Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

7.4 Inspection and metrology 4

Concepts (extracted from automatically generated subtitles):

Surface of a wafer of a mems device. Typical maximum scan length. Z displacement of the tip. D surface image. Video. Film thickness measurement. Mechanical surface profiler. Measured step height. High resolution. Atomic force microscope. Right side. Thickness of the chrome. Scan line. Particular case. Optical non-contact methods.

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

to video

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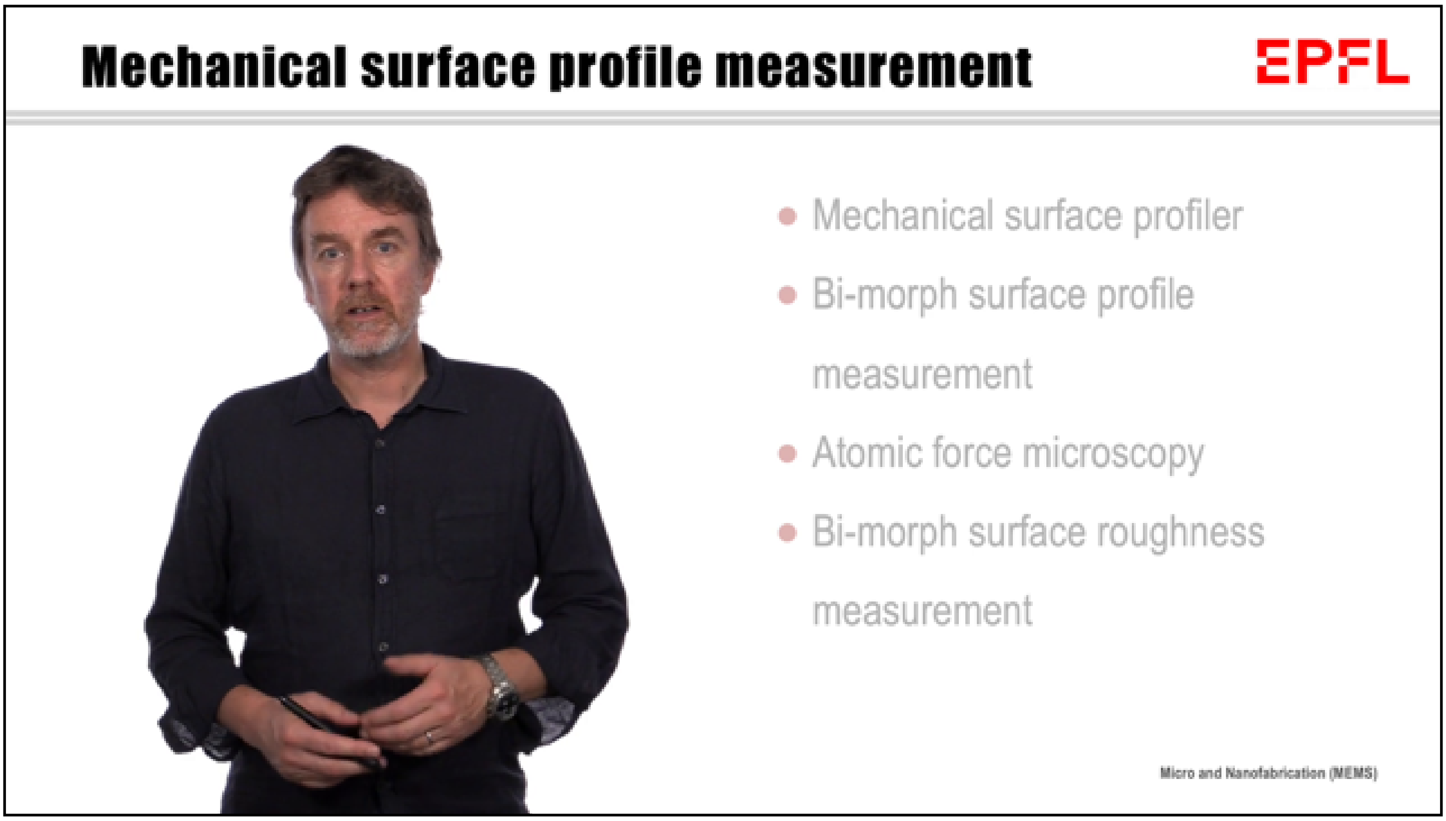
notes

summary

0m 0s



After the optical non-contact methods for wafer inspection, this lesson presents tools that

notes

summary

0m 1s

Mechanical surface profile measurement

EPFL

- Mechanical surface profiler
- Bi-morph surface profile measurement
- Atomic force microscopy
- Bi-morph surface roughness measurement

Micro and Nanofabrication (MEMS)

rely on mechanically probing the surface of a wafer of a MEMS device.

notes

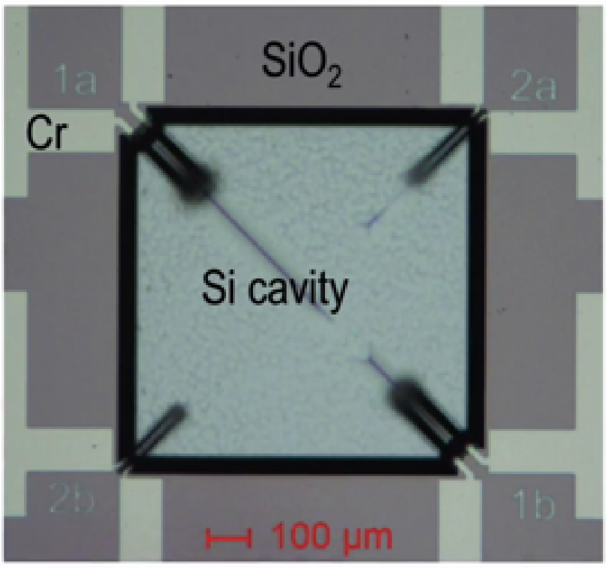
summary

0m 5s

Bi-morph surface profile measurement

EPFL

- Cr thin film thickness
- Cr and SiO_2 thin film surface roughness



Optical microscope

Micro and Nanofabrication (MEMS)

One example is the mechanical surface profiler for film thickness measurement. We will apply it to the wafer with the bi-morph cantilever to measure the thickness of the chrome thin films used to build the device. Then, I will show you how the atomic force microscope is used to characterize the surface properties in high resolution. We apply it here to quantify the roughness of the chrome and sio2 surfaces in the bi-morph device.

