Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

4.15 Lithography 7, Alternative patterning methods, I Scanning probe lithogra

Concepts (extracted from automatically generated subtitles):

Electron beam lithography. Resist coated substrate. Probe lithography. Alternative emerging lithography methods. Optical system. Equivalent of optical microscopy. Use of alignment markers. Sharp tip. Thermal scanning probe lithography. General setup of an afm. Case of the scanning electron system. Graphene-oxide patterns. High temperatures. Means of an ultra small capillary liquid cone. Main goal.

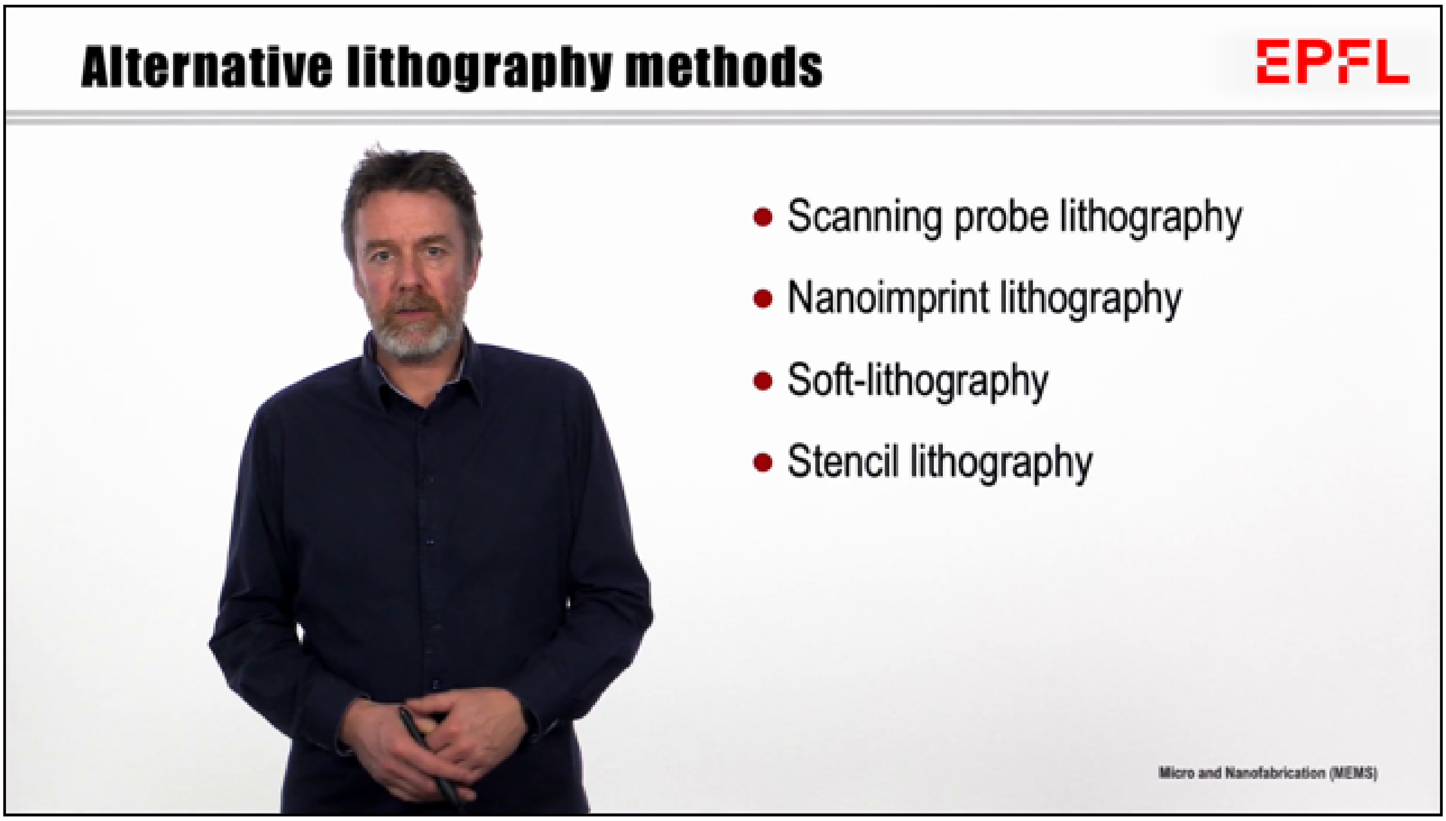
to video sequence search
(within Micro and Nanofabrication (MEMS).)

to video

...

