(Inferior) Resist Adhesion ...

... true and alleged adhesion problems, and how to improve

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This document explains how true and alleged resist adhesion problems can be separated from each other, and – in both cases - how the process can be optimized.

n Suited Photoresist?

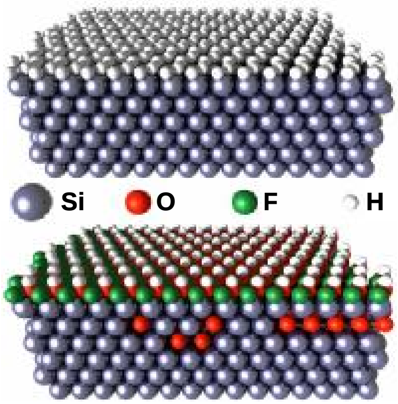
All resists supplied by us base on cresol resin with a certain distribution of the chain lengths, which impacts on the adhesion. The following two resist families are optimized on maximum adhesion during wet chemical (etching) processes: The AZ® 1500 (AZ® 1505, 1512HS, 1514H und 1518) thin resists for 0.5 .. 3 µm, and the AZ® 4500 (AZ® 4533, 4562) thick resist series for 3 to several 10 µm resist film thickness.

n Resist Adhesion and Substrate Pretreatment

Contamination as well as chemical surface modifications of the substrate impact on the resist adhesion:

§ In case of clean substrates, a baking step at 120°C-140°C for some minutes desorbs H_2O. Adhesion promotion is recommended applying a pretreatment with HMDS (only from the gaseous phase on the heated substrate!) or TI PRIME. Coating should be performed directly after cooling down the substrate in order to avoid re-adsorption of water.

§ Substrates contaminated with particles/organic impurities can be prepared with a two-stage substrate cleaning: Acetone removes organic impurities, a subsequent rinse in isopropyl removes the contaminated acetone thus avoiding striations.



§ In case of a more significant contamination (organic/metals), or, respectively, before contamination-critical high-temperature steps, Si-wafer require a so-called piranha-etch with subsequent RCA-cleaning.

§ After HF etching of SiO_2 (e.g. ‚HF-dip‘), the resist adhesion strongly depends on the completeness of SiO_2 removal: With SiO_2 completely removed, the now H-passivated Si-surface (schema right-hand, top) reveals a very good adhesion, while remaining SiO_2 (right-hand, bottom) often shows a very bad adhesion, which can be restored only at high temperatures (700°C oven).

§ Metals such as Al or Ti generally reveal a very good resist adhesion, while the wetting and adhesion on noble metals (Ag, Au) often is worse.

n Inferior Wetting during Spincoating

Inferior resist wetting during spincoating can have various reasons:

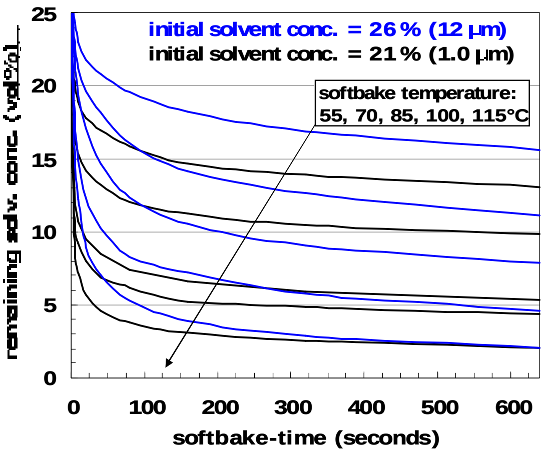
§ A hydrophilic substrate surface: Beside organic impurities, incompleted SiO_2 etching (see previous section) also decreases resist wetting on the substrate. Generally, a substrate pretreatment with TI PRIME improves wetting (and – in subsequent process steps – the resist adhesion).

§ A spin acceleration during spin coating on smooth substrates being too low promotes ‘comet-shaped’ uncoated areas on the wafer. Recommended ramps are 1.000-2.500 rpm/s.

§ On textured substrates, a spin acceleration too high may cause resist tear-off. In this case, we recommend dispersing the resist on the substrate before spin-coating or at a very small spin speed, followed by a moderate ramp to the final spin speed.

§ Particles or air bubbles (caused by a delay between transport/dilution/refilling, and dispensing being too short) also cause resist tear-offs during spin-coating.

§ If – with respect to its viscosity – the coated resist film thickness is too high, after coating/during the softbake (which initially thermally further reduces the resist viscosity), the resist may start contracting towards the center and border of the substrate. In this case, use a resist with a viscosity suited for the required film thickness, and/or introduce a delay between coating and softbake to reduce the solvent concentration before baking.



n Softbake and Resist Adhesion

Since during softbake, the solvent diffusion coefficient in the resist drops with the remaining solvent concentration, the substrate-near resist keeps much longer solvent-rich as compared to the resist surface (plot right-hand). In order to minimize the remaining solvent concentration thus improving the resist adhesion to the substrate, we recommend a softbake at 100°C on a contact hotplate for 1 minute/µm resist film thickness.

