1 Photolithographie

1.1 Exposure and resist coating

1.1.1 Overview

In the manufacturing of semiconductors, structures are created on wafers by means of lithographic methods. A light sensitive film, primarily a resist layer, is coated on top of the wafer, patterned, and transfered into the layer beneath.

Photolithography consists the following process steps:

- adding adhesives and removing moisture from the surface
- resist coating
- stabilization of the resist layer
- exposure
- development of the resist
- curing of the resist
- inspection

In some processes, as the ion implantation, the resist serves as a mask to cover certain areas which should not be doped. In this case there is no transfer of the patterned resist layer into the layer beneath.

1.1.2 Adhesives

First of all the wafers are cleaned and anneald (pre-bake) to remove adhesive particles and adsorbed moisture. The wafer surface is hydrophilic and has to be hydrophobic before deposition of the photoresist. For this reason adhesives, hexamethyldisilazane

(HMDS) in general, are added to the surface. The wafers are exposed to the vapor of this liquid and are dampened.

Because of moisture in the atmosphere even after the pre-bake there are hydrogen H oder hydroxyl groups OH^- attached to the surface. The HMDS decomposits into trimethylsilyl groups $Si{-}3\,CH_3$ and removes the hydrogen by forming ammonia NH_3.

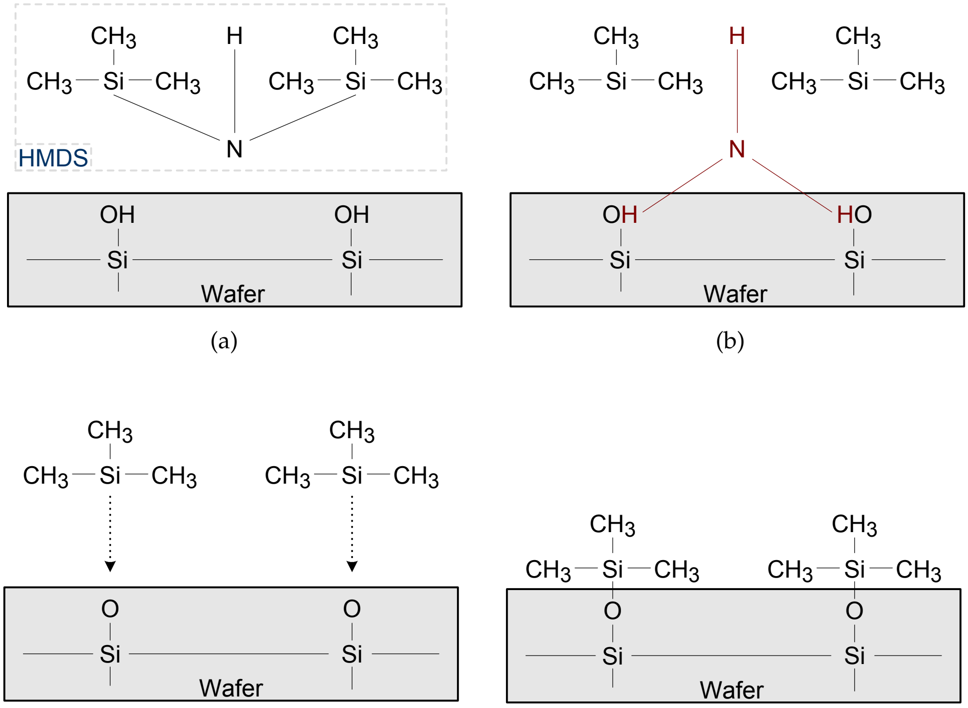

Fig. 1.1: Surface modifictation with HMDS

1.1.3 Coating

The coating of the wafer is done by spin on methods on a rotating chuck. On low rotation the resist is spun on and then planished at for example 2000 to 6000 rpm. Depending on the subsequent process the thickniss of the resist layer can be up to 2 microns. The thickness depends on the rpm and the viscosity of the resist.

To enable a homogeneous layer, the resist contains water and solvents which soften it. For stabilization reasons the wafer is annealed afterwards at about 100 °C (post-/soft-bake). Water and solvents are vaporized partially, some moisture has to remain

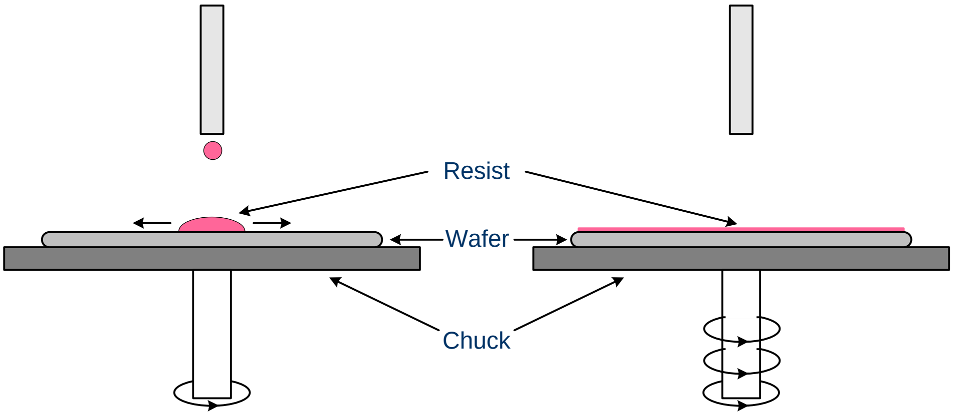

Fig. 1.2: Spin on coating

for subsequent exposure.