notes

summary

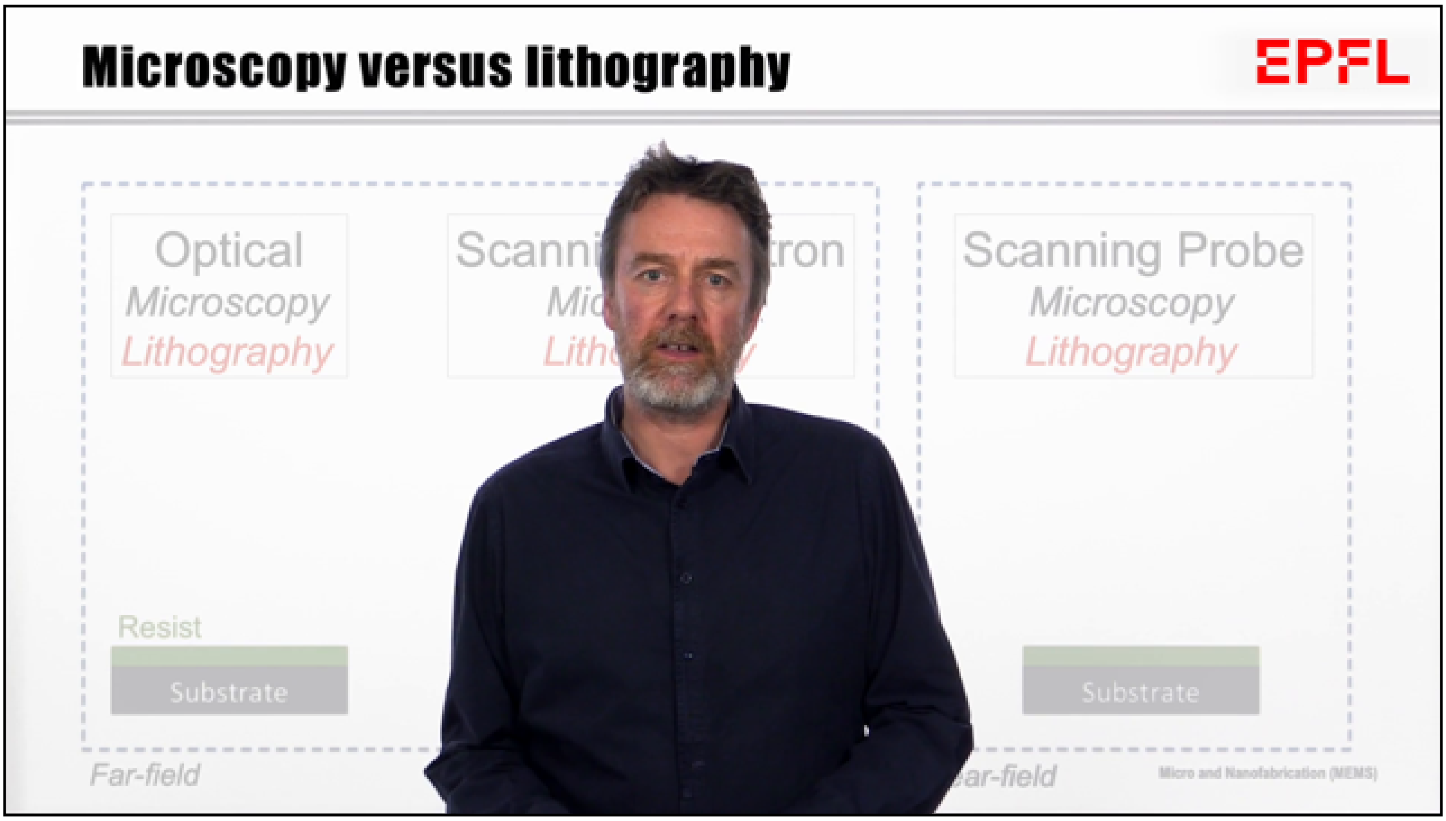


After the lessons in UV and electron beam lithography, this lesson

notes

summary

0m 1s

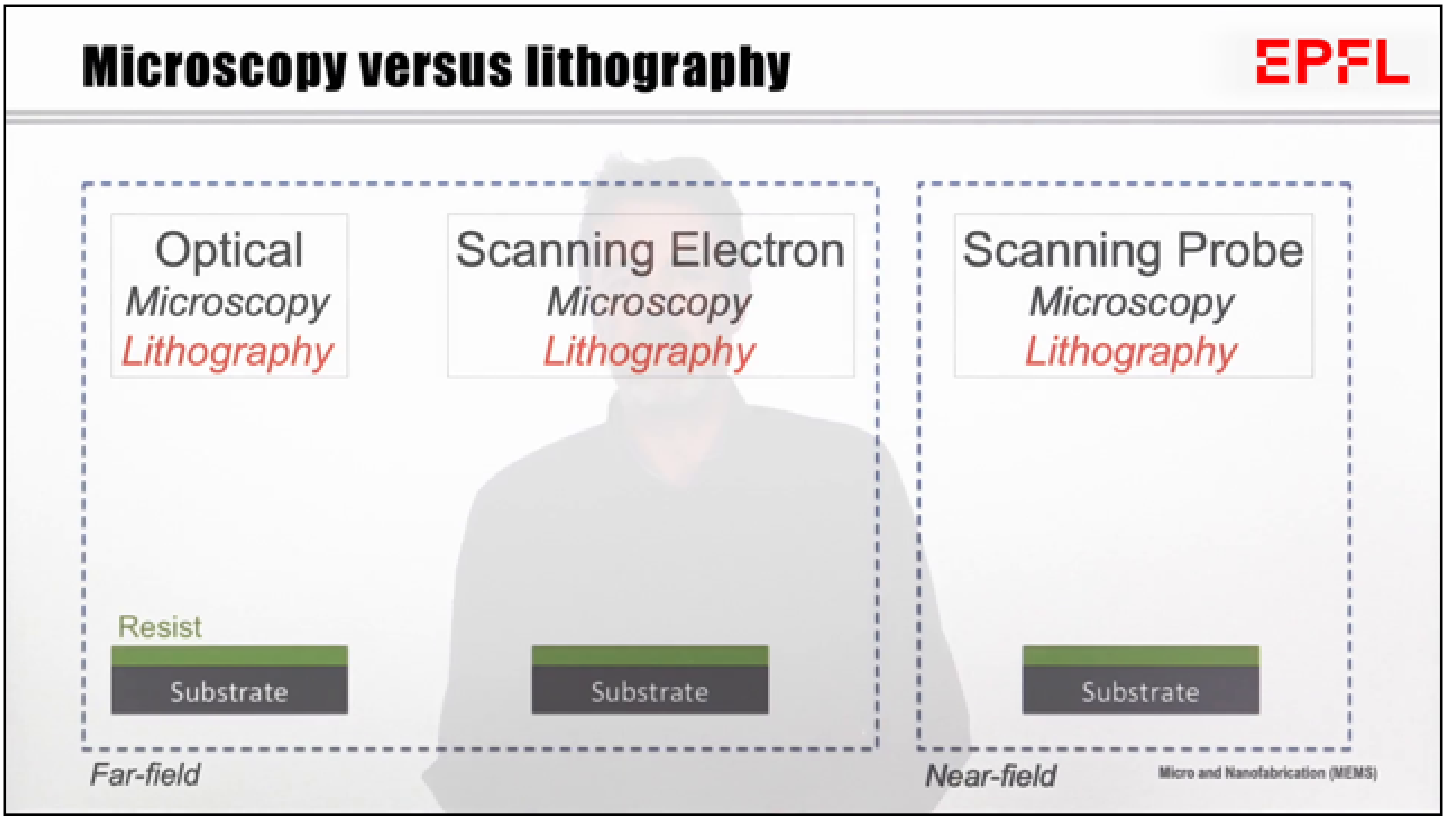


will show some alternative emerging lithography methods. They offer new functionalities, enable micro nano structures that are otherwise not feasible and allow for rapid prototyping at the nanometer scale. Some of them are also scalable for cost efficient nano manufacturing. I will begin with scanning probe lithography for direct writing. Then I will introduce nano imprint lithography, soft lithography, and stencil lithography for replication. Before looking into these new lithography techniques, let's quickly remind that lithography and microscopy have many similarities. In both cases the main goal is to achieve the best possible spatial resolution, for either imaging or patterning. A lithography tool is often very similar to the tool used for microscopy, with some added features

notes

summary

0m 5s

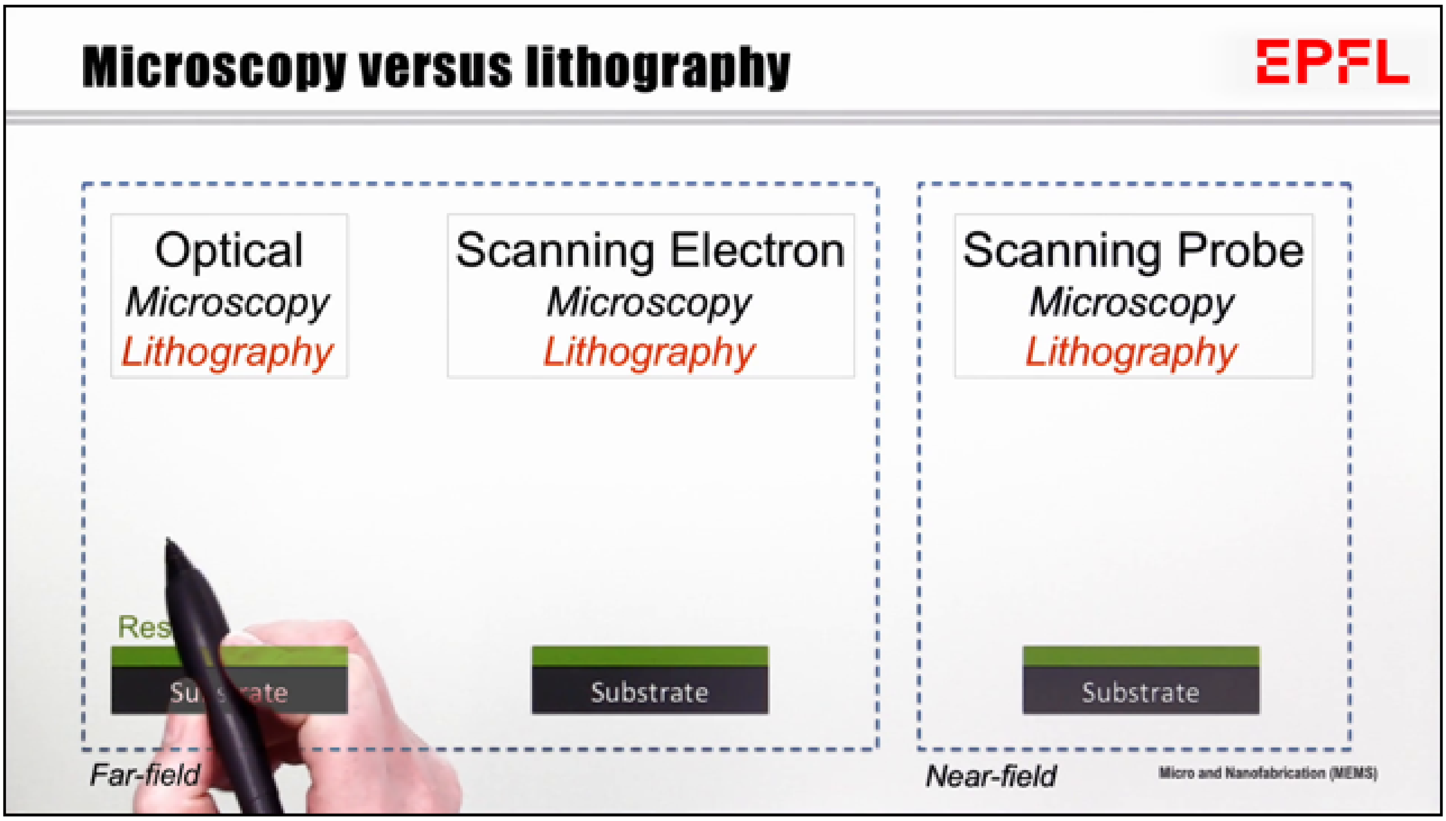


to control the dose of resist exposure for example.

