Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

7.6 Inspection and metrology 6

Concepts (extracted from automatically generated subtitles):

Focused ion beam. Sub surface structure. Fib system. Ion beam imaging. Cross section. In-situ sem image. Material of the sample surface. Layer deposition processes. Ion beam milling. Sample surface. Better image quality. Electron beam system. Larger area. Liquid metal ion source. Sub surface inspection.

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

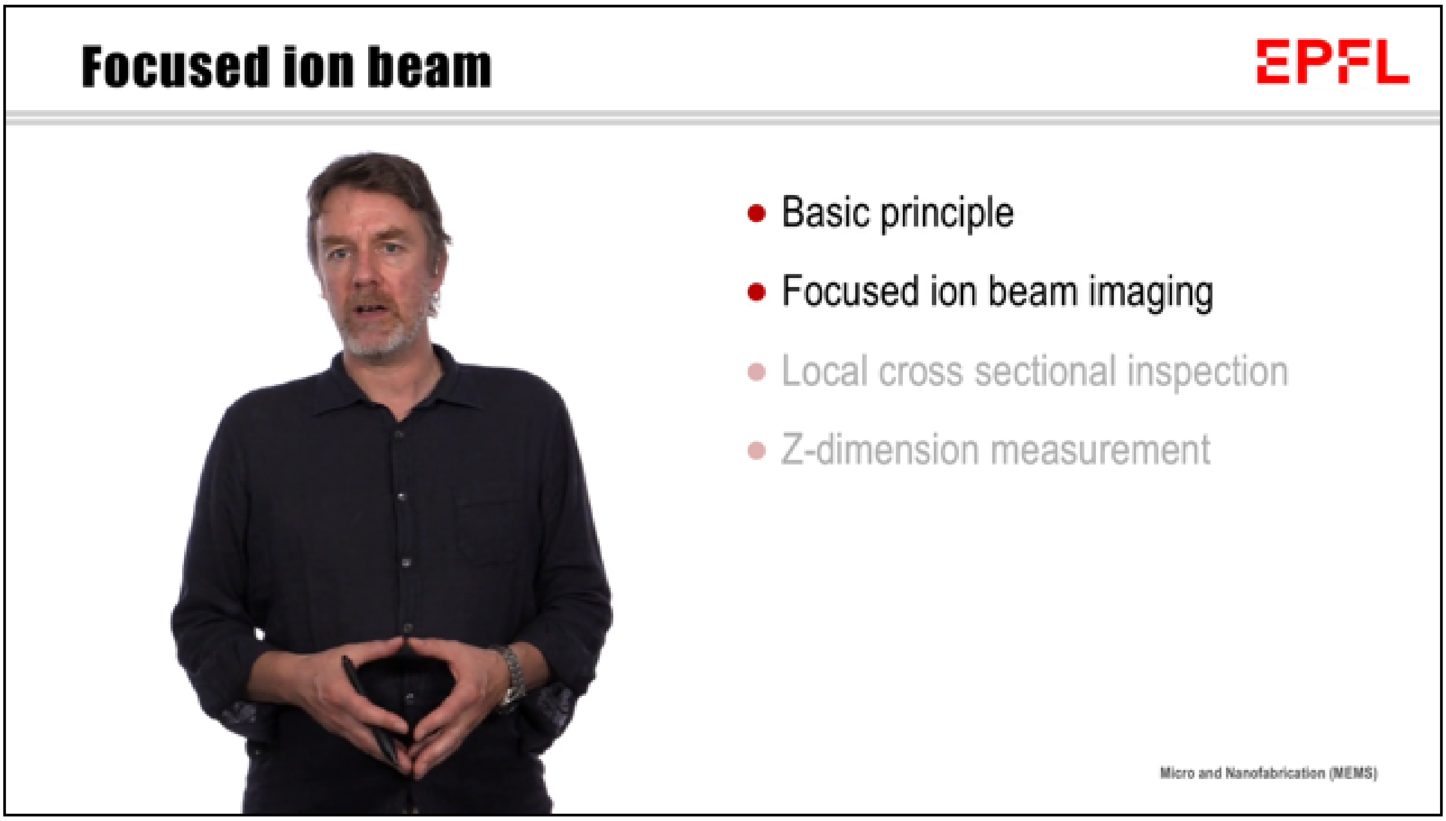
to video

...

