Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

7.7 Inspection and metrology 7

Concepts (extracted from automatically generated subtitles):

Resistivity of thin films. Electrical resistance of the chrome heaters. Well-controlled current. Resistivity of the deposited chrome. Sheet resistance. Point probe measurement. Bi-morph actuator. Measured values of voltage. Chrome resistor. Electrical properties of micro. Contact resistance. Automatic 4-point probe tool. So called van der pauw. Electrical signals. Silicon wafer.

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

to video

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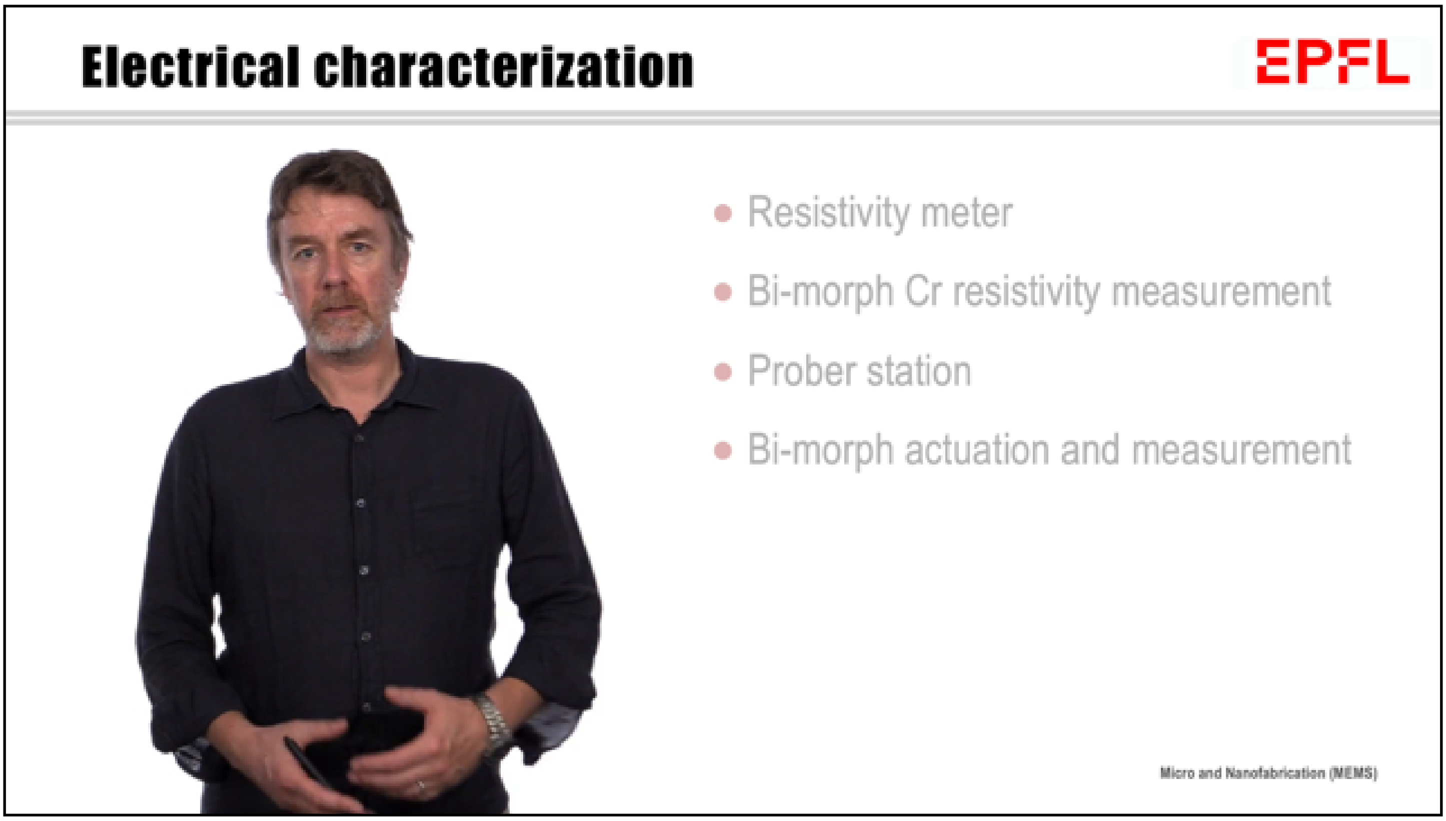
notes

