Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

4.4 Lithography 2, Mask and Laser writing

Concepts (extracted from automatically generated subtitles):

Use of a direct laser writer. Direct laser writing. Photo mask. Final write head. Scanning laser beam. Exposure duration. Additional features of direct laser writing. Process flow. Inch wafer. Serial writing. Final photomask. Physical mask. Exposed areas. Fabrication of a photo mask. Finer lens of different focal lengths.

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

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notes

summary

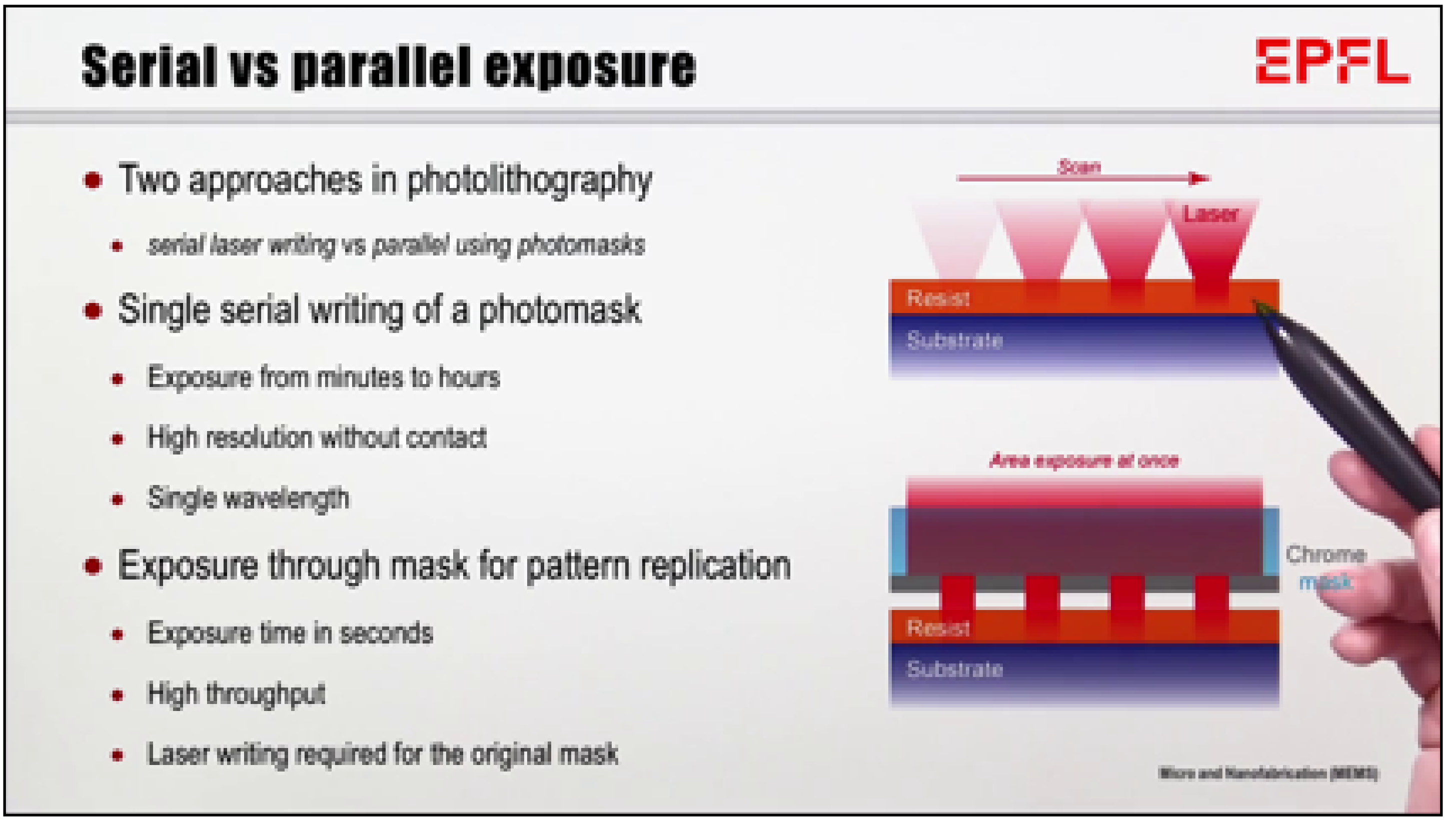
0m 0s

In this lecture I will describe the process flow for making a photo mask.

notes

summary

0m 1s



I will in particular focus on the use of a direct laser writer that allows to convert a CAT file into a physical mask. I will also show a couple of cleanroom videos that demonstrate the technique and conclude with some examples. In this lesson we are going to focus on the direct laser writing and the fabrication of a photo mask used in a mask aligner for UV photolithography. There are 2 main approaches in light based lithography. One being the serial writing using a scanning laser beam on the substrate referred to as 'direct laser writing'. The second approach consists of exposing the substrate through a mask. The exposure duration for direct laser writing, being a serial process will heavily depend on the surface and dose to deliver to the photoresist. In practice, the exposure of a 4 inch wafer or a 5 inch mask can take from a few minutes to more than an hour depending additionally on the required resolution. Direct laser writing is therefore mainly used for mask making and eventually for some prototyping and fabrication of small batches