notes

summary

1m 1s

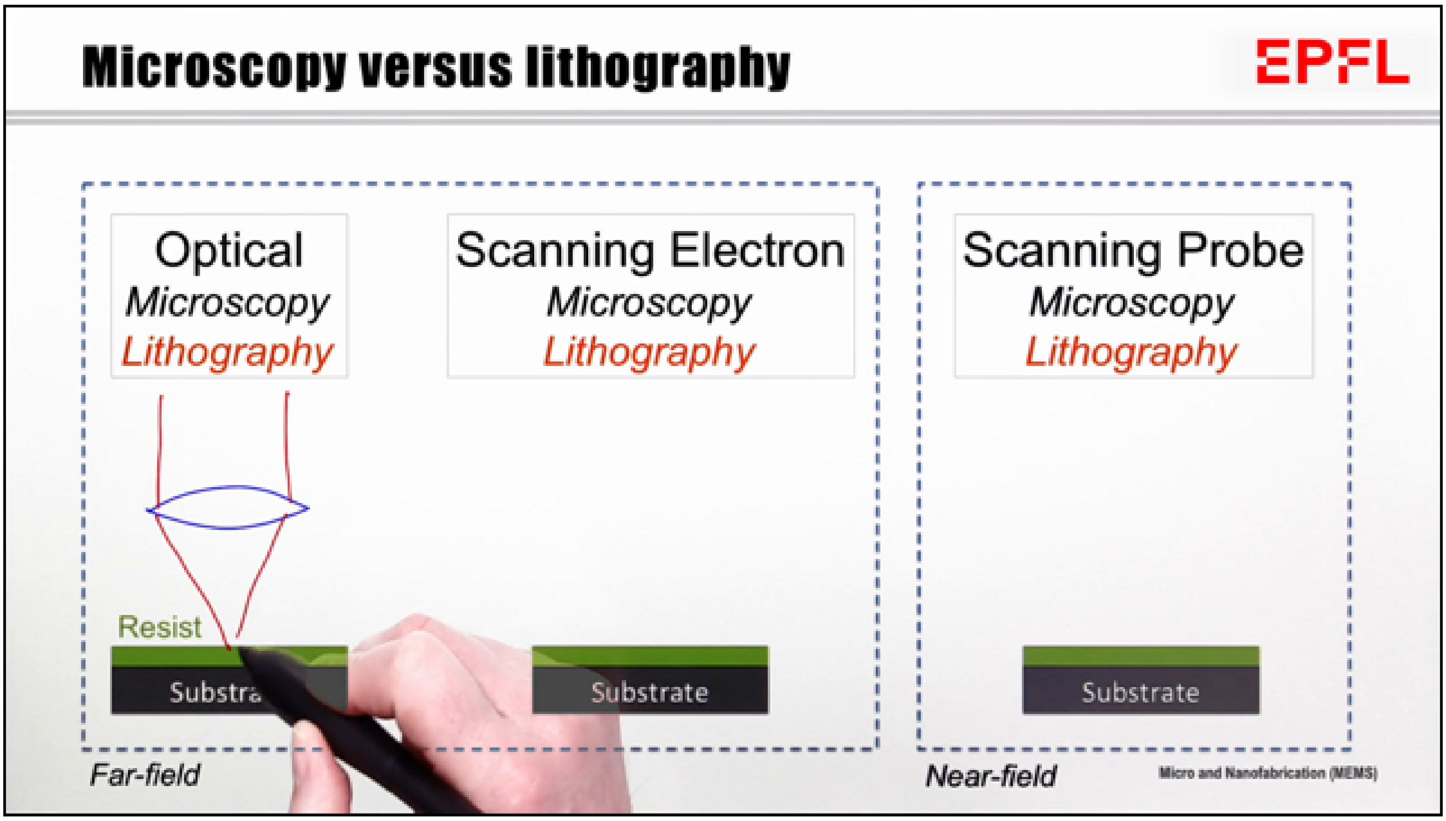


In microscopy, we inspect the sample ideally without changing it and in lithography, the goal is to modify the sample so to speak, to write into it.

notes

summary

1m 6s

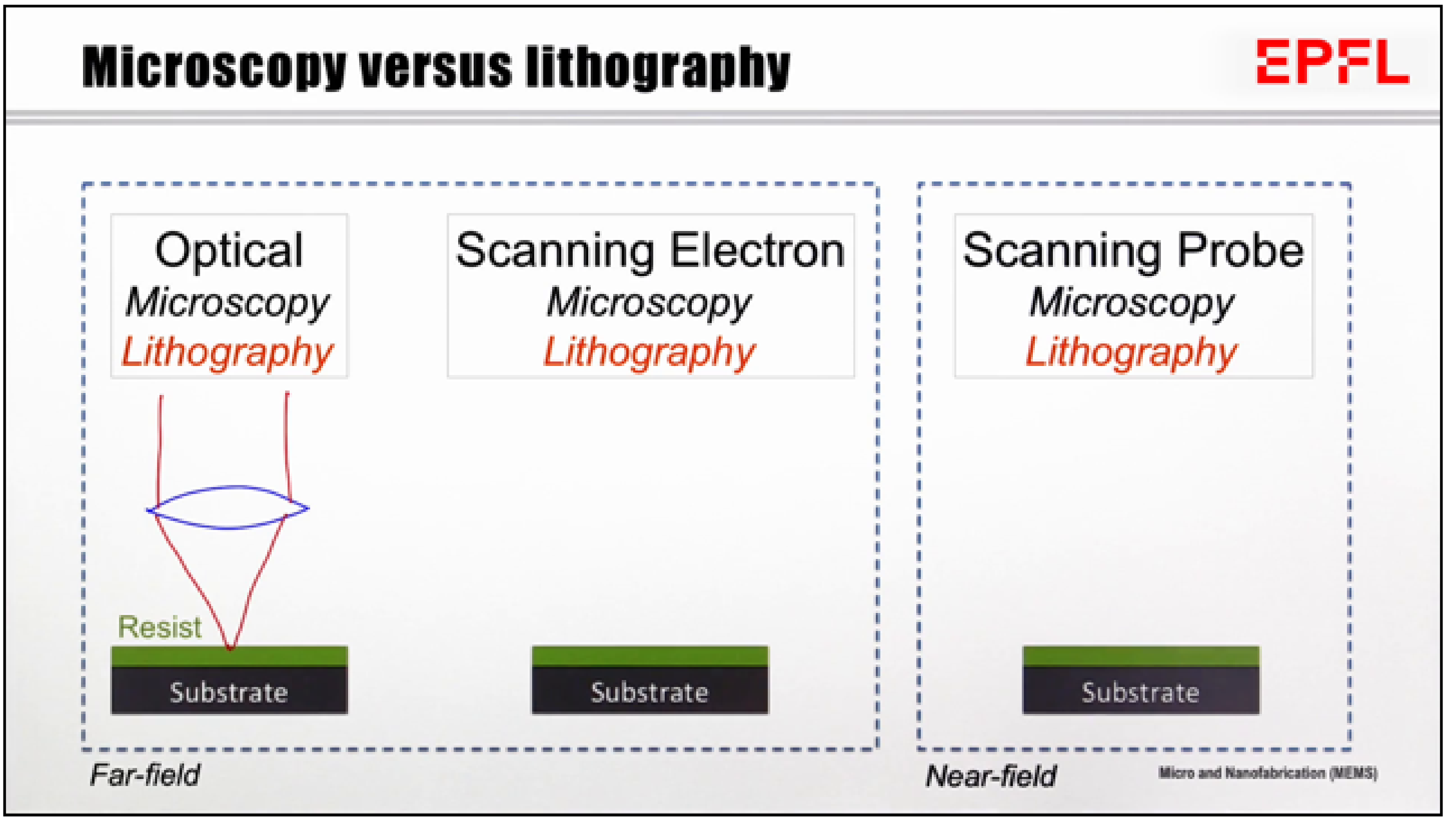


If we take the equivalent of optical microscopy and lithography we have an optical system with a lens and then our optical beam is focused through that lens system