summary

0m 0s



In this module, I will present methods to characterize the electrical properties of

notes

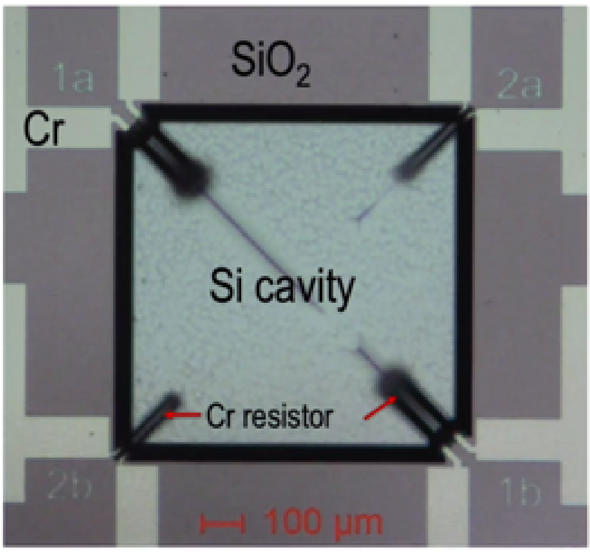
summary

0m 1s

Bi-morph electrical characterization

EPFL

How to evaluate the Cr film quality and determine the resistance of the Cr heaters?



Optical microscope

Micro and Nanofabrication (MEMS)

micro and nano fabricated devices and systems. I will first introduce how to measure the resistivity of thin films, and in particular provide measured details of the thin chrome film that we used for the bi-morph actuator. Then, I will show the functionalities of the prober station and show how to use it for electric characterization of the bi-morph actuator. Remember our case study of the bi-morph actuator that we used to run through the typical MEMS fabrication processes. We will now have a closer look how we can determine the resistivity of the deposited chrome thin film and show how we can calculate and measure

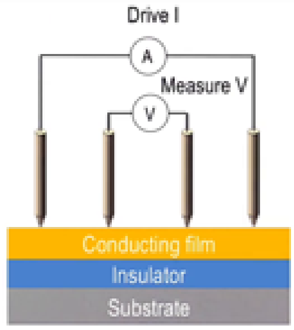
notes

summary

0m 5s

Resistivity meter

- To evaluate the metal film quality
- Van der Pauw 4-point measurement
- Probe spacing: ~ 1mm
- Unpatterned film with known thickness on an insulator
- Accuracy: +/- 0.5%



Van der Pauw formula for 4-point measurement: $$R_s = \frac{\pi}{ln2} \cdot \frac{V}{I}$$

Calculate resistivity: $$\rho = R_s \cdot t$$

R_s : Sheet resistance (ohm/sq)
V : Voltage (V)
I : Applied current (A)
ρ : Resistivity (ohm•m)
t : Film thickness (m)

Micro and Nanofabrication (MEMS)

the electrical resistance of the chrome heaters, that are used to induced their bending. A well-known and widely used method to determine the resistivity of a thin film is based on the so called Van der Pauw 4 point probe measurement. It is schematically shown here in this drawing. 4 needles with about 1 mm spacing in between are in contact with the thin film in yellow. A source applying a well-controlled current through the 2 outer probes induce a current flowing through the sample in thin film. The 2 inner probes are measuring the voltage difference. The strength of this method is that since we measure a voltage, and not a current, the contact resistance is not critical, and allows for more precise measurement of the resistivity.

notes

summary

0m 49s

Bi-morph Cr resistance calculation

EPFL

$$R = \rho \frac{L}{tW} = R_s \cdot sq. \quad where \quad R_s \equiv \frac{\rho}{t} \quad sq. \equiv \frac{L}{W}$$