notes

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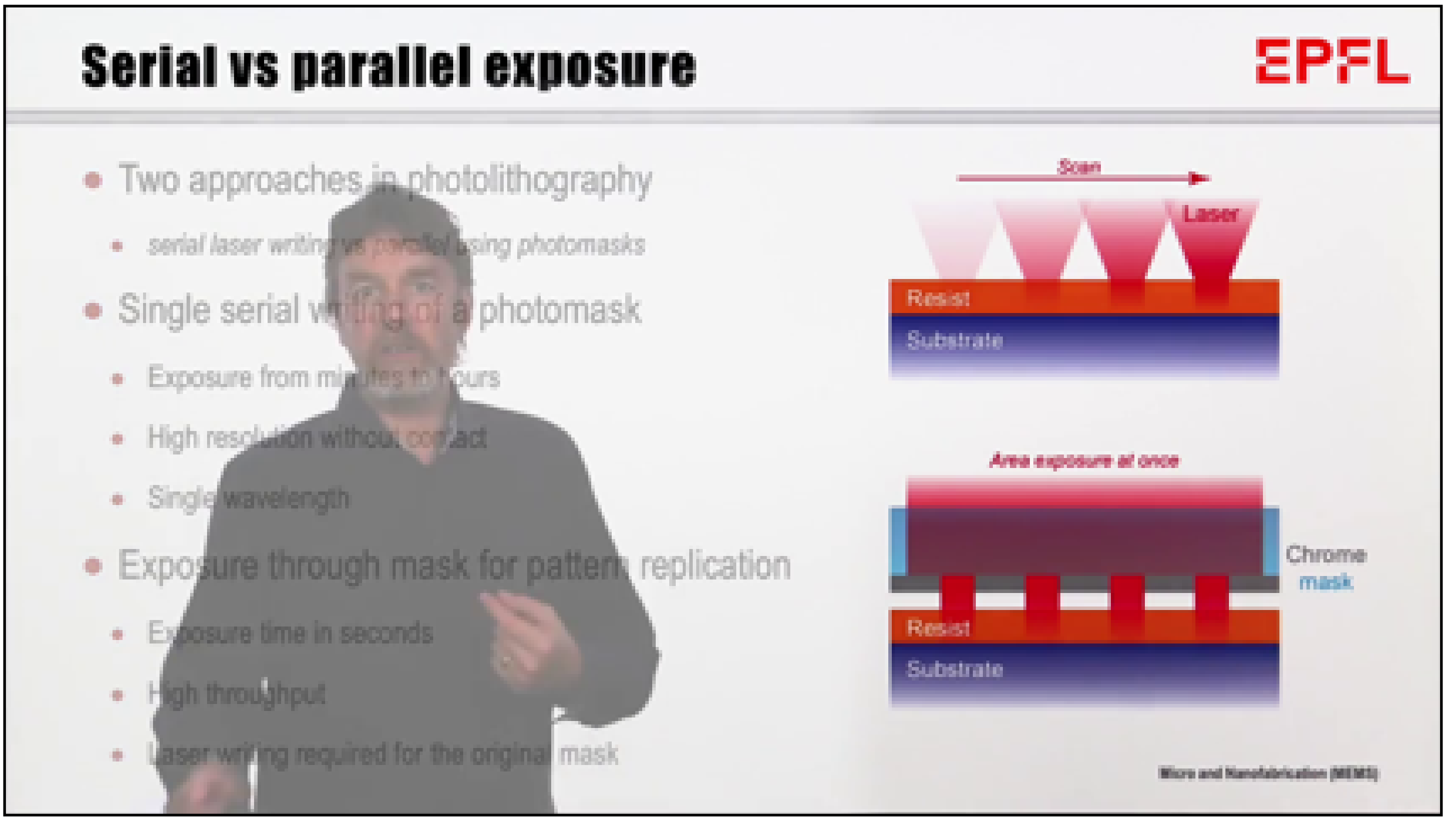
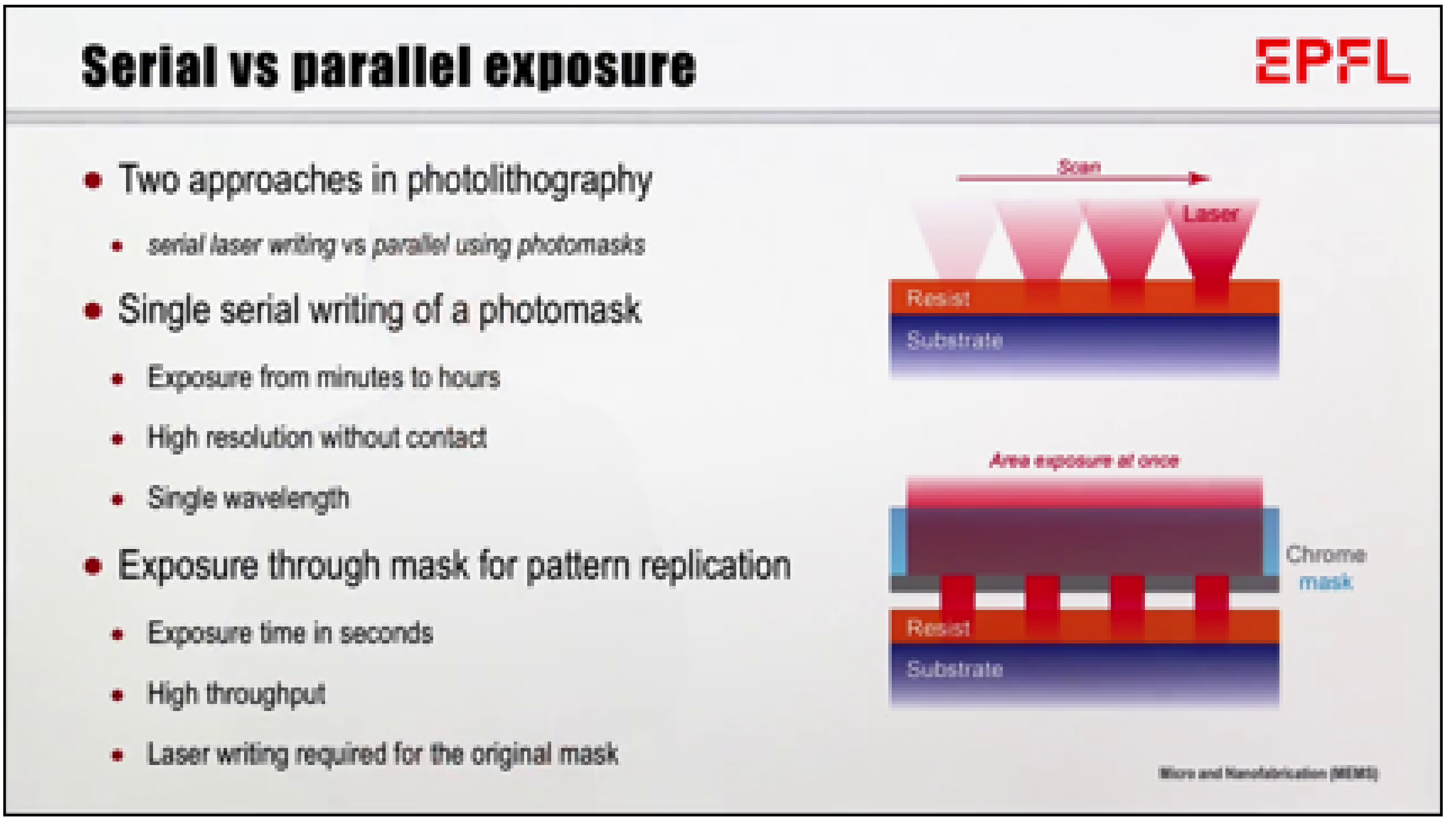


where a mask based exposure will be preferred in the case of large series.

notes

summary

1m 25s

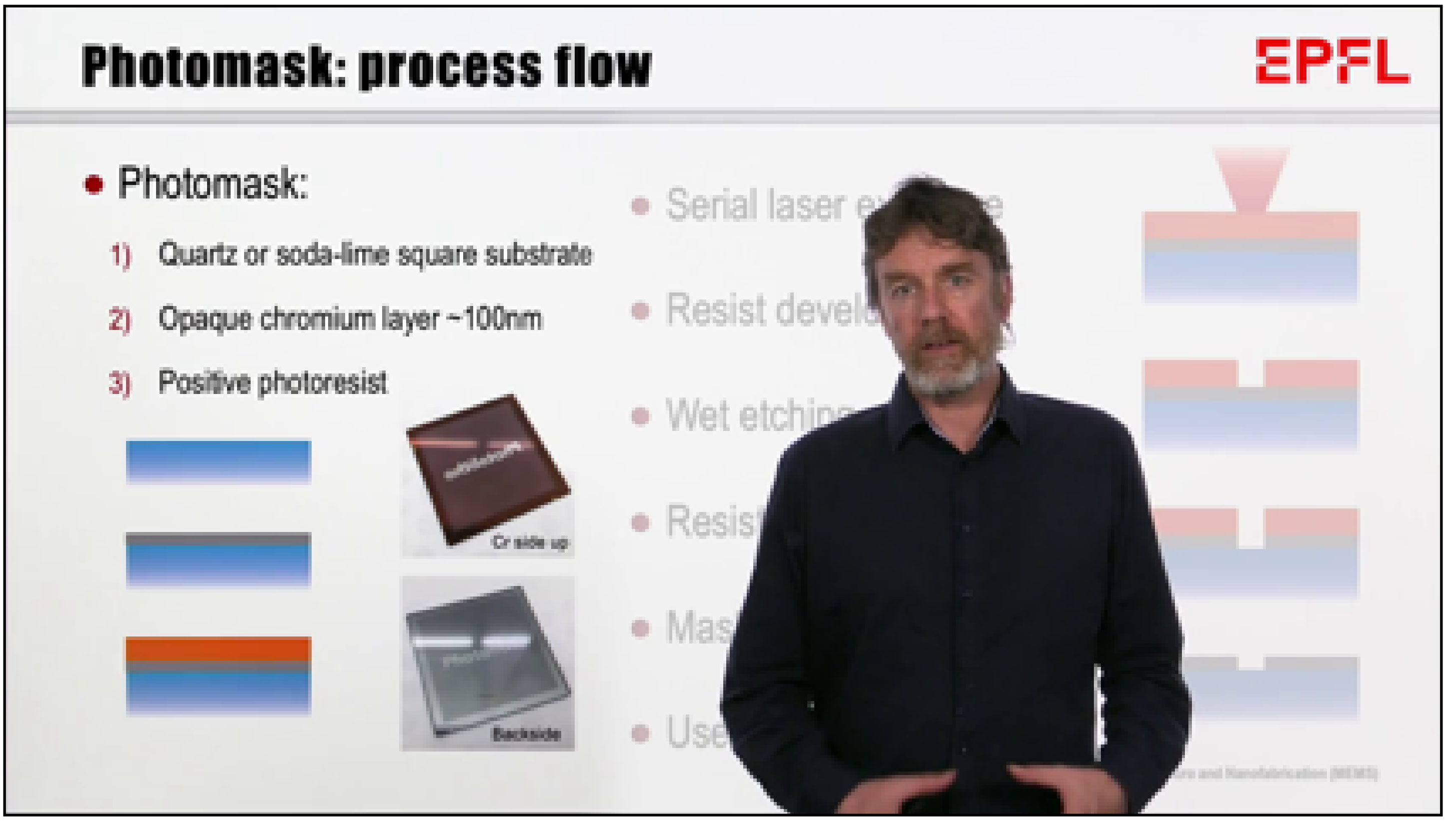


Additional features of direct laser writing include the possibility to obtain high resolution features in a non-contact manner. The laser-based light source additionally allows for very high power densities and narrow line width. For ultimate resolution of mask features such as needed for deep UV, e-beam lithography is an alternative.

notes

summary

1m 32s



In the exposure through a mask method, here shown, we gain a lot in time as now the entire wafer or part of it is exposed in just a few seconds so we can get high throughput and produce many wafers per hour. Still, for making the mask, we need a writer; either laser or electron based.