1.1.4 Exposure

In a lithographic exposure tool, there is a glass mask which is fractional covered with chrome to partial expose areas of the resist.

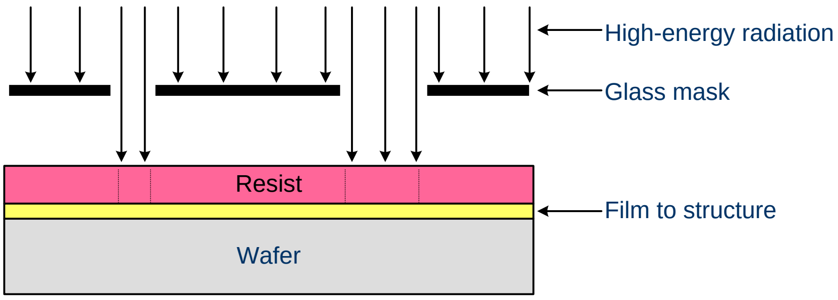

Fig. 1.3: Optical lithography

Depending on the type of the resist, exposured areas are solubly or insolubly. With a wet-chemical developer the solubly parts are removed, so that a patterned resist layer remains. The exposure time is a very important value to achieve the correct dimensions of the structures. The longer the wafers are exposed to the radiation, the larger the radiated area is. Due to fluctuating ambient temperatures a precise determination of the correct exposure time has to be investigated with one or more dummy wafers, because the characteristics of the resist can change with temperature.

An overexposure causes smaller resist patterns, and therefore smaller structures beneath, in contrast vias will be enlarged. With a too short exposure time the vias are not opened correctly, conductors are to wide or even in contact to each other (short circuit). In addition, a bad focusing leads to unexposed areas, so that vias can not be opened and conductors are in contact as well.

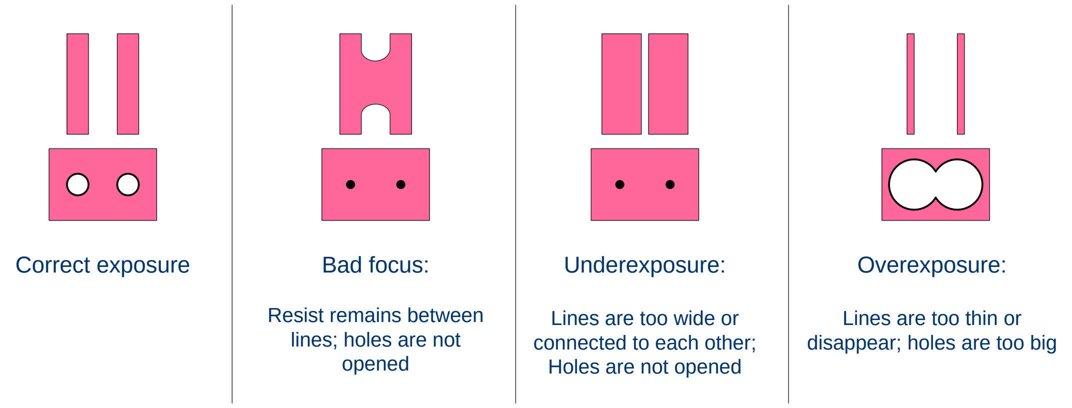

Fig. 1.4: Bad exposure due to focus issues, over exposure, or under exposure

Depending on the subsequent process, the width of the resist patterns or the diameter of the vias, respectively, has to be adjusted. In isotropic etch processes (etching in vertical and horizontal orientation) the resist mask is not transferred 1:1 into the layer beneath.

1.1.5 Exposure methods

For exposure there are different radiation sources, depending on the demands: ultraviolet radiation, electron beam, x-ray, and ion beams. The shorter the wavelength the smaller the possible structures.

For structures of 120 nm an argon fluoride laser is used, for ever smaller structures a nitrogen laser (wavelength 157 nm) or extreme ultra-violet radiation (EUV, wavelength 13 nm) is conceivable. X-rays do have a wavelength of 0.2 to 0.4 nm, electron beam writers about 0.02 nm and ion beams - in case of protons (hydrogen ions) - 0.0001 nm.

That one can fabricate structures with a width of less than x nm with a radiation of x nm is possible due to special photomasks which utilize the phase shift of light. In addition the resolution can be increased with liquid films inside the optical system (immersion lithography). These techniques made it possible to fabricate today's structure sizes of 32 nm still with a radiation wavelength of 193 nm.

While ultra-violet radiation (generated with mercury bulbs) and gas lasers are used for the exposure of the wafer, x-ray or ion beam lithography is used in research. Electron beams are used for photomask manufacturing.