



Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

4.3 Lithography 1, General concepts, III Photoresist sensitivity and modulation

Concepts (extracted from automatically generated subtitles):

Resist contrast. Optical transfer function. Function of several parameters. Important features. Intrinsic sensitivity. Modulation transfer function. Microscopic analysis of the resist. Exposure tool performance. Maximum intensity. High contrast. Transfer function of an optical exposure system. Intrinsic sensitivity ϕ of a photo. Yellow light. Single component. Line width b .



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



[to video](#)

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<https://www.epfl.ch/education/educational-initiatives/cede/educational-technologies-gallery/boocs-en/>
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Supplementary

Lithography 1: General concepts

III. Photoresist sensitivity and modulation transfer function

Micro and Nanofabrication (MEMS)

Prof. Jürgen Brugger & Prof. Martin A. M. Gijs

...

notes

summary

0m 0s



- Intrinsic sensitivity Φ = necessary incident energy needed to produce photochemical reaction
- single component resist \sim quantum yield
- # photon-induced events / # photons absorbed
- $\Phi_{\text{PMMA}} = 0.02$
- $\Phi_{\text{DQN}} = 0.2 - 0.3$



orication (MEMS)

The lithography resolution is the function of several parameters.

notes

summary

0m 1s



- Intrinsic sensitivity Φ = necessary incident energy needed to produce photochemical reaction
- single component resist ~ quantum yield
- # photon-induced events / # photons absorbed
- $\Phi_{\text{PMMA}} = 0.02$
- $\Phi_{\text{DQN}} = 0.2 - 0.3$



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Besides the exposure tool performance, it largely depends on the photoresist properties. Two important features are the intrinsic sensitivity, and the resist contrast. We will briefly discuss both. The intrinsic sensitivity ϕ of a photo resist, is the incident energy necessary to produce the photo chemical reactions required for defining patterns. For single component resists, it is given by the quantum yield, which is the number of photon-induced events over the number of photons absorbed. The intrinsic sensitivity of two typical photo resist PMMA and DQN are shown here. We can see that PMMA is ten fold less sensitive than DQN for instance. The intrinsic sensitivity can be determined experimentally by a systematic series of exposure tests with subsequent structural, and microscopic analysis of the resist. Details on how this is done can be found in the text books or resist data sheets. The resist that one plans to use must be insensitive to the ambient radiation, that means the yellow light in a clean room and must be sufficiently sensitive to the range of radiation energy provided by the exposure tool,

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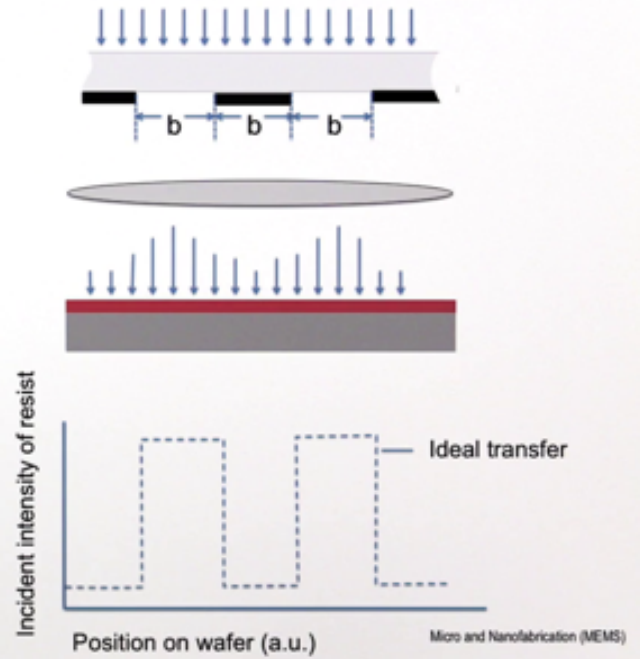
summary