notes

summary

1m 20s

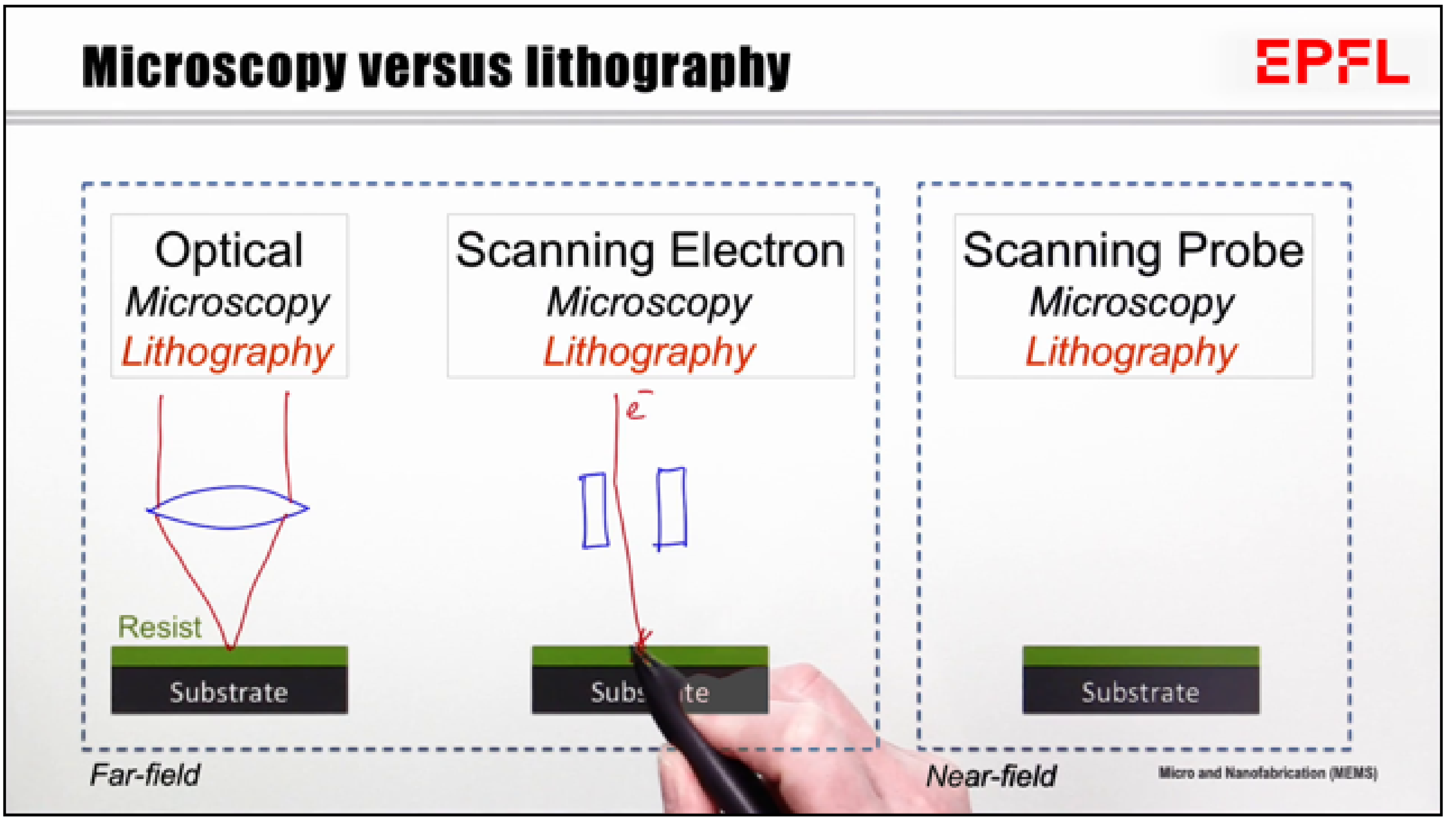


to the surface and the resolution is given here by diffraction limitations, lambda over 2.

notes

summary

1m 31s

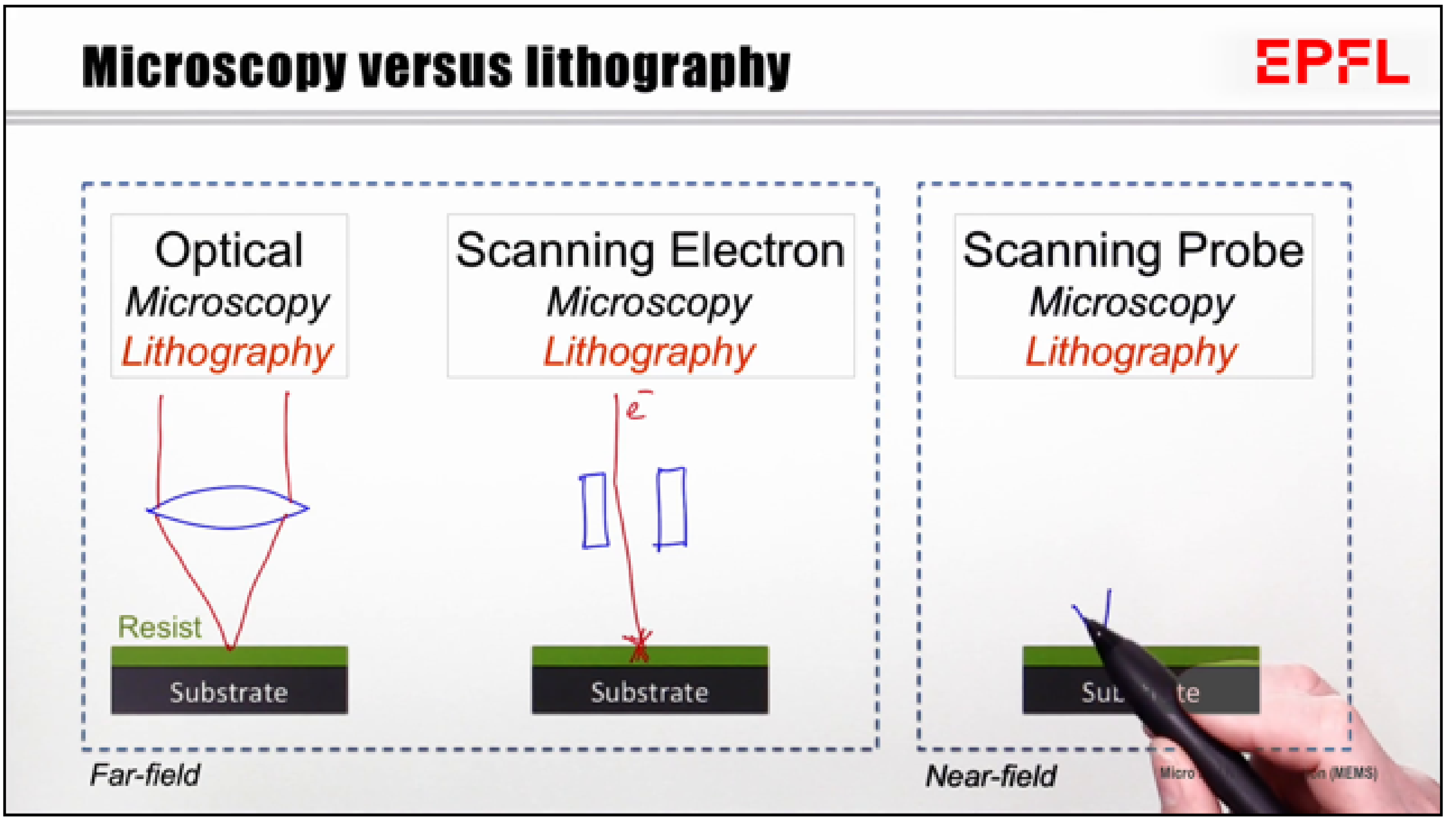


In the case of the scanning electron system for microscopy or lithography, we are using a system with electro-static lenses or magnetic lenses that can focus and control the electron beam that comes onto the resist coated substrate, and then here we have

