Subject 6: Electrical and optical characterization

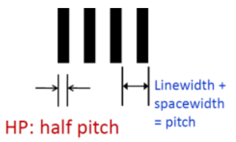
1. Objective

During this laboratory, you will learn how to use the four-point probe device for electrical characterization of aluminum thin films and an optical microscope to measure the dimensions of patterns and alignment errors.

2. Optical characterization

a. Alignment errors

This procedure is used to determine alignment capability using Vernier scales. They are patterns designed to resolve alignment errors for a given process. Figure 1 shows a vernier design. The blue structure has lines that are 4 µm wide and spaces that are 3.8 µm wide (resulting in a pitch of 7.8 µm). The red structure has both lines and spaces which are 4 µm wide (the corresponding pith is 8 µm). The difference between the two structures pitch, 0.2 µm, is the resolution of the vernier. A perfect alignment is obtained when the central lines (long lines) are well aligned. In case a misalignment exists, find where the first red and blue lines are aligned and count its position from the long line. The misalignment is the position number times the offset, 0.2 µm. A second vernier with a resolution of 1 □m is added in case where error alignement is very large.



The pattern of the vernier in your mask with features size are as follow:

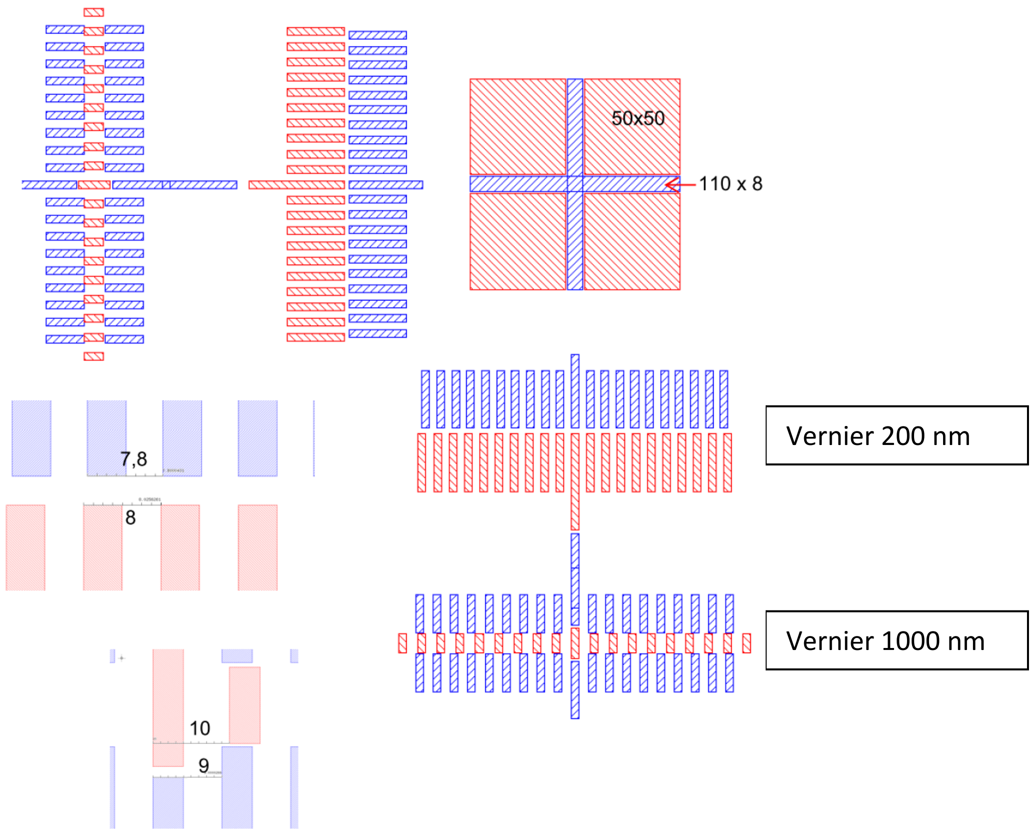
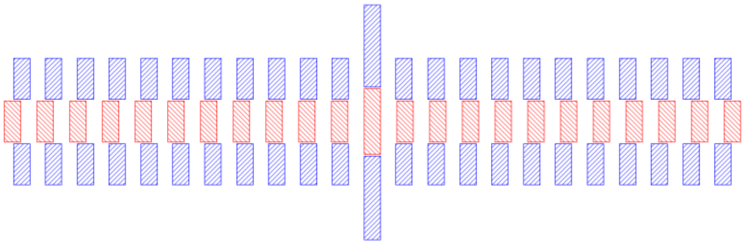
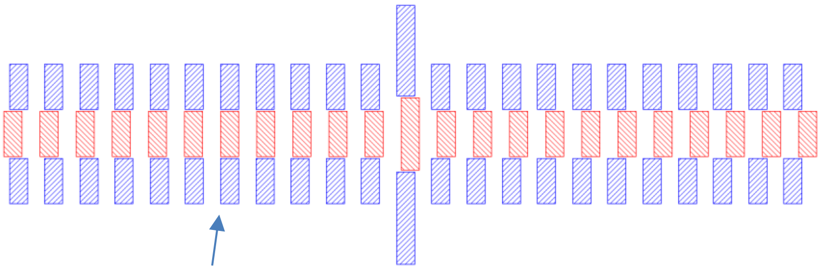