R	:	Resistance (ohm)
ρ	:	Resistivity (ohm•m)
L	:	Resistor length (m)
t	:	Resistor thickness (m)
W	:	Resistor width (m)
R_s	:	Sheet resistance (ohm/sq.)
sq.	:	Square number

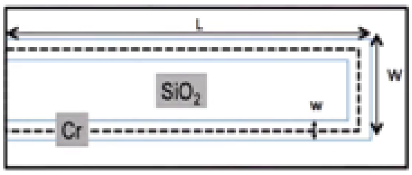
For Cr resistor:

R_s = 2.152 ohm/sq.

L = L_{eff} = 640 μm

W = 7.13 μm

The resistance of Cr = 2.152 x (640 / 7.13) = 193.2 ohm



$$L_{eff} = 2\left(L - \frac{w}{2}\right) + W - w$$

Micro and Nanofabrication (MEMS)

This method applies to conducting and semi-conducting thin films as well as to bulk samples not shown here in this lecture. With the measured values of voltage and current, we can use the Van der Pauw formulae as shown here, to calculate the sheet resistance. The pi over log of 2 here, is the geometric factor aid for using 4-point measurement for thin film with a thickness that is negligible with regard to the spacing between the probes. We then can calculate resistivity by multiplying the sheet resistance with the thickness of the thin film. The photograph on the right shows the automatic 4-point probe tool in our clean room, which can measure the sheet resistance on multiple sites on a wafer automatically. Here is a video showing the operation of the resistivity meter in our clean room. The wafer we measure is a sio2 coated silicon wafer, after the 500 nm thick chrome deposition. Once the wafer is placed on the sample holder, and the measurement recipe is set up, the probing head carrying 4 needles will start measuring the sheet resistance from 5 sites on the wafer, automatically. Here we average the 5 sites sheet resistance, and calculate the resistivity of the chrome film on the bi-morph to be 1.076 * 10power-6 ohm meter. This is a reasonable value for chrome film deposited on the silicon dioxide by means of thermal evaporation. The resistivity of the deposited metal film may have different values depending on how the film is deposited. It also depends on the underlying material. Please notice that the resistivity meter can only measure the un-patterned thin film. In the bi-morph device, the chrome resistor is patterned by lithography to form a conducting path with a certain length L, and a width W, in a U shape as shown here, in this drawing. Let us now calculate the resistance of the chrome heater. Resistance equals resistivity

notes

summary

1m 49s

Bi-morph Cr resistance calculation

EPFL

$$R = \rho \frac{L}{tW} = R_s \cdot sq. \quad where \quad R_s \equiv \frac{\rho}{t} \quad sq. \equiv \frac{L}{W}$$

R : Resistance (ohm)
ρ : Resistivity (ohm•m)
L : Resistor length (m)
t : Resistor thickness (m)
W : Resistor width (m)
R_s : Sheet resistance (ohm/sq.)
sq. : Square number

For Cr resistor:

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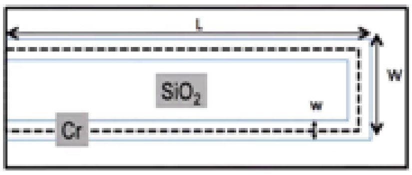
The resistance of Cr = 2.152 x (640 / 7.13) = 193.2 ohm



$$L_{eff} = 2\left(L - \frac{w}{2}\right) + W - w$$

Micro and Nanofabrication (MEMS)

times the resistor length over the thickness and the width. The definition of sheet resistance = resistivity /resistor thickness and the squared number defined as resistor length / resistor width. The resistance = sheet resistance * sq. In this case, the sheet resistance of chrome film is obtained from resistivity meter as 2.152 ohm square. The effective length of the u shaped chrome resistor is defined as shown here, and the value is 640 um.

