OPTICAL PARAMETERS OF PHOTORESISTS

Mathematical Formulation of Exposure: Absorption, Cauchy and Dill

Absorption

The absorption coefficient α, the light intensity I in the depth d of the resist film (based on the incident intensity I_0) and the extinction coefficient k are related to the wavelength λ as follows:

$$\alpha = \frac{4\pi\ k}{\lambda} \qquad\qquad I = I_0\ \exp(-\alpha\ d)$$

The reciprocal value of α denotes the penetration depth of light after which the light intensity has dropped to 1/e. In the case of typical positive resists, the penetration depth is between about 0.5 and 2.0 µm.

Cauchy Constants

The Cauchy constants N_1, N_2 and N_3 which are dependent on the already absorbed light dose for each photoresist (generally assumed to be solvent-free), describe the refractive index n as a function of the wavelength (unit µm) as follows:

$$n = N_1 + \frac{N_2}{\lambda^2} + \frac{N_3}{\lambda^4}$$

The Cauchy constants are usually given in the unexposed (unbleached) and fully exposed (bleached) state. It should be noted that the Cauchy constants are fitted from the values of n measured in the visible spectral range and only apply there. The spectral progression $n(\lambda)$ in the spectral range of the absorption of the photoresist *cannot* be calculated from the Cauchy constants.

Dill Parameters

The wavelength-dependent Dill parameters describe the extinction coefficients of photoresist as a function of the (possibly reduced by exposure) concentration of photoinitiator *PAC* (0 = fully exposed, 1 = unexposed) as follows:

$$k = \lambda \frac{A(\lambda) \cdot PAC + B(\lambda)}{4\pi}$$

Numerical Values for Photoresists

Data on the Cauchy constants and Dill parameters as well as the refractive index and extinction coefficients with the g-, h- and i-line for certain photoresists can be found in the tables on the next page. Each column lists the values for a particular resist family (e.g. AZ® 4500 for the AZ® 4533 and 4562, the values of the AZ® ECI 3027 also apply to the AZ® ECI 3012 and AZ® ECI 3007).

Resist Series:	AZ® 1500	AZ® 5214E	AZ® 6600	AZ® 9200	AZ® 701MiR	AZ® ECI 3027	AZ® nLOF 2000
Refractive Index and Extinction							
bleached							
n (365 nm)	1.6994	1.6904	1.6967	1.6954	---	1.6913	
k (365 nm)	0.0058	0.0012	0.0036	0.0002	---	0.0017	
n (405 nm)	1.6714	1.6667	1.6720	1.6724	---	1.6670	
k (405 nm)	0.0010	0.0005	0.0021	0.0002	---	0.0010	
n (435 nm)	1.6571	1.6534	1.6586	1.6572	---	1.6530	
k (435 nm)	0.0003	0.0004	0.0018	0.0002	---	0	
unbleached							
n (365 nm)	1.7123	1.6990	1.7112	1.6963	1.7039	1.7014	1.6389
k (365 nm)	0.0358	0.0175	0.0353	0.0117	0.0214	0.0202	
n (405 nm)	1.6906	1.6888	1.6953	1.6862	---	1.6803	1.6173
k (405 nm)	0.0336	0.0179	0.0383	0.0134	---	0.0244	
n (435 nm)	1.6948	1.6758	1.7035	1.6722	1.6917	1.6826	1.6015
k (435 nm)	0.0227	0.0040	0.0222	0.0019	0.0189	0.0166	
Cauchy Constants							
bleached							
d_{Layer} (nm)	1589	1390.3	1571.4	2035	---	---	
N_1	1.5966	1.5908	1.6032	1.6089	1.6057	1.5952	
N_2 (µm²)	0.0037577	0.011525	0.01088	0.0025069	0.00673	0.008451	
N_3 (µm⁴)	2.45E-3	6.70E-07	2.48E-04	4.28E-03	0.00094	0.000656	
unbleached							
d_{Layer} (nm)	1584.6	1414.7	1645.2	2018.2	---	---	---
N_1	1.5996	1.6035	1.6139	1.5995	1.6104	1.6018	1.4402
N_2 (µm²)	0.013498	0.0055741	0.01135	0.0099583	0.00505	0.009896	0,040151
N_3 (µm⁴)	1.88E-04	2.34E-03	8.93E-04	7.16E-04	0.00171	0.000686	-1,8223E-03
Dill Parameters							
365 nm							
A (µm⁻¹)	1.0133	0.6181	---	0.4388	0.7090	0.64	
B (µm⁻¹)	0.2177	0.0314	---	0.0219	0.0342	0.075	
C (cm²/mJ)	0.0239	0.0284	---	0.0222	0.0220	0.0159	
405 nm							
A (µm⁻¹)	---	---	---	0.4245	---	0.76	
B (µm⁻¹)	---	---	---	0.0212	---	0.035	
C (cm²/mJ)	---	---	---	0.0215	---	0.0244	
435 nm							
A (µm⁻¹)	---	---	0.5193	0.0965	---	0.45	
B (µm⁻¹)	---	---	0.0332	0.0220	---	0.036	
C (cm²/mJ)	---	---	0.0079	0.0175	---	0.0152	