notes

summary

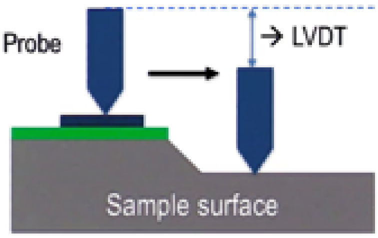
0m 16s

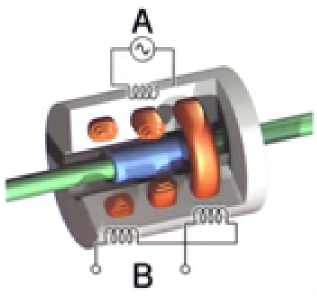
Mechanical surface profiler

EPFL

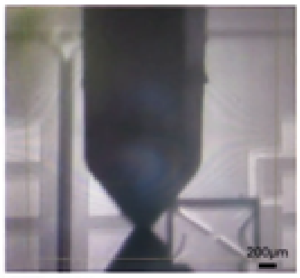
- Diamond probe scans the surface
- Surface height ➔ probe position ➔ electrical signal
- Resolution in Z: ~1nm
- Measurement range in Z: up to 1mm
- Scan length up to 55mm
- Risk to damage the probe or sample

LVDT = linear variable differential transformer





https://commons.wikimedia.org/wiki/File:LVDT.png



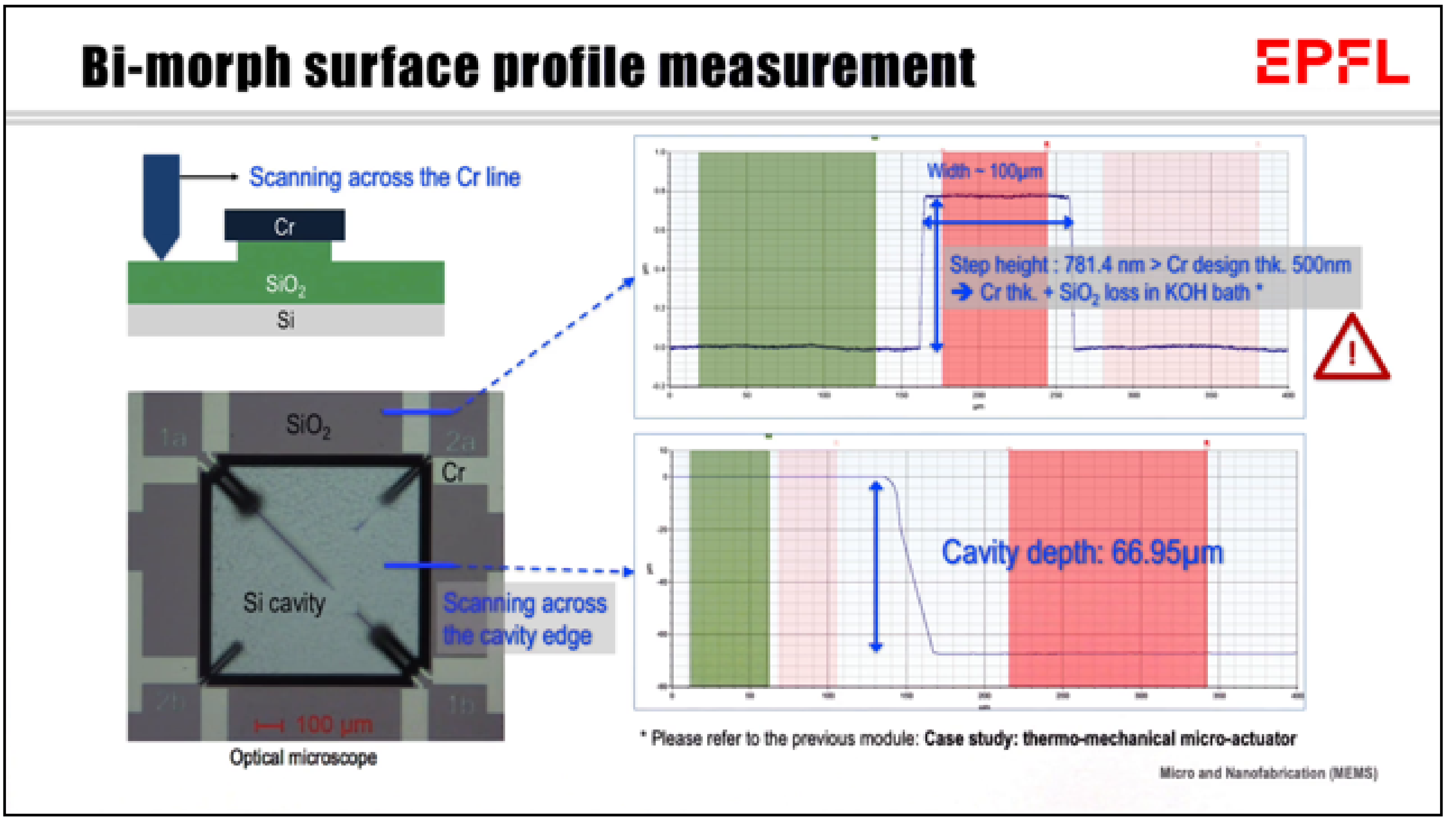
Micro and Nanofabrication (MEMS)

The position where we intend to measure the chrome layer on top of the sio2 layer is here. To determine the device property, we need to know precisely the thickness of the chrome film as well as the surface quality, because they influence the device performance. For the first measurement, we used the mechanical surface profiler, which is basically a diamond needle that scans along a linear path in contact with the device surface. Here, we apply it to determine the thickness of the chrome, film thickness, and here, we apply it to measure the depth of the etched silicon part. Typically, a linear variable differential transformer or LVDT is used to measure the z displacement of the tip. Here, you can see an illustration of an LVDT device. This particular case is based on electromagnetic transducers. It is composed of a moving part in green, with a ferromagnetic material attached to it in blue, and a fix part with three coils embedded. Please see in the study documents how such LVDT is working in detail. You perform so well measurement down to 1 nm of resolution along the z axis. Typical maximum scan length are in the order 55 mm. which is a bit more than half a 4 inch wafer. Since the contact force is not well controlled,

