





- General concepts
- Mask writing and Direct Write Laser
- UV lithography
- Electron Beam Lithography (EBL)
- Alternative lithographies

Micro and Nanofabrication (MEMS)

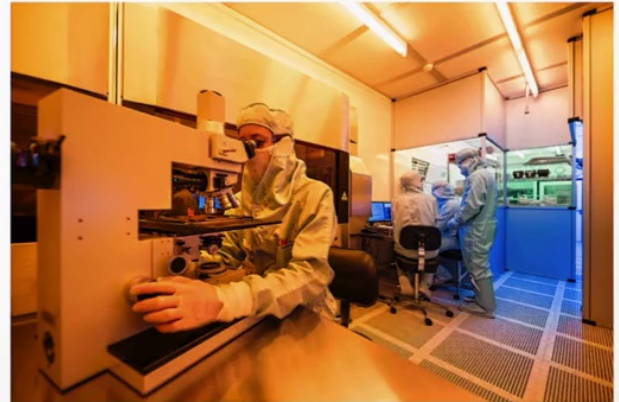
---

As there are several possibilities to perform lithography, I will start by providing some definitions and by explaining some general concepts that are recurring for all the lithography variations. Then I will dive into details how one fabricates the lithography masks using a direct write laser tool. This will be followed by a closer look into UV lithography and electron beam lithography which are to date the two main categories of lithography. I will then conclude by presenting new emerging and alternative lithographies which are not yet part of the main stream applications, but that offer interesting opportunities for niche applications.

---

# General concepts in lithography

- Fundamental step in microfabrication
  - From design to physical patterning
  - Enabling step for local dry etching or metal deposition
- The lithography step is based on
  - Electromagnetic interaction and modification of a resist via photons or electrons, followed by development
- In a cleanroom & under yellow light



Micro and Nanofabrication (MEMS)

---

Lithography is the fundamental process of transferring geometric shape from a design to a thin layer of radiation sensitive material called resist, which is covering the surface of a wafer substrate. These shapes or patterns define the various regions in an integrated circuit, such as the implantation regions, the contact windows, the metallic wiring etc. The resist patterns made by lithography are not permanent but only temporary replicas of circuit or MEMS features. To produce the final features in the material of interest, these resist patterns must be transferred once more into the underlying layers, for instance by an etching process which selectively removes unmasked portions of a layer. The pattern transfer techniques are described in more details in the lesson on wet and dry etching.

---

# General concepts in lithography

- Fundamental step in microfabrication
  - From design to physical patterning
  - Enabling step for local dry etching or metal deposition
- The lithography step is based on
  - Electromagnetic interaction and modification of a resist via photons or electrons, followed by development
- In a cleanroom & under yellow light