notes

summary

0m 0s



MEMs processes like the ones shown in this mooc, involves layer by layer deposition processes similar to the fabrication of integrated micro electronic circuits. Once the fabrication is finished, it is sometimes necessary to check and characterize the sub surface structure, to perform a quality check, and eventually analyze when there is a device failure.

notes

summary

0m 1s

One very useful tool enabling sub surface inspection is the focused ion beam or FIB. It allows removing locally material, and is therefore invasive. I will show you how a FIB system can be used to determine the z-axis dimension of the layers in the micro fabricated MEMs device.

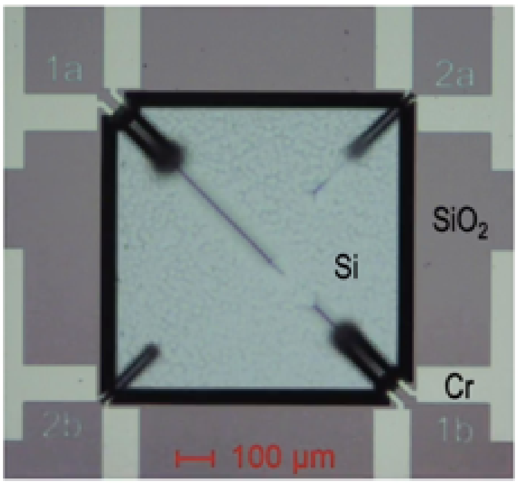
notes

summary

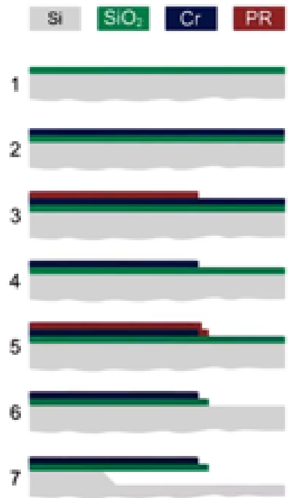
0m 32s

Bi-morph thermal actuator

EPFL



Optical microscope



1. Oxidation
2. Cr layer deposition
3. Lithography 1 (heater)
4. Cr etch
5. Lithography 2 (cantilever)
6. SiO$_2$ etch in BHF
7. Silicon etch in KOH

How to check the device cross section without breaking the wafer?