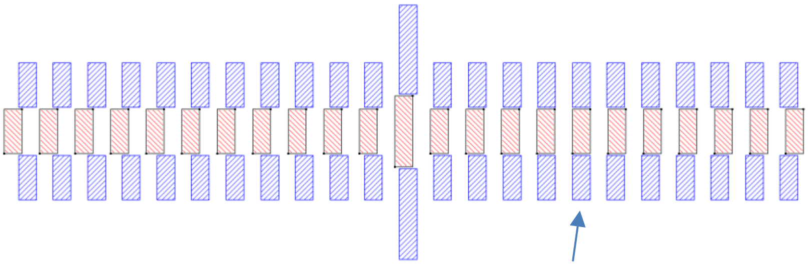
Figure 1: layout of the Vernier, in red is level one and in blue is the level two. The two levels are shown superimposed.



Example of 0 misalignment.



Example of -1 μm misalignment (fifth position times 0.2 μm).



Example of 1 μm misalignment (fifth position times 0.2 μm)

b. Laboratory Procedure

Under the optical microscope (Keyence digital microscope), observe your wafer in which you have already aligned the second-level photoresist on the patterned first-level wafer (in the cleanroom session).

- Each student characterizes a vernier located at (x,y) position.
- Inspect the vernier on the wafer and take a picture.
- Record misalignment errors for x and y positions at different locations on the wafer:

Student name				
Vernier coordinates (x,y)	(0,28)	(28,0)	(-28,0)	(0,-28)
Δx (unit)				
Δy (unit)				

- Observe under optical microscope, your wafer with aluminum patterns obtained by the etching process and the one by lift-off process.
- Take pictures of the same pattern with the same magnification.
- Measure their dimensions.
- Inspect and compare the difference between the patterns obtained by the two methods.

3. Electrical characterization

a. Transmission line method (TLM)

Resistors are tested and characterized with Karl Suss PM6 Probe station and the Keysight 34420A Nano_Volt/Micro_Ohm Meter. The devices to be tested are aluminum resistors obtained by chemical etching and lift-off methods. The layout of the resistors is shown in figure 2.

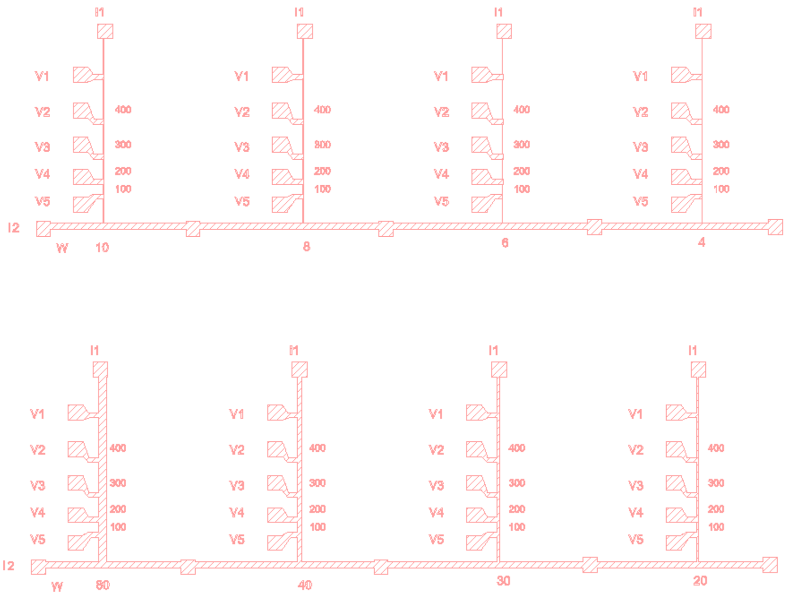
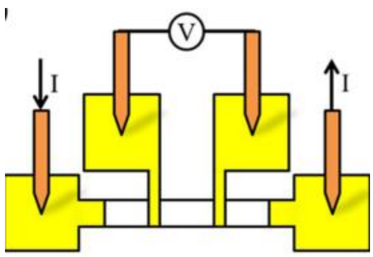