notes

summary

0m 42s

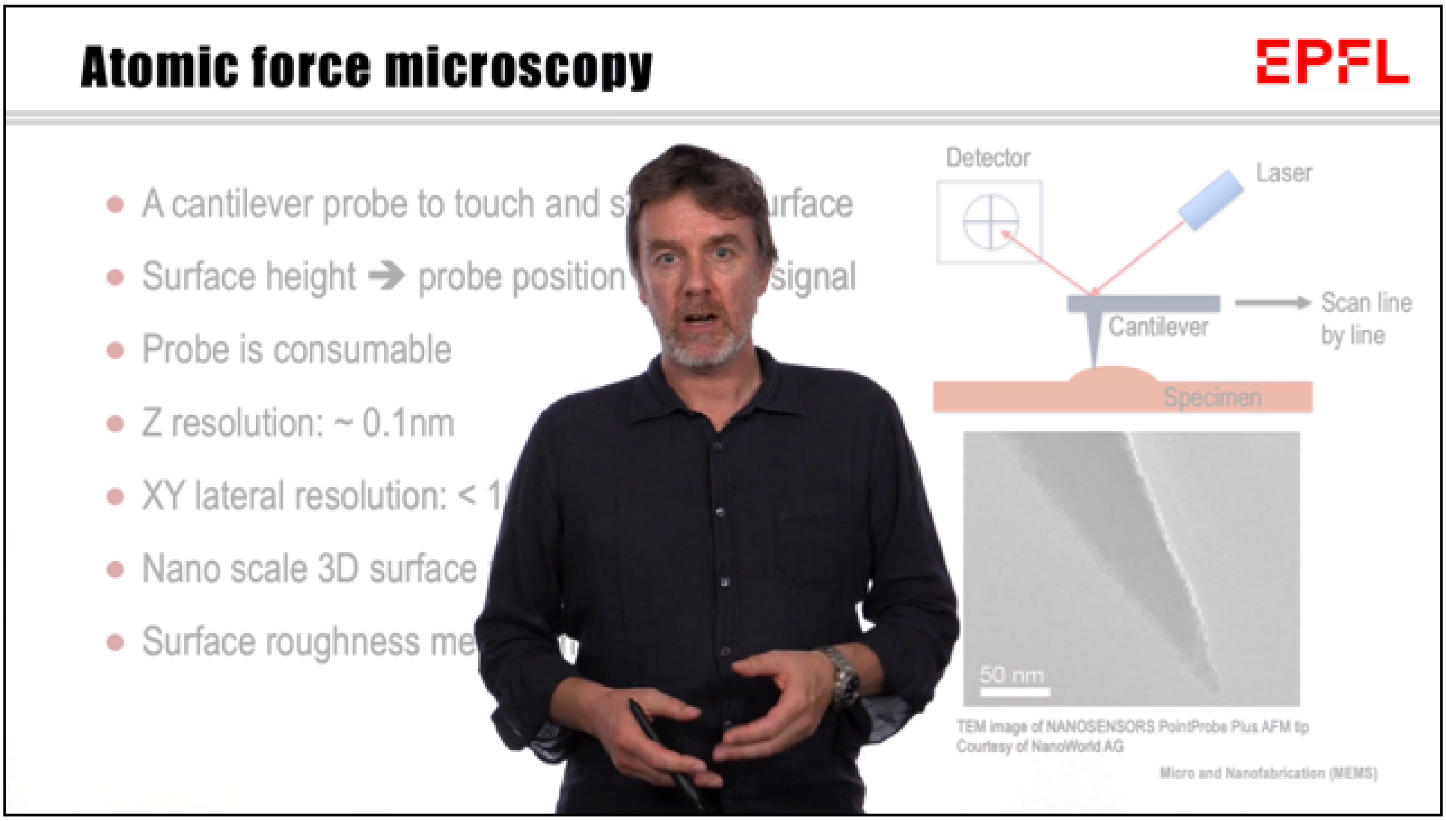


it may damage the surface of soft films and cannot be applied to elastic structures. The photo on the right side shows a screen shot from the camera on the tool in our clean room. It shows here the tip above and its shadow below. We can also see the bi-morph device here. Here, we see a schematic of the measurement that will be formed. On the surface, we have the pattern chrome, on the sio2 layer on silicon. The drawing is not to scale. We do this measurement after the KOH etching. As we know, KOH also etches to sio2 slowly. So we expect to see this in the profile. The tip is scanned over a chrome thin film pattern from left to right. The scan line is highlighted here in blue on the photo of the device. The diagram here shows the height profile on the z axis as a function of the scan location on the x axis. The measured step height is 781.4 nm which is as expected more than the targeted 500 nm chrome thickness. The additional step comes from the loss of