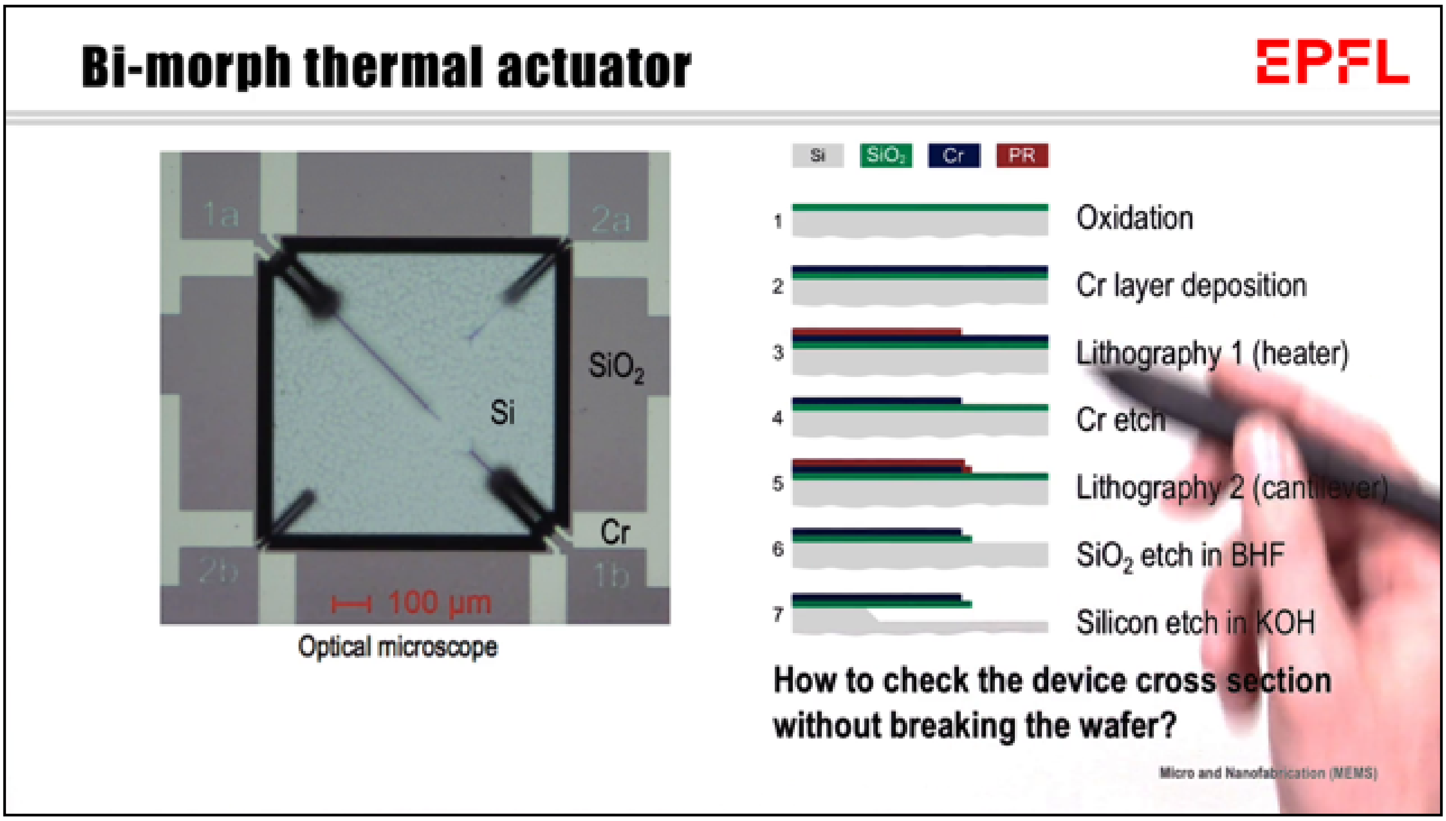
Micro and Nanofabrication (MEMS)

Here, we show again the bi-morph cantilever device, our case study, where we fabricated

notes

summary

0m 49s



the bi-morph with a layer by layer micro fabrication process shown again here on the right side

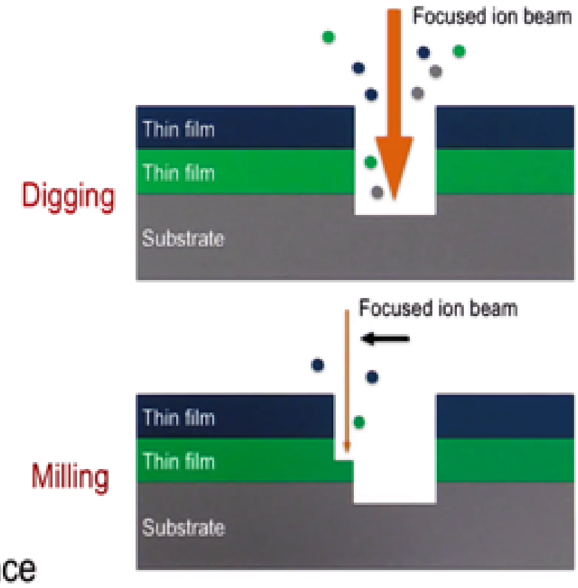
notes

summary

0m 50s

FIB basic principle

- Ion imaging:
  - System similar to SEM: Ions (Ga+) instead of e⁻
  - Resolution: < 10nm
  - Damages the sample surface
- Sample sputtering & milling
  - Sub-µm spatial resolution
  - Depth up to hundreds of µm
- Localized deposition
- Embedded SEM (Dual-beam system)
- Conductive samples for better performance