0m 5s



Modulation transfer function

- MTF is a measure of the optical contrast in the areal image of an exposure system.
- The higher the MTF, the better the optical contrast.
- MTF of an image is defined as:



in order to absorb the maximum of energy in a minimum of time. The resist should not be too sensitive either to avoid too short exposure times for a more comfortable process window.

notes

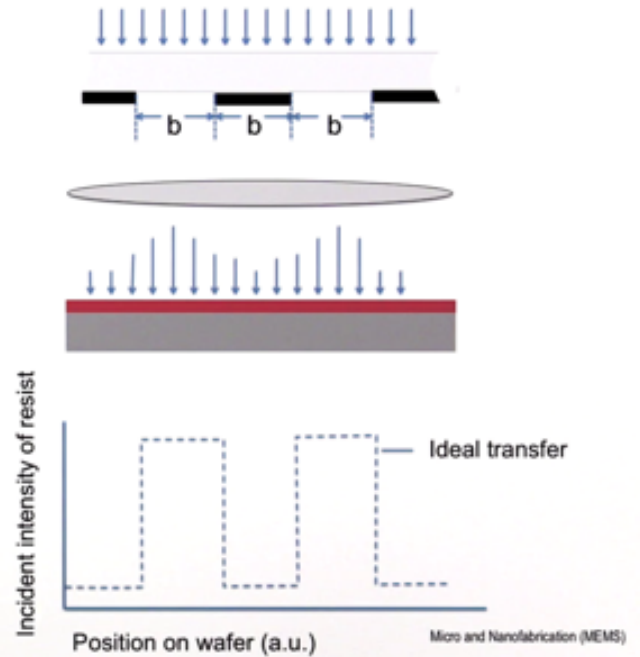
summary

1m 25s



Modulation transfer function

- MTF is a measure of the optical contrast in the areal image by the exposure system.
- The higher the MTF the better the optical contrast.
- MTF of an image is defined as:



The optical transfer function (OTF) also called modulation transfer function (MTF), is the transfer function of an optical exposure system onto a resist. The function specifies the translation and contrast reduction of a periodic sine wave pattern after passing through the lens system as a function of its periodicity and orientation.

notes

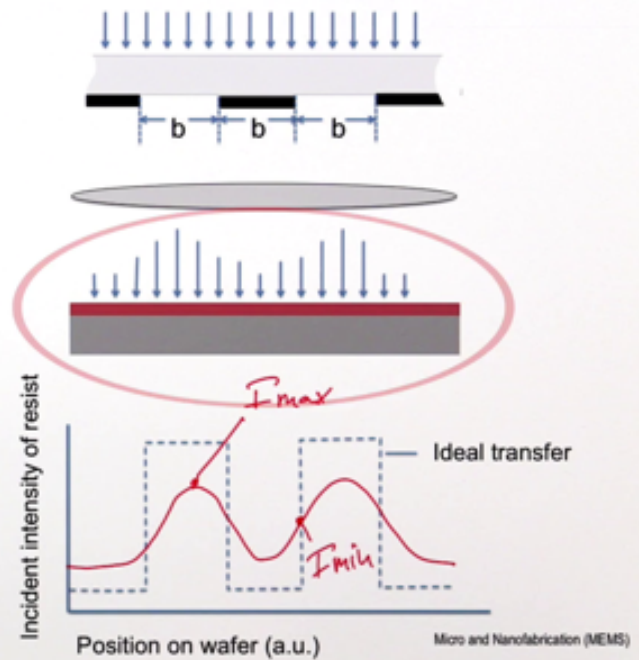
summary

1m 38s



- MTF is a measure of the optical contrast in the areal image by the exposure system.
- The higher the MTF the better the optical contrast.
- MTF of an image is defined as:

$$MTF = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$



Formally, the optical transfer function is defined as the Fourier transform of the point spread function or impulse response of the optics. That means the image of a point source. While figures of merit such as contrast, sensitivity, and resolution give an intuitive indication of performance, the optical transfer function provides a comprehensive and well defined characterization of optical systems. When using a lithography mask, with line width b and pitch b the light beam passing the mask, and reaching the wafer at a certain modulation due to diffraction.