notes

summary

2m 13s

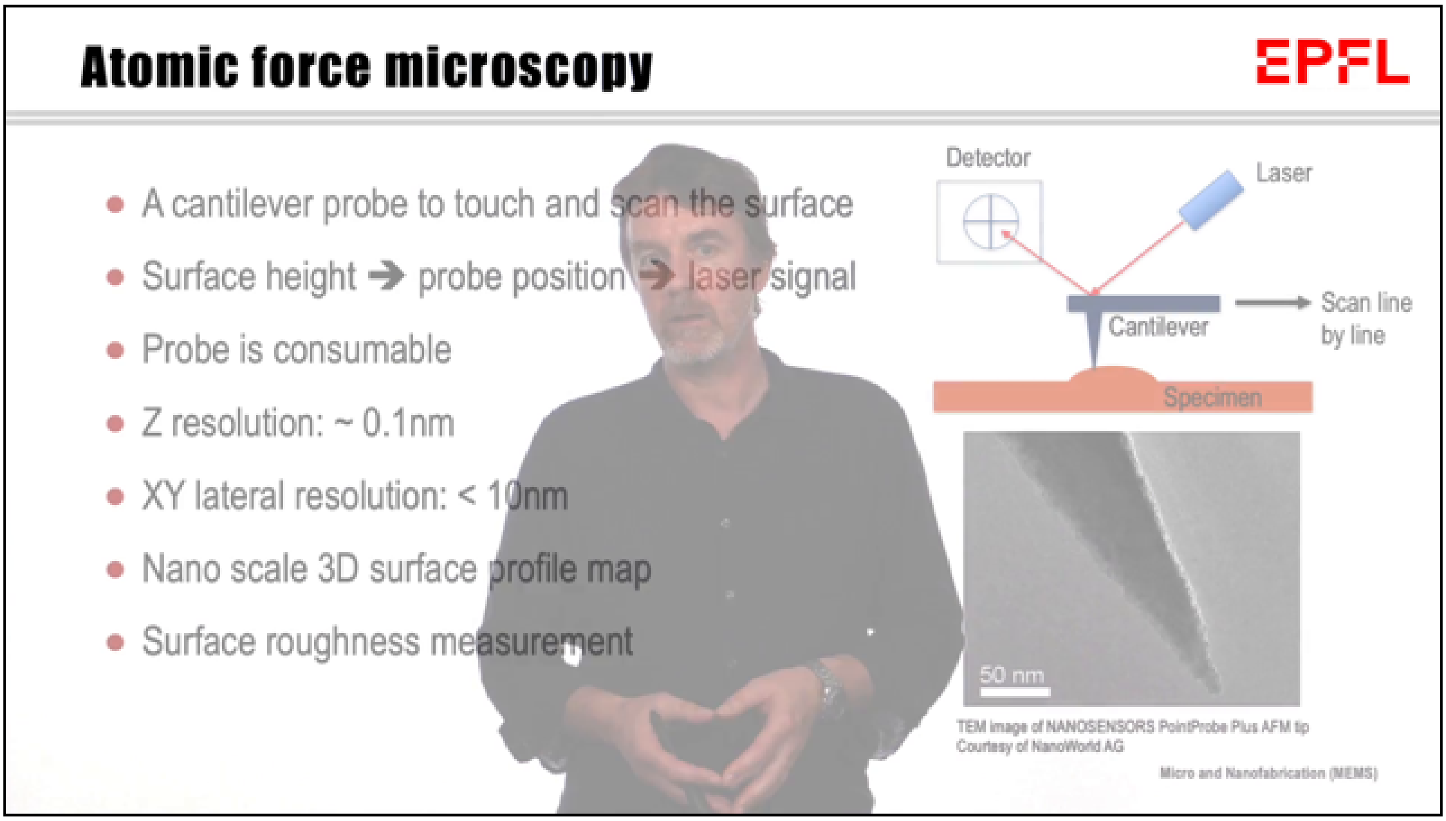


sio2 during the KOH aching. The second curve here shows the scan across the KOH etch shown here on the photo. Here, the depth is about 67 um which agrees well with the design value and also with the optical measurement shown in the previous lesson. Please note while the surface profilometer is very accurate for vertical displacement, it has a poor lateral resolution due to the

notes

summary

3m 25s



convolution of a relatively blunt tip. To overcome this resolution limit, we now consider the atomic force microscope or AFM. The AFM is a highly sensitive and high resolution mechanical surface scanner just like the surface profiler we introduced before. The key distinction of the AFM is that it operates in force feedback. By doing so, it reduces the contact force between tip and surface. Due to the high force sensitivity, it does not harm or scratch the surface and can be

notes

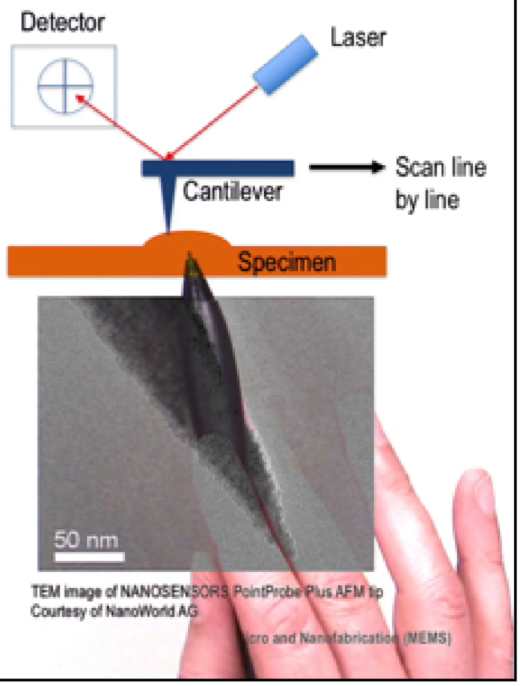
summary

3m 53s

Atomic force microscopy

EPFL

- A cantilever probe to touch and scan the surface
- Surface height → probe position → laser signal
- Probe is consumable
- Z resolution: ~ 0.1nm
- XY lateral resolution: < 10nm
- Nano scale 3D surface profile map
- Surface roughness measurement

