Spin coating

The wafer is covered with photoresist by spin coating. A viscous, liquid solution of photoresist is dispensed onto the wafer, and the wafer is spun rapidly to produce a uniformly thick layer. The spin coating typically runs at 1200 to 4800 rpm for 30 to 60 seconds, and produces a layer between 0.5 and 2.5 micrometres thick. T

he spin coating process results in a uniform thin layer, usually with uniformity of within 5 to 10 nanometres. This uniformity can be explained by detailed fluidmechanical modelling, which shows that the resist moves much faster at the top of the layer than at the bottom, where viscous forces bind the resist to the wafer surface. Thus, the top layer of resist is quickly ejected from the wafer's edge while the bottom layer still creeps slowly radially along the wafer. In this way, any 'bump' or 'ridge' of resist is removed, leaving a very flat layer.

Final thickness is also determined by the evaporation of liquid solvents from the resist. For very small, dense features (< 125 or so nm), lower resist thicknesses (< 0.5 micrometres) are needed to overcome collapse effects at high aspect ratios; typical aspect ratios are < 4:1. The photo resistcoated wafer is then prebaked to drive off excess photoresist solvent, typically at 90 to 100 °C for 30 to 60 seconds on a hot plate.

After prebaking, the photoresist is exposed to a pattern of intense light. The exposure to light causes a chemical change that allows some of the photoresist to be removed by a special solution, called "developer" by analogy with photographic developer.

Optical lithography

Introduction

Optical lithography or photolithography is the process of forming a micro or nano pattern in a layer of light sensitive polymer called photoresist, that can be transferred by selective etching, into an underlying film. The most widely used lithography technique today is optical lithography, which uses UV light, however there are other technologies such as x-ray and electron beam lithographies that promise better fresolution. These newer technologies have many drawbacks that, to date, make them unattractive for use in integrated circuits or microprocessors production

Working Mechanism

Almost all top-down manufacturing involves one or more lithography fabrication steps, so we give a brief outline of this technique here. A generic photolithography process is sketched in Fig. 2.1. The substrate wafer is typically a very pure silicon disk with a thickness around 500 μm and diameter of 10 cm (for historic reasons denoted a 4 inch wafer). Wafers of different purities are purchased at various manufacturers.

Spin coating of resist: The substrate is spin coated with a thin layer of light sensitive resist (polymer), called photoresist.

Light exposure via optical mask: From a lightsource light is directed through a mask carrying the circuit design down onto the photoresist, which is **chemically changed** under exposure to the light.
Development: For positive resist, the exposed part of the resist is removed using a photoresist developper, leaving behind the desired pattern. For negative resist the exposed part remains there and the un-exposed part is removed by photoresist developer. This process is called development in analogy with development of photographic films and at this step we obtained **nanotemplate in photoresist-resist thin film**. These patterns are used as template for deposition of required materials.

Required nanostructure material deposition: After the removal of the exposed resist a thin required material layer is deposited on the photoresist nano template deposited on a substrate. On the areas exposed to the electron beam the deposited metal sticks to the substrate, while on the unexposed areas the metal sticks to the resist surface.

Lift-Off: After metal deposition the remaining (unexposed) e resist is dissolved in an aggressive solvent (usually acetone). The metal sticking to the resist looses "footing" and so only the metal sticking to the substrate remains **giving us required nanostructures pattern.**

