# TI 35ESX
# image reversal resist

## Technical Data Sheet
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## General Information

The TI 35ESX resist is specially designed for the application in the so called “image reversal technology” for:

- subsequent **lift-off** of deposited layers with a thickness up to 4 µm
- **plasma etching**

The viscosity of the resist leads to a thickness range depending on the spin-speed from 2.5-3.5 µm. The typical aspect ratio of the structured features achievable is in the range of 1.0 … 2.0.
This technical data sheet intends to give you a guide-line for process parameters for various applications. However, the optimum values for e.g. spin profile, exposure dose, or development depend on the individual equipment and need to be adjusted on each individual demand.

*For **general information** and trouble shooting on image reversal resists, consult our work sheet "Processing of image reversal resists"*

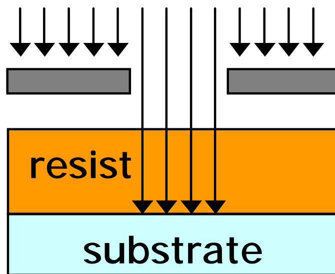
*http://www.microchemicals.com/downloads/application_notes.html*

*Zur **generellen Prozessierung** von Umkehrlacken und dabei häufig auftauchenden Fragestellungen konsultieren Sie bitte die aktuelle Version unseres Datenblattes "Prozessierung von Umkehrlacken"*

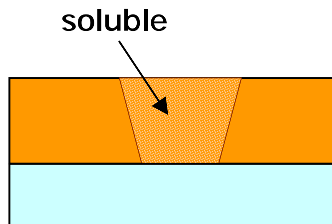
*http://www.microchemicals.com/de/downloads/anwendungshinweise.html*

# 'Image Reversal' – A Short Introduction

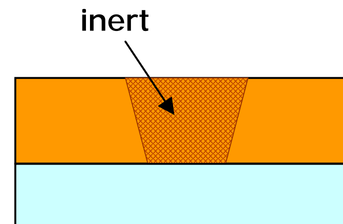
## What 'image reversal' generally means



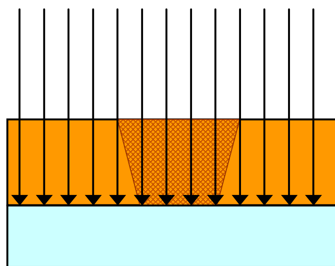

**(1) Exposure** using an inverted mask (the exposed areas finally remain)



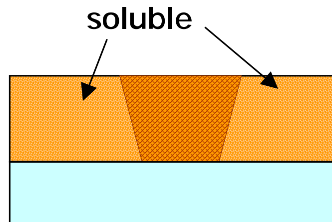

**(2)** The resist now would behaves like an exposed positive resist.



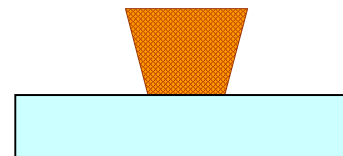

**(3)** The **reversal bake** cross-links the exposed area, while the unexposed area remains photo-active



**(4)** The **flood exposure** (without mask) …



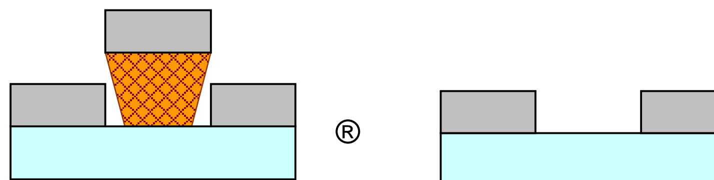

… **(5)** makes the resists, which was not exposed in the first step, soluble in developer



**(6)** After developing, the areas exposed in the first step now remain

## … and for what image reversal is good for:

® Adjustable undercut for lift-off of thin and thick sputtered, CVD, and evaporated films like metals, a-Si:H, a-SiN:H etc.




® **High thermal-** and **chemical stability** allow the inverted TI 35ESX as mask for wet-chemical and plasma **etching under harsh conditions**

## TI 35ESX – Fields of Application

### Lift-off of PECVD layers

- Amorphous Si layer deposited in device quality at 110°C
- Amorphous $SiN_x$

### Lift-off of sputtered layers

- Due to non-directional deposition, lower thickness achievable (approx. 1 µm)
- Possibly ultra sonic treatment necessary
- Lift ability dependent on operating pressure

## Technological Requirements

Since the TI 35ESX yields an inverted structure in the image reversal mode, an inverted exposure mask is needed. Beyond this, compared to standard positive resist processing, **no further upgrade** in existing technological infrastructure is necessary.

As compared to standard positive resist processing, applying the TI 35ESX implements just two further process steps: The **reversal bake** and the **flood exposure** without mask. Both are very easy to be performed and explained in the following.