notes

summary

1m 39s

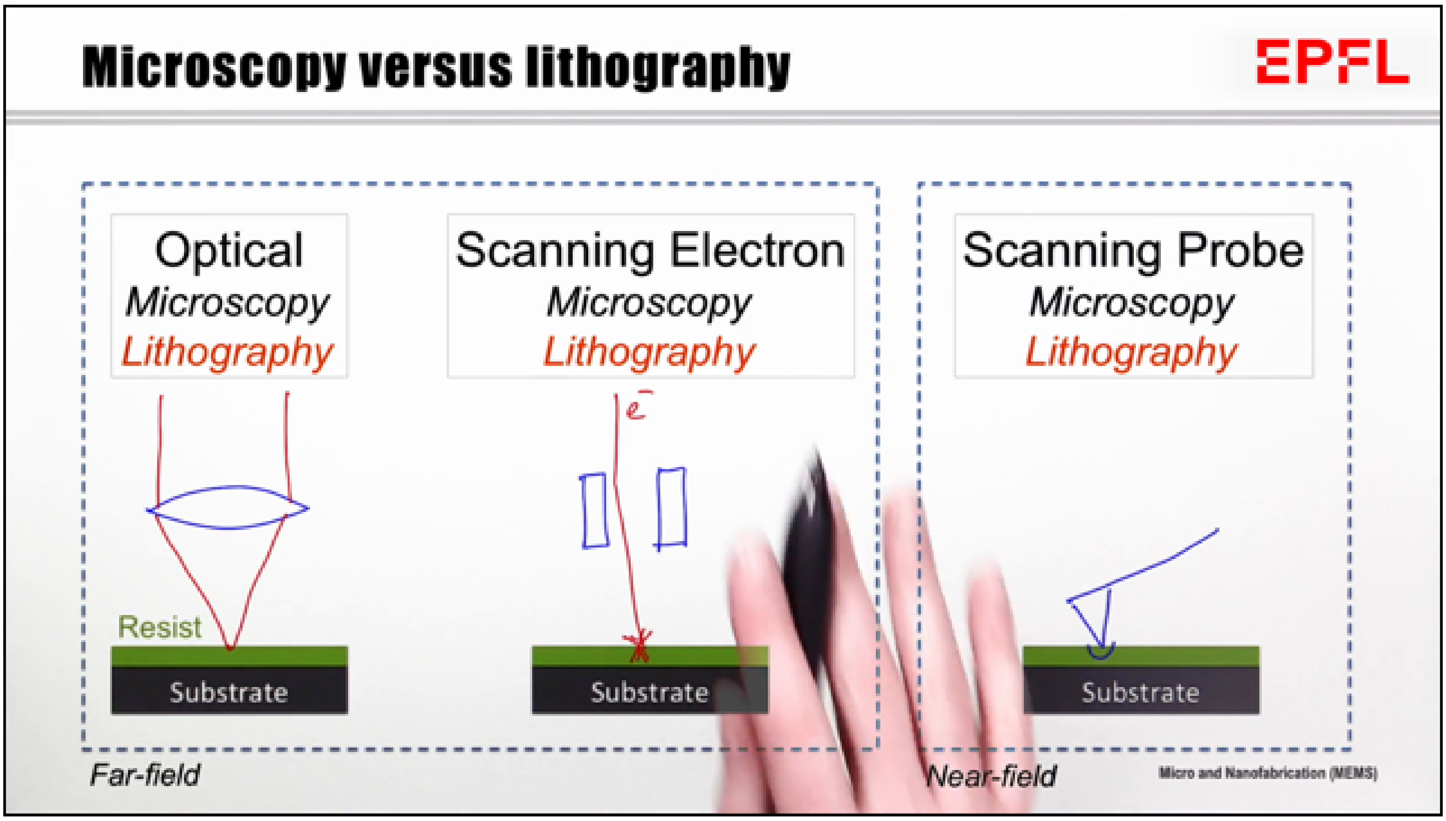


a limitation by electron scattering and focusing and charging effects. The last example is scanning probes, where we are using

notes

summary

2m 1s

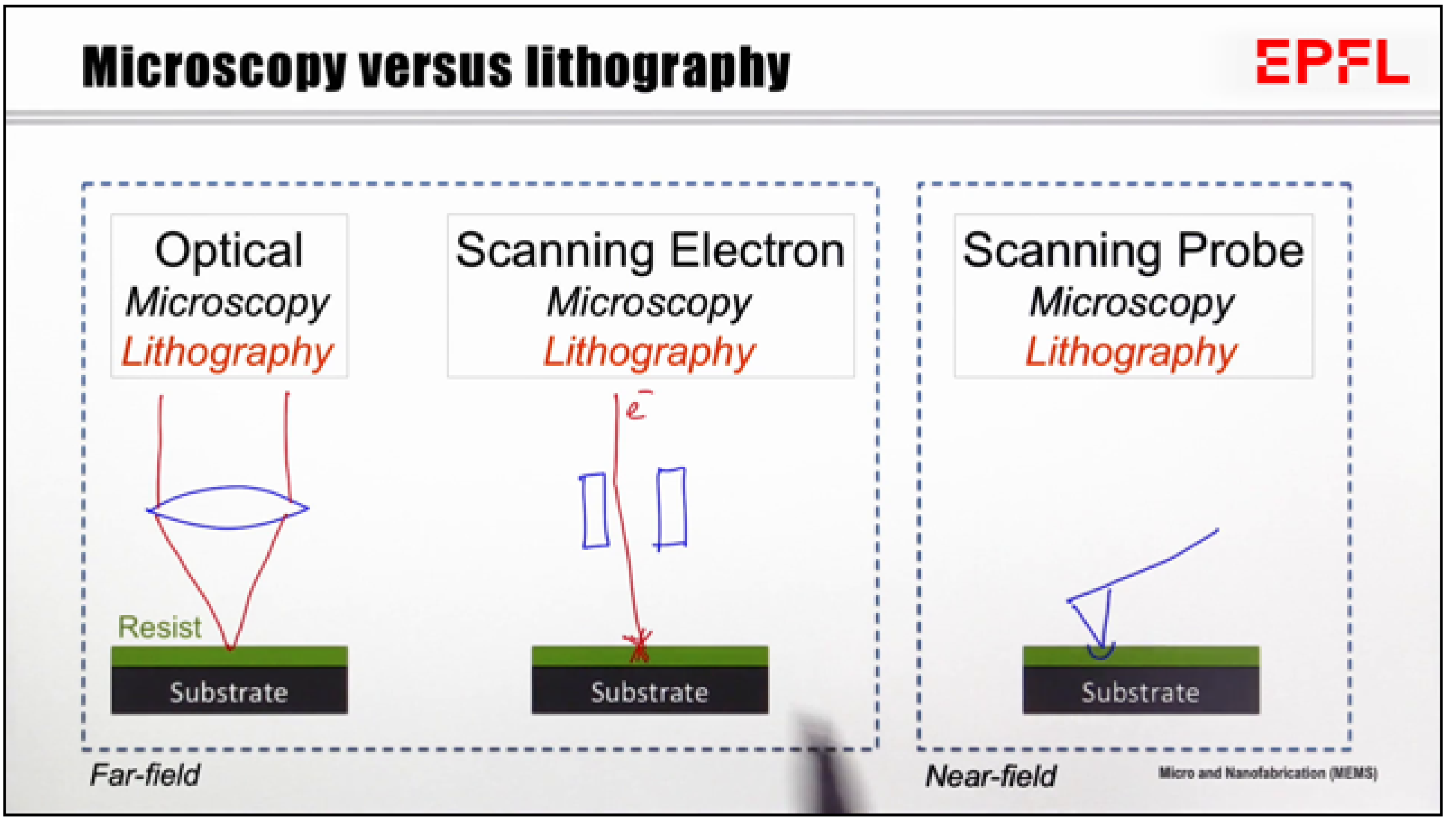


a sharp tip on a cantilever, and the resolution of this microscope or lithography as you will see, is given by the near field effect between the tip and the substrate.