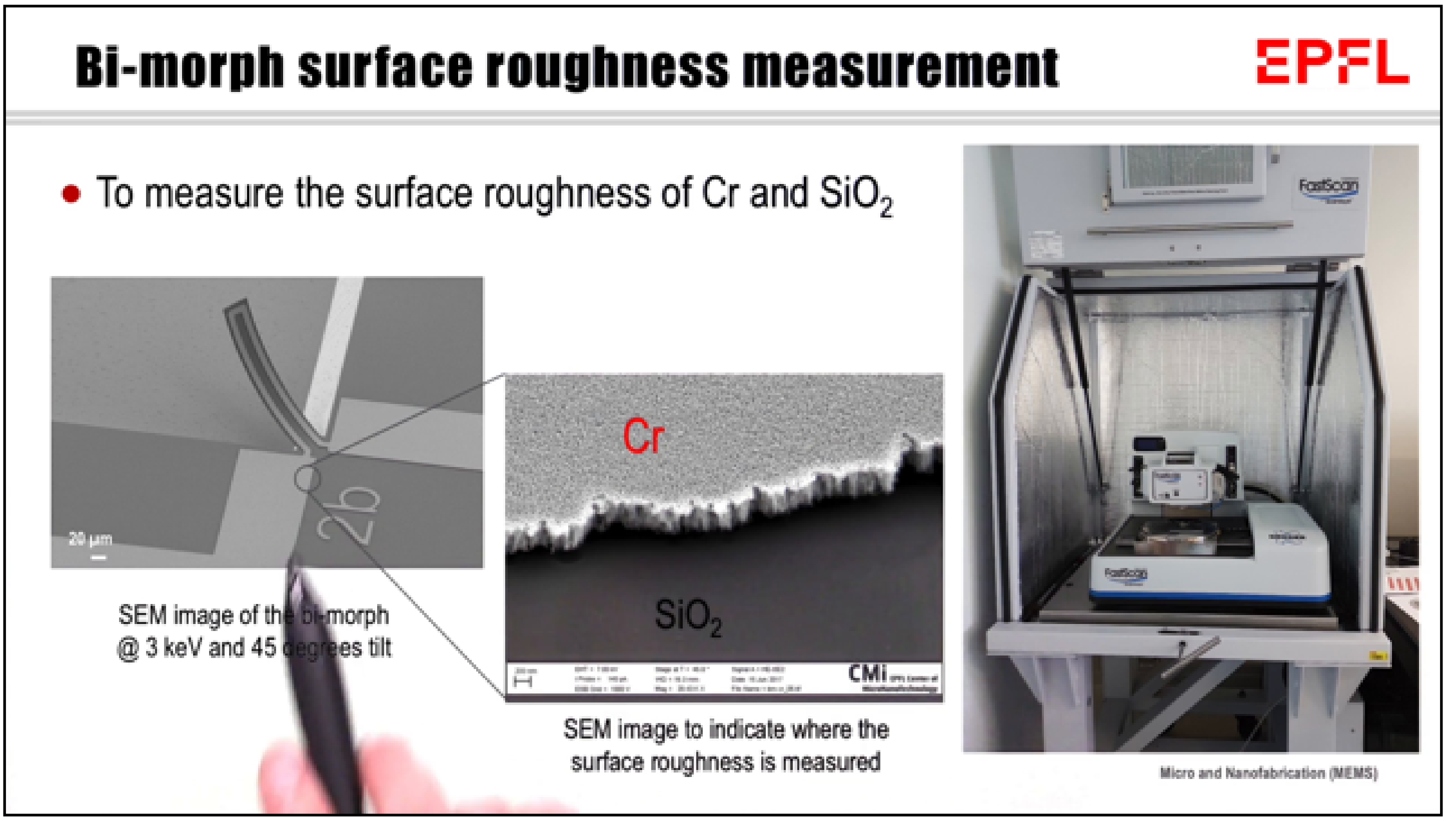


applied to very fragile surfaces. Very sharp tip is at the end of a flexible cantilever that bends when a force is applied to its end. The bending is measured by a laser beam deflection system as shown here.

notes

summary

4m 23s



Here, the tip is a raster scanned with an area of interest and the vertical deflection is recorded for each x-y position. Thus providing a 3 d surface image. The z axis resolution is in the order of 1 Amstrong or below. Lateral resolutions are below 10 nm. Besides making 3d images of the surface at high resolution, it allows quantifying the surface roughness that is often playing a role for device performance. The image on the right side here shows a TEM image of a commercial AFM tip, showing the very sharp epics that provides a higher lateral resolution. Let us now apply AFM to measure the surface roughness of the chrome, and sio2 layer in the bi-morph device. On the left side, you see an SEM image of one of the bi-morph cantilever. The circle here indicates the area of interest that we want

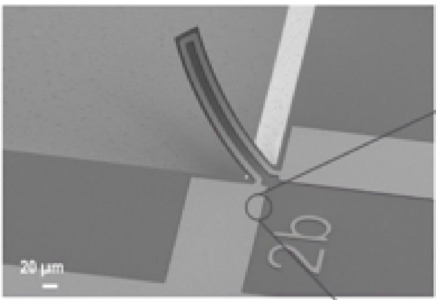
notes

summary

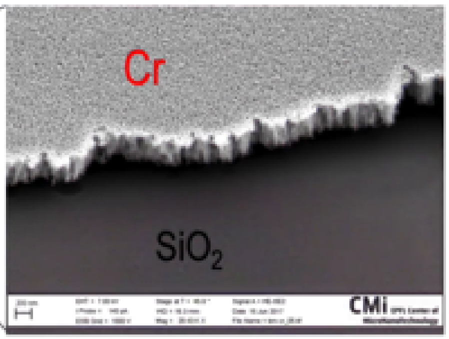
4m 37s

Bi-morph surface roughness measurement

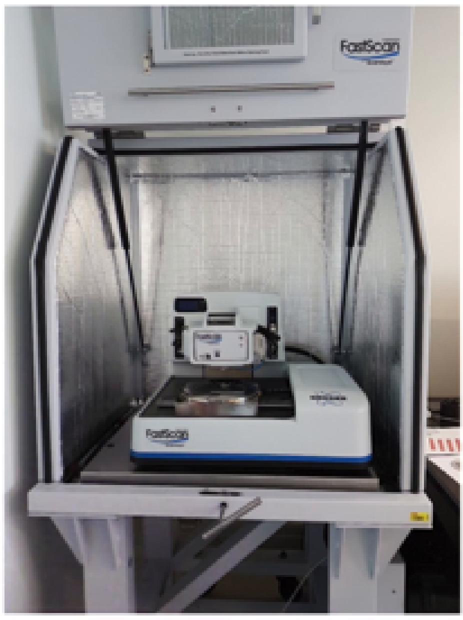
- To measure the surface roughness of Cr and SiO_2