After softbake, especially in case of high resist film thicknesses, the substrate should not be cooled down abruptly in order to prevent a crackling of the resist film.

n Resist Sticking to the Photomask during Exposure

Resist sticking to the mask during mask alignment or exposure, sometimes accompanied by a peeling of the resist film from the substrate, points toward inferior resist adhesion. If neither an extended softbake (to reduce the sticking coefficient to the mask), nor the recommendations for adhesion promotion listed in this document (resist selection, substrate pretreatment), prevent the sticking, try the following: A short (!) dip of the coated and softbaked resist (before exposure) in concentrated developer (corresponding to 1.5-2.5% NaOH or KOH), immediately followed by rinsing with DI-H_2O, roughens the resist surface which often suppresses the sticking to the mask. However, this step may cause T-topping of the developed structures.

n Bubble Formation during Exposure

In case of DNQ containing positive tone or image reversal resists, an inferior resist adhesion promotes the formation of N_2 bubbles during exposure. If the recommendations for adhesion improvement listed in this document help not to suppress the bubble formation, we recommend reducing the exposure intensity at fixed exposure dose (by prolonging the exposure time). Additionally, thick resist films always require 'thick resists' with a comparable low concentration of the photoactive compound, such as AZ® 4562 or AZ® 9260.

n Positive Tone Resists: Lifting of small/narrow Structures during Development

A lifting of small/narrow resist structures from the substrate in the final state of development may have the following reason(s):

§ In case of inferior resist adhesion, the resist swelling by penetrating developer may cause resist lift-off.

§ Especially thick resist films (mechanically strained by the solvent loss during softbake, and N_2 formation during exposure) relax after through-development and may subsequently (partially) peel from the substrate.

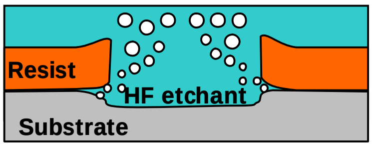
§ Especially in case of exposure doses too high, UV-transparent substrates (glass, quartz, many polymers, thick SiO_2) laterally guide light and thereby cause an exposure of the substrate-near resist film and – in case of positive tone resists - make it soluble in developer.

n Image Reversal Resists: Lifting of small/narrow Structures during Development

If – in case of image reversal processing - primarily small/narrow resist structures peel from the substrate during development, an undercut too extended may be the reason: If either a 1st exposure dose too low, or an image reversal bake too short/cool, or an expired image reversal resist keeps the 'reversed' resist film close to the surface too thin, the developer may laterally 'undermine' resist structures.

n Lifting of small/narrow Structures during wet chemical (etching) Steps

A peeling of primarily small/narrow resist structures during wet chemical etching processes points towards under-etching of the resist with a decrease of the contact area between resist and substrate as a consequence.

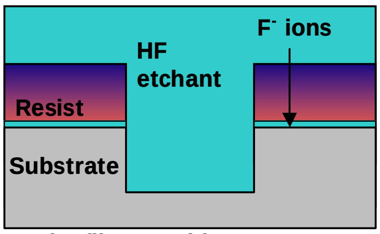


Sometimes accompanied by elevated temperatures or/and gas formation, small resist structures lift from the substrate during etching.

In case of isotropic etchants, the grade of under-etching cannot be minimized under a certain minimum. However, the recommendations for adhesion improvement given in this document will help to reduce the consequences.

n (Large-scale) Resist Peeling during wet chemical (etching) Steps

Wet chemical etchants (especially HF) diffuse into the resist film and may lead to a large scale resist peeling either during the etching, or after the subsequent rinsing by one or both of the two following reasons:

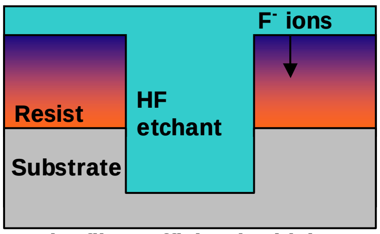


Resist film too thin

§ Resist swelling caused by the etchant diffusing into the resist film

§ Large-scale etching of the resist covered substrate after the etchant has diffused through the resist film towards the substrate (schema left-hand in case of HF etching of glass or SiO_2).

Beside an adjusted etchant, both mechanisms can be reduced by a thicker resist film.



Resist film sufficiently thick

Double-sided metalized substrates (e.g. Ag & Al) for a galvanic cell in aqueous solutions, sometimes accompanied by H_2 formation lifting the resist film beyond. In this case, coat the opposite side of the substrate with protective coating (such as AZ® 520D) or any other resist.