Micro and Nanofabrication (MEMS)

in cross section. In the previous lessons, the sio2 loss in the KOH path during the silicon etching in step 7 here, was already mentioned. We have already measured this by the mechanical and optical profilometer. Here, we will show you how to use the FIB to inspect and measure the amount of sio2 loss in more detail and without breaking the entire wafer. An FIB system is like an electron beam system, and can also be used for both ion beam imaging and ion beam milling. Instead of using electrons with very small mass, we are now using positively charged ions. The liquid metal ion source is made of Gallium which is heavy, has low melting temperature and thus allows for convenient ion generation. Imaging with gallium plus ions also damages the surface during scanning. One can now utilize this fact to sputter material of the sample surface. The digging or sputtering mode removes material from the sample surface in a larger area and in a faster speed using high ion current. The milling mode removes material from the surface with slower rate and better spatial precision. It results in smoother cross section, and performs some polishing, which is essential to perform cross sectional inspection and dimension measurement.

notes

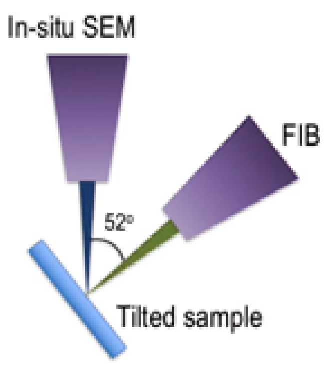
summary

1m 2s

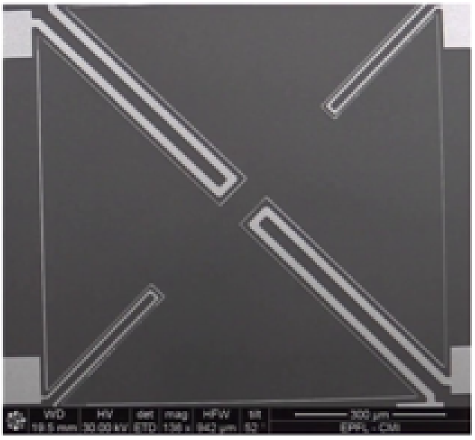
Focused ion beam imaging

EPFL

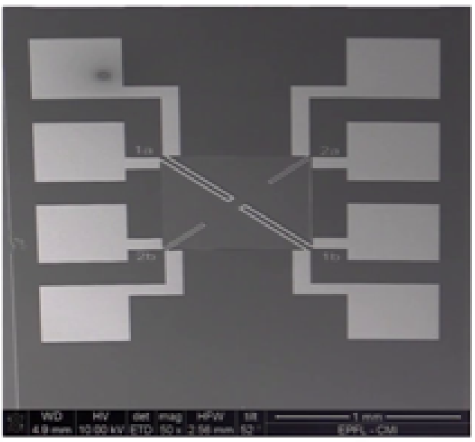
- Sample: bi-morph wafer before KOH wet etch (20nm Cr coated to reduce charging)



Dual-beam system



Ion imaging
(Top view)



In-situ SEM
(Tilted view)

Micro and Nanofabrication (MEMS)

In order to have a well-defined cross section of the sample, there is a need to locally protect the surface from unwanted erosion by the milling. This function is integrated in the FIB system by local platinum deposition. Since ions are damaging the surface when imaging and modern systems is conflicted into a so called dual beam system. That incorporates both an ion beam and an electron beam column. As for the SEM, it is better to perform FIB on a conducting sample. In the dual beam system, the in-situ SEM and FIB columns are arranged at an angle of about 52 degree with respect to each other. In the FIB chamber, we usually tilt the sample so that it faces the ion beam in the normal direction, in order to obtain vertical cross section with respect to the sample surface. Therefore, the in-situ SEM image is taken at the tilting angle of 52 degree with respect to the surface.

