LIFT-OFF

While the structuring via etching is done via the partial erosion of a full-surface coating of the substrate through a (e. g. resist) mask, in the lift-off procedure, the material is only deposited at sites which are not protected by a resist mask.

This chapter describes the requirements for obtaining a suitable resist mask, problems in terms of their coating, as well as the final removal of the resist mask with the material deposited on it.

Basic Principle

Process Sequence

Fig. 124 shows the basic differences in process sequences when structuring films via etching (left column) and lift-off (right column).

While for etching processes, photoresist processing is performed on a previously applied coating, in lift-off processing, the coating is applied to existing photoresist structures.

The subsequent actual lift-off removes the resist structures together with the material deposited thereon, while the material applied directly to the substrate through the openings of the resist mask remains there as desired.

As the diagram shows, the photo mask for resist processing must be inverted or alternated between a positive and a negative processing of the photoresist when changing between an etching and lift-off process.

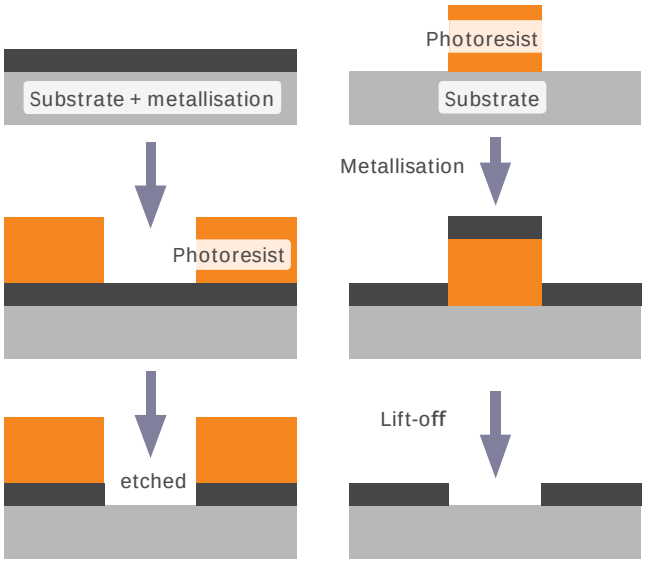


Fig. 124: The basic process sequence of the structuring of a (e.g. metal) layer via etching processes (left) and lift-off (right).

Advantages and Disadvantages Compared to Etching Processes

The lift-off procedure only then achieves reproducible defined structures when a coating of the resist sidewalls is prevented which is impossible in isotropic sputter processes.

With some materials such as gold or silicon nitride, wet-chemical etching is problematic due to the poor adhesion of the resist masks applied to it and therefore dry etching or lift-off is a reasonable alternative. Wet-chemical etching processes are not applicable if the required chemicals cannot be used for, e.g. work safety reasons.

If there is a high heating of the substrate due to the coating process and its duration, lift-off processes are critical, because here the already existing photoresist structures are thermally affected (softening or strong cross-linking).

Photoresists for Lift-off Processes

Positive Resists

If neither the need for a high thermal stability against softening during the coating of resist structures, nor the specification of undercut resist profiles is present, the use of positive resists for lift-off processes can be in principle reasonable.

To minimise unwanted coating of the resist sidewalls, we recommend to achieve resist profiles which are as vertical as possible. For coating processes carried out at higher temperatures, the use of thermally stable photoresists with comparatively high softening temperatures for positive resists such as the AZ® 701 MiR or the AZ® ECI 3000 series can make sense.

Negative Resists

For lift-off optimized negative resists combine two often important properties: Depending on the resist, a

more or less pronounced undercut can be achieved in the developed resist profiles, and the cross-linking prevents thermal softening of the resist structures during the coating. If, however, the temperature rises too much, the cross-linking degree of the resist can increase so far that the subsequent lift-off becomes difficult or impossible.

The resist series optimised for lift-off applications are the negative resists of the AZ® nLOF 2000 family with resist thicknesses between approx. 2 and 10 µm.

Image Reversal Resists

In the negative mode, reversal resists enable a resist profile that is undercut within certain limits without any appreciable cross-linking during processing. As a result, the resist structures remain susceptible to thermal softening rounding during the coating, but can be lifted more easily compared to cross-linking negative resists.

The Deposition

Sputtering or Evaporation?

During sputtering, the deposition of the material is more or less isotropic, resulting in the sidewalls of even greatly undercut resist structures also being coated. The lift-off medium can only dissolve the resist structures if it manages to diffuse through the coated resist sidewalls, which limits the thickness of the sputtered layers to a maximum of a few 100 nm for reproducible lift-off applications.

The evaporation of the films is directionally which results in even positive resist sidewalls only being coated to a slight extent and the sidewalls of undercut resist profiles are not coated at all. As a result, a clean lift-off is possible usually trouble-free even with thicker films.

Thermal Effects on the Resist Structures

When coating resist structures via evaporation, sputtering or CVD, the substrate and thus the resist structures can be heated via a substrate heater, the radiation from the evaporator source, the condensing heat of the growing film or the kinetic energy of the ions from the plasma above the softening temperature of the resist used.

In this case, the resist structures deform and soften and thus are fully coated over their entire surface, which makes the subsequent lift-off more difficult or impossible.

Remedies against thermal rounding provide

- a thermally more stable photoresist like the AZ® 701 MiR or the AZ® ECI 3000 series
- an optimised heat coupling of the substrate to its holder (e.g. some drops of turbo pump oil for proper heat transfer from strained, curved substrates)
- a sufficiently high heat buffer (massive substrate holder construction) or
- heat removal (e.g. black anodised aluminium as rear infrared radiator) from the substrate holder
- deep UV curing or
- a reduced deposition rate or a multi-level coating with intermediate cooling pauses.