SEM image of the bi-morph @ 3 keV and 45 degrees tilt



SEM image to indicate where the surface roughness is measured



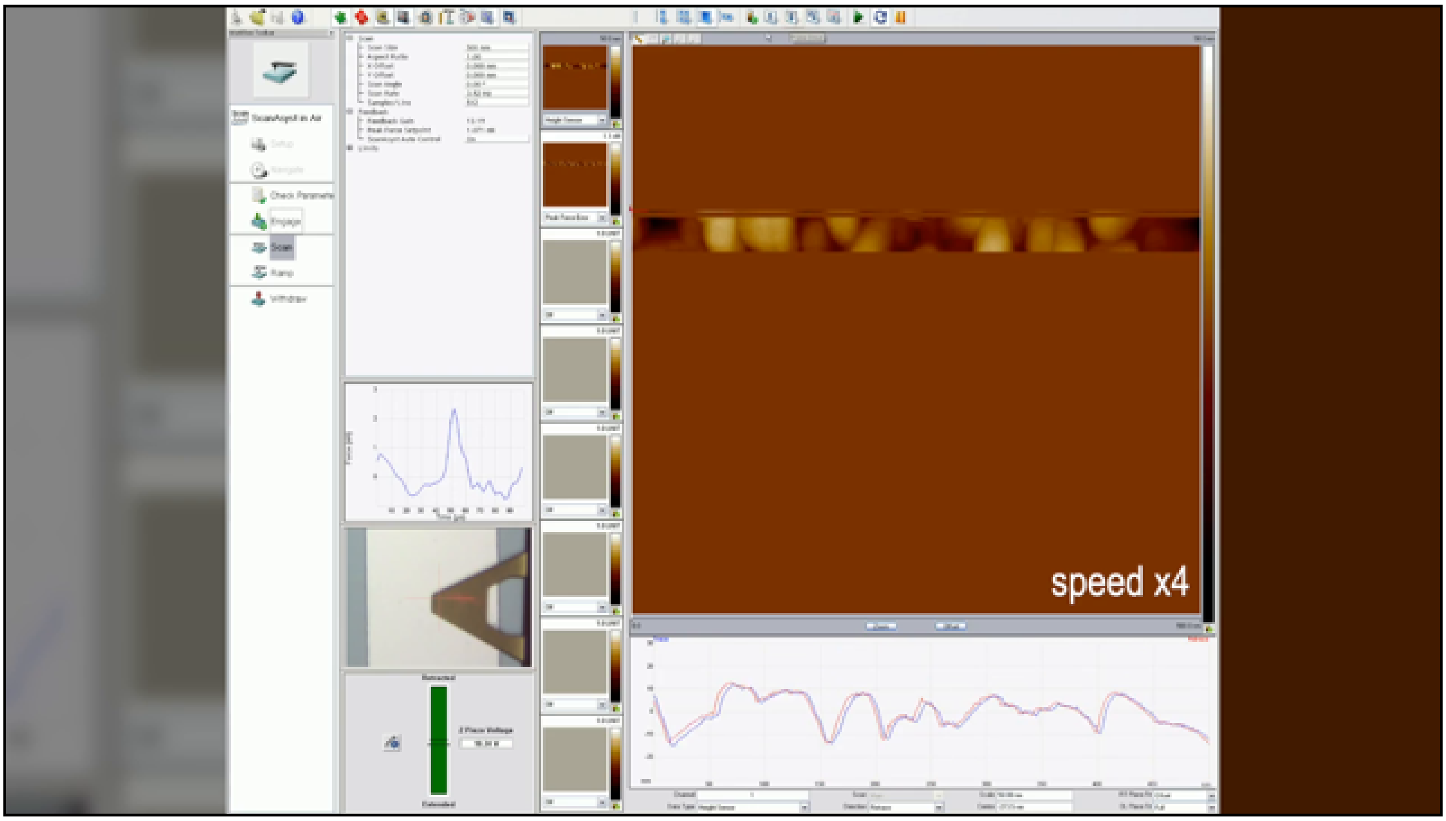
Micro and Nanofabrication (MEMS)

to inspect in detail with the AFM. To this end, we mount the sample into an AFM

notes

summary

5m 37s

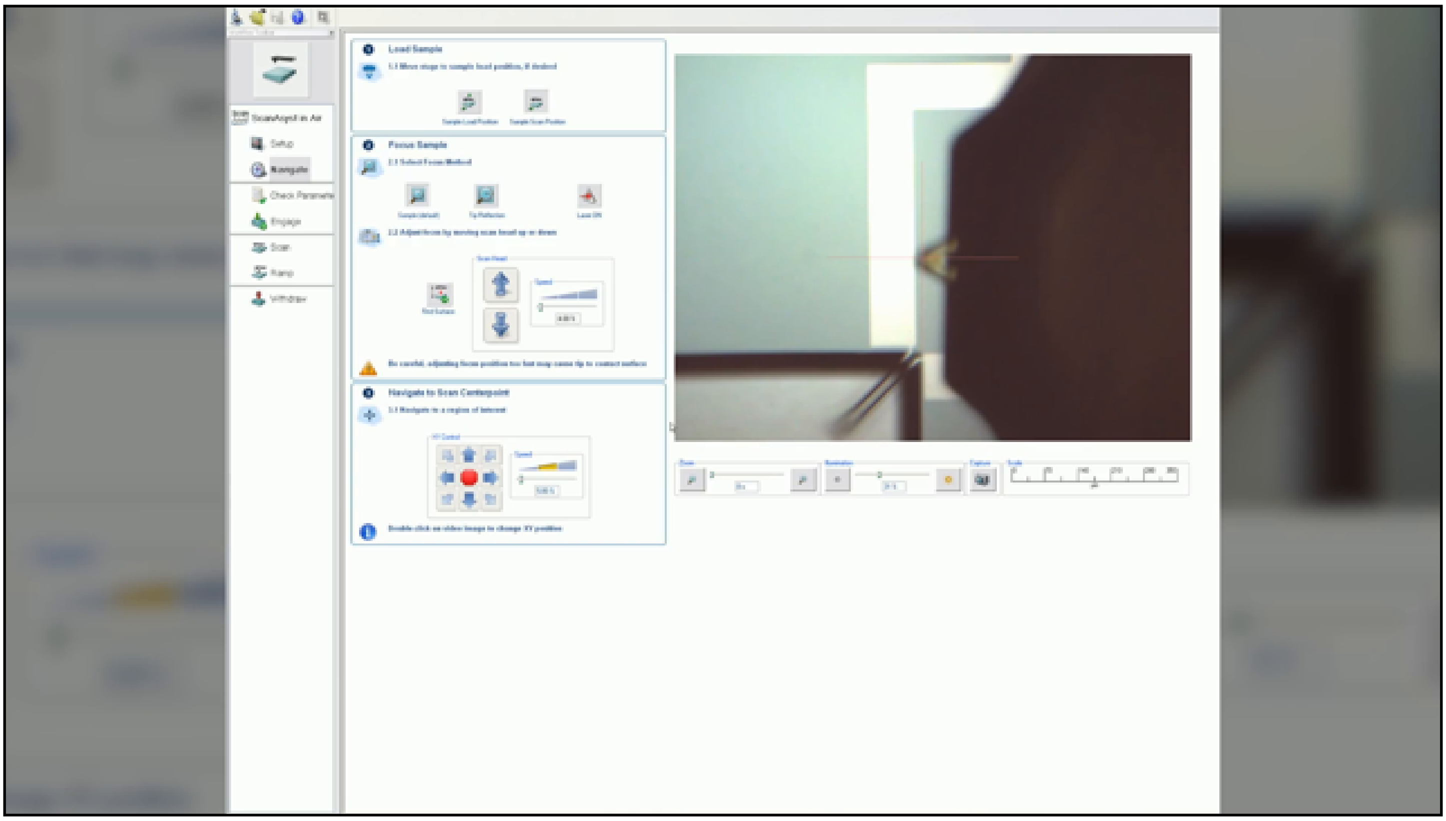


system, and we align the AFM tip to scan the area here on the chrome, and here on the sio2. A photo of the AFM setup in our clean room is shown here.