notes

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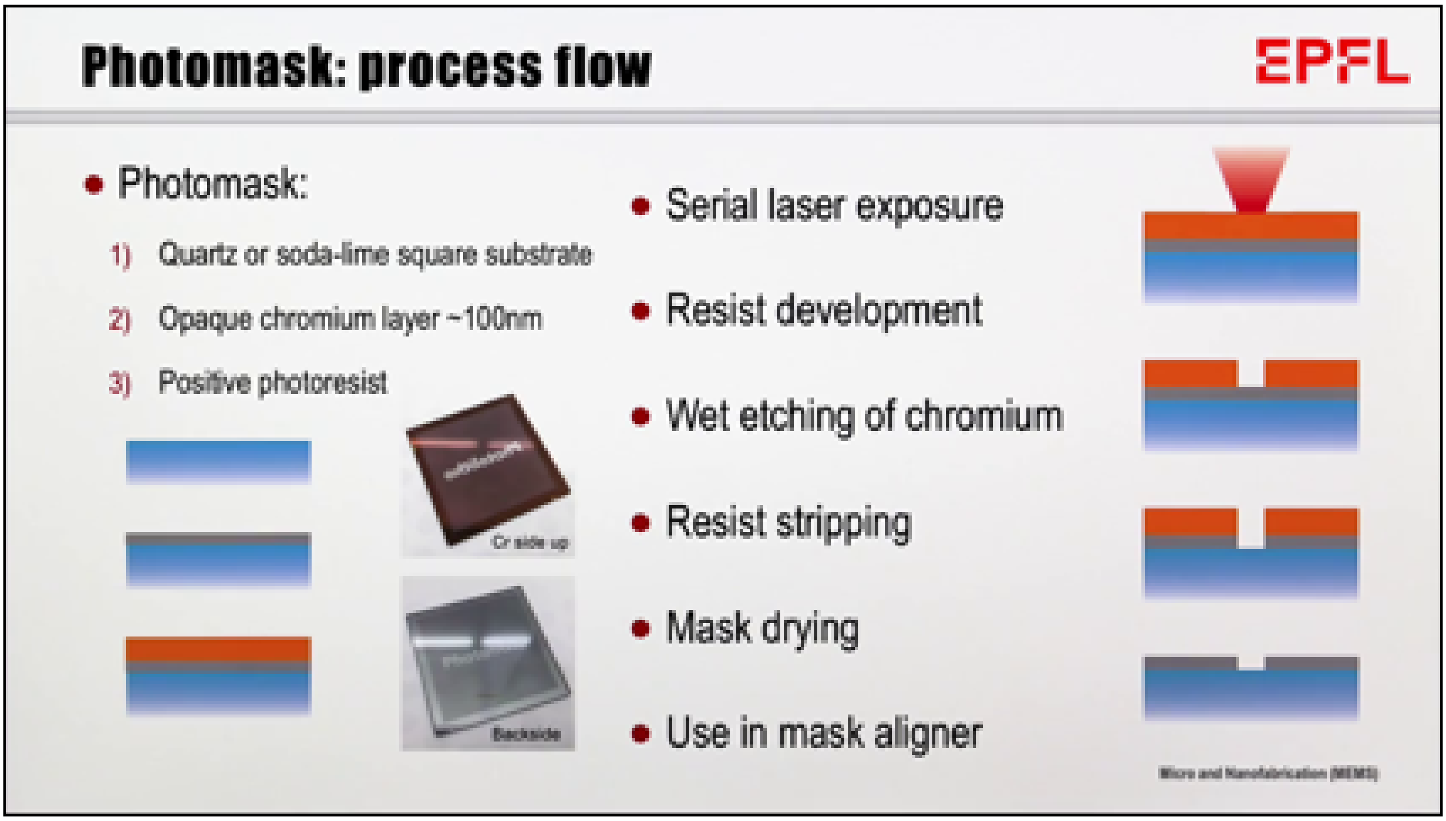
1m 56s

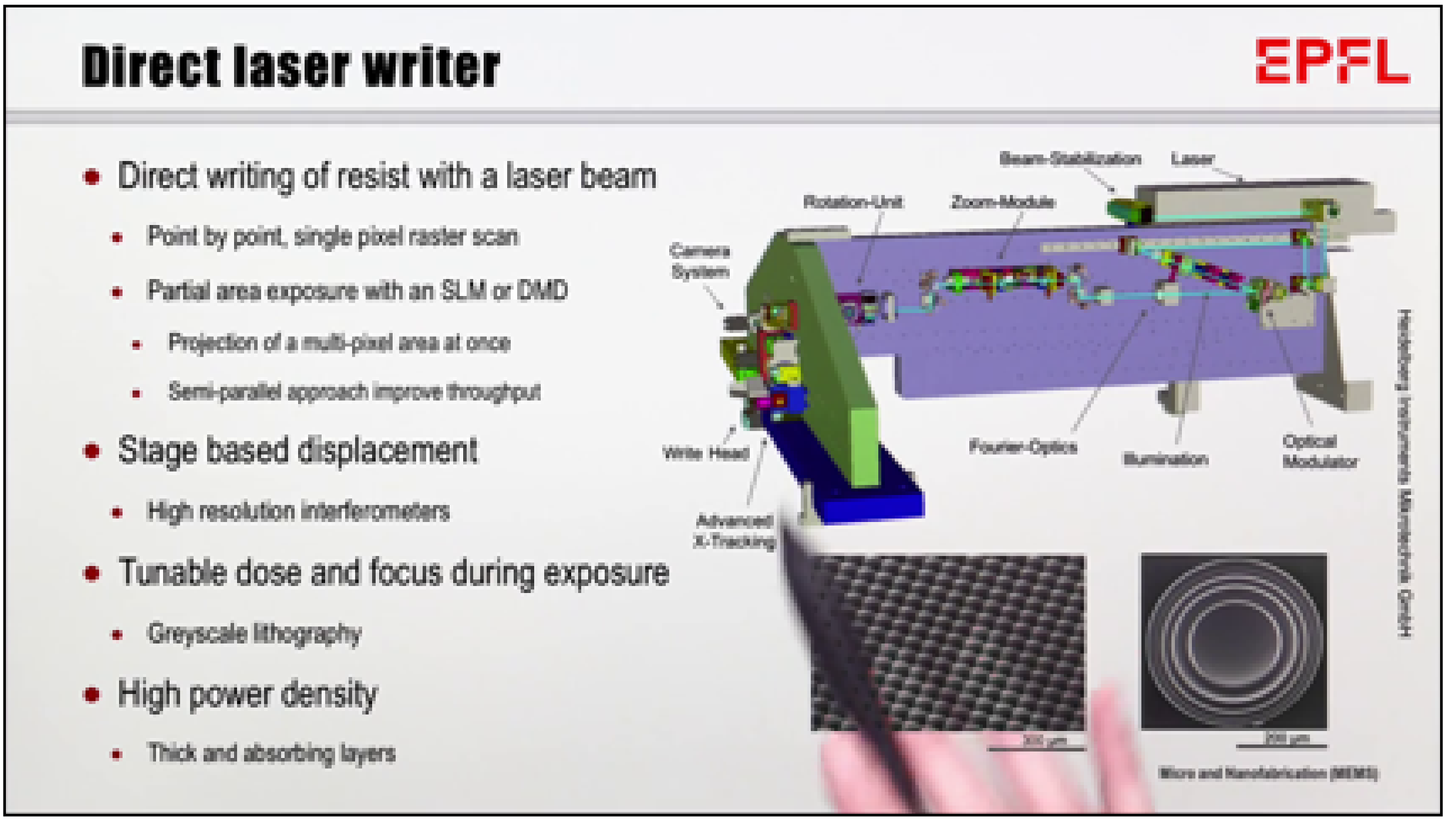


Before going into details of direct laser writers we will first have a look at the process flow for the fabrication of a photomask that will stand as a motivation throughout this chapter. A photomask consist of a thick quartz or soda-lime square plate coated with a thin, opaque chromium layer. In order to pattern this chromium layer, that will selectively block or allow light to pass during the exposure, we must perform the following sequence of steps.

notes

summary

2m 19s



After coating the mask with a layer of photoresist, that is typically of positive tone and sub-micrometer thick, a laser writer is used. By scanning and blanking the laser beam one can expose arbitrary patterns into the resist layer. Then follows the development of the resist to reveal the desired portions of chromium. The metal can then be etched in wet chemistry before removing the resist in solvents to obtain the final photomask. A direct laser writer consists of a laser light source and a variety of optical components that will shape the beam and tune its intensity before impinging the wafer, which would be down here. This would be the place where we place the wafer. The beam may either be focussed into a single spot or shaped by a spatial light modulator (SLM) or digital mirror display (DMD) to project a line or area of pixel at once in order to improve throughput. Various elements, including the final write head enable the control of demagnification of the projected pattern as well as final resolution. Additional important elements include a high resolution mechanical stage equipped with an optical interferometer to displace the wafer under the static write head