Nitrogen Formation in Case of Positive Resists

The developed structures of DNQ-based positive resists are still photoactive and when coated by short-wavelength radiation from the evaporator source or plasma, can be exposed to ultraviolet radiation during sputtering or CVD processes.

Hereby nitrogen is released, which, enclosed under the growing (metal) film, can form bubbles in the resist film which softens at higher temperatures.

Structures Look "Torn" or Wavy after Coating.

In order to anticipate this unwanted exposure together with the release of the nitrogen of the coating, a flood exposure without a mask is used with a sufficiently high (approximately two to three-fold light dose of the structure-providing exposure) dose of the developed positive resist structures. In order to

allow the nitrogen formed to be diffused out before the following vacuum coating process, a subsequent waiting time is important, whose duration is strongly dependent on the resist film thickness and typically lasts between a few minutes for resist films of a few µm thickness and up to hours for 10 µm or thicker photoresists.

Image reversal resists in the reversal mode do not need this flood exposure, since the resist structures are no longer photosensitive due to the image reversal process. The negative resists optimised for the lift-off, such as the AZ® nLOF 2000 negative resist series, do not release any nitrogen or other gases during exposure.

The Lift-off

Suitable Lift-off Media

Generally all organic solvents are suitable as a lift-off medium, but low-boiling solvents such as acetone are not recommended: For one, it cannot be heated up to accelerate the lift-off, for another, quickly evaporating solvents carry the risk of the re-depositing of lifted (metal) particles on the substrate, which can hardly be removed.

For clean and reproducible lift-off processes, we recommend high boiling solvent mixtures in the TechniStrip® series (such as the NI 555 for the AZ® nLOF 2000 negative resists), which can also lift off cross-linked resist structures at higher temperatures and are compatible with most common substrate materials except III/V compounds.

"Fences" after Lift-off

If the resist sidewalls have been coated during deposition, lift-off occurs at a more or less random location where the lift-off medium manages to penetrate the coated film. As a consequence, fence-like structures keep on the substrate after lift-off.

In this case, the following work-arounds might help:

- Thermal evaporation instead of sputtering makes the deposition much more directed, and the resist sidewalls remain uncoated.
- In case of the requirement to use positive resists in combination with directed evaporation, the realisation and maintenance of steep resist sidewalls
- When using image reversal - or negative resists, the application of process parameters for pronounced undercut resist profiles
- If the resist features are not cross-linked, care has to be taken that no thermal softening occurs during coating

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® 2026 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® 2026 MIF	
		AZ® PL 177	AZ® PL 177	≈ 3 - 8 µm	AZ® 351B, AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 2026 MIF	
	Spray coating	AZ® 4999		≈ 1 - 15 µm	AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 2026 MIF	
	Dip coating	MC Dip Coating Resist		≈ 2 - 15 µm	AZ® 351B, AZ® 400K, AZ® 326 MIF, AZ® 726 MIF, AZ® 2026 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 Reversal	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® 2026 MIF	TechniStrip® NI555 TechniStrip® NF52 TechniStrip® MLO 07
		AZ® nLOF 5500	AZ® nLOF 5510	≈ 0.7 - 1.5 µm		
	Improved adhesion, steep resist sidewalls 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® 2026 MIF	
			AZ® 125 nXT	≈ 20 - 100 µm	AZ® 326 MIF, AZ® 726 MIF, AZ® 2026 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 required.

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. Not compatible with Au.

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

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

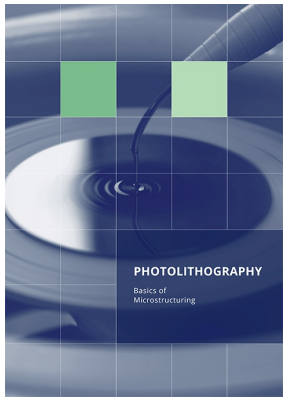
for e. g. chromium, gold, silicon, copper, titanium, ... **è** www.microchemicals.com/products/etching_mixtures.html

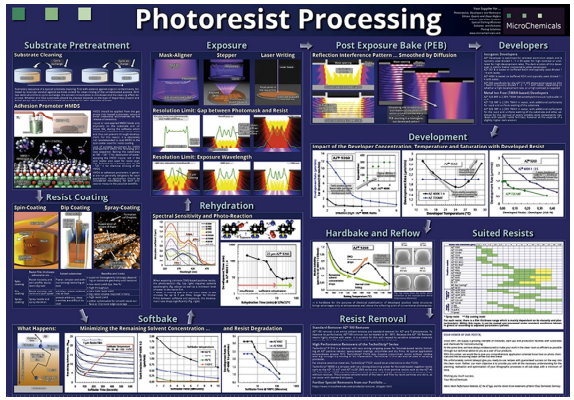
Further Information

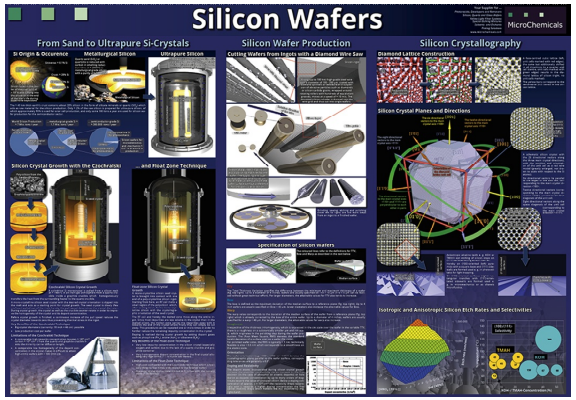
Technical Data Sheets: www.microchemicals.com/downloads/product_data_sheets/photoresists.html

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):

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