Figure 2. layout of resistor patterns

These structures will be used to plot the curve R versus L, where R is the electrical resistance and L is the length of the resistor segment.

b. Laboratory Procedure

- Place the sample on the wafer stage



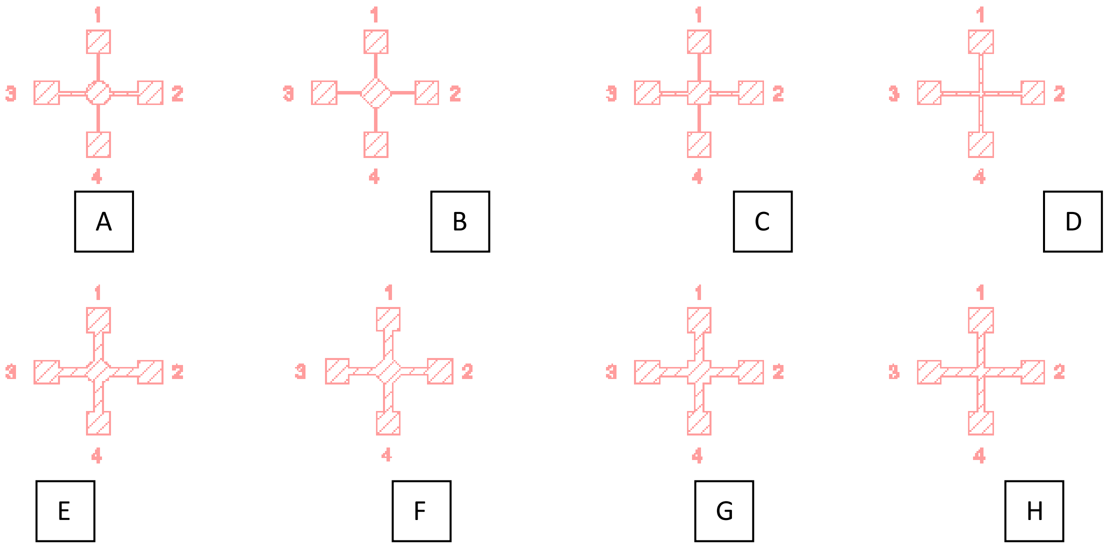
- Place the probe tips on the contact areas as follows:
  - Two probe tips for current injection, these probes are labeled I_1 and I_2. Under the optical microscope, use the micropositioning stage to place each tip on the corresponding pad on your sample with the same label of the probe tip.
  - Two probe tips for voltage measurement with labels V_1 and V_2. Under the optical microscope, place each tip on the corresponding pad on your sample.
  - Select the 4W mode on the Keysight 34420A Nano_Volt/Micro_Ohm Meter, the resistance value is directly displayed.
  - complete the following table:

contact	V1-V2	V1-V3	V2-V3	V2-V4	V3-V4	V4-V5	W (unit)	Student name
L(µm)	400	750	300	550	200	100		
R(unit)								
R(unit)								
R(unit)								
R(unit)								

- Plot R versus L and calculate the slope of the curve.

c. Sheet resistance measurement

The following Structures will be used to measure the sheet resistance.



d. Laboratory Procedure

- Place the probe tips on the contact areas as follows:
  - for current injection: pads 1 and 2
  - for voltage measurement: pads 3 and 4.
  - The resistance value displayed is used to calculate the square resistance by the following formula:

$$Rs = \frac{\pi}{\ln 2} \times \frac{V_{34}}{I_{12}}$$

- Complete the following table :

structure	A	B	C	D	E	F	G	H
Rs (unit)								

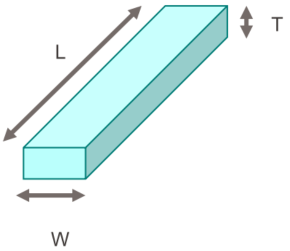
- Compare the value of Rs for the different structures.
- From Rs and the slope of the curve R versus L, calculate the width of the measured structure.
- Compare this value to the one obtained by optical measurement.
- Compare the measured value of W to the one registered on the photomask.