notes

summary

2m 12s

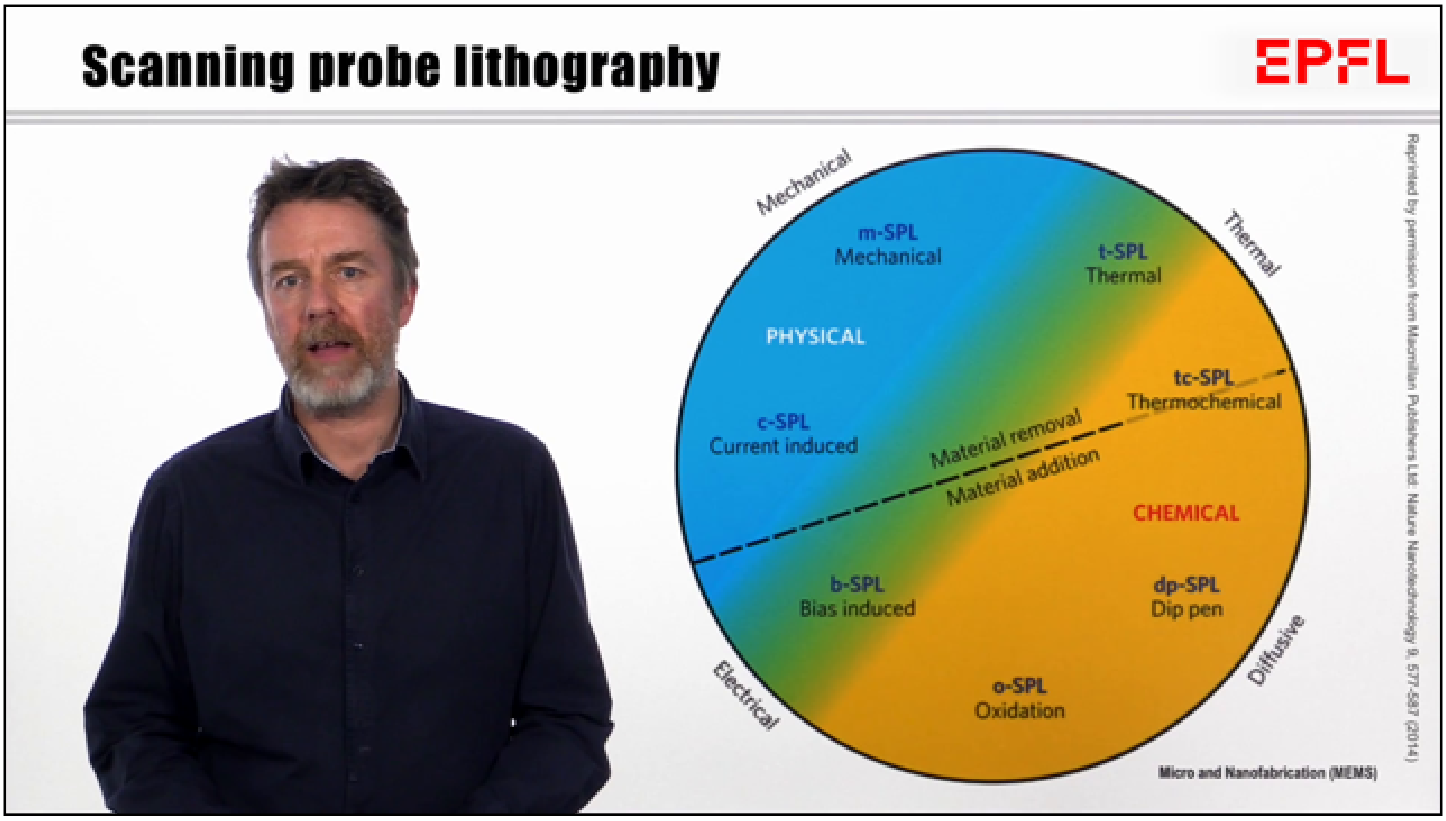


So these two systems are called far-field microscopy or lithography, because the energy source is coming from far away

notes

summary

2m 32s



and is focused on the substrate and the scanning probe is a near-field system, where we are approaching our probe very close to the surface to interact with it either for imaging microscopy, or for patterning in lithography. Here you see an overview and classification of scanning probe lithography according to the tip surface and the action used for patterning.

notes

summary

2m 39s

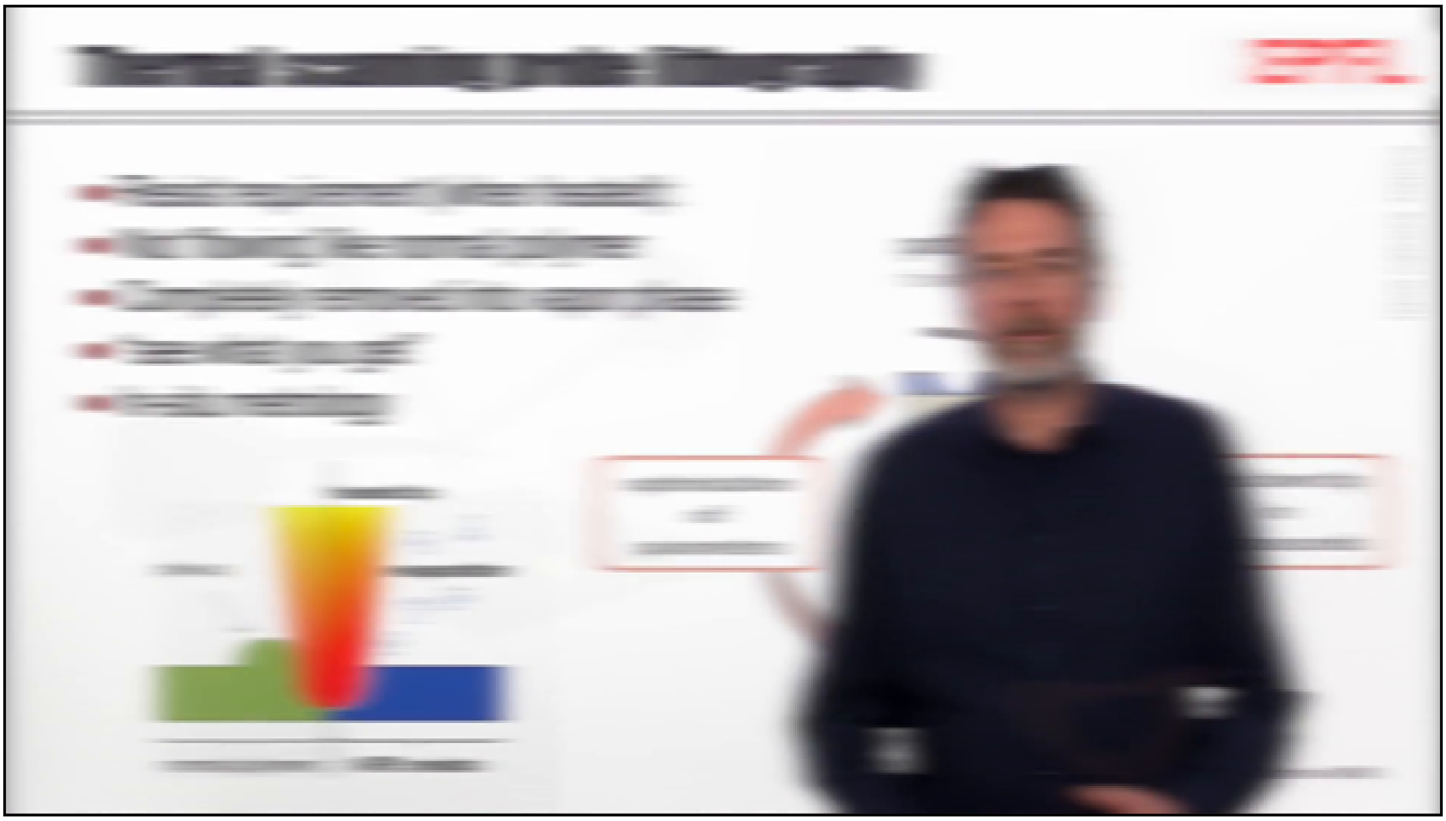
Scanning probe lithography

These interactions can be electrical, thermal, or mechanical. They can also be based on diffusive processes. We can see that there are interactions that are rather physical or chemical, and which can be used to remove material from the surface or to add material onto the surface. So it is evident that there are quite a variety of effects between a tip and the surface that can be used for patterning. The illustration here shows the general setup of an AFM based probe lithography technique. You can see the AFM cantilever, the sharp AFM tip, and the laser beam based deflection sensing, to monitor the probe position. What is also shown here is that the material underneath the tip is altered. This is done typically by means of an ultra small capillary liquid cone that exists between the tip and substrate due

