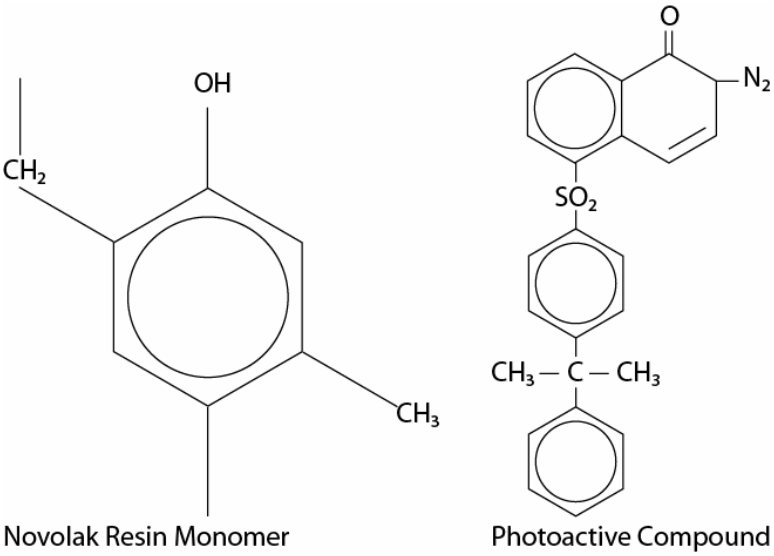
The Photolithography Process

Photolithography Fundamentals

Photoresist (PR) Components

PR consists of three components: a base material (resin), a photoactive compound (PAC) and a solvent.



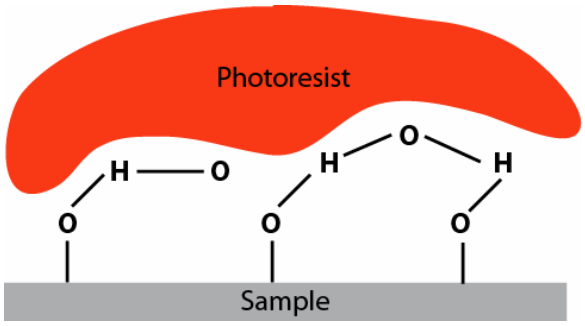
The solvent controls the mechanical properties of the PR. It is what makes the PR liquid, and also controls the viscosity.

The PAC inhibits the dissolution rate in developer before exposure to UV light. However, after exposure to UV light it makes the PR highly soluble in developer.

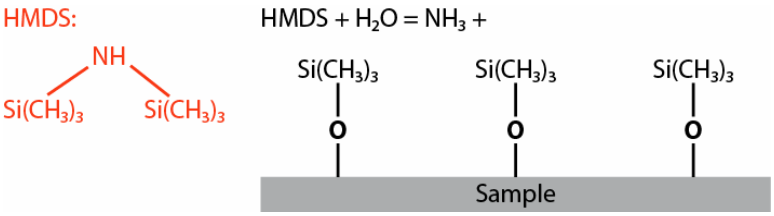
Cleaning and Dehydration Baking

Cleaning the sample is very important to make sure that it is free from dust, dirt, or residual PR.

Dehydration baking will ensure that any H_2O on the sample evaporates out. This is especially important for samples that oxidize easily (Silicon, for example). The oxides will then bond to water vapor available in the air. When the PR is then coated onto the sample, the PR will adhere to the H_2O and not to the sample.



After dehydration baking these oxidized samples, it is important to spin coat them first with HMDS primer. The HMDS primer will bond with the oxide groups to seal out the moisture. In addition, the $Si(CH_3)_3$ groups are compatible with the PR, creating adhesion between the sample and the PR.



It is important to make sure that the sample is not coated with an excess amount of HMDS, as it reduces the photosensitivity of PR.