notes

summary

5m 41s



This video shows a sequence of screenshots recorded during a real AFM imaging of the chrome sample as discussed before. The video is partially accelerated and edited to make it shorter. In reality, you should count for about 3 to 5 min to setup and prepare the measurements. And then, count about 3 min to record an entire

notes

summary

5m 55s

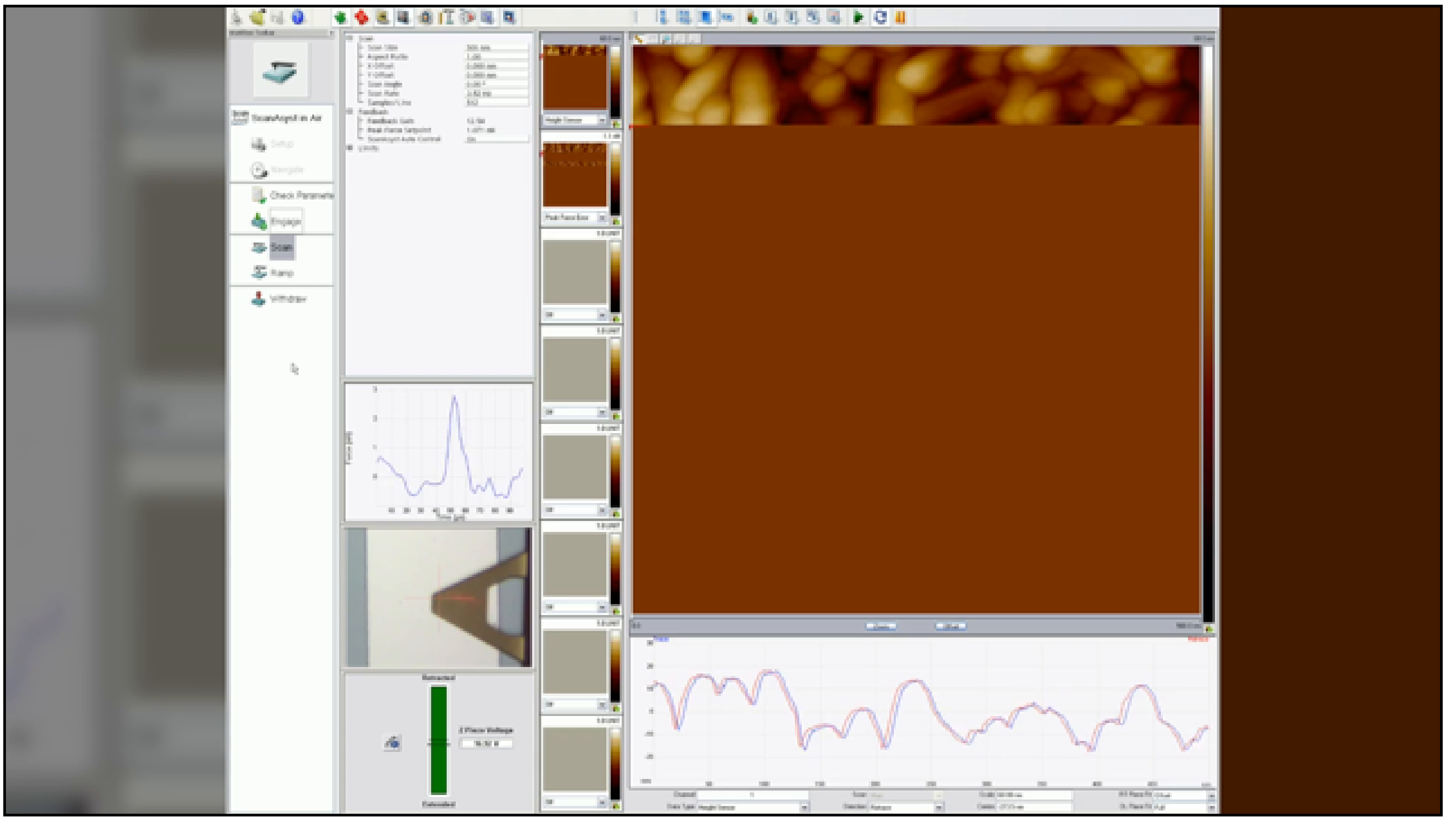


image of about 500 by 500 nm in good resolution. First we locate the measurement site of interest with the aid of the integrated optical microscope. In this case, we aim to inspect a chrome surface on the bi-morph wafer which is the bright area on the image. The AFM cantilever tip is not in contact with the surface during the navigation. Once we are at the right spot to measure, we setup and check the measurement parameters such as the scan size, scan rate, and sampling rate, then we approach the tip to the surface and start scanning. The approach between the tip and the surface is done automatically while monitoring the cantilever response. After approaching the surface, the scanning begins. Here in this sequence, you see the