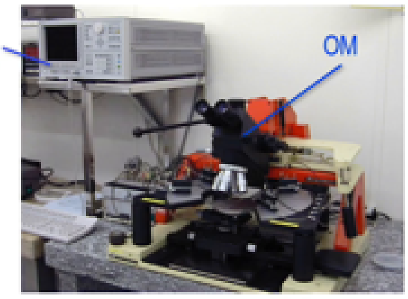
notes

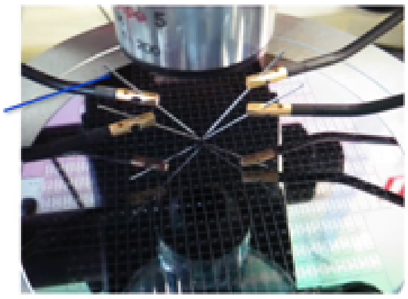
summary

Prober station

EPFL

- OM + tungsten micro probes + multimeter & power supply
- Metal pads needed: > 50 x 50 μm^2
- Electronics characterization
  - Current (0.1 fA – 1 A), voltage (0.5 µV – 200 V)
- I-V, C-V, C-f, C-t curves
- MEMS resonant frequency





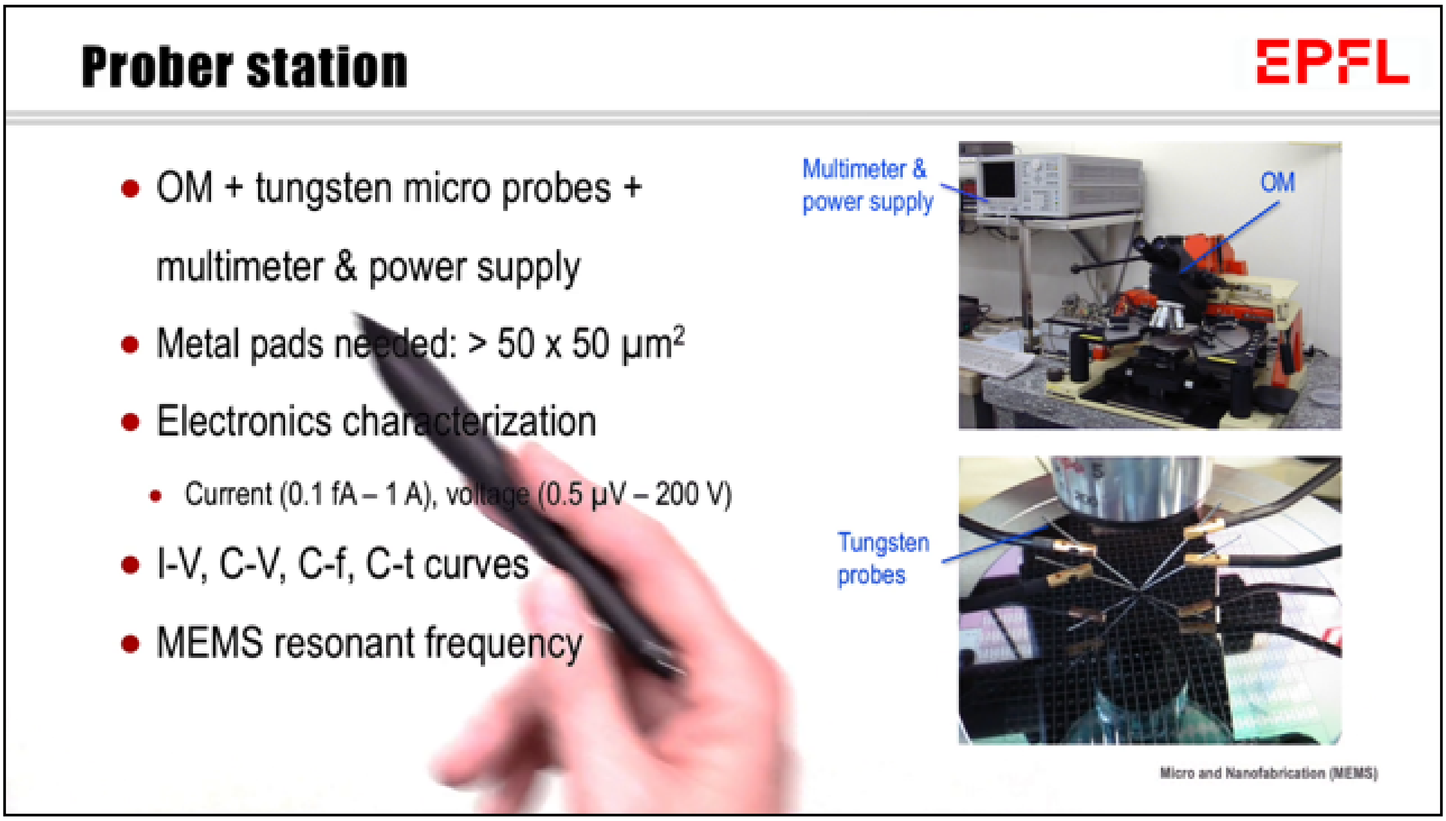
Micro and Nanofabrication (MEMS)