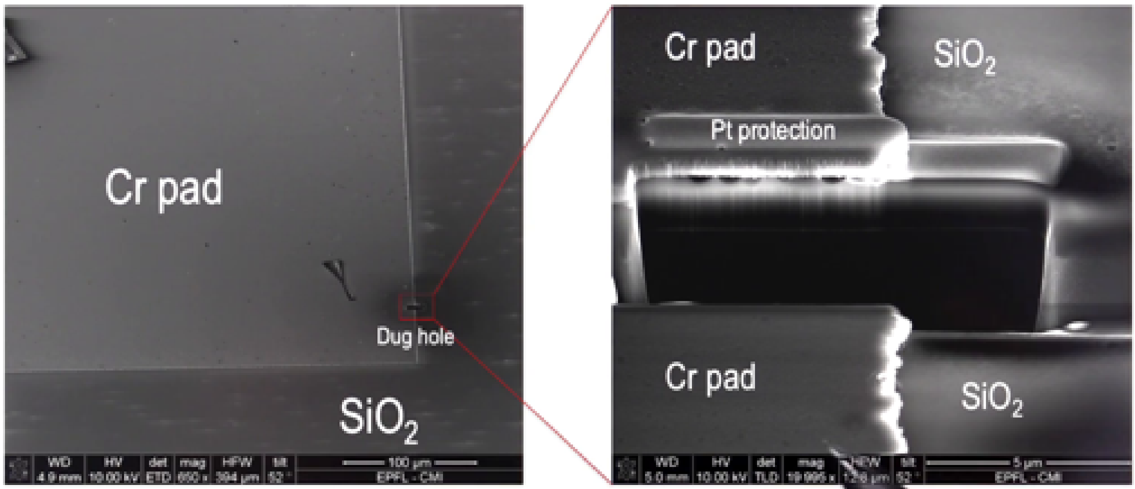
notes

summary

2m 25s

Local cross sectional inspection

- Sample: Bi-morph wafer after KOH wet etch, without extra Cr coating
- In-situ Pt deposition ➔ FIB digging ➔ FIB milling



Micro and Nanofabrication (MEMS)

In order to have a better image quality for us to compare the ion imaging and SEM imaging, and avoid charging, we coat the bi-morph device with a 20 nm thick chrome layer. The sample here is at the process stage before the KOH wet etching of the silicon. You can see the image quality is quite comparable between ion imaging here, and the SEM electron imaging. So keep in mind however, that the surface is damaged by the ions in the left image. We will now use the FIB for what it is actually designed for, namely to inspect in detail the cross section in the area where the chrome pattern forms and etch on the sio2 layer, shown here. This time, we use the bio-morph wafer after the KOH etch. Remember we know that KOH that we used to etch the silicon, also etches the sio2, and now, we want to verify this etching in detail. We used the focused ion to drill a hole at the edge of the chrome pad. First we add a local layer of platinum protection shown here, in very fine details, by the focused ion beam induced deposition. This platinum layer, not only reduces the charging during FIB milling, but it also provides a smoother top surface to reduce ion scattering during digging and milling, and thus provides a smoother side wall.