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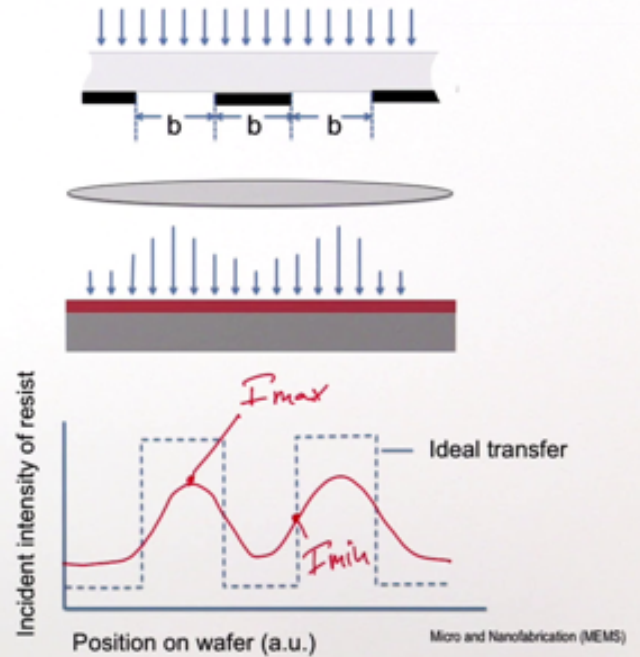
2m 1s



Modulation transfer function

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This modulation can be described by the MT effect expression which is

notes

summary

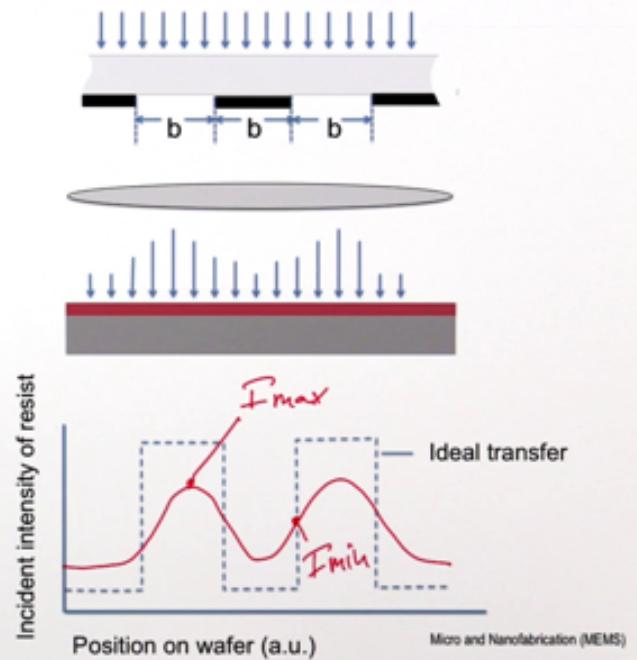
2m 37s



Modulation transfer function

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the maximum intensity minus the minimum intensity over the maximum intensity plus the minimum intensity that passes the mask. This transfer function combined with the resist characteristic, the contrast, allow to define the condition for the optical image. For high contrast resist, it is easier

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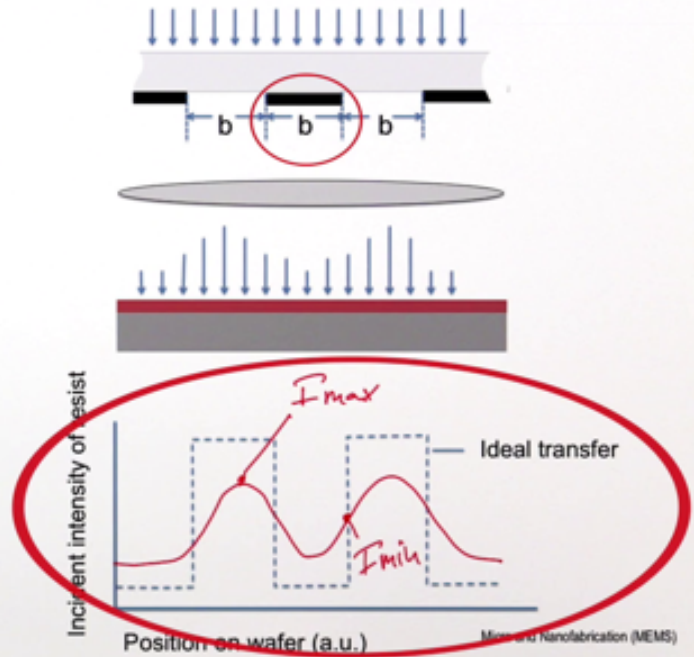
2m 40s