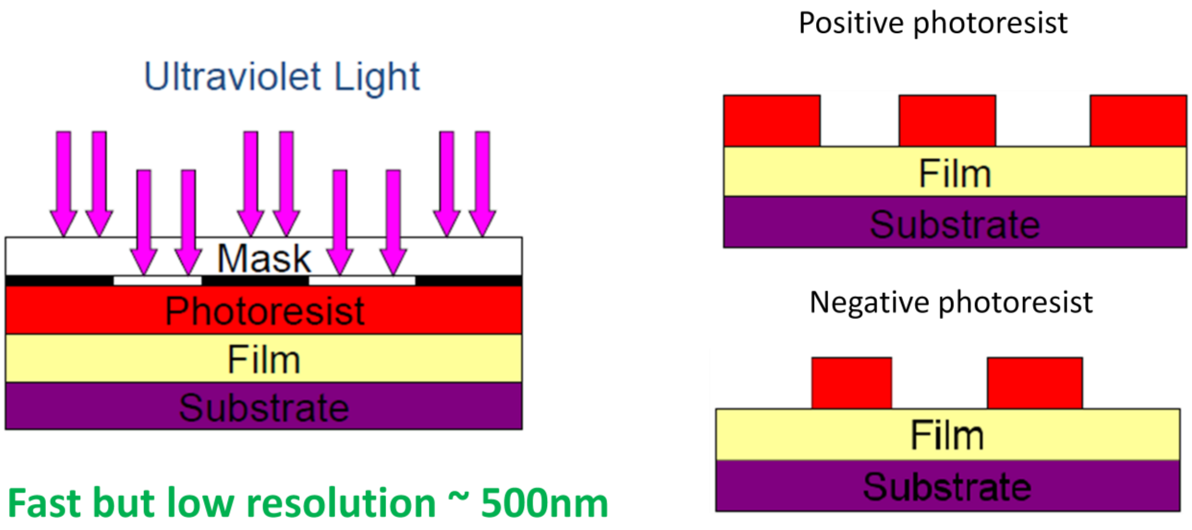

Fig 2.1: Schematics UV lithography. After insulation by UV light using a mask, the exposed part of positive resist is removed in a developper, while negative resist becomes harder after insulation and remains there.

Factors effecting Resolution and Quality of Nanostructures

The resolution and quality of the patterns depend on:

- The wavelength of the light used
- The UV lamp power
- Light exposure time
- Type of the resist
- Thickness of the resist
- Material of the mask
- Distance between resist and mask

There is a minimum limit of the pattern size that can be achieved by UV lithography of about (~500 nm), due to diffraction limit of the light wavelength. The photo exposure is typically performed using the 356 nm UV light from a mercury lamp, but to achieve the line widths of sub 100 nm an extreme UV source or even an X-ray source is needed.

To achieve the best resolution must minimize not only the wavelength λ of the exposure light, but also the distance d between the photolithographic mask and the photoresist-covered substrate wafer, and the thickness t of the photoresist layer. The minimum line width W_{min} (or Highest resolution) is given by the approximate expression

$$w_{\mathrm{min}} = \frac{3}{2}\sqrt{\lambda(d+t)}.$$

If $d = 0$ nm the mask is touching the photo-resist. This situation, denoted contact printing, improves the resolution but wears down the mask. If $d > 0$ nm, a case denoted proximity printing, the resolution is poorer but the mask may last longer. It is difficult to obtain $w_{\mathrm{min}} <$ few100 *n*m using standard UV photolithography.

Photoresist

A **photoresist** is a light-sensitive material used in several industrial processes, such as photolithography and photoengraving to form a patterned coating on a surface.

Positive photoresist

A *positive resist* is a type of photoresist in which the portion of the photoresist that is exposed to light becomes soluble to the photoresist developer. The portion of the photoresist that is unexposed remains insoluble to the photoresist developer.

Negative photoresist

A *negative resist* is a type of photoresist in which the portion of the photoresist that is exposed to light becomes insoluble to the photoresist developer. The unexposed portion of the photoresist is dissolved by the photoresist developer.

The solubility of the resists is proportional to the square of the molecular weight of the polymer. The photo-processes in a polymer photoresist will either cut the polymer chains in small pieces (chain scission) and thus lower the molecular weight, or they will induces cross-linking between the polymer chains and thus increase the molecular weight. The first type of resists is denoted the positive one photoresists, they will be removed where they have been exposed to light. The second type is denoted the negative tone photoresists, they will remain where they have been exposed to light

Materials used as photoresist for optical lithography

Poly methyl methacrylate (PMMA)

Poly methyl glutarimide (PMGI)

diazonaphthoquinone (DNQ) etc.

Photoresists are most commonly used at wavelengths in the ultraviolet spectrum or shorter (<400nm). For example, diazonaphthoquinone (DNQ) absorbs strongly from approximately 300 nm to 450 nm.

Photolithographic mask

The photolithographic mask contains (part of) the design of the microsystem that is to be fabricated. This design is created using computer-aided design (CAD) software. Once completed the computer file containing the design is sent to a company producing the mask. At the company the design is transferred to a glass plate covered with a thin but non-transparent layer of chromium.

The transfer process is normally based on either the relatively cheap and fast laser writing with a resolution of approximately few 100 or sub 100 *n*m and a delivery time of around few weeks, or the expensive and rather slow electron beam writing with a resolution of few 10's or sub 10 *n*m and a delivery time of several months.

Applications of Photolithography

- Fabrication of printed circuit boards
- Micro and nano electronic devices (IC's, Computer chips etc.)
- Photonic devices (LED's, Quantum dots based Soller Cells etc)