Spin Coating

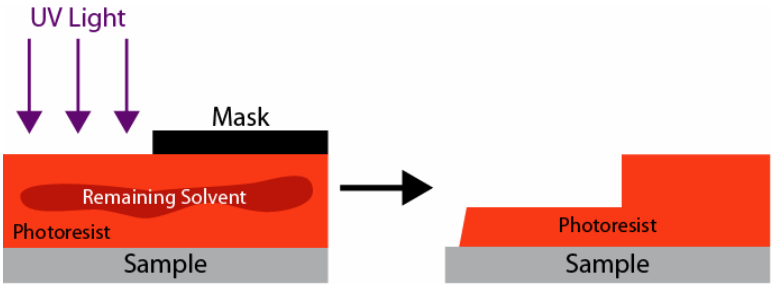
Spin coating produces a constant thickness of PR across the sample. The thickness of the PR (T_{PR}) after spin coating has a proportional relationship to the speed of the spin coater (in RPM):

$$T_{PR} \propto \frac{1}{\sqrt{speed}}$$

Pre-baking (Soft baking)

Prebaking makes the PR sensitive to UV light by removing the solvent component of the PR. Because the solvent is now mostly removed, the thickness of the PR is usually decreased by about 25 %.

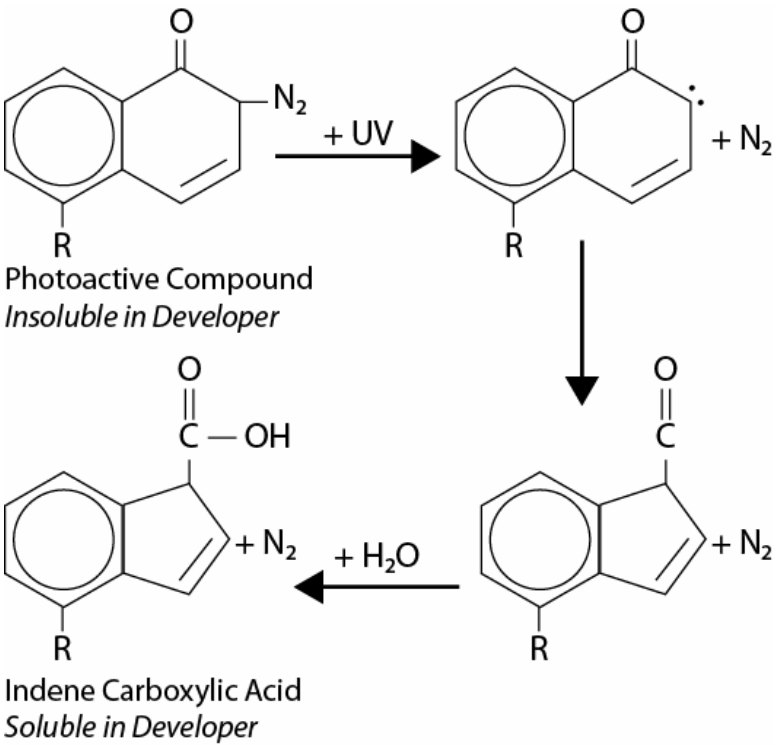
A short prebake will prevent UV light from reaching the PAC due to an excess of solvent remaining in the PR.



Over-baking the sample will increase the sensitivity to UV light and, in severe cases, may destroy the PAC and reduce the solubility of the PR in the developer.

Exposure

The next step is exposing the sample to UV light, using a mask to create both exposed and unexposed portions of PR. The areas that are exposed to the UV light will undergo a chemical reaction.



The water in this reaction is obtained from humidity in the air. If the air is not humid enough, the remaining carbon bond will bond with the resin, creating an insoluble material.

It is important to keep the mask as close to the sample as possible by using the high precision vacuum seal on the aligner. This reduces diffraction of light caused by the gap between the mask and the sample, and hence improves the resolution. This also makes a steady distribution of UV light across all of the exposure area.

