Laser-Exposure of Photoresists

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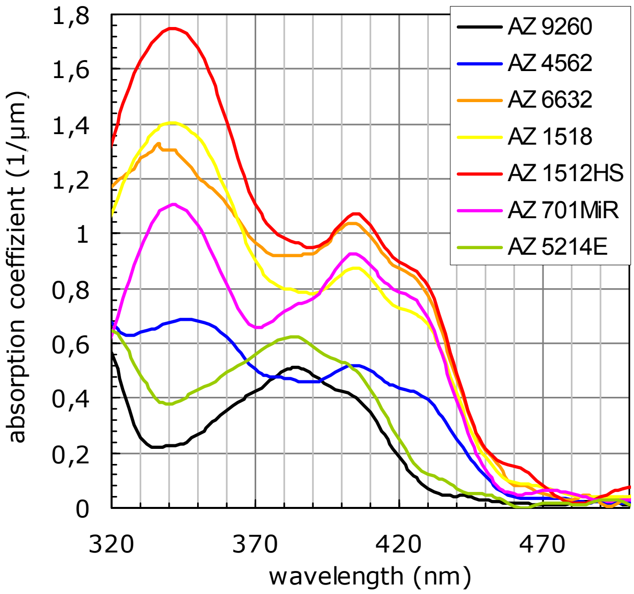
Laser-Exposure: Basics

When using a laser beam as light source for photoresist exposure in stead of the usually used Hg bulbs, one has to consider two main points:

The light intensity is quite different: While in laser interference lithography, the light intensity is rather low, laser scribing causes intensities many orders of magnitude beyond the intensity of a mask aligner or stepper. Furthermore, the laser exposure wavelengths often differs from the 365, 405, or 435 nm Hg lines which are matched to the spectral sensitivity of photoresists.

Suited Exposure Wavelengths



The optical absorption of most unexposed photoresist ranges from approx. 440 nm in the VIS to near UV. This spectral sensitivity (fig. right-hand) is matched to the emission spectrum of Hg lamps (i-line = 365 nm, h-line = 405 nm, g-line = 435 nm) in mask aligners or steppers and causes the typical reddish-brownish colour of many photoresists.

Some modern resists such as the AZ® 9260 or 5214E miss the g-line absorption, and modern negative resists such as the AZ® nLOF 2000 series or the AZ® 15 nXT / 125 nXT are i-line resists with an absorption limited to below approx. 380 nm.

The optical absorption does not abruptly vanish towards higher wavelengths, but smoothly drops to zero. Therefore, the very high light intensity of a laser spot allows laser scribing of photo resists at wavelengths several 10 nm away from the absorption maximum. However, the low sensitivity of the resist at higher wavelengths will significantly increase the required exposure time.

The document Photoresists, Developers, and Removers gives further details on the resists mentioned in this section, while the application note Thick Resist Processing focuses on typical questions and problems concerning the application of typical thick resists such as the AZ® 4562, 9260, or AZ® 40 XT.

Laser Interference Lithography - Suited Photoresists

Laser interference lithography often requires resists with a very high possible resolution. Additionally, very thin films of typically 150 - 300 nm are necessary to realize smallest feature sizes which requires a dilution of available resists. However, not all resists are suited for high dilution due to particle formation. The thermally stable AZ® 701 MiR (optimized for dry etching or lift-off), or the AZ® ECI 3000 series with improved adhesion (optimized for wet etching) meet both demands: High resolution, and capable for high dilutions.

The document High Resolution Resist Processing gives further information on how to improve the resist resolution via suited resists and adjusted process parameters.

Laser-Scribing: Suited Resist and Typical Problems

Bubble Formation during Laser Writing

All DNQ-based resists (= almost all AZ® positive and image reversal resists) release nitrogen during exposure (for details please consult the document Exposure of Photoresists). If the light intensity is not too high e. g. when using a mask-aligner or stepper, and the resist film thickness not too big, the nitrogen will be able to outgas before forming bubbles in the resist film. During laser-scribing, however, the N_2 volume is instantly formed due to the very high exposure intensities. Therefore, the formation of bubbles or stress cracks induced by the N_2 pressure might be a consequence.

These bubbles or cracks cause rough, bumpy resist sidewalls after development. Additionally, bubbles or cracks scatter light during exposure in all directions which deteriorates the attained resolution, and makes it difficult to expose also the substrate-near resist with reasonable exposure doses.

In order to avoid the formation of bubbles or cracks during laser exposure, we recommend:

- A sufficient softbake: We recommend 100°C on a hotplate for 1 minute per µm resist film thickness. If an oven is used for softbake, approx. 5 minutes softbake time should be added to allow the substrate to heat to the final temperature.
- If thick (> 5 µm) resist film are required, a suited thick resist with a low photo active compound concentration (= lower N_2 volume formed during exposure) such as the AZ® 9260 should be used.
- If the laser wavelengths is below 400 nm, chemically amplified i-line resists such as the AZ® 40 XT (positive), or the negative resists AZ® 15 nXT or 125 nXT are a good choice since these resists do not release N_2 during exposure.
- If applicable, a multistage laser writing with each a lower exposure dose will suppress bubble or crack formation, since N_2 can outgas between two writing steps.

Poor Development Rate, or Through-Development is Impossible

Photoresists require an exposure energy in the range of 1 kJ/cm^3, which, considering an exposure quantum efficiency of 20-30 %, would be enough to heat the resist to approx. 1000°C. While an exposure with mask-aligner or stepper allows the heat to dissipate via the substrate and the substrate holder, the very short exposure time during laser scribing may cause a strong heating of the resist film which might cause:

- A thermal decomposition of a significant fraction of the photo active compound
- Cross-linking of the resin of the resist, which makes the resist insoluble in solvents or developers
- Stress cracks in the resist film which scatter light and hereby lower the light intensity near the substrate.

These mechanism significantly lower the development rate or make a through-development of the resist film impossible. Possible work-arounds are:

- If the laser wavelengths is below 400 nm, chemically amplified i-line resists such as the AZ® 40 XT (positive), or the negative resists AZ® 15 nXT or 125 nXT require a much lower exposure energy.
- If applicable, a multistage laser writing with each lower exposure dose will lower thermal stress, since the heat formed during exposure can dissipate between two writing steps.

Another general (not limited to laser writing) reason for a poor development rate, especially in case of thick resist films, is a poor rehydration, as explained in the document Rehydration of Photoresists.

Interested?

We supply all mentioned resists also in 250 ml, 500 ml, and 1.000 ml units. Please contact 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.