## Processing the TI 35ESX

(in chronological order)

- Put the **substrate** on the hotplate at a minimum temperature of 120 °C (150°C would be best if applicable) for 10 minutes to remove adsorbed water from the substrates surface. Alternatively, use a furnace at same temperature for 30 min. Standard HMDS procedure (only from vapor phase at an optimum substrate temperature of 125°C!) or recommended TI PRIME adhesion promoter is also an adequate preparation.
- **Spin-coat** the resist after cooling down the substrates, spin at the final speed level for 30-40 seconds.
- **Softbake** the coated substrate at 100°C for 3 minutes on the hotplate (when using a furnace, 100°C for 20 min is recommended)

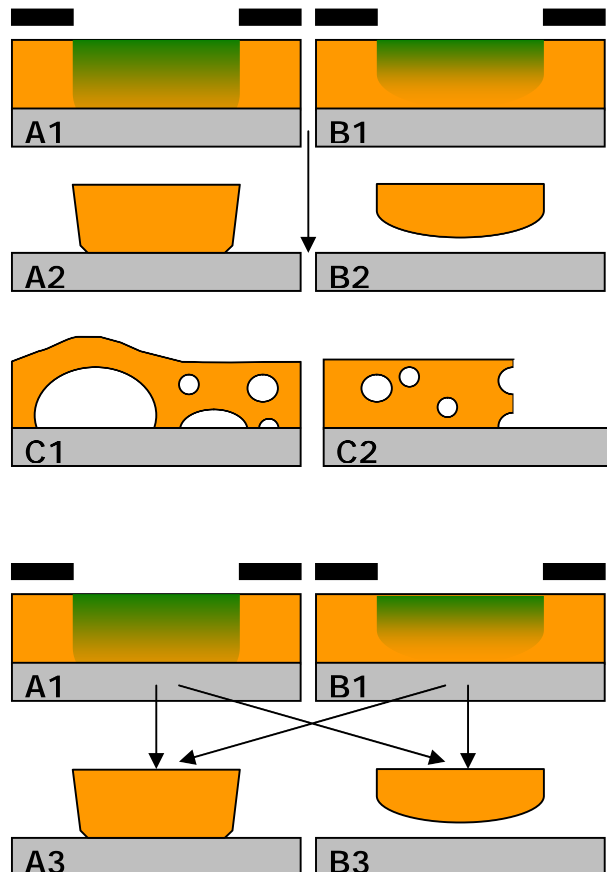
- **Exposure** the coated substrate with the mask. This 1st exposure dose adjusts the negative wall profile ("undercut"). 120 mJ/cm² will be a good choice for most applications, lower 1st exposure doses increase the undercut. A too low 1st exposure dose will increase the erosion of the resist not to be cleared (see appendix). Note: Exposure doses refer to i-line (365nm). A standard mask aligner with a 350W Hg light source has approx. 6-15 mW/cm$^2$ i-line intensity, while in many cases 20-30 mW/cm² are measured meeting the total (g-, h- and i-line) intensity!
- **Delay time:** Keep the coated substrate at room temperature after the exposure for at least 10 minutes. In this delay time nitrogen, generated during exposure, will diffuse out the resist. If square shaped substrates are used, the resist thickness on the edges is significant thicker than 3-4 µm. In this case the $N_2$ needs more time to diffuse out, in this case double the delay time.
- After the delay, bake the coated substrate at a temperature of 115 .. 135°C on the hotplate for two minutes (when using furnace try 20 minutes at 115°C-120°C. Because this step is very temperature critical furnace baking is not recommended). This step is the **reversal bake** where the image is reversed due to cross-linking of the exposed areas making them insoluble in the developer.
- Exposure the coated substrate for the 2nd time **without a mask (flood exposure)**. Use a dose (not critical) of » 540 mJ/cm$^2$ (300-800 mJ/cm$^2$ has no dominant effect). When UV-light is present during a subsequent deposition (plasma coating, thermal evaporation), especially when the temperature raises beyond approx. 60°C, use a high flood exposure dose to avoid an 'exposure' during deposition with bubbles/foaming as a consequence.
- **Develop** in AZ developer such as AZ 826 MIF or 726 MIF (metal ion free) or potassium-/sodium based (AZ 400K 1:4) developer. When the structure is through-developed (cleared), add another 10-30% of the time in the bath of the total development time to finalize the side wall profile. The development time for this resist until the undercut is formed can be up to 3-7 minutes!
- **Hardbake** the coated substrate only when using the resist as an etching mask under harsh conditions (For hard etch attack, prefer TI 35E). For mesa grooving hardbake at 135°C to 145°C for 2 minutes on the hotplate. The side-wall profile will loose the undercut during this step if the hardbake temperature is higher than the reversal bake temperature. In this case lift-off processes become more problematic. If you need a high hardbake temperature and subsequent lift-off or very high temperatures during deposition, make a UV-curing to harden the resist after development (or contact us for further information).