Modulation transfer function

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to get a high resolution than for a low contrast resist with the same MTF. On the other hand, the MTF depends heavily on the motif and the mask. The more b is reduced, the more the difference between

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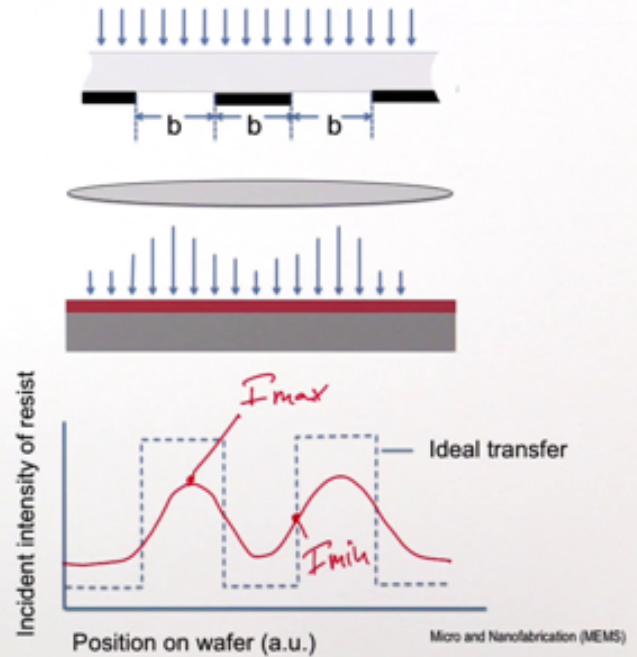
3m 1s



Modulation transfer function

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the minimal and the maximal irradiation intensity reduces and it becomes difficult or impossible to selectively irradiate the different resist parts under the mask. For low contrast resist, it becomes difficult to resolve the image of the mask and to clear the resist under exposure, while keeping the full thickness of the opaque regions

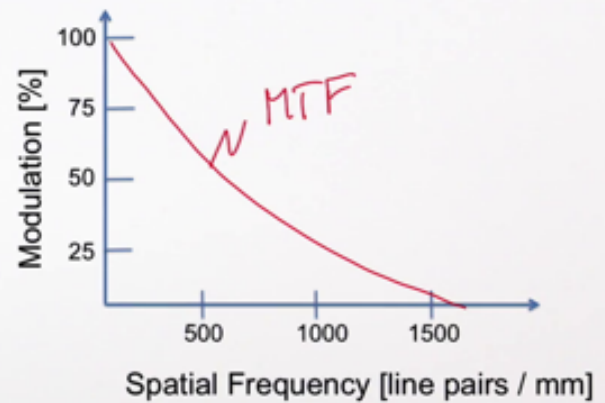
notes

summary

3m 13s



- MTF increases with decreasing λ
- MTF = 1 for larger features
- MTF \rightarrow 0 for closely spaced features



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in the case of a positive resist. The modulation transfer function can also be expressed in a curve, shown here, that relates the spatial frequency, line pairs per millimeter, versus the modulation in percentage. For increasing spatial frequency of closely spaced opaque patterns in a chrome mask, as expected, the modulation drops. This all depends of course on the wavelength used, the optical transfer function as well as the resist contrast.

notes

summary

3m 37s