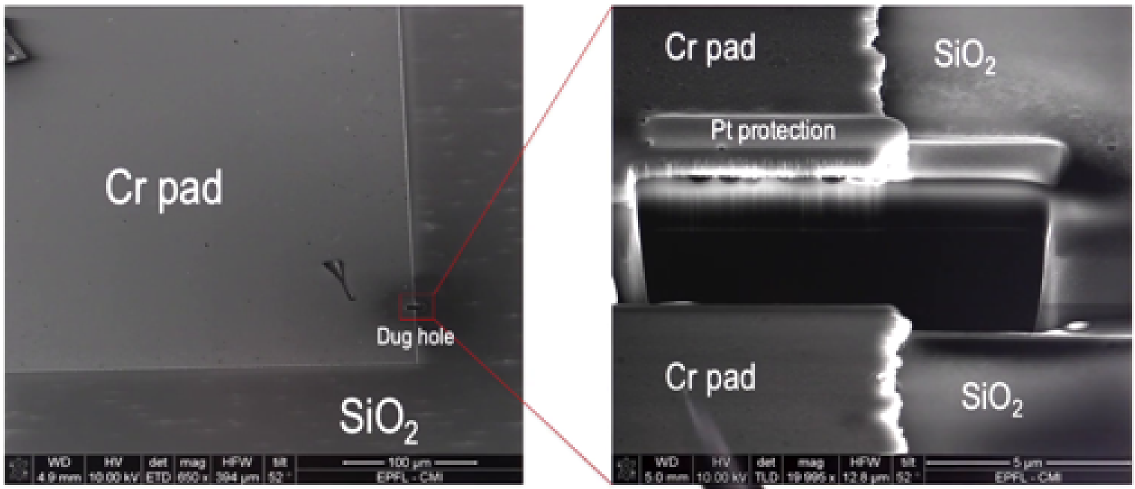
notes

summary

3m 25s

Local cross sectional inspection

- Sample: Bi-morph wafer after KOH wet etch, without extra Cr coating
- In-situ Pt deposition ➔ FIB digging ➔ FIB milling



Micro and Nanofabrication (MEMS)

The photo on the right side shows the structure after the FIB has been used to mill the hole

notes

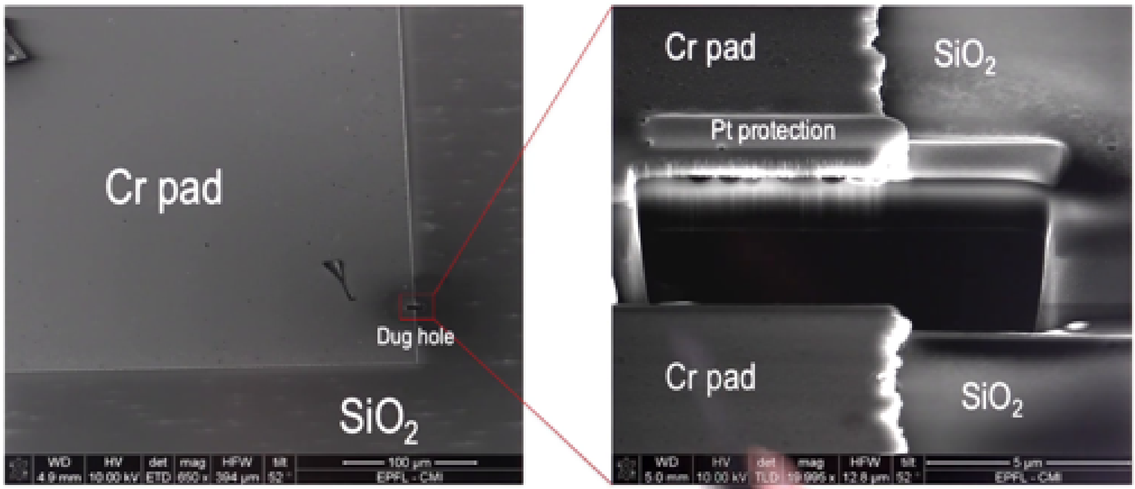
summary

5m 1s

Local cross sectional inspection

EPFL

- Sample: Bi-morph wafer after KOH wet etch, without extra Cr coating
- In-situ Pt deposition ➔ FIB digging ➔ FIB milling



Micro and Nanofabrication (MEMS)

at the cross section between the chrome pad and the sio2.