The width of the chrome resistor is obtained by averaging sub measurements resulting in the previous chapter, about 7.13 um. All together we calculate the resistance of the chrome resistor to be 193.2 ohm.

notes

summary

4m 37s

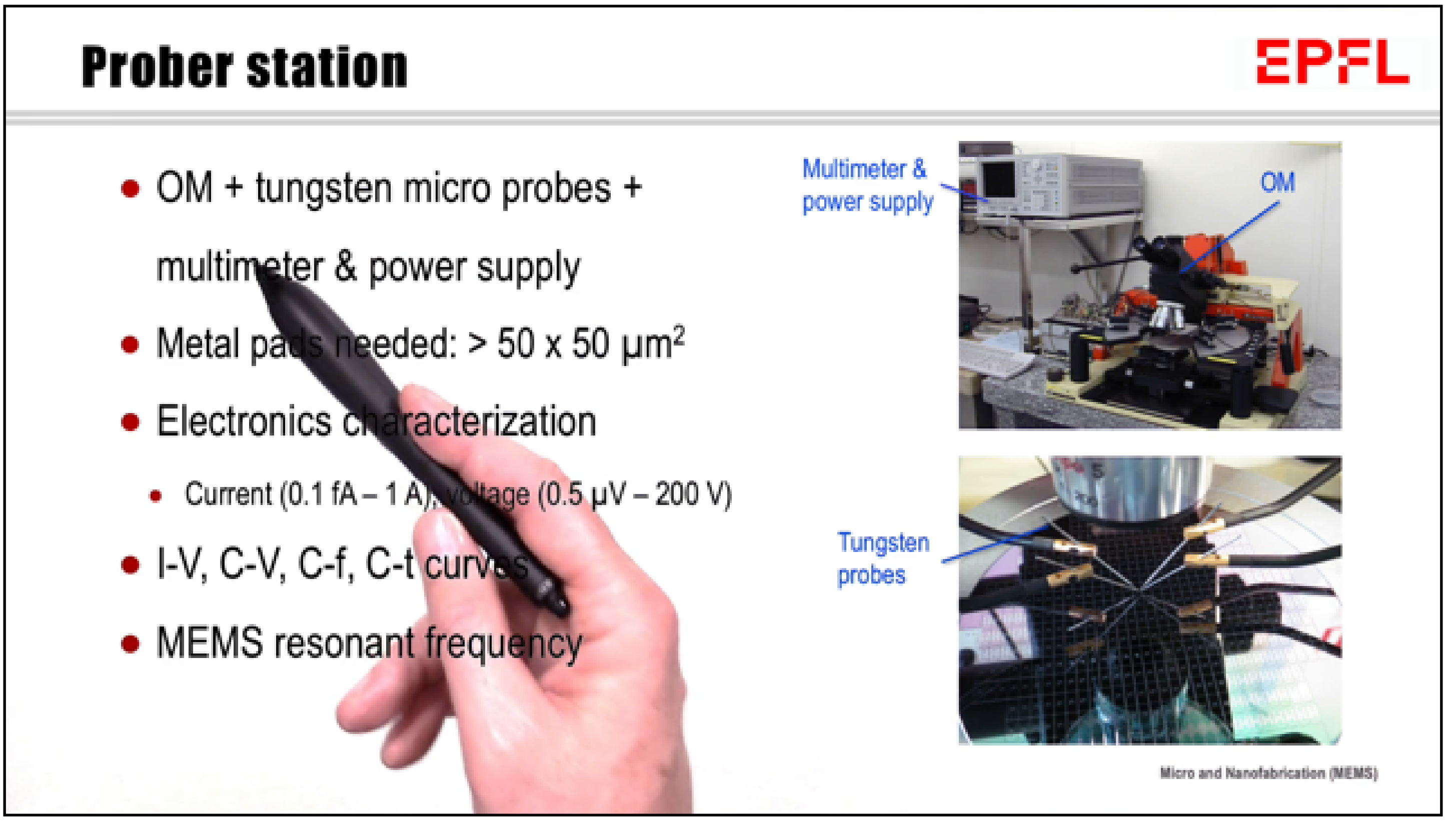


The tool to access to the inner parts of a MEMS and to apply electrical signals is often based on a prober, which is nothing else than fine needles that can be positioned with micrometer precision on a specific location of a MEMS device.

notes

summary

4m 54s



Tungsten needles can be controlled under an optical microscope, with micrometer precision and

notes

summary

5m 12s

Prober station

- OM + tungsten micro probes + multimeter & power supply
- Metal pads needed: > 50 x 50 μm^2
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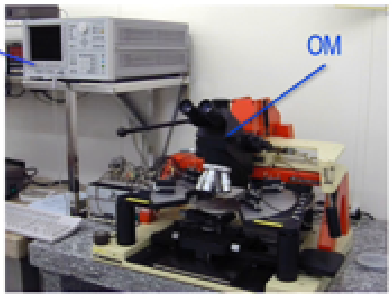
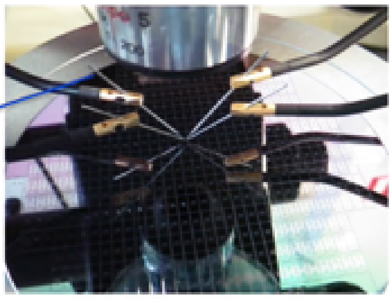
  - Current (0.1 fA – 1 A), voltage (0.5 µV – 200 V)
- I-V, C-V, C-f, C-t curves
- MEMS resonant frequency



