Hardbake of Photoresist Structures

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General

A hardbake can be performed after development in order to increase the thermal, chemical, and physical stability of developed resist structures for subsequent processes such as electroplating, wet- and dry-chemical etching. Hereby, the following mechanisms have to be considered:

Embrittlement of the Resist Film

Coated photoresists react with atmospheric oxygen and start to embrittle from approx. 130°C on. The different thermal expansion coefficient of resist and substrate can lead to stress cracks in the resist film especially in case of thick resist films, making the resist mask useless as mask for e. g. wet etching or electroplating.

If the hardbake cannot be waived, nor the hardbake temperature reduced, the cracking can be suppressed by a slow cooling (e. g. by keeping the substrate in/on the switched-off oven/hotplate for soft cooling, if feasible).

Reflow

Non-crosslinked positive resist structures start roundening above their softening temperature of typically 110°C (holds for e. g. the AZ® 1500, 4500, 9200, or ECI 3000 series), or respectively, approx. 130°C (e. g. the AZ® 6600 series, the AZ® 701 MiR, or the image reversal resists AZ® 5214E or TI 35ES). In this case, the point of contact between resist and substrate remains, while the upper edges of the resist structures will rounden.

Crosslinked negative resists such as the AZ® nLOF 2000 series, or the AZ® 15 / 125 nXT do not soften at any temperature. Hereby, the degree of crosslinking increases.

The document Reflow of Photoresists gives more details on the thermal reflow of resist patterns.

Resist Adhesion

A hardbake can improve the resist adhesion for subsequent wet etching in two ways:

Near or beyond the softening temperature of the resist, the resist structures mechanically relax which suppresses a peeling of small structures as well as an underetching. From 140-150°C on, chemical bonds between the resist and substrate are formed further improving the resist adhesion. For this purpose, we recommend a hardbake at approx. 145°C for approx. 5 minutes, followed by a moderate cooling down to room temperature in order to suppress the formation of cracks in the resist film.

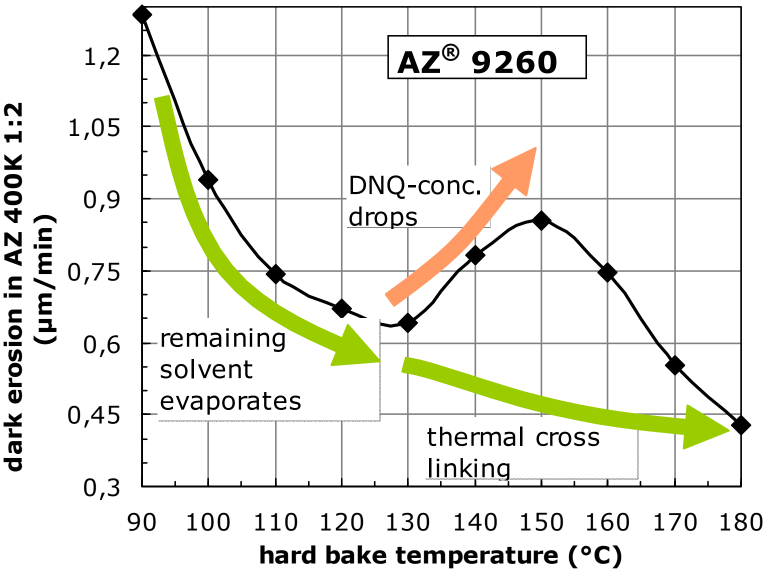
It has to be considered that the resist structures will rounden as these temperatures (for details, please consult the document Reflow of Photoresists), which is generally not a problem for subsequent wet etching.

The document Substrate Cleaning and Adhesion Promotion gives more details on an optimized substrate pre-treatment concerning improved resist adhesion.

Chemical Stability

Below a hardbake temperature of approx. 140°C, an increase of the chemical stability of positive resists can at best be attained via lowering the remaining solvent concentration, which is around 3-5% after a typical softbake. Crosslinking negative resists such as the AZ® nLOF 2000 series, or the AZ® 15 / 125 nXT further increase their degree of crosslinking from approx. 100°C on (only reasonable if the hardbake temperature lies above the PEB temperature) which also increases the chemical stability.

From 140-150°C on, positive resists start to thermally crosslink which also increases the chemical stability. However, lower hardbake temperatures < 140°C decrease the alkaline stability of positive resists, since the inhibitor DNQ (= the unexposed photo active compound) is thermally cracked (compare plot right-hand).



At different temperatures, various physical and chemical reactions impact the alkaline solubility of a resist film.

Photoresist Removal after Hardbake

Chemically stabilizing the resist by a hardbake is always accompanied by an improved stability against the final resist removal.

From >160°C on, the degree of thermal crosslinking in positive resists makes them more and more stable in common removers. Crosslinking negative resists already become hard to remove after a hardbake of approx. 140°C.

The document Photoresist Removal lists which removers are suited for different applications.

Hardbake - Yes or No?

The intrinsic high wet-chemical stability of AZ® and TI resists, together with an optimum substrate pretreatment, in many cases makes the hardbake redundant, which simplifies the processing and arranges following wet-chemical processes more reproducible.

In most cases, choosing an optimized resist helps to avoid a hardbake: For electroplating, the negative resists AZ® 15 nXT and 125 nXT show an improved adhesion and stability against most electrolytes. The AZ® ECI 3000 series has an optimized adhesion for wet etching, and the AZ® 6600 series as well as the AZ® 701 MiR an elevated thermal stability for dry etching.

However, for harsh attack (e. g. mesa etching with HNO_3), a hardbake at > 130-140°C is sometimes inevitable.

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.