notes

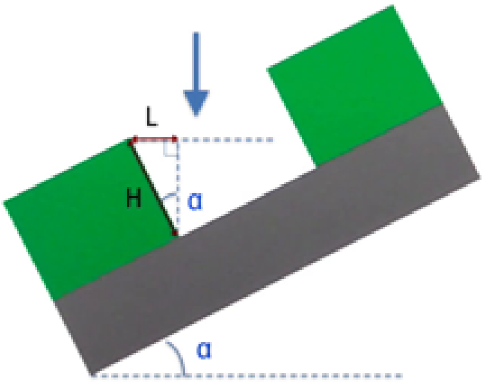
summary

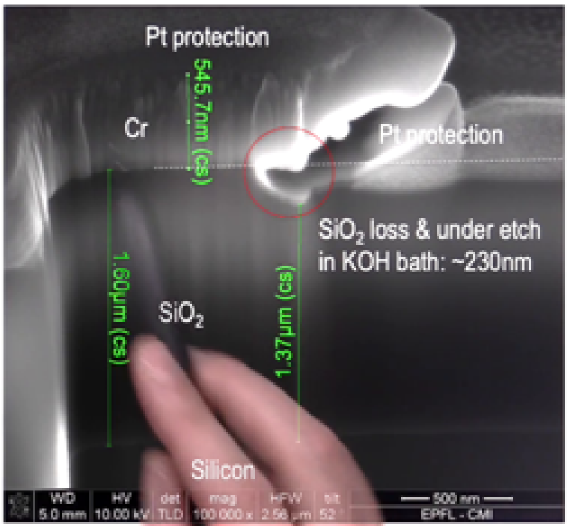
5m 5s

Z-dimension measurement

EPFL

- Sample tilting is needed for better cross sectional view
- Z dimension compensation: $H = L / \sin(\alpha)$





Magnified cross section after milling

Micro and Nanofabrication (MEMS)

The platinum protection here, and the hole created here that goes then deeper into the silicon. We now zoom into the area of interest, with the SEM after the ion milling, so now we don't damage the sample anymore. And for better measurement, we tilt the sample to see clearly into the cross section. We see the silicon substrate here. We see the sio2 which is 1.6um thick here. And we see the chrome layer 545 nm thick.

notes

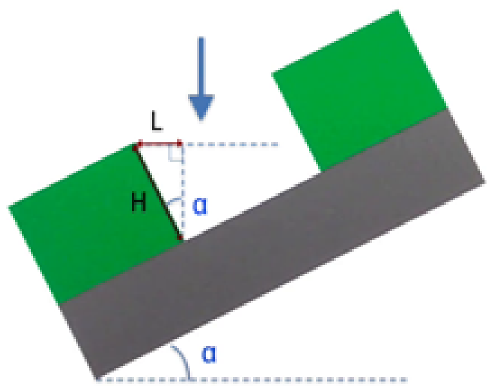
summary

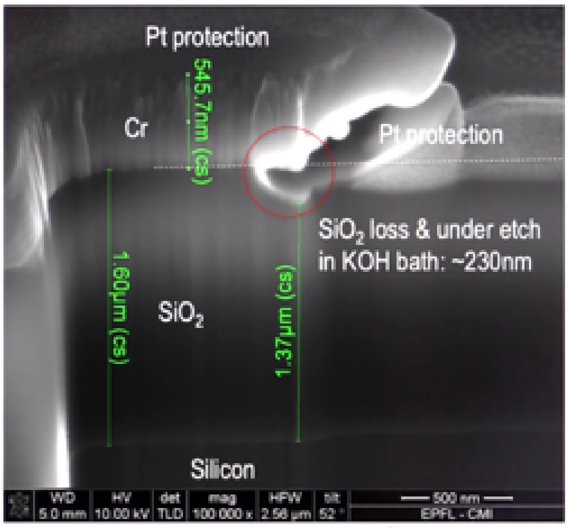
5m 14s

Z-dimension measurement

EPFL

- Sample tilting is needed for better cross sectional view
- Z dimension compensation: $H = L / \sin(\alpha)$