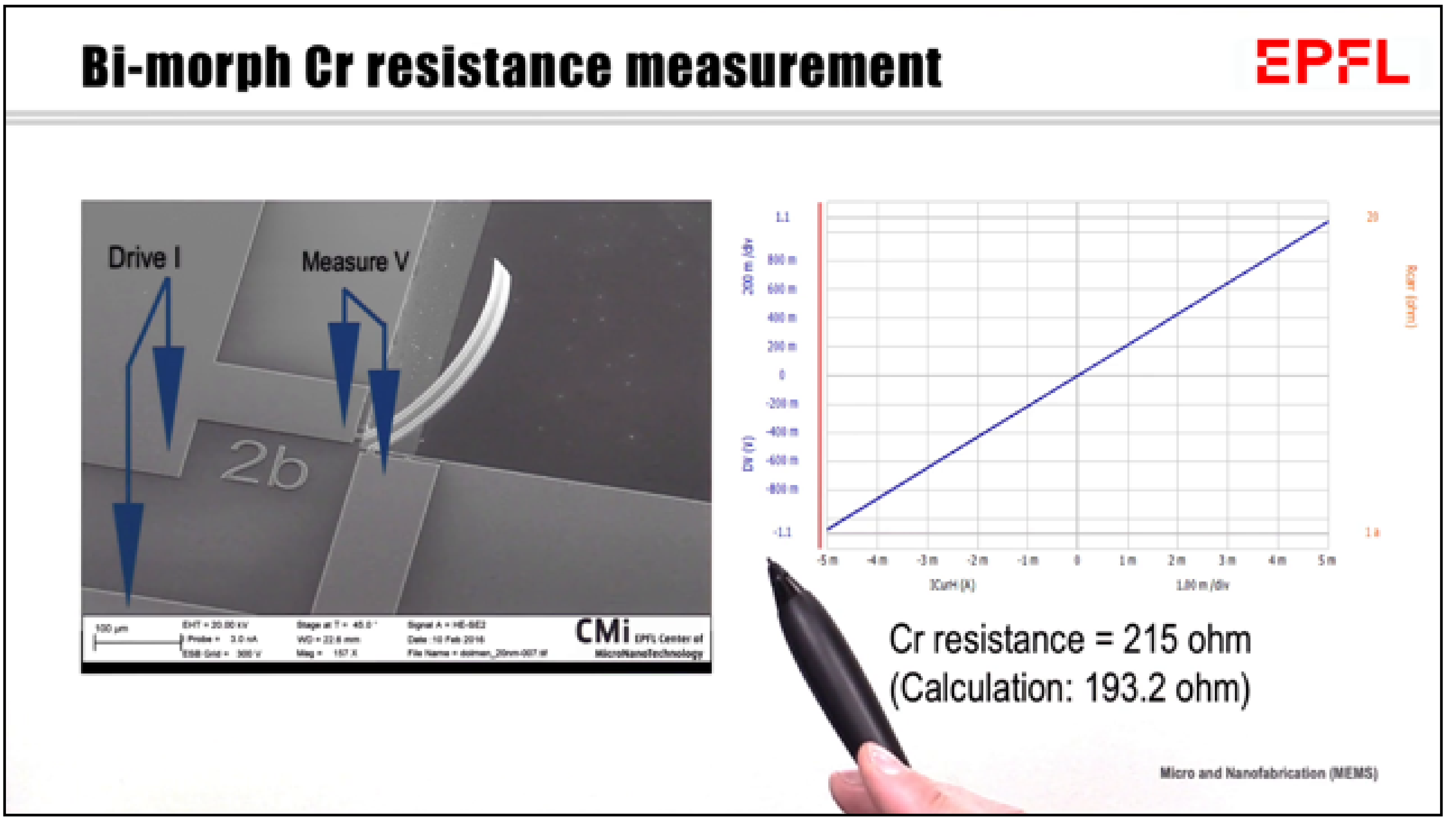


controlled electrical signals, such as voltage and current can be applied. A minimum contact area of 50 by 50 um is needed to position the needles properly. Typical curves that one can extract are IV, CV, C-f and C-t measurements. To some extent, also high frequency measurements can be done.

