill Prime- nor Test-grade for different possible reasons (e. g. very broad or missing specification of one or several parameters, reclaim wafers, no particle specification) but might be a cheap alternative for e. g. resist coating tests or equipment start-up.

Our Silicon-, Quartz-, Fused Silica and Glass Wafers

Our frequently updated wafer stock list can be found here: è www.microchemicals.com/products/wafers/waferlist.html

Further Products from our Portfolio

Plating

Plating solutions for e. g. gold, copper, nickel, tin or palladium: è www.microchemicals.com/products/electroplating.html

Solvents (MOS, VLSI, ULSI)

Acetone, isopropyl alcohol, MEK, DMSO, cyclopentanone, butylacetate, ... è www.microchemicals.com/products/solvents.html

Acids and Bases (MOS, VLSI, ULSI)

Hydrochloric acid, sulphuric acid, nitric acid, KOH, TMAH, … è www.microchemicals.com/products/etchants.html

Etching Mixtures

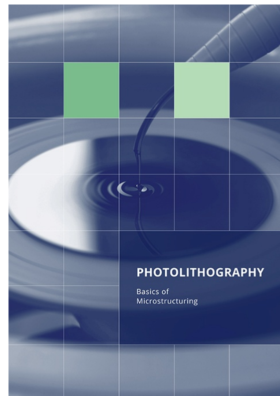
for e. g. chromium, gold, silicon, copper, titanium, ... è www.microchemicals.com/products/etching_mixtures.html

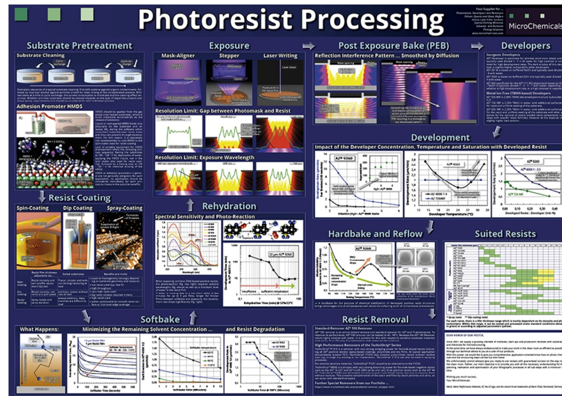
Further Information

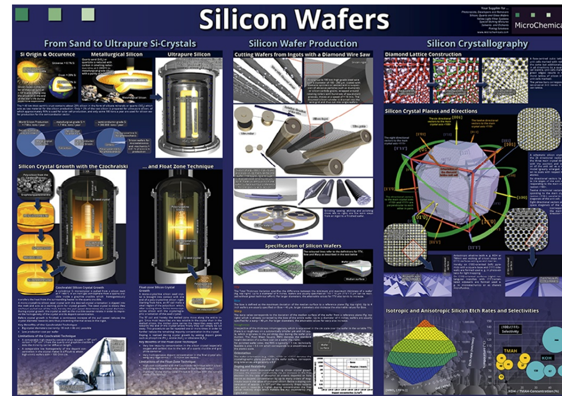
Technical Data Sheets: www.microchemicals.com/downloads/product_data_sheets/photoresists.html

Material Safety Data Sheets (MSDS): www.microchemicals.com/downloads/safety_data_sheets/msds_links.html

Our Photolithography Book and -Posters







We see it as our main task to make you understand all aspects of microstructuring in an application-oriented way.

At present, we have implemented this claim with our book **Photolithography** on over 200 pages, as well as attractively designed DIN A0 posters for your office or laboratory.

We will gladly send both of these to you free of charge as our customer (if applicable, we charge shipping costs for non-European deliveries):

www.microchemicals.com/downloads/brochures.html

www.microchemicals.com/downloads/posters.html

Thank you for your interest!

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The safe sequence of mixing components of a recipe usually does not correspond to the order of their listing. We do not warrant the full disclosure of any indications (among other things, health, work safety) of the risks associated with the preparation and use of the recipes and processes. The information in this book is based on our current knowledge and experience. Due to the abundance of possible influences in the processing and application of our products, they do not exempt the user from their own tests and trials. A guarantee of certain properties or suitability for a specific application can not be derived from our data. As a matter of principle, each employee is required to provide sufficient information in advance in the appropriate cases in order to prevent damage to persons and equipment. All descriptions, illustrations, data, conditions, weights, etc. can be changed without prior notice and do not constitute a contractually agreed product characteristics. The user of our products is responsible for any proprietary rights and existing laws.

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