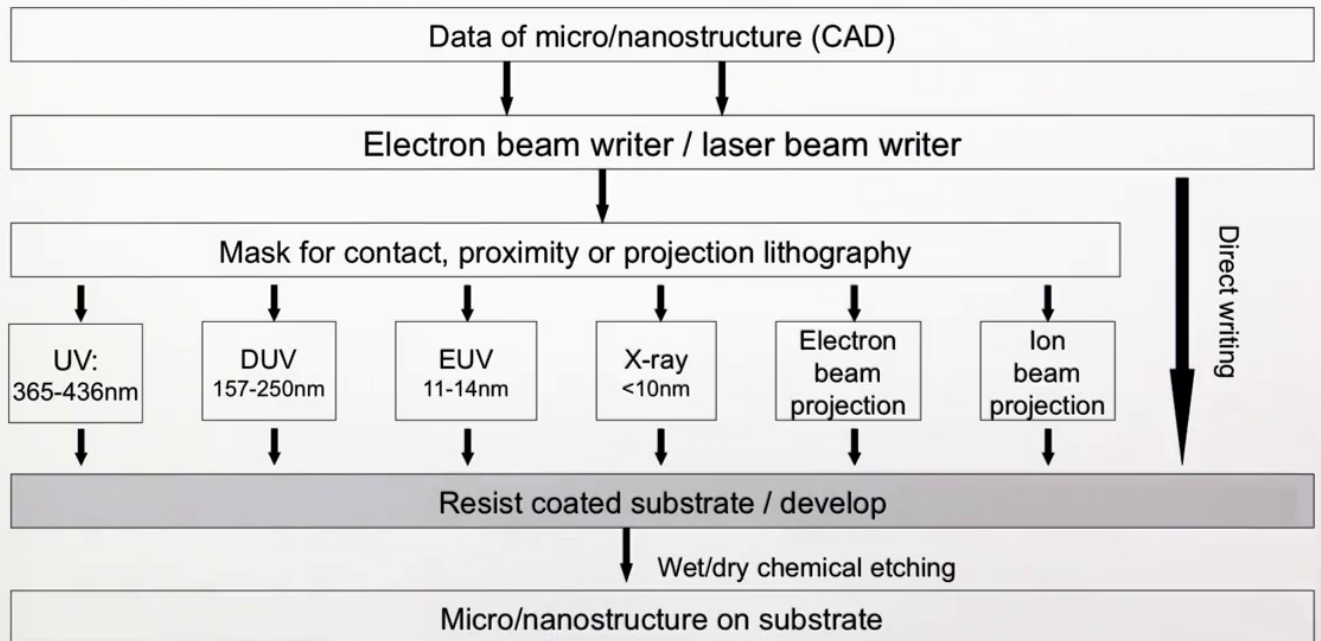
Microfabrication (MEMS)

---

The lithography exposure step itself can be done by various sources of electromagnetic radiation, either by using photons or electrons. All lithography processes must be performed in an ultra clean environment to avoid that any dust particle in the air can settle on the wafers or lithography masks and can cause defects in the device. Lithography is also carried out in yellow light. Indeed, the photo resist is sensitive to light with shorter wavelengths. UV light is therefore filtered out from lithography areas in a clean room. More on clean room specific features are given in the corresponding lesson.

---

# From design to a micro/nanodevice



Micro and Nanofabrication (MEMS)

This slide provides an overview of possible parts from a design file or a CAD file, on a computer to define a micro or nano structure or circuit on a wafer. Here is the start of the data on the CAD file, on a computer. And at the end, we want to have the micro or nano structures on a substrate. From the CAD file, we can steer by computer control, the write head of a beam writer that uses either focused laser or electrons. This is the first conversion from a virtual computer design feature into a physical reality. In the majority of the cases the beam writer is used to fabricate masks for lithography. This is because the writing can take a lot of time. Only in cases of RD when only few devices are needed. One considers the direct writing of the final structure. Depending on the radiation source, one speaks about UV, deep UV, extreme UV, x-ray, electron beam projection, or ion beam projection masks, all with their own specificities. In each case, the radiation impinges locally onto a resist coated substrate and modifies the resist which can then be developed. The resist subsequently serves as a mask for pattern transfer by etching to complete the micro or nano fabrication step.

# Concept of lithography

- Processes involved

- Radiation generation and shaping by an exposure tool to tune the intensity, wavelength and surface where the resist is exposed.
- A chemical reaction involving both the resist and developer
- Mechanical control over the relative position of substrate and exposure tool for alignment of possibly multiple layers



Nanofabrication (MEMS)

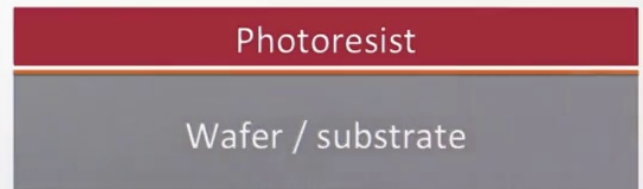
---

So once again to summarize, the processes involved in lithography firstly include the generation of a radiation that needs to be tuned and precisely shaped to impinge on the sensitive resist where needed. Second, it involves a chemical reaction between the resist radiation, and then the resist and the developer. Last but not least, it requires a very precise mechanical tool for the positioning of the mask or the beam on the resist coated substrate, in particular for the patterning of alignment and multi-layer features.