notes

summary

6m 22s

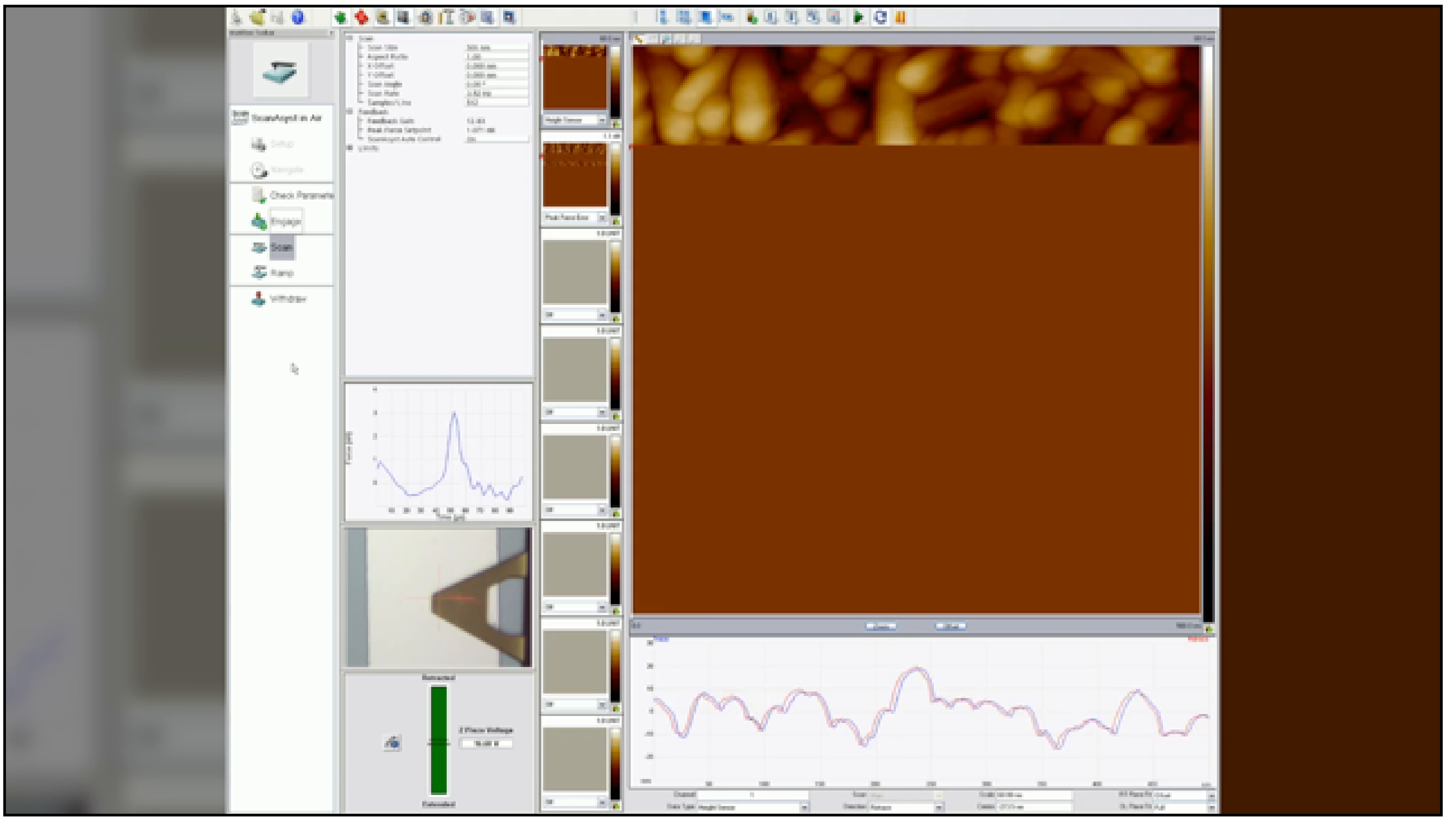


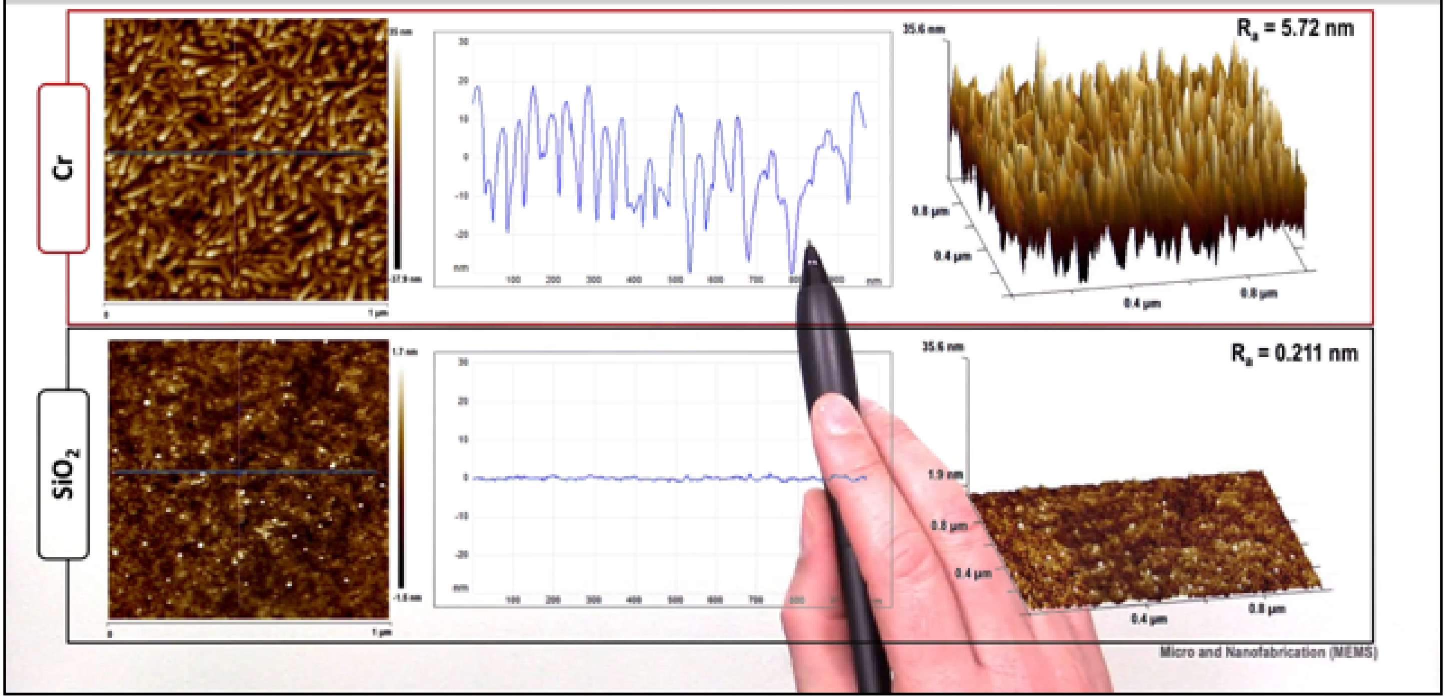
image built up in real time with a real time topographical profile here at the bottom.

notes

summary

7m 11s

Bi-morph surface roughness measurement



Now we accelerate the video, in reality the entire image takes 3 min to build up. Please notice that the x and z axis are not in scale and the blue and red lines are the result of forward and backward scanning respectively. The scanning range here, again, is 500 by 500 nm. Here, are shown the AFM scan data of the chrome film here, and sio2 here. The left shows the top few in color code with x y scan area and the z scale here in this color bar. The surface topography profile along the blue line is shown in the center where we see the chrome has a roughness of about 5.72 nm in average. We also see that the sio2 is much smoother and has a roughness of about 0.211 nm in average. To make this difference clear, we show these 2 scanned data with the same z-x value. Here and here. Images on the right are a tilted 3d view of the same scan as shown on the left. They allow for our eyes to see easier the surface nanoscale landscape. This lesson presented 2 mechanical surface profiler instruments. Remember that in some cases the physical contact between the tip and the surface can induce some damage. On the other hand, unlike the optical method seen before, we can also measure the thickness of opaque film which is not available with optical methods. Hence, we can also use AFM to obtain nanoscale images on both conducting and insulating materials. This is an advantage compared to methods using charged beams as you will see in the next lesson.

notes

summary

7m 14s