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LITHOGRAPHY BASICS

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- SCOPE: Introduction to Photolithography

Lithography is the process of patterning the surface of a substrate to build up a complex design or structure. Lithography has been used as a manufacturing technique for hundreds of years. Originally developed for printing presses, it has been adapted for use as a microfabrication technique known as photolithography.

Photolithography
Photo (or UV) lithography is the technique of pattering through the use of a light sensitive polymer (called photoresist) and a stencil (called a photomask). Through a series of chemical treatments this pattern is inscribed by either etching away of exposed areas or the deposition of new material to fabricate the desired device. For the manufacture of complex devices the number of photolithographic cycles increases.

The first step in any photolithographic process is to prepare the substrate – in most cases the substrate is a silicon wafer but can in theory be any material. Substrate preparation is undertaken to improve the adhesion of the photoresist to the substrate. Typical steps include substrate cleaning - to remove any dirt/contaminates; dehydration bake - to remove any water and then the addition of an adhesion promoter. Going through these steps will reduce the number of contaminates - both organic and inorganic - which will ensure the best results as we move through the lithography process.

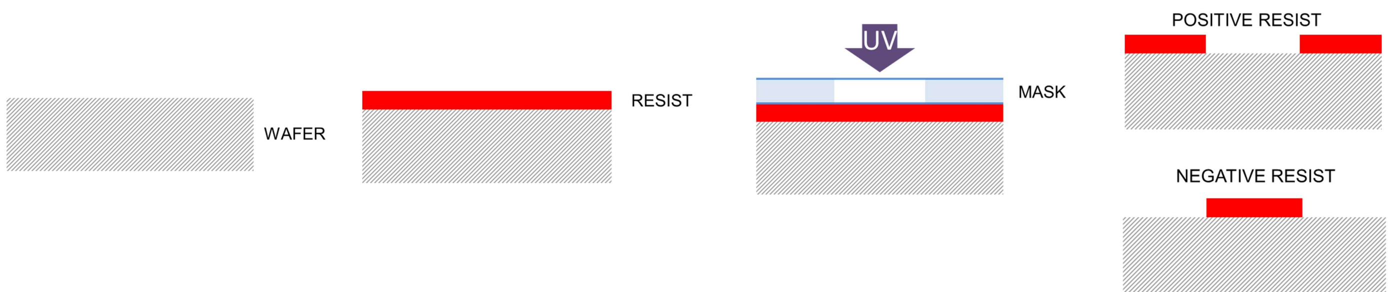
Once the substrate has been prepared the photoresist can be applied to the surface. To get the best results a thin uniform coating is required. The thickness of this film is of extreme importance and so the manner in which the resist is dispensed must be precisely controlled. A number of methods have been developed to dispense and coat a substrate with photoresist, the most common deployed of these is spin-coating. A summary of these coating methods can also be found on the Inseto Knowledge base.

In spin-coating the photoresist is deposited onto the substrate and the substrate and resist are then spun on a turntable at 1000s of rpm, spreading out the viscous photoresist into a thin layer. This thin resist is then soft-baked on a hotplate to remove excess solvent and to stabilise the resist film.

The next step in the photolithography process is to align the resist-covered substrate to the photomask and to expose it with ultraviolet (UV) light. The critical principle in photolithography is that the solubility of the photoresist is changed once exposed to UV light. How this solubility changes defines the type of photoresist - either positive or negative – and the details of the manufacturing process that should be used.

- In a positive resist, the part of the film that is exposed to the UV light becomes more soluble and can be removed with a developer.
- In a negative resist the opposite happens, where the resist has been exposed to light the resist becomes harder and can't be removed by the developer.

There are many different compositions and versions of resist, allowing for different heights, temperatures, exposure settings and structures to be manufactured. A typical photolithographic process is depicted in the diagram below:



a) Cleaned & prepared wafer or substrate | b) Thin film of photoresist coated onto substrate | c) Align to photomask and expose to UV light | d) Develop photoresist to expose features

When aligning the substrate to the mask we use a mask aligner or a stepper to control where the pattern on the mask is projected onto the substrate below. A mask aligner is a faster process, taking a pattern the same size as the wafer and projecting it onto the wafer. A stepper takes a small pattern and exposes that onto the wafer before moving the substrate a short distance and exposing the same pattern onto a different part of the wafer - replicating the same pattern over and over again.

The crucial aspect of the align and expose step is the exposure of the photoresist with UV light. The UV source can either be a broadband mercury light or a UV LED array. The UV source defines the resolution (smallest features) of the lithography process. A rough rule of thumb is that the resolution achievable is slightly more than half the wavelength of light. UV light has a wavelength of ~365nm, so the resolution achieved will be ~182 nm. There are a number of exposure modes available which will also affect the resolution achievable.

Once exposed, the next step is to develop the resist. The developer will wash away either the exposed or unexposed parts of the resist film, depending on the nature of the photoresist. Development is either done as a spray, where a fine mist of developer is sprayed onto the exposed substrate or as a puddle, where a pool of developer is poured onto the exposed substrate. In both cases it will remove the unwanted photoresist leaving the desired pattern.

Now the substrate is ready for the next step of the processing, either the deposition of a thin film onto the surface of the substrate or the etching and removal of the substrate. These techniques can be combined together with multiple iterations of photolithography to make complex designs and patterns.

Other microfabrication techniques similar to lithography such as imprint lithography or electron-beam lithography can also be incorporated into the manufacturing process to produce devices with increasing complexity and functionality.