---

# Lithography process flow

- Substrate preparation
- Resist coating and pre-baking
- Resist exposure
- Resist development
- Pattern transfer (etching, lift-off)
- Resist stripping



Micro and Nanofabrication (MEMS)

Each lithography follows a well defined series of process steps, called process flow. It may vary according to the lithography used and the materials involved. But a typical generic example is shown here, where we go step by step through it. First the substrate - it can be a silicon wafer or glass plate - is cleaned and prepared and eventually coated with a thin film of material that needs to be patterned. Second, the photo resist is being coated on the substrate to form a layer of it with a well controlled thickness in the order of a micrometer, but this can vary a lot. And most importantly, with a very uniform thickness over the entire substrate surface. Some pre-baking is done to remove excess solvent and to dry the resist.

# Lithography process flow

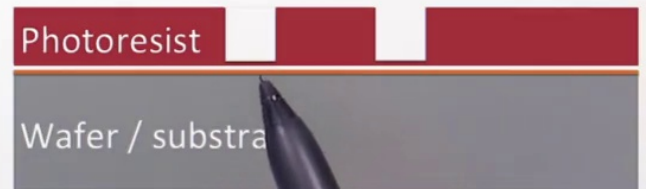
- Substrate preparation
- Resist coating and pre-baking
- Resist exposure
- Resist development
- Pattern transfer (etching, lift-off)
- Resist stripping



Then comes the essential step, which is the resist exposure. This step can be done either by photons or electrons. In this example shown here, I show the use of a UV light source and expose the resist through a photomask that contains transparent (here), and opaque regions. Only under the transparent portions of the mask we will expose the resist. The other method would be using electrons that can be scanned over the surface, and thereby writing the pattern - this will be shown in details later. In both cases, the goal is to chemically modify the resist under the radiation so that it becomes either polymerized by creating new chemical bonds, or by breaking existing chemical bonds. The choice to use either optical UV lithography or electron beam is driven by the quest for resolution and throughput.

# Lithography process flow

- Substrate preparation
- Resist coating and pre-baking
- Resist exposure
- Resist development
- Pattern transfer (etching, lift-off)
- Resist stripping



Micro and Nanofabrication (MEMS)

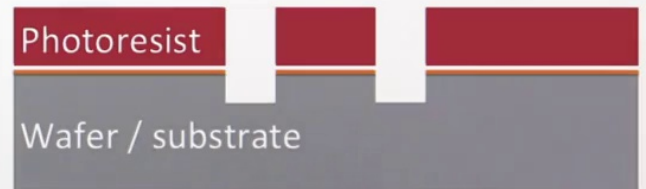
---

The step after the exposure is resist development, shown here, which is a chemical bath that dissolves the part of the resist that has not been polymerized or whose bonds have been weakened by the exposure.

---

# Lithography process flow

- Substrate preparation
- Resist coating and pre-baking
- Resist exposure
- Resist development
- Pattern transfer (etching, lift-off)
- Resist stripping



Micro and Nanofabrication (MEMS)

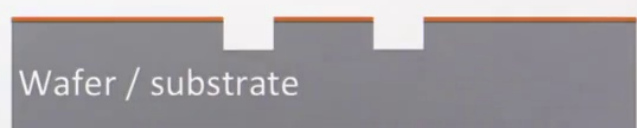
---

Then the resist pattern is transferred into the layer of interest by etching or by lift-off. These steps will be explained elsewhere in this course.

---

# Lithography process flow

- Substrate preparation
- Resist coating and pre-baking
- Resist exposure
- Resist development
- Pattern transfer (etching, lift-off)
- Resist stripping



Wafer / substrate

Micro and Nanofabrication (MEMS)

---

At the end, the resist is not used anymore and can be removed by a so-called stripping process in solvent and cleaning acids. And the target device pattern is now completed.

---