notes

summary

3m 1s

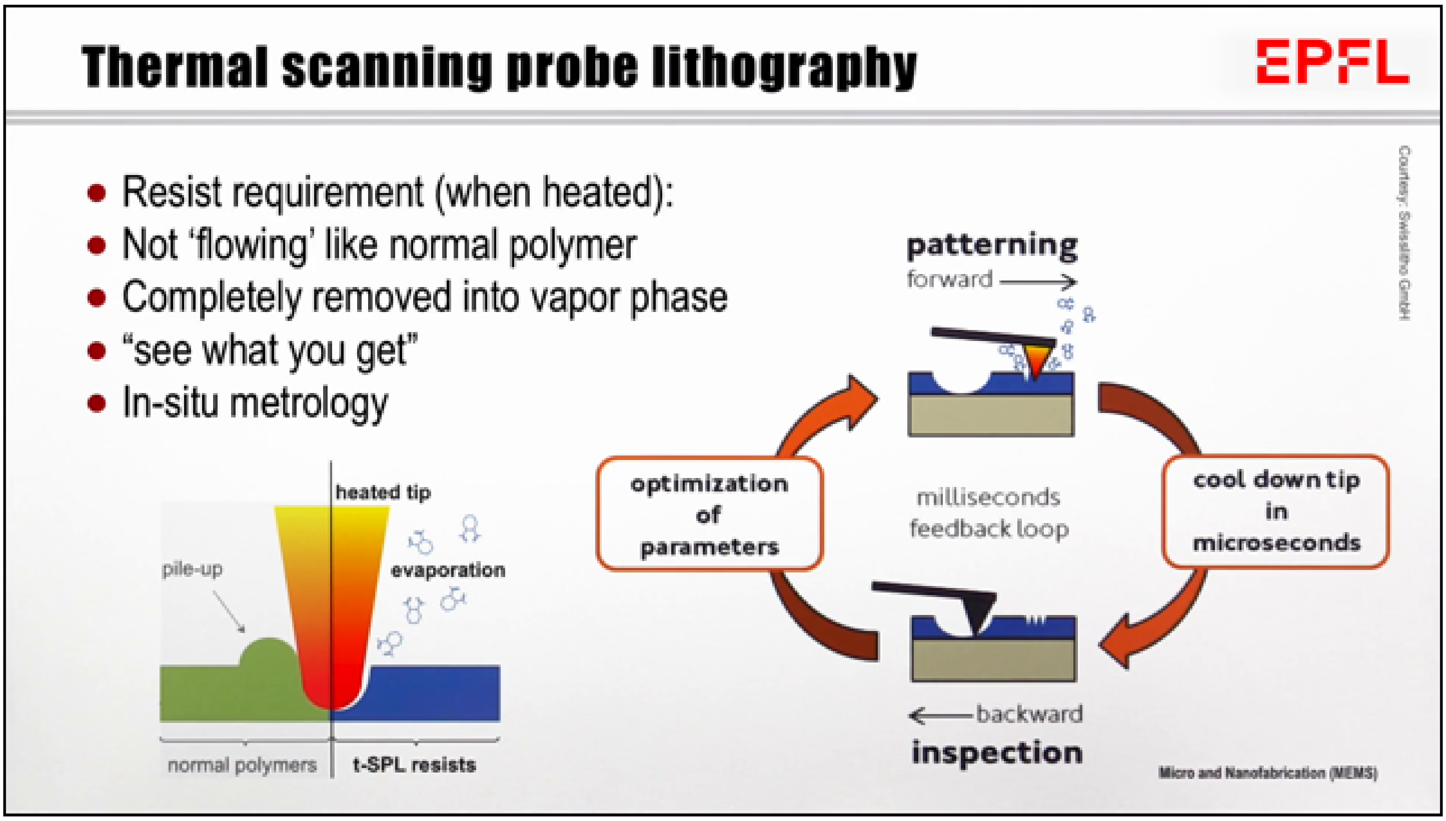


to humidity effects. Due to this capillary liquid, and eventually an applied bias voltage, one can induce specific and very local electro-chemical reactions that modify the surface material directly for lithography purposes. In such a way for instance, patterned graphene-oxide patterns can be created directly in the graphene film.

notes

summary

4m 1s



The previous examples are still on an exploratory level. They have potential as future nano-fabrications as they allow creating patterning directly in functional materials. But they are not easily adaptable for general purpose lithography that we know so well, using resist layers. Patterning resist however would ease the implementation of these new lithography methods as one could benefit from existing know-how, such as pattern transfer by etching. This is where thermal scanning probe lithography comes into play. Here, a resist is locally removed, which is therefore very close to what we normally do in photo lithography. Let me explain in detail how this works. A nanotip at the end of an AFM cantilever is heated to very high temperatures, up to 800°C or more, by an integrated resistive micro heater and is brought close to a polymer. A normal polymer reacts by softening and can be displaced or piled up under the pressure of the tip as shown here. In case one uses special polymers, that evaporate when brought above a threshold temperature, then the local heat of the AFM will not push the polymer away, but the resist will be completely removed, thereby creating an open pattern in the resist. This resist pattern can then be transferred by an etch step into the underlying substrate material, and the patterning step is completed. The resolution that can be obtained is in the order of 10 nanometers corresponding more or less to the apex radius of the tip. This is the benefit of the near field interaction. It is also a function of the nano probe thermal time constant which is in the order of 10 microseconds. A unique feature of thermal scanning probe lithography is that writing and reading of the pattern can be done hand in hand. Indeed, the integrated heaters enable not only the writing but also the in situ reading and metrology of the written patterns. This

notes

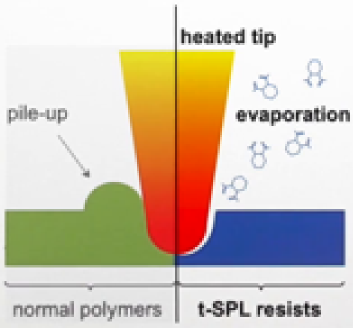
summary

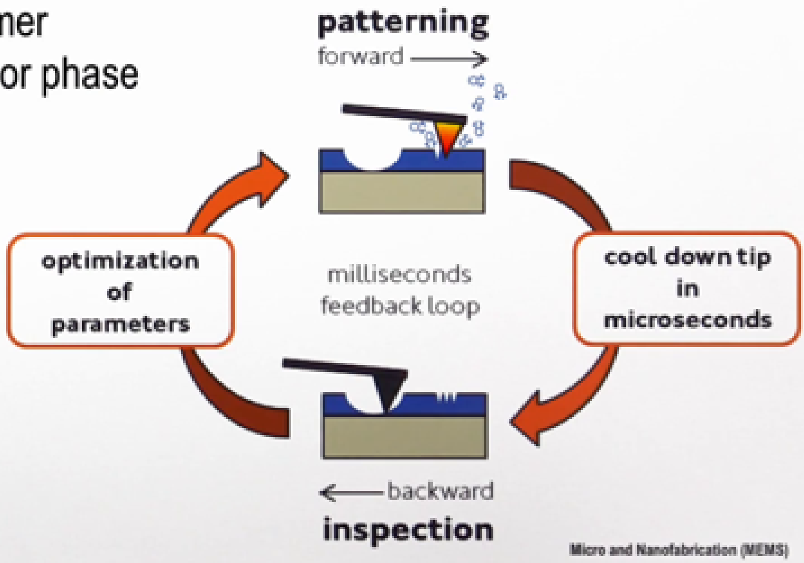
4m 25s

Thermal scanning probe lithography

EPFL

- Resist requirement (when heated):
- Not 'flowing' like normal polymer
- Completely removed into vapor phase
- "see what you get"
- In-situ metrology





Courtesy: Swisslitho GmbH

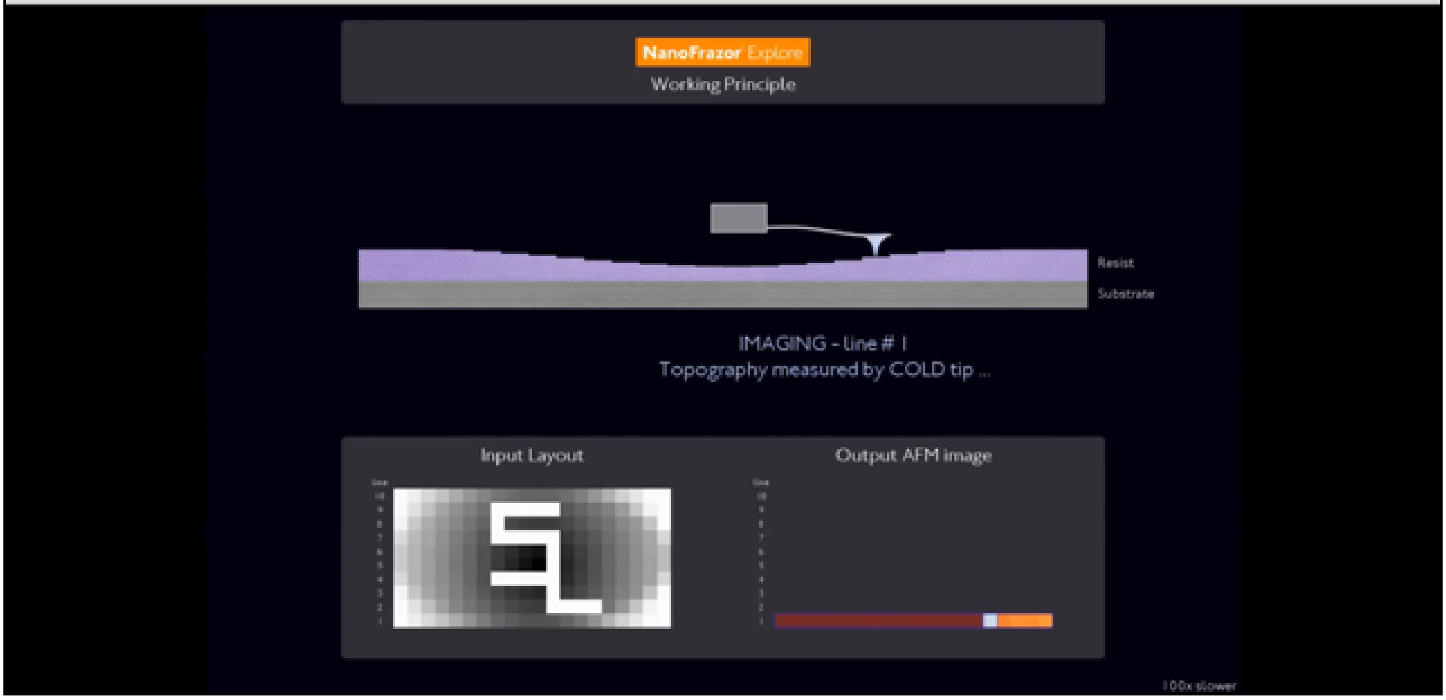
Micro and Nanofabrication (MEMS)

