Optical Parameters of Photoresists
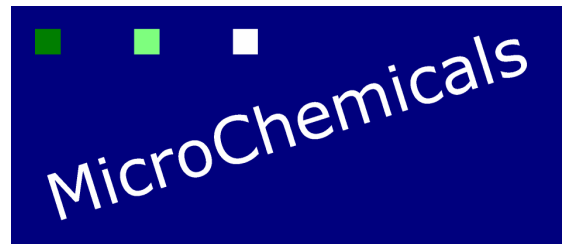
MicroChemicals

Optical Absorption and Spectral Sensitivity

The optical absorption of most unexposed photoresist ranges from the approx. 440 nm in the VIS to near UV. This spectral sensitivity is matched to the emission spectrum of Hg lamps (i-line = 365 nm, h-line = 405 nm, g-line = 435 nm) in mask aligners (fig. bottom, left-hand) and causes the typical reddish-brownish color of many photoresists. Some modern resists such as the AZ® 9260 or 5324E miss the g-line absorption, and modern negative resists such as the AZ® nLOF 2000 serie or the AZ® 15 nXT / 125 nXT are i-line resists with an absorption only below approx. 380 nm.
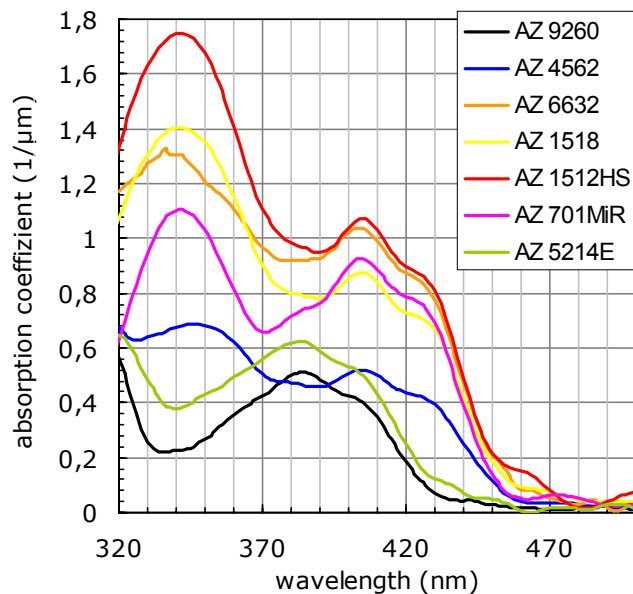
During exposure, positive photoresists almost completely bleach down to approx. 300 nm (fig. bottom):
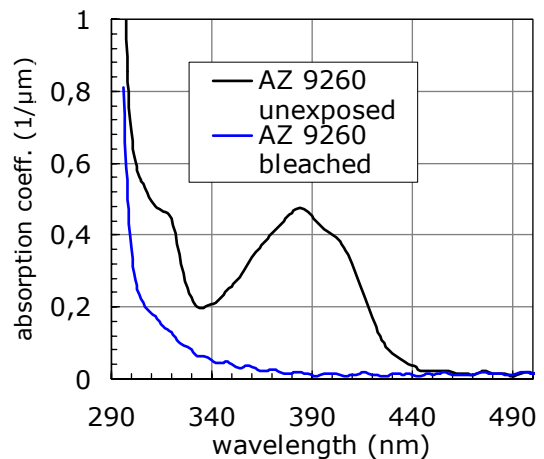
Optical Absorption, Cauchy and Dill: Some Mathematics

The optical **absorption coefficient** α, the light intensity I at a depth d below the resist surface (with respect to the incident intensity I_0), and the **extinction coefficient** k depend from the wavelength λ as follows:

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

With a photoresist film assumed to be solvent free, the **Cauchy constants** N_1, N_2 and N_3 describe the spectral refractive index n as a function of the wavelength λ (in µm units) as follows:

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

In general, the Cauchy constants are given in the unexposed (*unbleached*) and completely exposed (*bleached*) state. It has to be considered, that the Cauchy constants are usually fitted from values measured in the visible part of the spectrum and therefore do not match $n(\lambda)$ in the ultraviolet range (e. g. i-line!).

The wavelength dependant **Dill parameters** describe the photoresist extinction coefficient as a function of the photo active compound concentration *PAC* (which is reduced during exposure) as follows:

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

Cauchy constants and Dill parameters as well as refractive index and extinction coefficient at g-, h-, and i-line for various photoresists are listed in the two tables overleaf.

us for further information!

Disclaimer of Warranty

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

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

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

Refractive Index and Extinction / Cauchy Constants / Dill Parameters

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					
$d_{Schicht}$ (nm)					
N_1					
N_2 (µm²)					
N_3 (µm⁴)					
unbleached					
$d_{Schicht}$ (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)		---			

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	