Processing image reversal resists

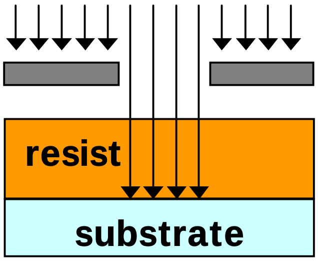
… symptoms, diagnosis, and trouble-shooting

revised 2003-09-25

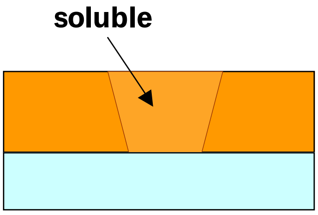
n General information about image reversal resists

Detailed processing guidelines are given in the individual technical data sheets of MicroChemicals® TI und Clariant AZ® image reversal resists. The present document aims for a basic understanding of the impact of the parameters exposure dose, reversal bake time and –temperature, and development time.

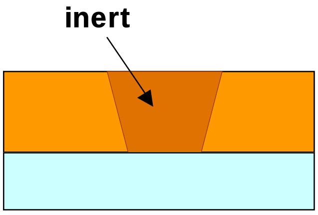
n How image reversal resists work …



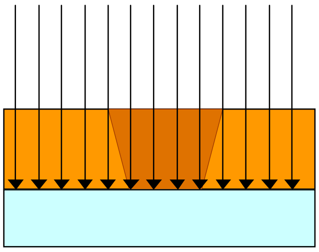
(1) Exposure using an inverted mask (the exposed areas finally remain)



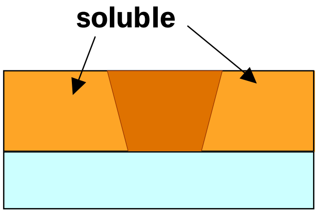
(2) The resist now would behave like an exposed positive resist.



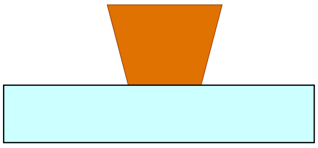
(3) The reversal bake cross-links the exposed area, while the unexposed area remains photo-active



(4) The flood exposure (without mask) …



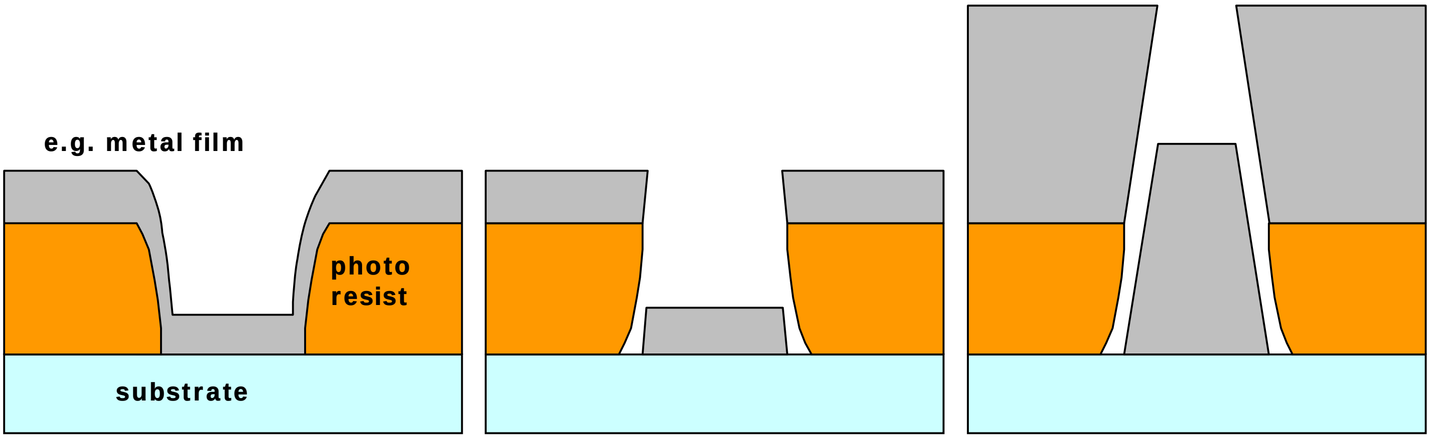
… (5) makes the resists, which was not exposed in the first step, soluble in developer



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

n … and their benefit for lift-off

An undercut allows reproducible lift-off of films (coated by e.g. evaporation, sputtering or PECVD) with thicknesses even exceeding the resist film thickness in case of evaporated metals:

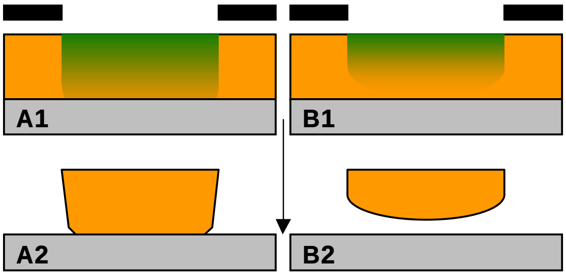


positive resist

image reversal resist

image reversal resist

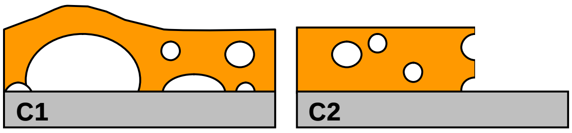
Impact and interaction of various process parameters

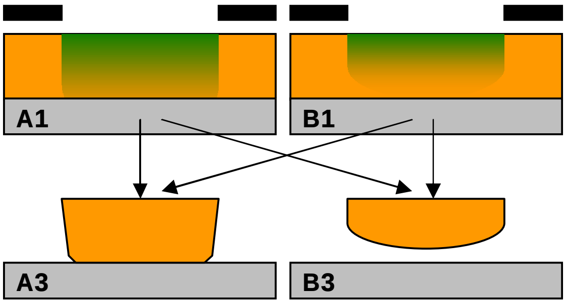


1st exposure dose

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

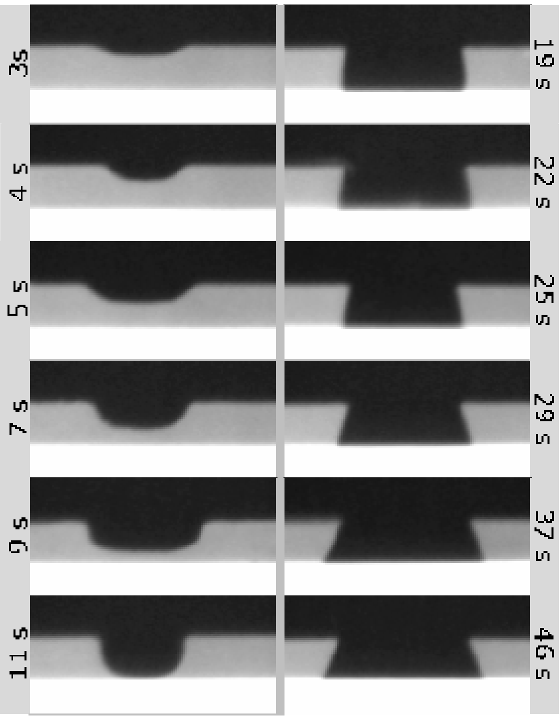




Before the reversal bake is applied, the exposed resist needs a certain time – depending on the resist type and thickness – to outgas nitrogen (N_2) formed during exposure. This will avoid bubbling (irregular developed structures (C2)) and foaming (C1) of the resist by thermally activated N_2. Nitrogen 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 (figure left-hand). We recommend an approx. 30% over-developing.

Trouble-shooting

Wrong/not calibrated exposure equipment or wrong translation to i-line (365 nm) intensity on which the resist technical data sheets base may cause too low 1st exposure doses with resist structures lifted in the developer (B2) or holes in the resist after developing as a consequence.

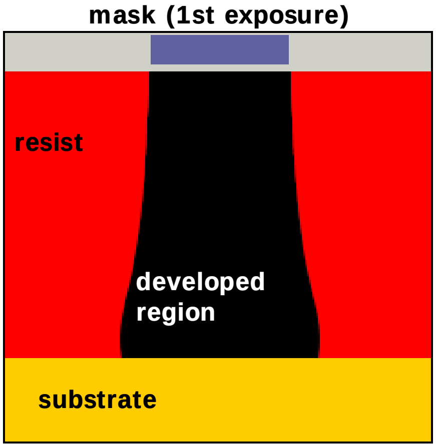
Too low reversal bake temperatures or –times (e.g. caused by thick glass substrates or imprecise temperature measurement in an oven) may cause an incomplete image reversal reaction with resist structures lifted in the developer (B2) or holes in the resist after developing as a consequence.

Too low development times prohibit the formation of the desired undercut resist profile especially for small-sized features.

A Hardbake after development or process temperatures (e.g. metallisation) above the softening point of the resist (100°C .. 130°C depending on the resist) smoothens the attained undercut and complicates lift-off.