notes

summary

5m 14s

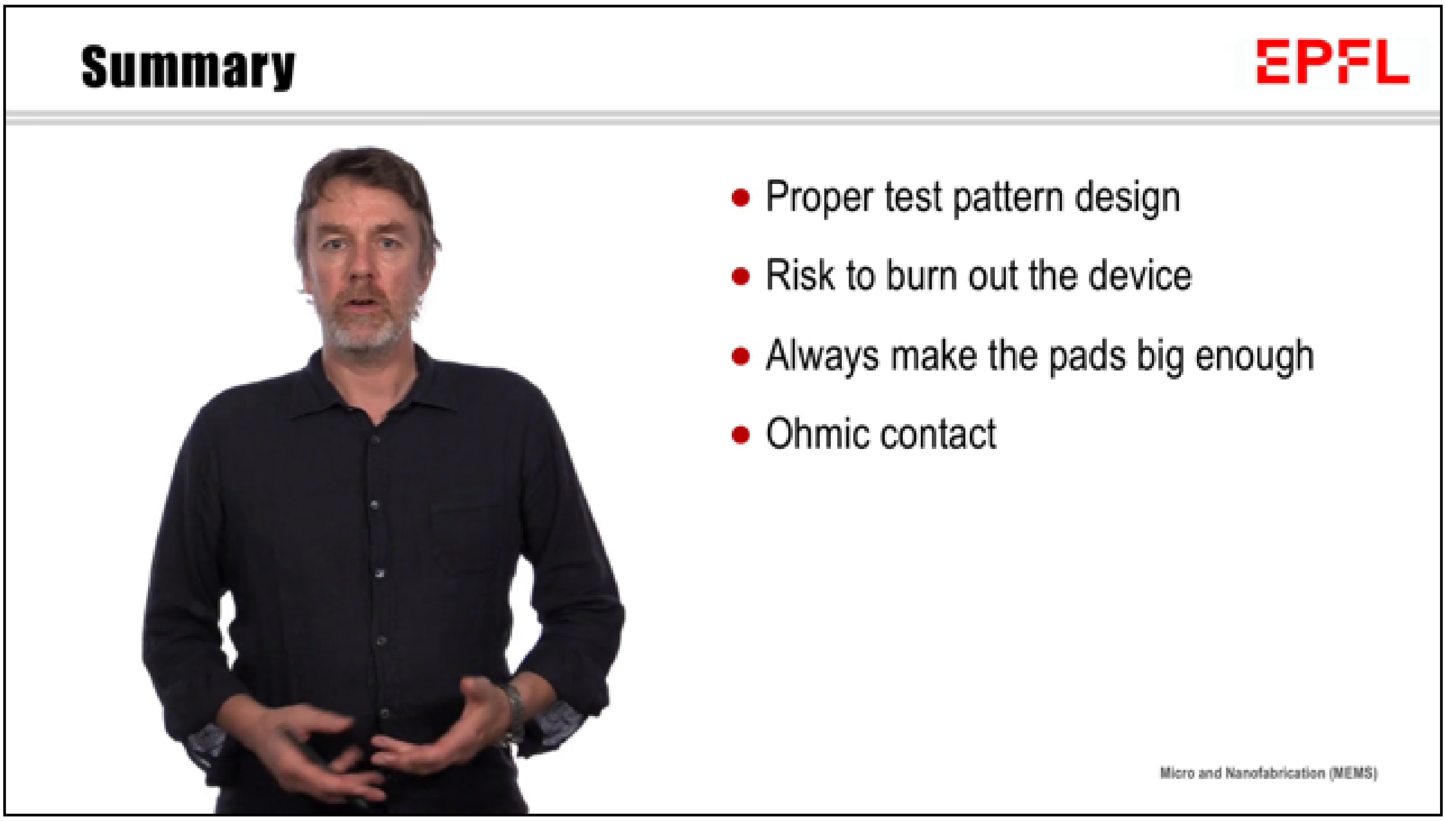


In our case, we apply a DC voltage to determine the resistive value of our bi-morph MEMS device. Here you see now on the left side an SEM image, one of our chrome bi-morph actuator beams, the blue arrows show where we apply the prober needles. Here again, we use a 4 probe principle to inject the current here, and to measure the voltage here. The current will then flows through the cantilever in and out in this 'u' shaped wire. By doing so, we are not influenced by the contact resistances between the needles and the contact pads. Which is often not well defined and could induce some errors. The right plot here shows the resulting IV curve of the measurement. The applied current on the x axis and the resulting voltage on the y-axis.

notes

summary

5m 37s



By calculating the slope, we can find that resistance of the bi-morph actuator is 215 ohms. It is about 10 % deviated from what we just calculated in the slides before. We have seen a few simple, but essential methods to determine the electrical properties of fabricated micro devices, it allows ultimately determining whether the process has been successful, and allows further to study new materials, and their electrical properties. This is very important to improve the device performance of new MEMS and MEMS. This last metrology and inspection lessons, closes the MEMS mooc lectures. On behalf of the entire mooc MEMS team, I would like to thank you for your interest and active participation. As always, we are eager to read your comments and feedback to further improve these lessons in upcoming sessions. Bye for now and enjoy the quizzes.

notes

summary

6m 37s