- Knowing the thickness of the aluminum film (measure done in the cleanroom session), determine the resistivity of the film?

EPFL

Résistance électrique

Piste de section rectangulaire



$$R = \rho \frac{L}{W.T}$$

$$L = W \rightarrow R = \frac{\rho}{T} = R_{\blacksquare}$$

$$R = R_{\blacksquare} \frac{L}{W}$$

L (longueur) et W (largeur): caractérisent la géométrie du masque

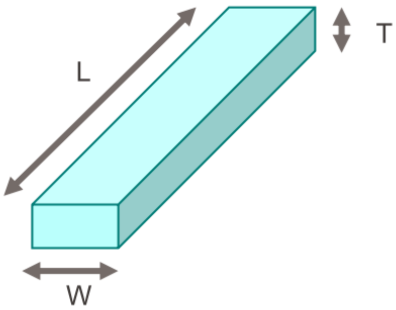
$R_{\blacksquare}$ Résistance par carrée : caractérise la technologie

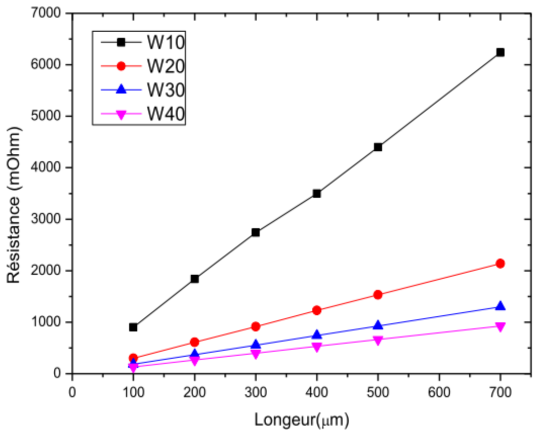
ρ Résistivité du film

T Epaisseur du film

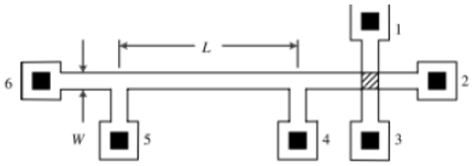
Barre de section rectangulaire

$$R = R_{\blacksquare} \frac{L}{W}$$

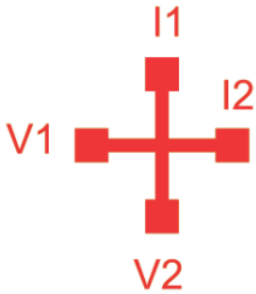


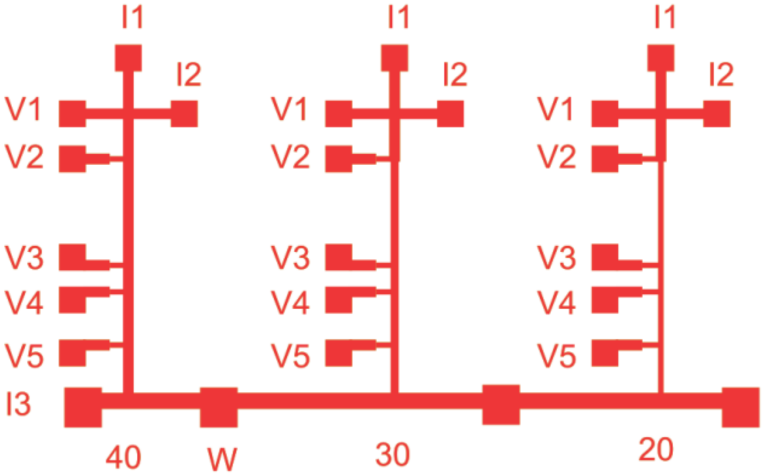


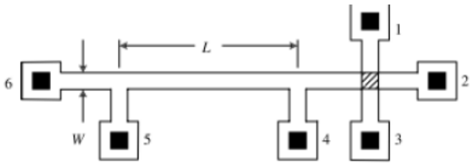
$$pente = \frac{R_{\blacksquare}}{W}$$



$$R_{\blacksquare} = R_{sh} = \frac{\pi}{\ln(2)} \frac{V_{34}}{I_{12}} \qquad V_{45} = \frac{R_{sh} L I_{26}}{W}$$







$$R_{\blacksquare} = R_{sh} = \frac{\pi}{\ln(2)} \frac{V_{34}}{I_{12}} \qquad V_{45} = \frac{R_{sh} L I_{26}}{W}$$