## Processing the TI 35ESX - Overview

| | |
|---|---|
| Resist thickness (µm) | 2.5… 3.5 |
| Exposure Broadband or g, h, i ($mJ/cm^{-2}$)<br><br>Typical Exposure time (sec)* | 90 .. 250, 120 (typ.)<br><br>8-25, 12 (typ.) |
| Delay | 10 min … 30 min<br>dependet on resist thickness and substrate shape |
| Reversal Bake Time<br>(Hot plate Temperature) | 2 min<br>(115 … 135, 130°C) (typ.) |
| Flood exposure ($mJ/cm^{-2}$)<br>(without any mask) | 540 (typ.)<br>300-800 |
| Developer | AZ® 726MIF, AZ® 826MIF, AZ® 400K 1:4,<br>(time: 180 ... 420 s) |
| Hardbake 135 … 145°C<br>(only for hard etching, avoid it for lift-off ) | 2 min |
| Lift off media | DMSO, NMP, DMF, P1316 |
| Remover (Stripper) | AZ® 100 remover, P1316, P1331 |

* i-line (365nm) exposure dose. A standard mask aligner with a 350W Hg source has approx. 6-15 $mW/cm^2$ i-line intensity, in many cases 20-30 mW are measured meeting the total (g-, h- and i-line) intensity!

## Process Parameters and Undercut ...




**1st exposure dose**
A *high* 1st exposure dose (A1) yields - after reversal bake, flood exposure, and development - to a steep resist profile with minor undercut (A2), while a *small* 1st exposure dose (B1) not exposing the substrate-near resist layer leads to a strong undercut and sometimes to peeling of narrow resist structures in the developer (B2). Die *optimum* 1st exposure dose therefore depends on the desired undercut and the minimum lateral feature sizes. At the beginning of new processes, an exposure series is recommended.

**Reversal bake**
Before the reversal bake is applied, the exposed resist needs a certain time – depending on the resist type and thickness – to outgas nitrogen ($N_2$) formed during exposure. This will avoid bubbling (irregular developed structures (C2)) and foaming (C1) of the resist by thermally activated $N_2$. Nitrogen preferentially accumulates near locations with inferior resist adhesion to the substrate, which has to be optimised with i) an optimum substrate pre-treatment (e.g. TI PRIME) and ii) a sufficient softbake.
*Higher* values for reversal bake temperature and –time require *smaller* 1st exposure doses. Both, high (A1) as well as low (B1) 1st exposure doses may yield a huge range of undercut profiles when applying low (A1® B3), medium (A1® A3, B1® B3) and high (B1® A3) values for the parameters reversal bake temperature and –time.

**Development**
The undercut forms in the last stage of development when the structures are already cleared (see p. 10). We recommend an approx. 30% **over-developing**.

## Trouble Shooting

**Bubbles after coating (but before exposure)**
If the resist has been refilled before coating, a delay time for at least a few hours may be necessary to outgas air bubbles.

**Bubbles after 1st exposure (but before reversal bake)**
Nitrogen ($N_2$) formed during the exposure of the resist normally diffuses out of the film. Bubble formation during exposure may be caused by:

- A remaining solvent concentration too high with expansion of $N_2$ preferentially in substrate-near regions as a consequence. In this case, increase the softbake time (e.g. 1 minute at 100°C per µm resist film thickness) which, however, will increase development time, but reduce dark erosion.
- A sub-optimum resist adhesion to the substrate. Check if contact angel is not in the range of 45-65°. In that case, we recommend the application of TI PRIME adhesion promoter, or the use of HMDS from vapour phase in an HMDS station.

**Bubbles during reversal bake**
Nitrogen ($N_2$) formed during the 1st exposure needs time to diffuse out of the resist film, strongly dependant from the film thickness, the temperature, and the first exposure dose. In that case, increase the delay time between exposure and reversal bake, and/or perform the delay at a moderately elevated temperature (approx. 30°C)

**Bubbles/holes after development**

**I)** Either the bubbles already have formed during any previous process step (coating, exposure, reversal bake) and finally become visible after development. In this case, consult the previous sections.

**II)** Or the bubbles represent spatial inhomogeneous dark erosion. This points towards a 1st exposure dose or/and reversal bake temperature/time too low.

General information on processing of AZ® and TI resists in our work sheets

- Processing of image reversal resists
- Reproducible litho-processes
- Baking and delays
- Exposure and development
- Processing of thick resists

available on request.