Resist Series:	AZ® 4500	AZ® 520D	AZ® 40 XT	AZ® 15 nXT	AZ® 125 nXT
Refractive Index and Extinction					
bleached					
n (365 nm)					
k (365 nm)					
n (405 nm)					
k (405 nm)					
n (435 nm)					
k (435 nm)					
unbleached					
n (365 nm)		---	1.644	1.6807	1.582
k (365 nm)		---		0.0027	0.0013
n (405 nm)		---			
k (405 nm)		---			
n (435 nm)		---			
k (435 nm)		---			
Cauchy Constants					
bleached					
d_{Layer} (nm)					
N_1					
N_2 (µm²)					
N_3 (µm⁴)					
unbleached					
d_{Layer} (nm)	6000				
N_1	1,5761	1.6403	1.560	1,5754	1.5206
N_2 (µm²)	-0.0047025	-0.054863	0.007	0.013242	0.008114
N_3 (µm⁴)	0.003569	0.018217	0.0006	0	-0.000217
Dill Parameters					
365 nm					
A (µm⁻¹)		---			
B (µm⁻¹)		---			
C (cm²/mJ)		---			
405 nm					
A (µm⁻¹)		---			
B (µm⁻¹)		---			
C (cm²/mJ)		---			
435 nm					
A (µm⁻¹)		---			
B (µm⁻¹)		---			
C (cm²/mJ)		---			

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

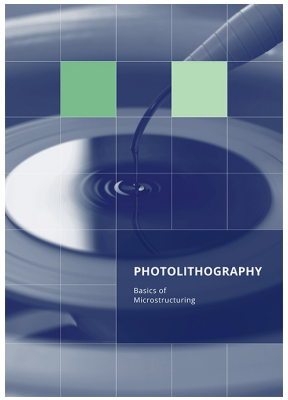
for e. g. chromium, gold, silicon, copper, titanium, ... **è** www.microchemicals.com/products/etching_mixtures.html

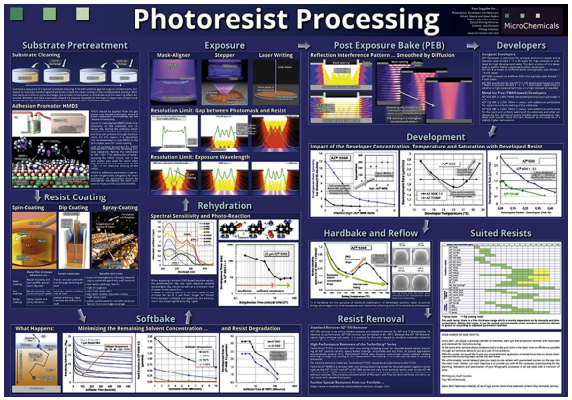
Further Information

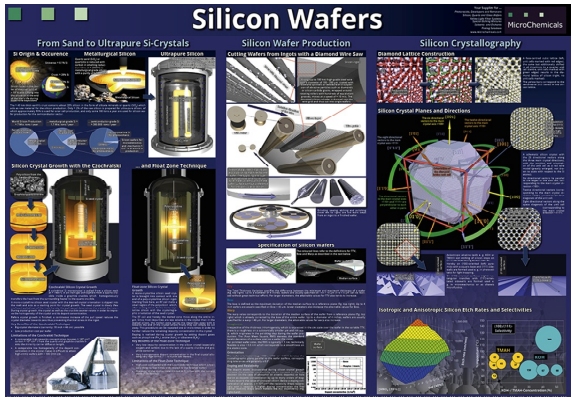
Technical Data Sheets: www.microchemicals.com/downloads/product_data_sheets/photoresists.html

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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