Detailed information on individual processes and parameters are given in our process guide ‘reproducible litho processes’ available on request.

n Modelling: process parameters and resist profile



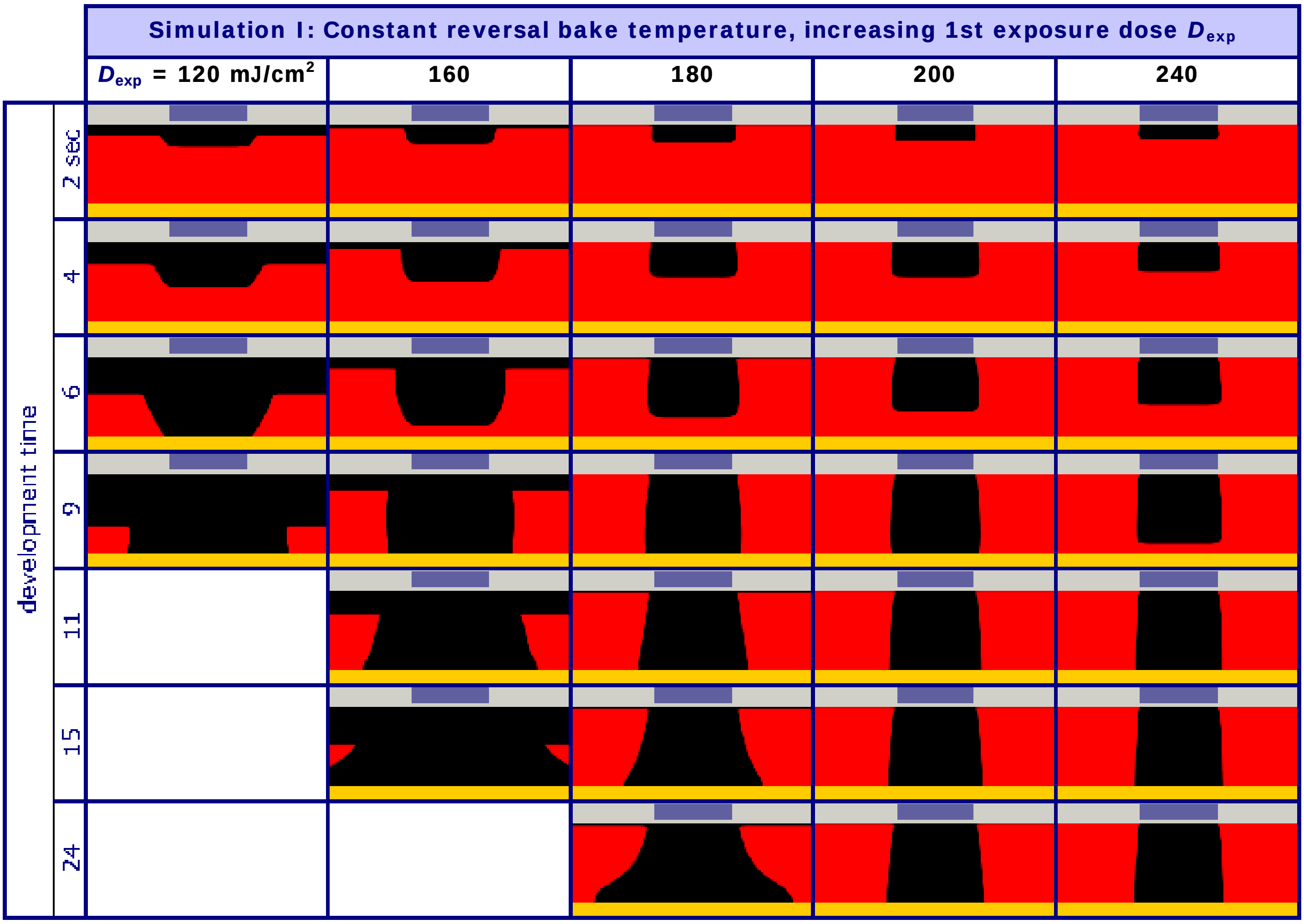
The following parameter studies are numerical modelling. The impact of various process parameters on the resulting resist profile bases on the chemical and physical properties of AZ and TI resists, but does not explicitly represent a special resist.

The results shown in the following tables therefore are not to be transferred to the experiment quantitatively, but qualitatively, and principally show the dependency between the process parameters *resist thickness, 1st exposure dose*, *reversal bake temperature* and *–time* and the *development time,* and the resulting *resist profile*. With this background, the resist profiles of realized structures allow an optimization towards the desired resist profile.