allows immediate feedback control, field stitching without the use of alignment markers and the use of pre-patterned structures. Another important difference compared to other lithography techniques is the following. Due to the ablative nature of the patterning process, no development step is needed. Neither are optical proximity corrections or issues

notes

summary

Thermal scanning probe lithography



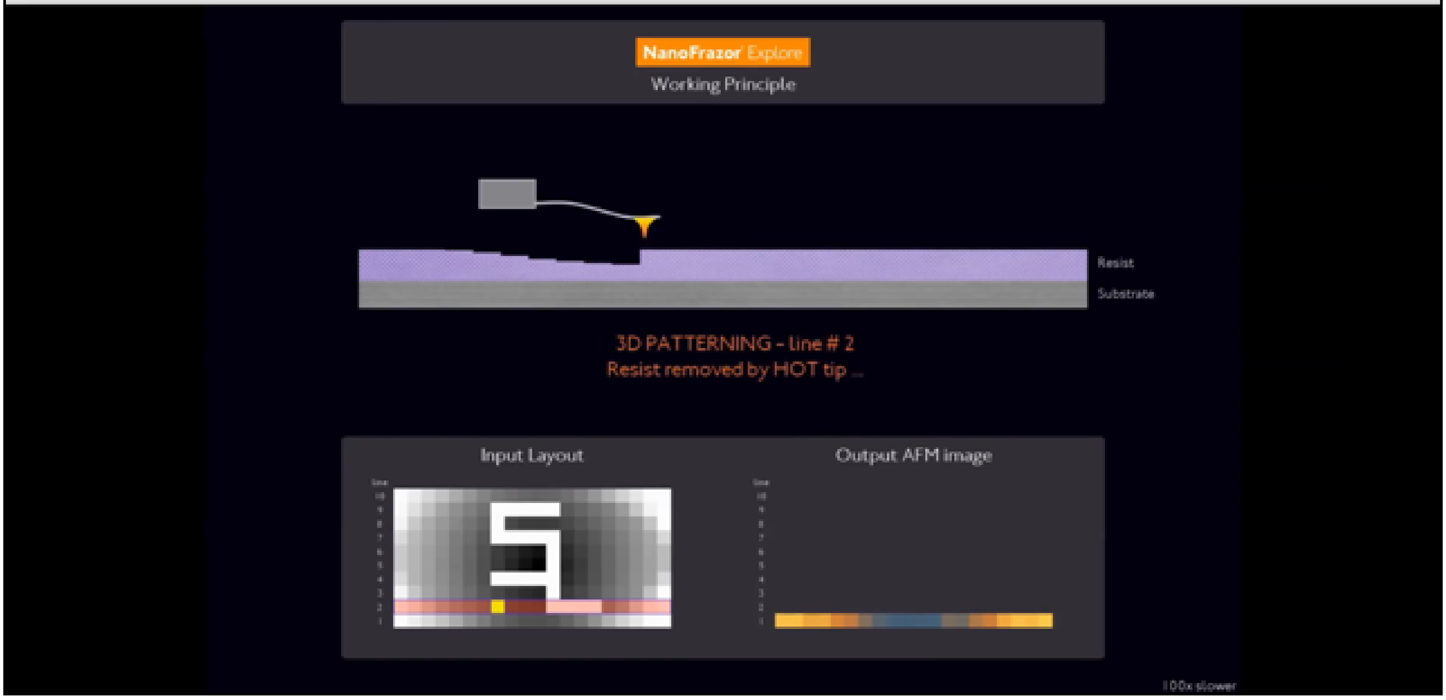
with electron scattering or electron damage in electron beam lithography to worry about. Here you see an animation of how the thermal scanning probe lithography tool is working.

notes

summary

7m 1s

Thermal scanning probe lithography



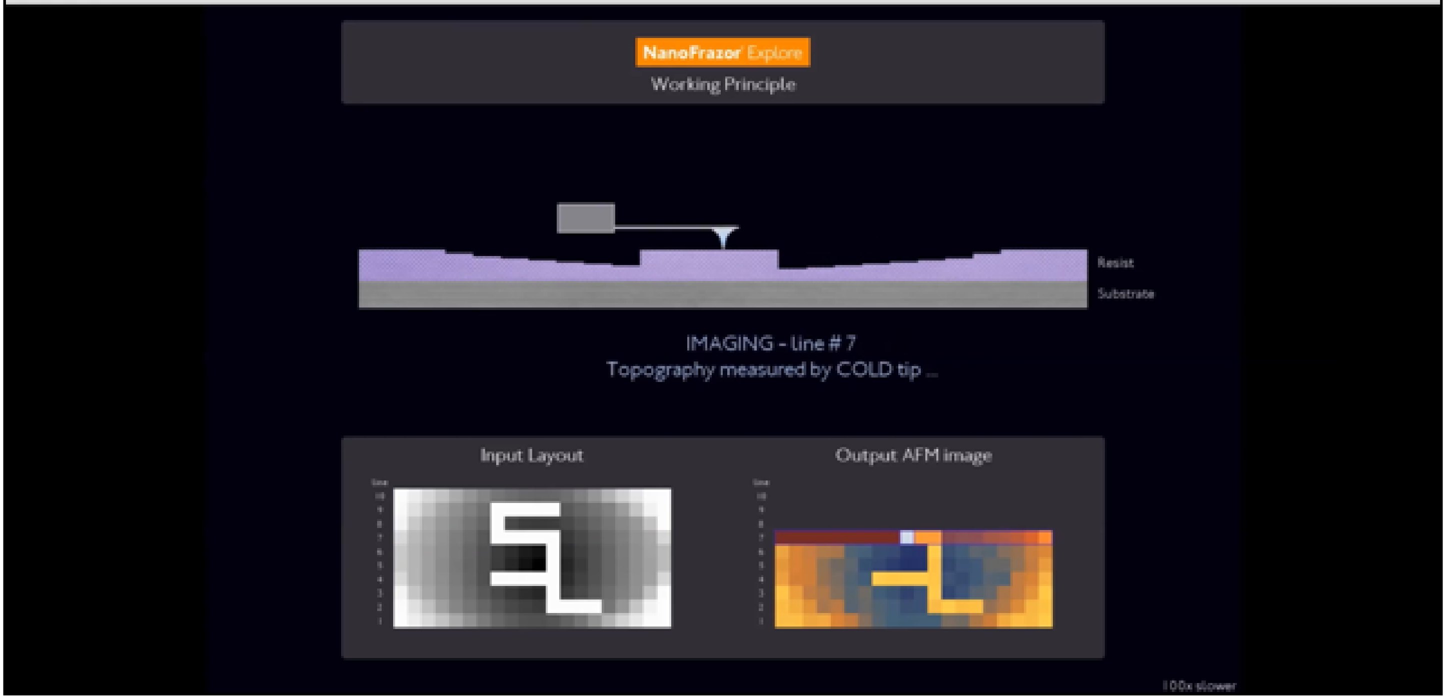
On the top, you see the side view, with the cantilever and thermal

notes

summary

7m 11s

Thermal scanning probe lithography



sensitive resist, and on the bottom, you see a top view of the scanning surface. The layout on the left, and the output AFM image on the right. The tool writes line by line. On the way from left to right, the hot tip is writing into the resist, and on the way from right to left, the tip is reading the written pattern. This is repeated line by line, until the 2D pattern has been completed.

notes

summary

7m 14s