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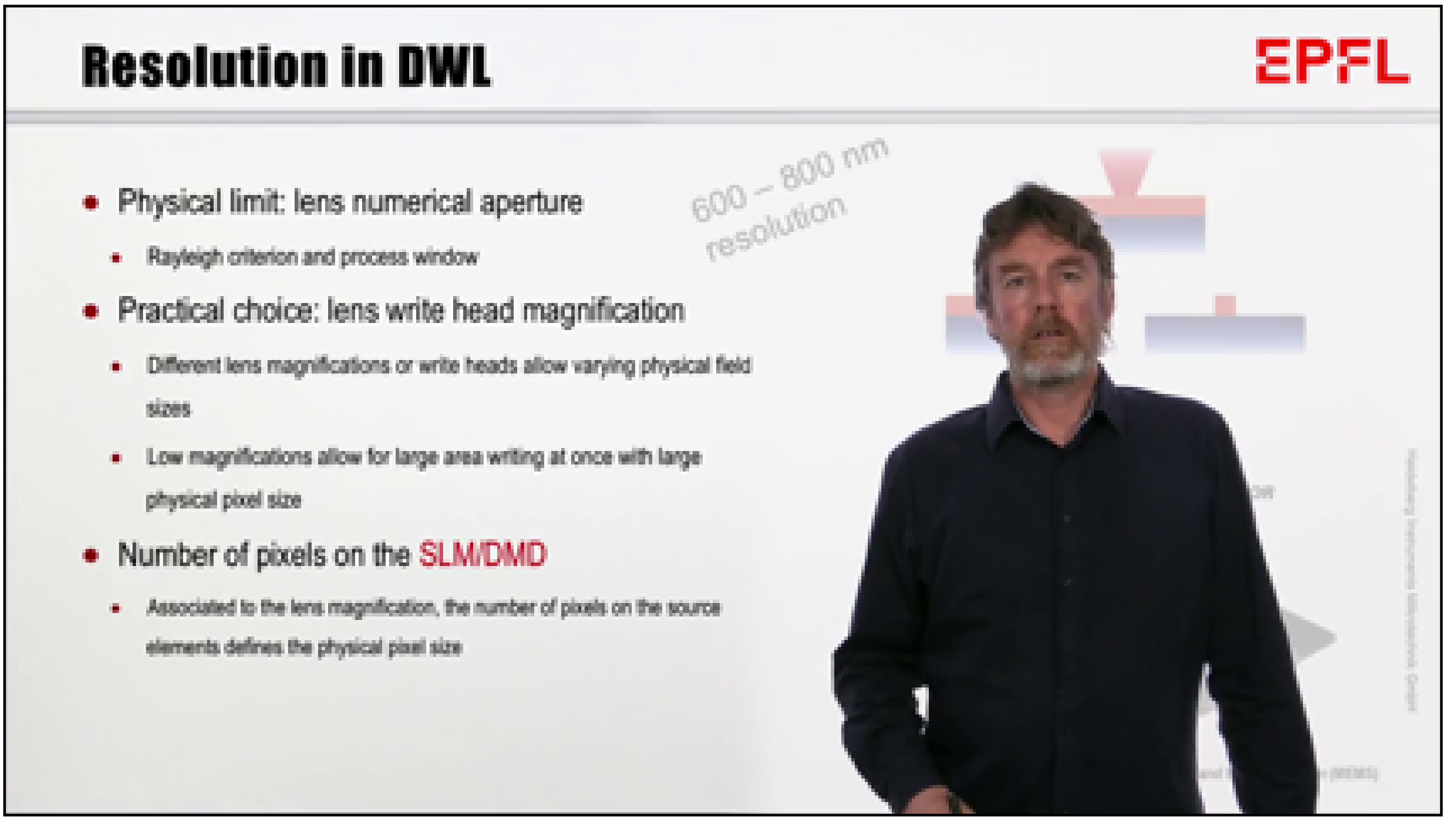
2m 49s



as well as an independent camera and illumination system in order to image and register alignment marks for multiple layer processes. When compared to parallel exposure in a mask aligner, direct laser writing enables convenient dose modulation throughout the exposure. This allows, for example, greyscale lithography where the dose is modulated to partially expose the resist layer and tune its final form in 3D. This is additionally useful to perform dose tests on sensitive patterns. The 2 SEM images here show examples of such 3D greyscale lithography. A micro-lens area here on the left and the planar lens with circular fragmented slopes here. But these patterns are impossible to make with planar UV lithography and can only be made by a direct laser writer where one can control the exposure dose locally on the photoresist.

notes

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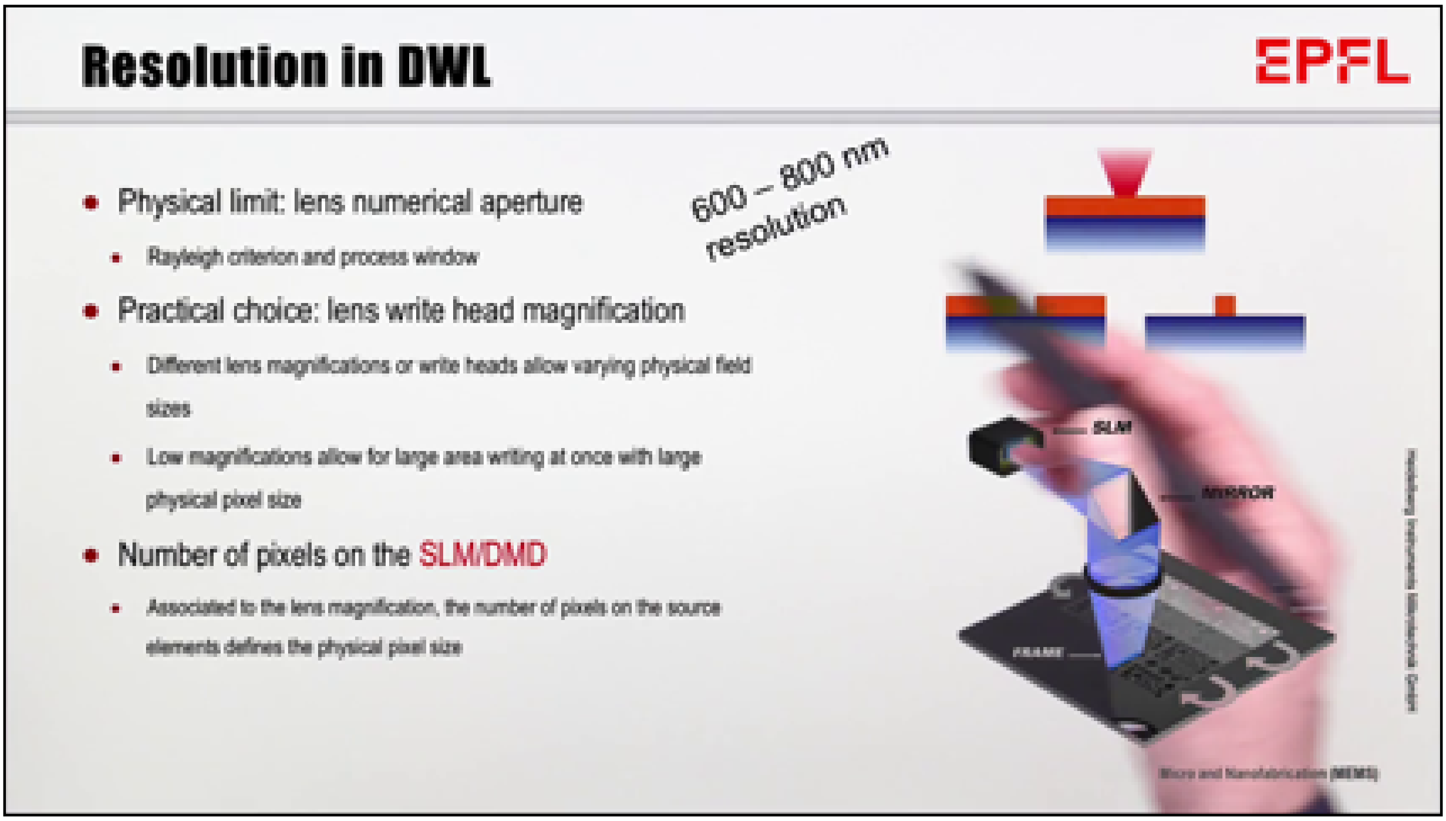
4m 13s