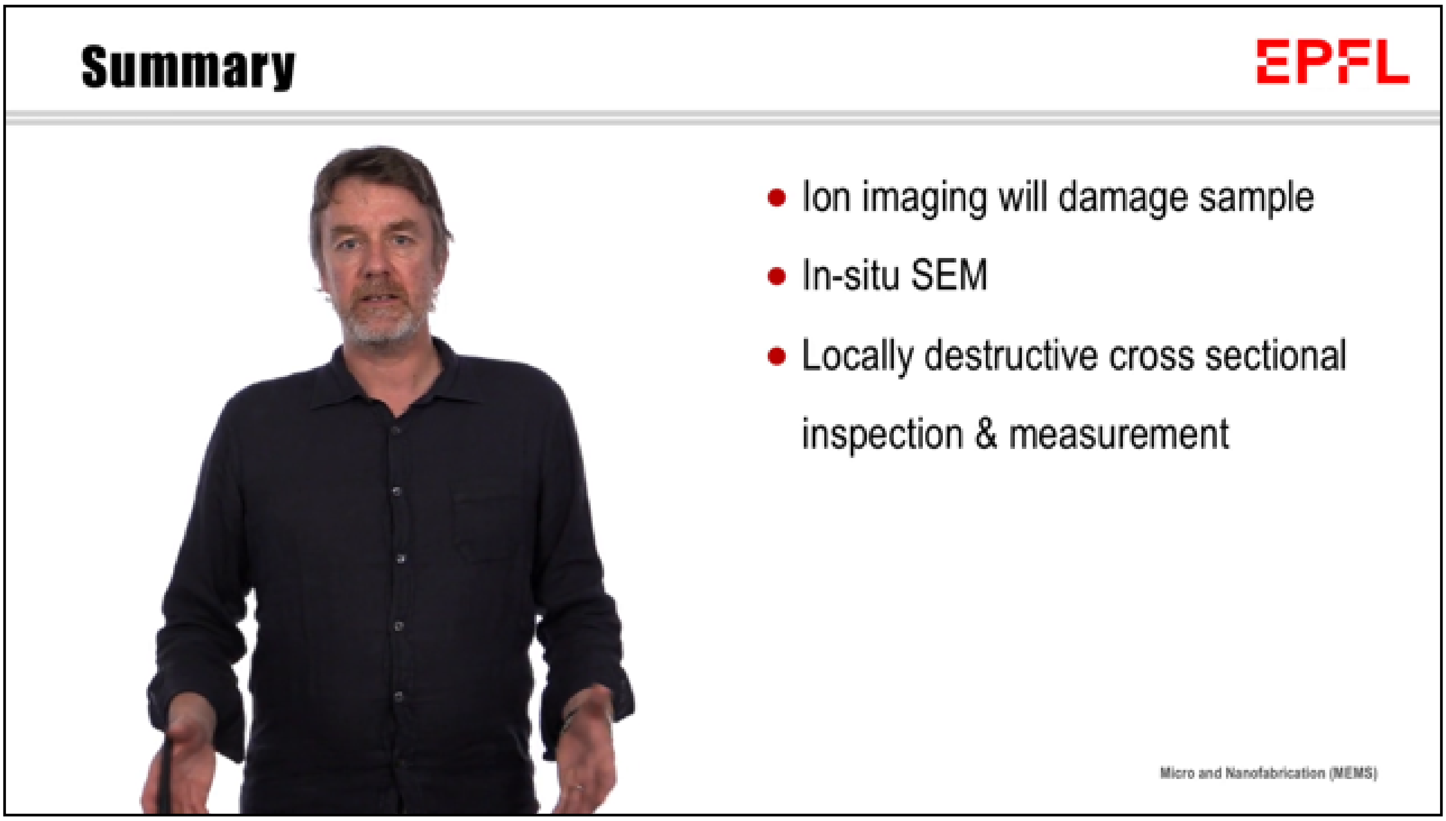
Magnified cross section after milling

We also see the Pt platinum protection layer here. We see in particular, the under etched sio2 layer that is about 230 nm under etch. Which is exactly the value that we expect from the KOH etching, from the values already

notes

summary

5m 51s



obtained by the optical and mechanical surface metrology done in the previous lessons. In the additional study materials, you can find more details on FIB techniques for post process sample inspection and Feeler analysis, and to what one should pay particular attention. In this lesson, you have seen how to use FI to inspect the MEMS device with very high resolution. Remember that this technique is invasive and damages at least locally the devices. But it can be applied to a full wafer in mid process.

notes

summary

6m 6s