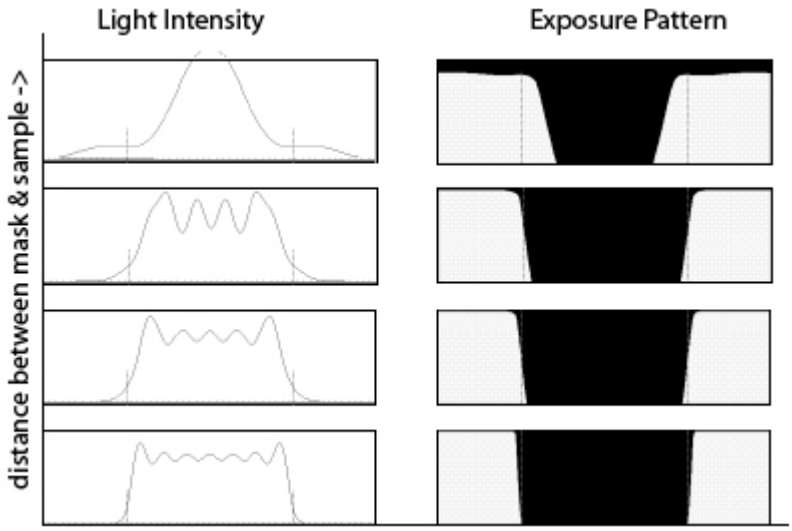
Positive Photoresist

Develop

After developing the sample, the remaining PR will have a profile that looks like:

The profile of the PR is due to diffraction of the UV light, caused by a gap between the mask and the sample. The PR around the edges of the mask pattern will receive light with a lower intensity than the areas in the center of the patterns, and will therefore not develop as quickly.

The profile slope changes as the distance between the mask and the sample changes.



Hard baking

Hard baking the sample at temperatures around 110 ^{o}C will strengthen the remaining PR and improve adhesion between PR and the wafer. This is an important step to take before etching the sample to ensure that the PR will not be removed by the etching.

Image Reversal Photoresist

Post baking

The critical step in image reversal photolithography is post baking the sample. A typical post baking temperatures is around 110 ^{o}C. This post baking promotes crosslinking of the polymer resin in the exposed areas of PR. (Above 130 ^{o}C the unexposed areas of PR will start to crosslink as well.) This crosslinked PR is now insoluble in the developer solution.

Flood Exposure

A flood exposure of UV light (no mask is used) of between 150 – 500 mJ/cm^2 will now cause all previously unexposed areas of PR to undergo the chemical reaction to make them soluble in developer.

Develop

After developing, the remaining PR will have a pattern that looks like:

This pattern is ideal for material deposition on the sample, since the remaining PR will be able to lift-off with applied acetone.

Image Reversal Recipe

- Clean the sample in a beaker filled with acetone, immediately followed by cleansing in a beaker filled with IPA, immediately followed by cleaning in a beaker filled with DI H_2O.
- Blow dry sample with an N_2 gun.
- Dehydration bake 120^oC for 3 minutes on a hot plate.
- Spin coat HMDS primer (if needed) at 7500 RPM for 35 seconds.
- Spin coat AZ 5214 E photoresist at 7500 RPM for 35 seconds.
- (PRE BAKE) Bake the sample at 90^oC for 60 seconds on a hot plate.
- Expose sample under mask for 1 second at 19mW/cm^2.
- (POST BAKE) Bake at 110^oC for between 15 and 60 seconds on a hot plate.
- Flood expose for 60 seconds at 19mW/cm^2.
- Develop in undiluted MIF 300 developer.

Positive PR Recipe

- Clean the sample in a beaker filled with acetone, immediately followed by cleansing in a beaker filled with IPA, immediately followed by cleaning in a beaker filled with DI H_2O.
- Blow dry the sample with an N_2 gun.
- Dehydration bake 120^oC for 3 minutes on a hot plate.
- Spin coat HMDS primer (if needed) at 7500 RPM for 35 seconds.
- Spin coat S1813 photoresist at 5000 RPM for 35 seconds.
- (PRE BAKE) Bake the sample 100^oC for 60 seconds on a hot plate.
- Expose under mask for 4 seconds at 19mW/cm^2.
- Develop in undiluted MIF 300 developer.
- (HARD BAKE) Bake 110^oC for 3 minutes

References

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