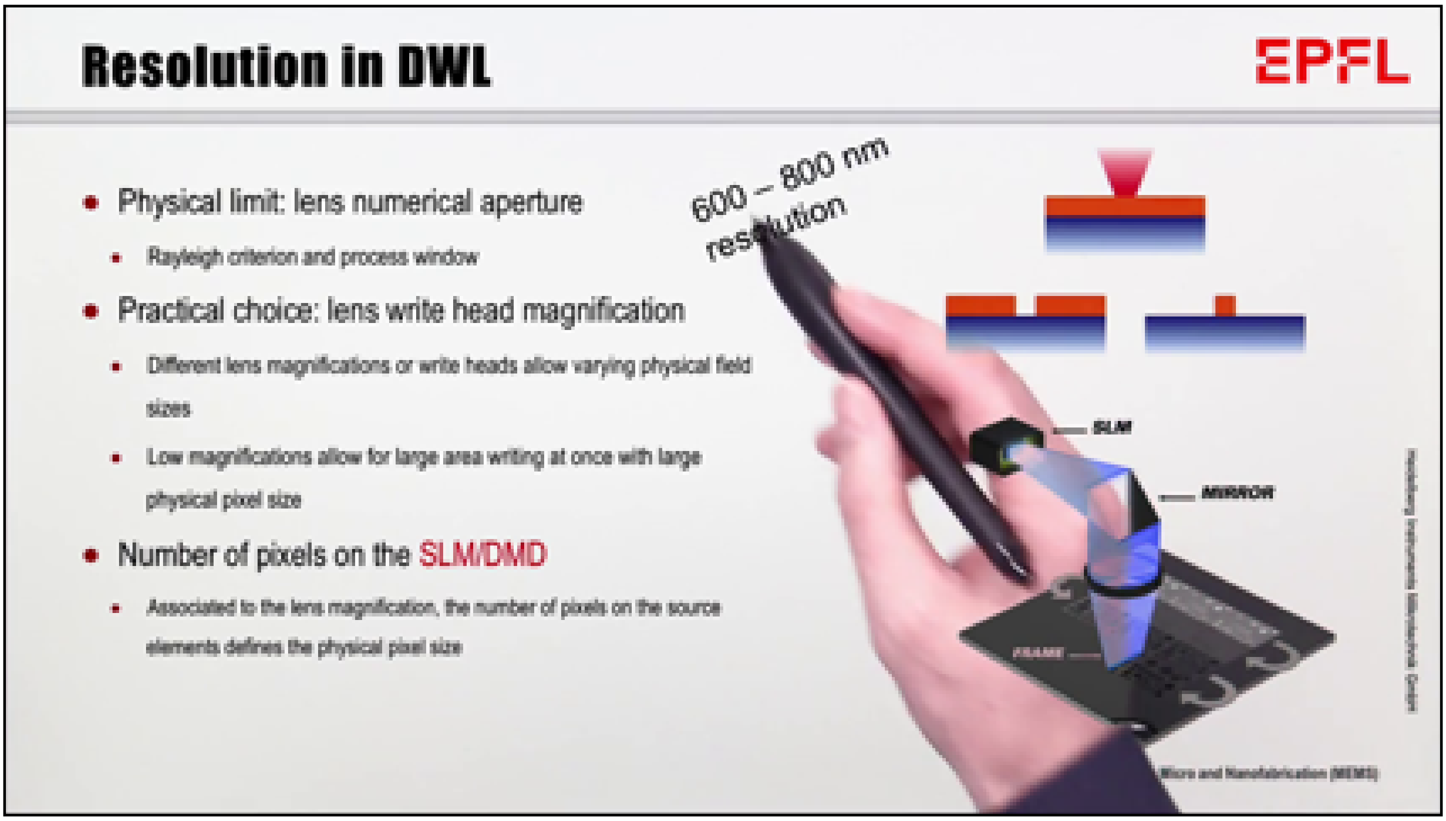


The ultimate resolution limit in direct laser writing is based on the Rayleigh criterion and is approximately λ/2 times the objective numerical aperture. This gives a good idea of how finely the laser beam may be focussed on the surface of the resist. In practice this theoretical value must also be compared to the resolution limit and processing of the photoresist, resulting in an ultimate resolution

notes

summary

5m 13s

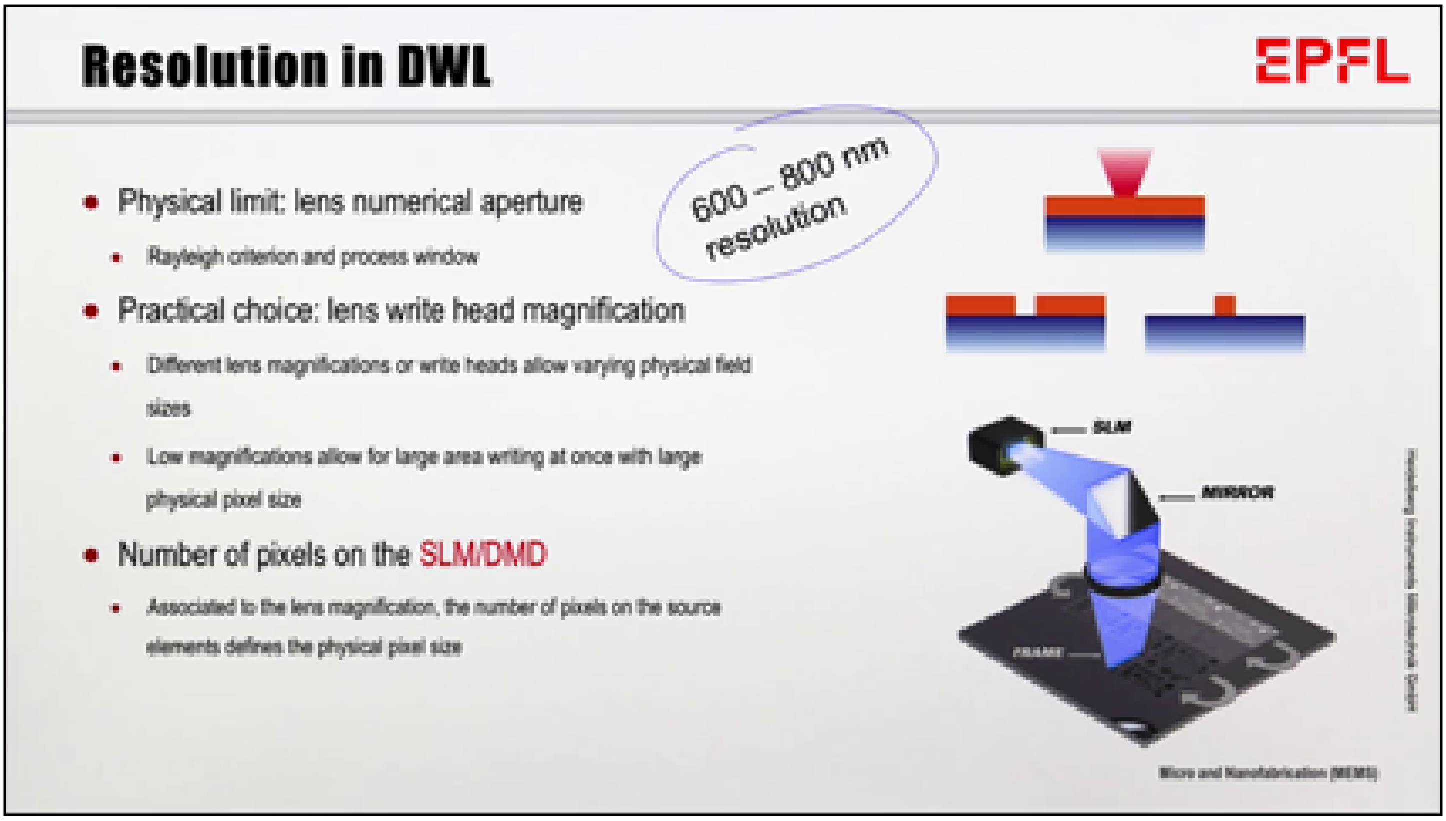


which is typically in the order of 600 to 800 nm.

notes

summary

5m 37s



The final write head of the laser writer may also be exchanged with a finer lens of different focal lengths to adapt to the writing surfaces and required resolution. Longer focal lengths will allow, for example for the projection of a space light modulator over a larger area and thus allowing for faster writing but will result in a lower resolution. This is due to 2 effects: First, the contribution of longer focal lengths reduces the length's numerical aperture for a given entrance pupil and second, the fact that the same number of pixels being projected over a large area effectively increases the pixel size