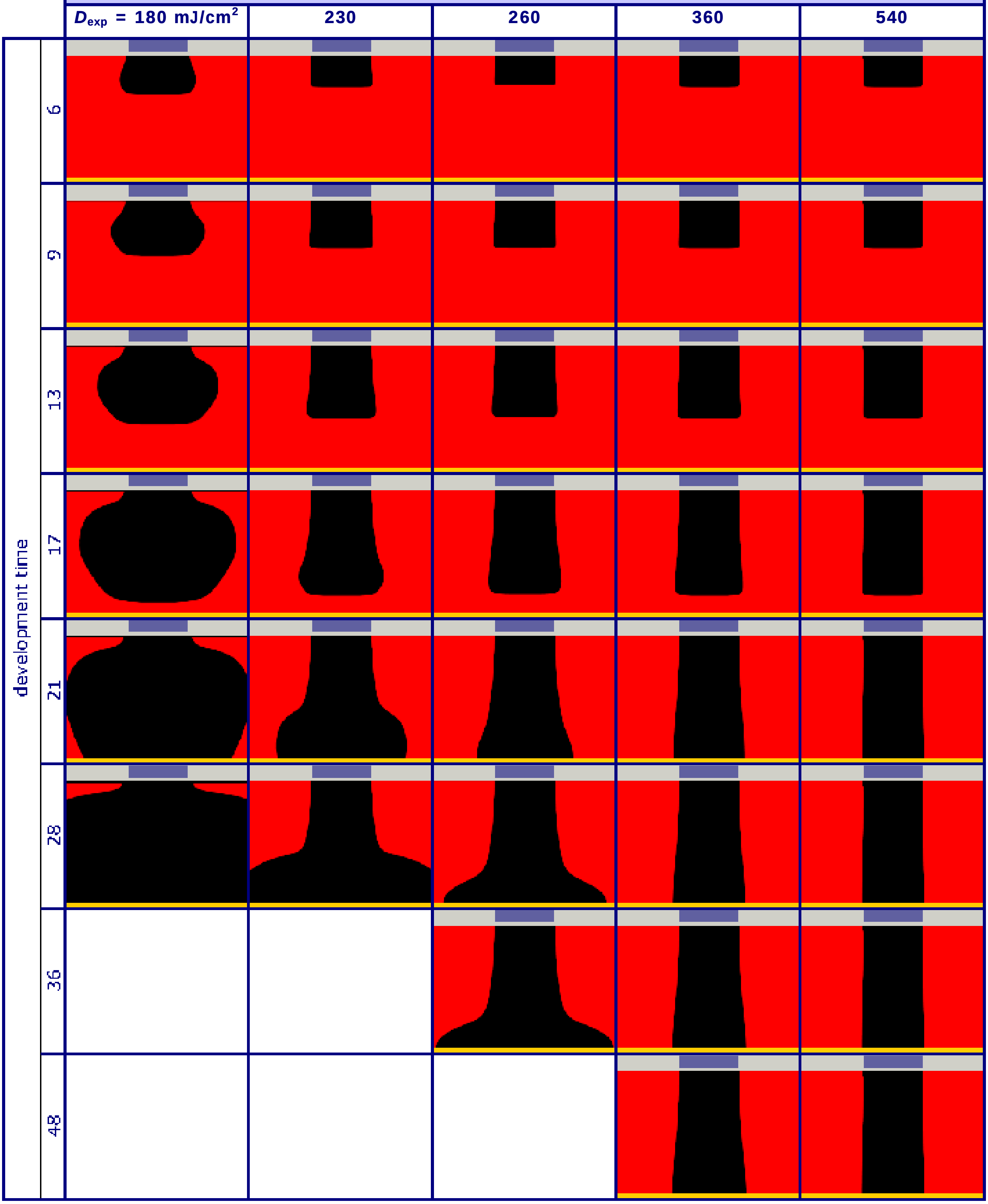
Simulation I: An approx. 3 µm thick resist film with various 1. exposure doses D_{exp} in different stages of development. Too small values for D_{exp} drastically increase the 'dark erosion', a reduced undercut stems small too high exposure doses. Medium D_{exp} require an approx. 30% 'over-development' for an optimum undercut.

Simulation II: Similar to I, but using an approx. 8 µm thick resist film.

Simulation III: With the 1st exposure dose kept constant, towards higher reversal bake temperatures T_{IR}, the reversed resist region (remaining after development) expands more and more into the weak exposed resist.



Simulation II: Constant reversal bake temperature, increasing 1st exposure dose D_{exp}



Simulation III: Constant 1st exposure dose, increasing reversal bake temperature T_{IR}