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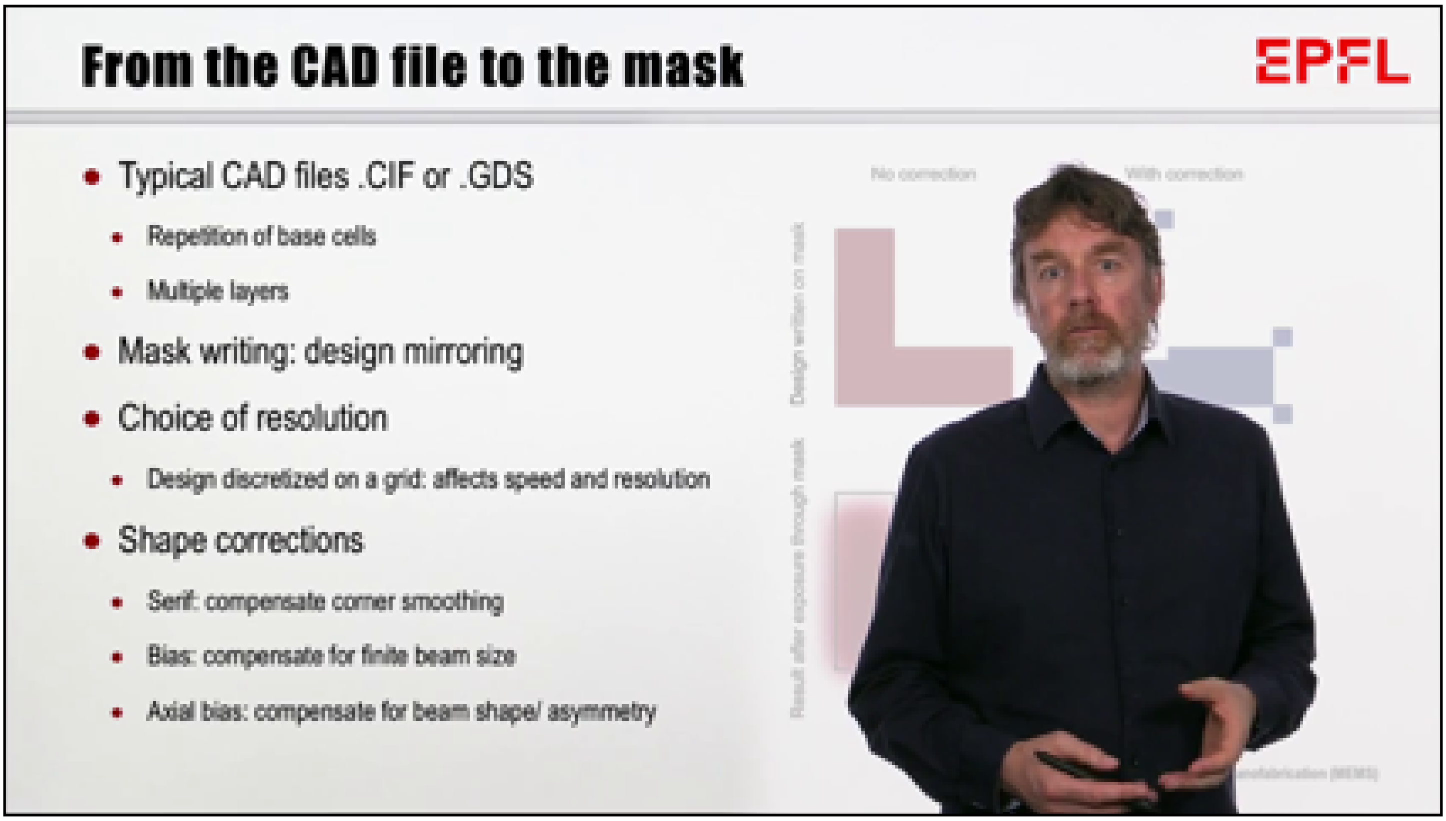
summary

5m 38s

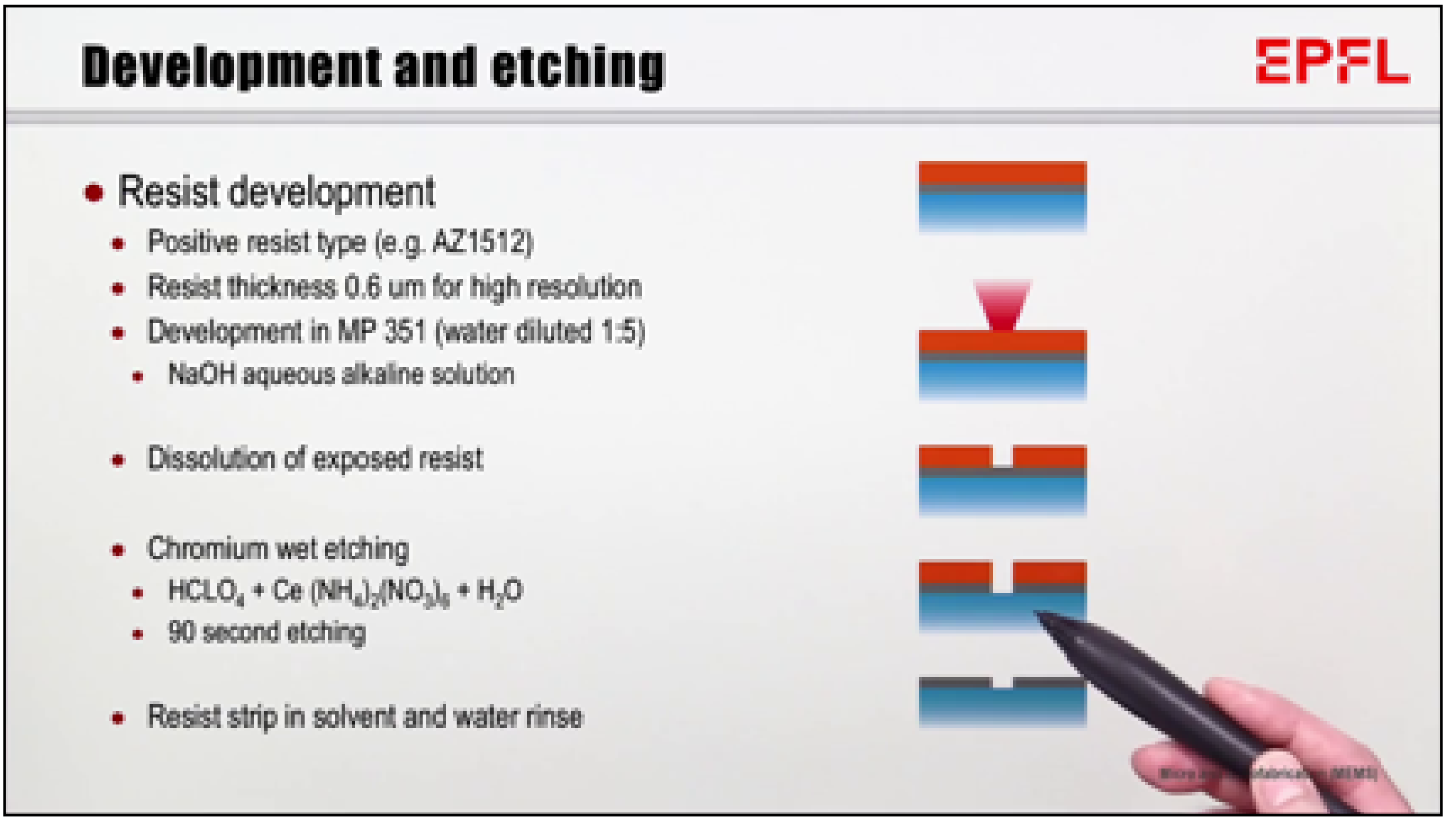


and minimal feature size. In this context, one may also indirectly relate the number of assignable elements on the SLM to the final resolution of a system. Typically the CAT files that define the design to write consist of a vectorial description of different layers and repetition of basic cells. They are of a standard format called CIF or GDS. It is interesting to point out that the fully written 4 inch wafer may contain hundreds of millions of features that must be handled

notes

summary

6m 25s



when converting the design from its original form to a laser writable one. Essentially the final design preparation may include simple steps such as the mirroring of the design in order to obtain the desired pattern after projection through a photo mask. More complex operations include the fracture of the design into sub-elements or stripes that the laser writer will write. This will essentially depend on the desired resolution. Advanced features include shape corrections that take the entire process into account in order to obtain final features as close as possible to the original design. One example is the use of serifs, shown here to compensate for diffraction at sharp edges or to add some bias to the exposure to compensate for the final beam size as well as the axial asymmetry. Now that the resist layer on the chrome coated mask has been exposed the positive resist is developed. Here we are using 600 nm thick positive photoresist. The development is performed in an alkaline solution. After thorough rinsing, the exposed areas are cleared and ready for the etching. The etching of chromium is here done via wet chemistry. The process is isotropic and may result in

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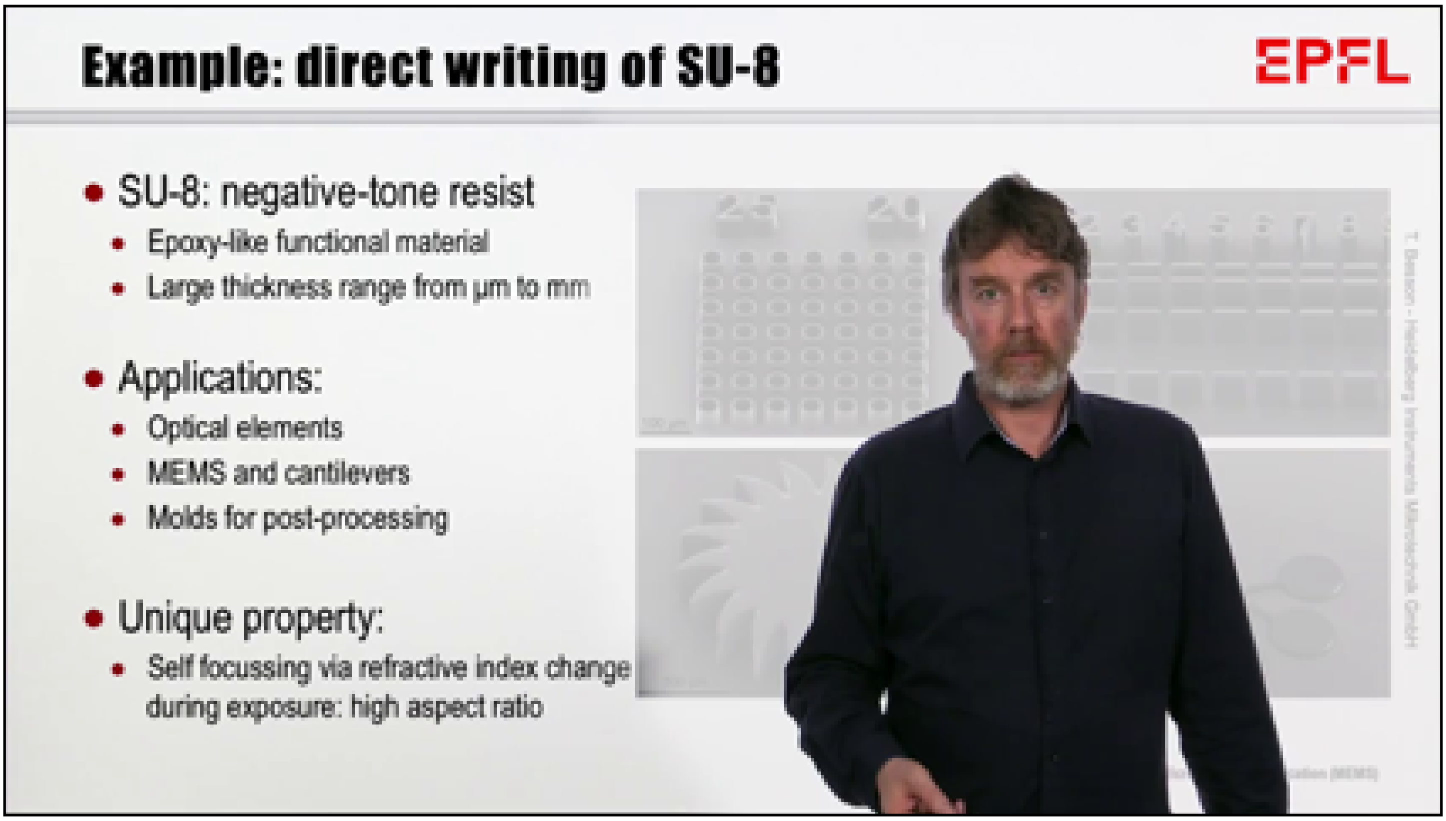
summary

7m 1s

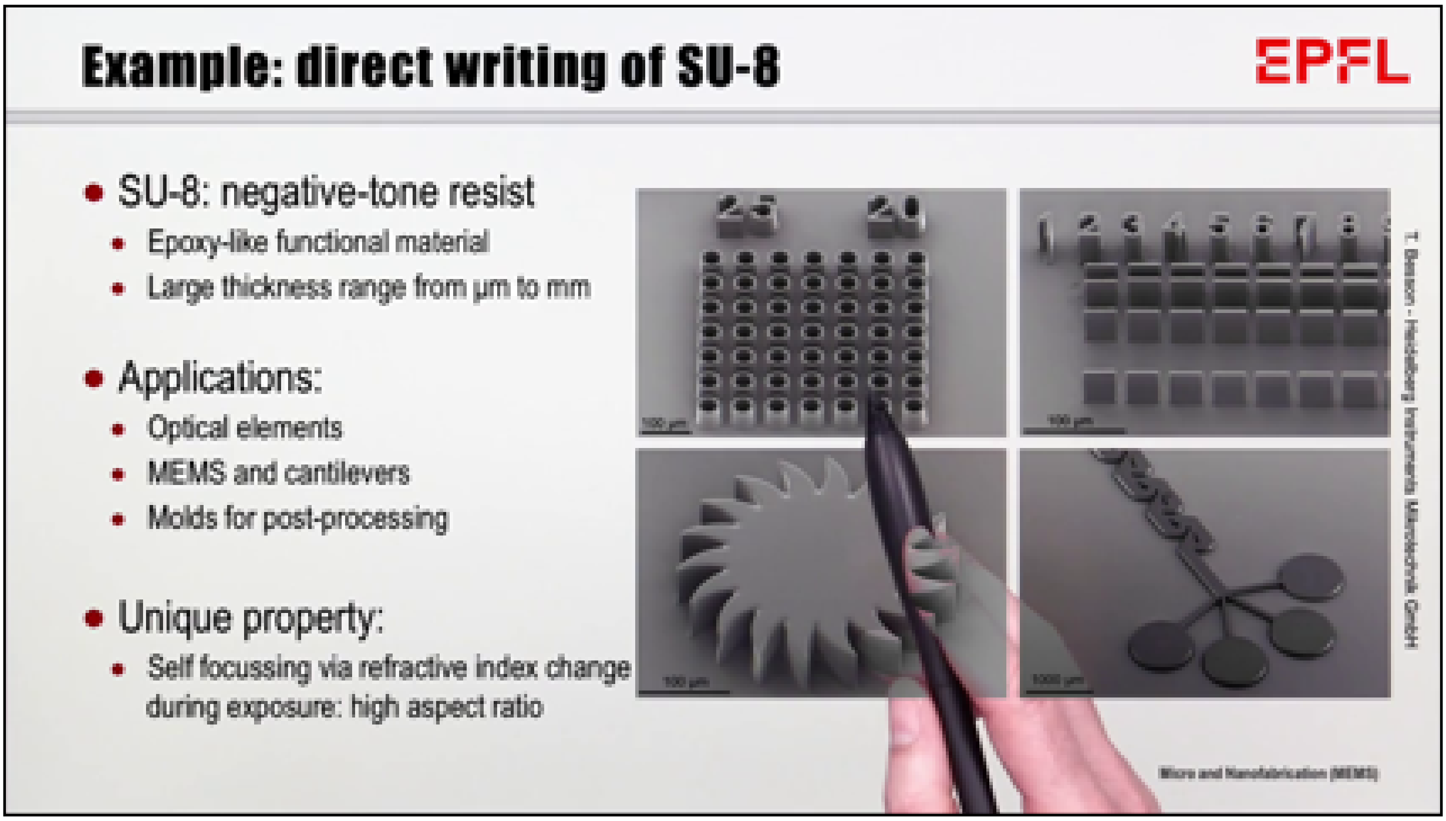


a slight under-edge. It may also take longer time to clear the chromium in small apertures due to limited chemical renewal at the surface. These aspects may be compensated for at the design stage and will have a strong impact when aiming for ultimate resolution. After the chrome etch, the photoresist is removed from the mask using solvents before a final rinsing and drying of the photo mask. Here you can see a photomask in chrome and glass that has been written by the laser writer in our cleanroom and that will be used for the UV lithography.

notes

summary

8m 25s

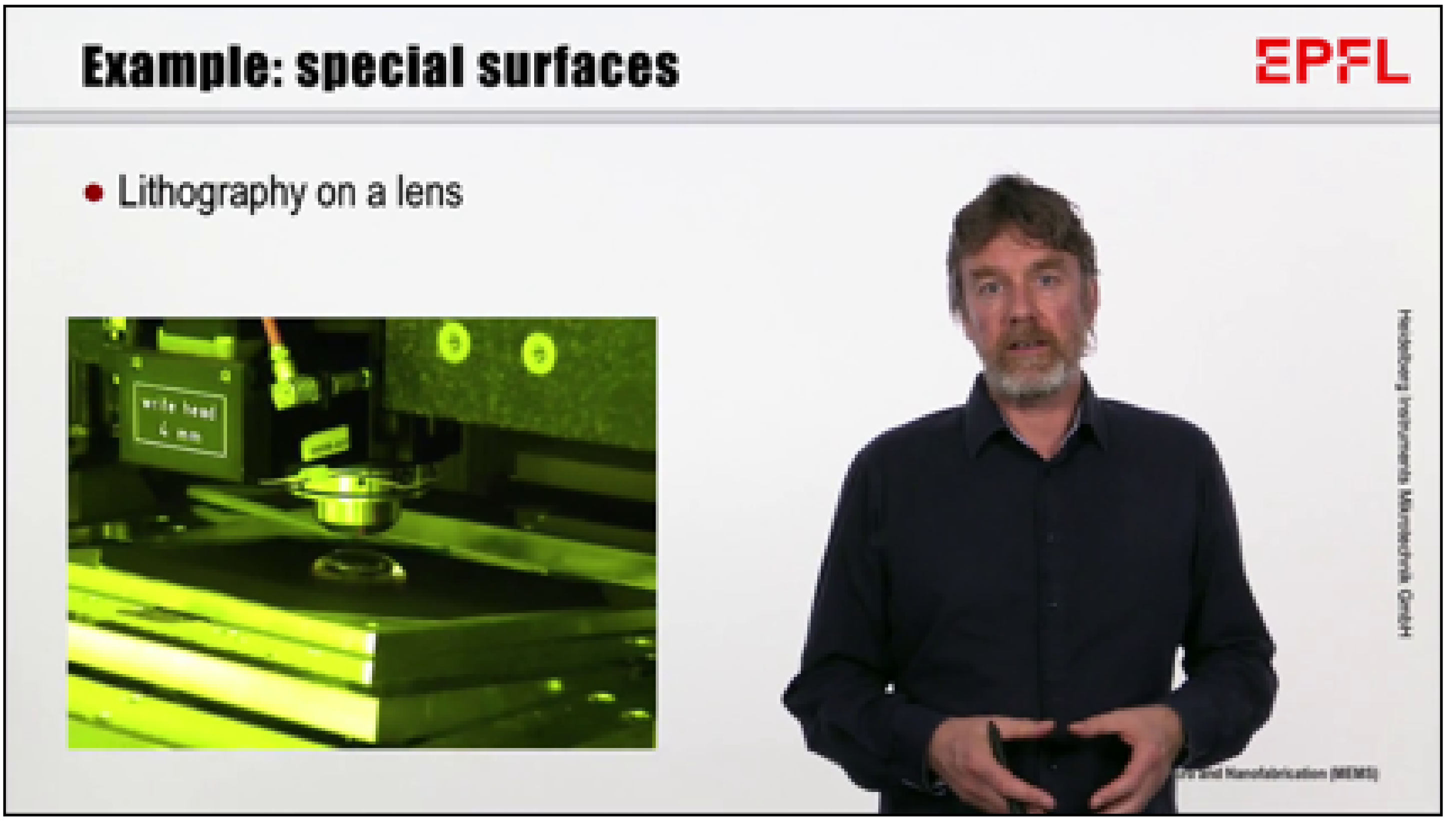


As said, the main application field of direct laser writing is mask writing however, one further interesting application of direct laser writing is the fabrication of, for example, SU-8 structures. This epoxy like negative resist can be coated up to mm thick and stands as a robust functioning material used for optical elements, MEMS and master molds for further processing. As the mold may be further replicated and only one single master is needed, direct write laser is ideal for the production of such elements. On the top you can see 2 images with test patterns that demonstrate

notes

summary

9m 7s

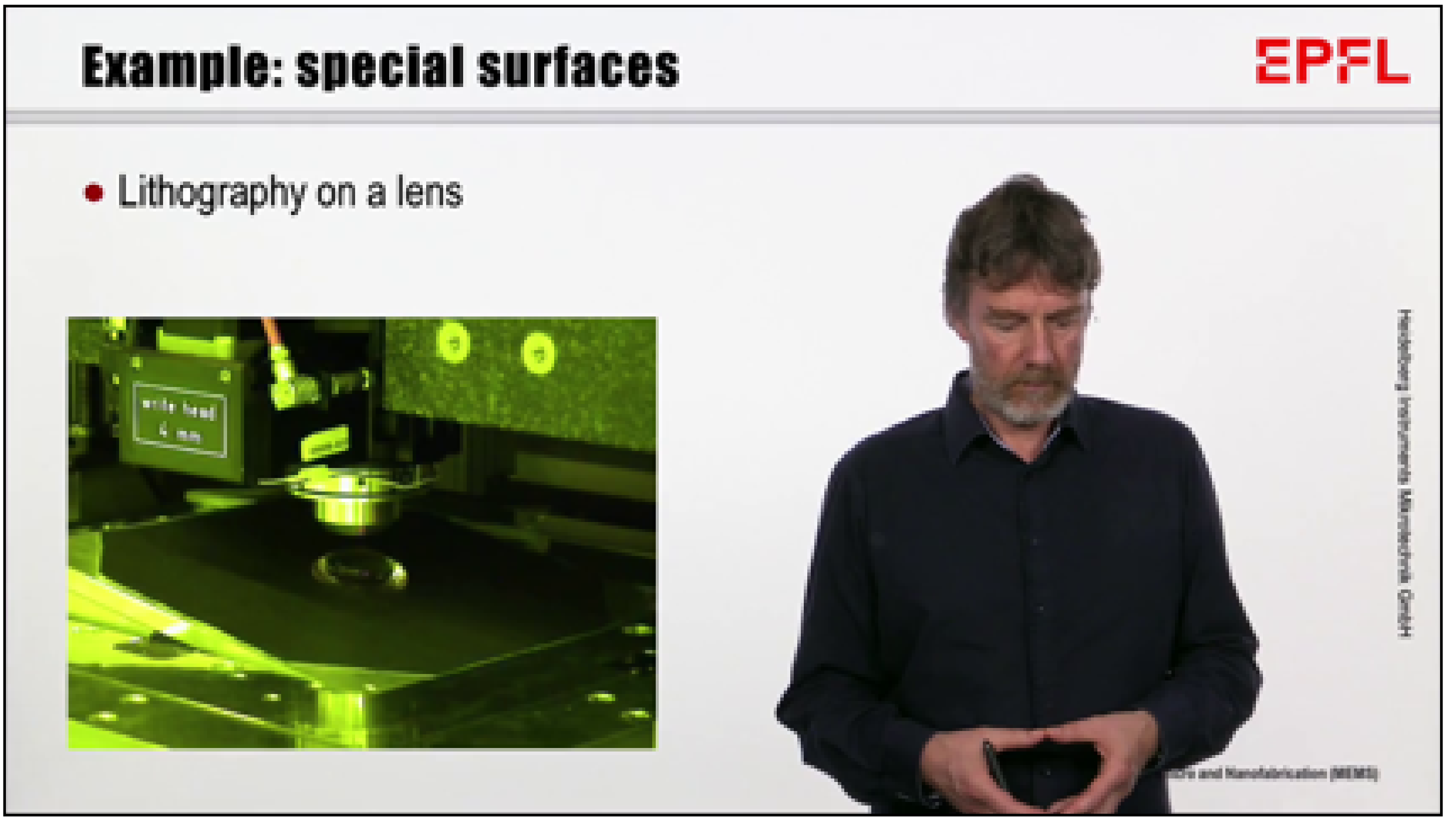


the high aspect ratios; up to 10:1 in this case, reached in direct writing laser and below you can see 2 examples of structural elements. A radial test structure with narrow tapers here on the left and the mold for microfluidic channel here.

notes

summary

9m 49s



Direct laser writing is not limited to flat 4 inch wafers as seen up to now. In the direct laser writing setup the laser head is fixed but if the substrate motion can be controlled freely, lithography on 3D features is possible as shown here in this video.

notes

summary

10m 9s

Another extreme application of direct laser writing is that it may be scaled up for the writing of several square meters surfaces for example, in the case of large displays which are used in production in consumer electronics. Here you can see some specialists preparing the table and stage of such a large system. This concludes this chapter in the lithography where I introduced to you the mask making process using a direct laser writer. I have shown you some details about the process flow of the photomask fabrication and showed you some insights into the direct laser writer equipment and how we get from the CAT file to the mask. At the end I showed you some examples that can be done by playing with the energy and the dose of the direct laser writer.

notes

summary

10m 27s