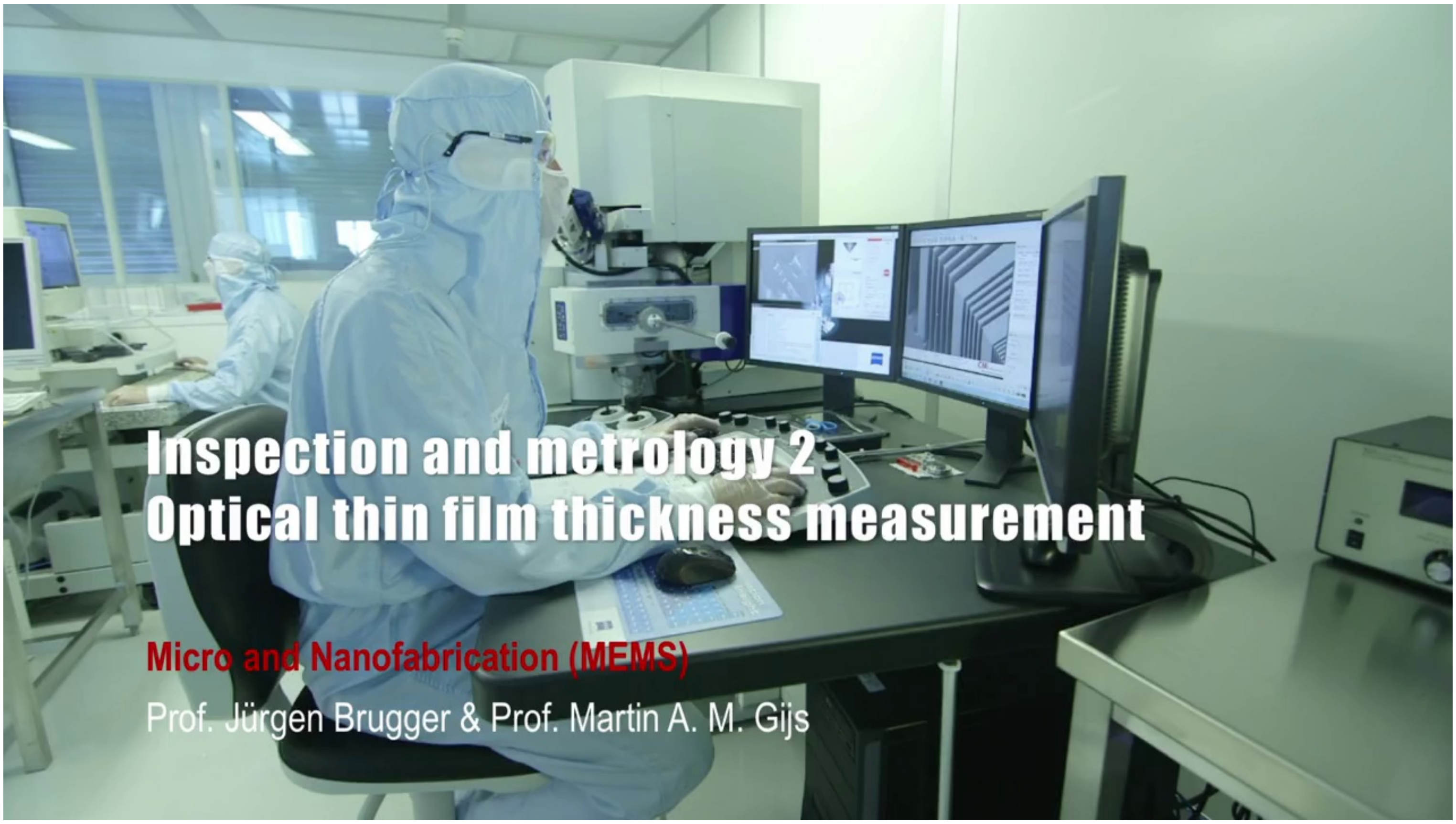

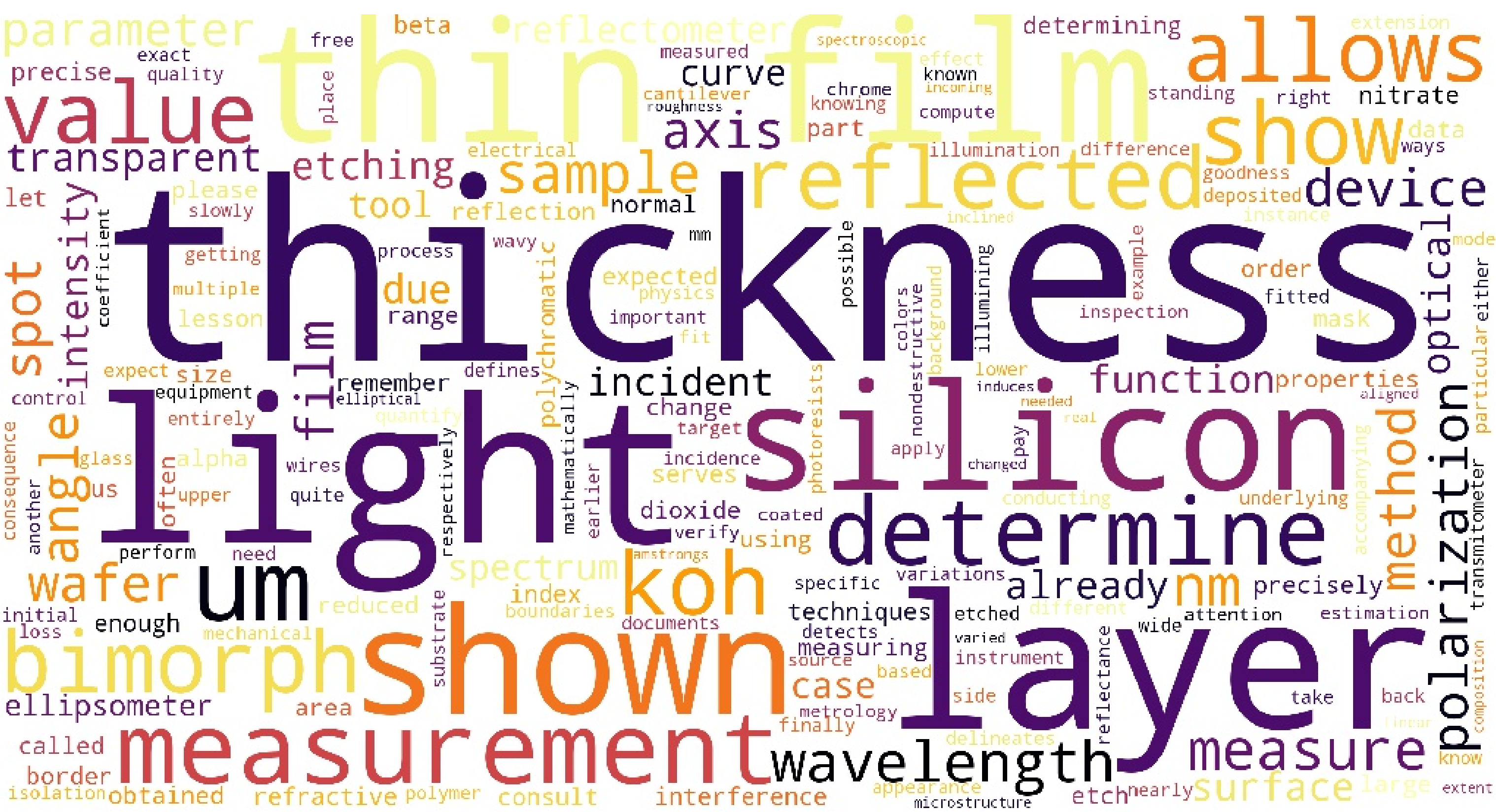

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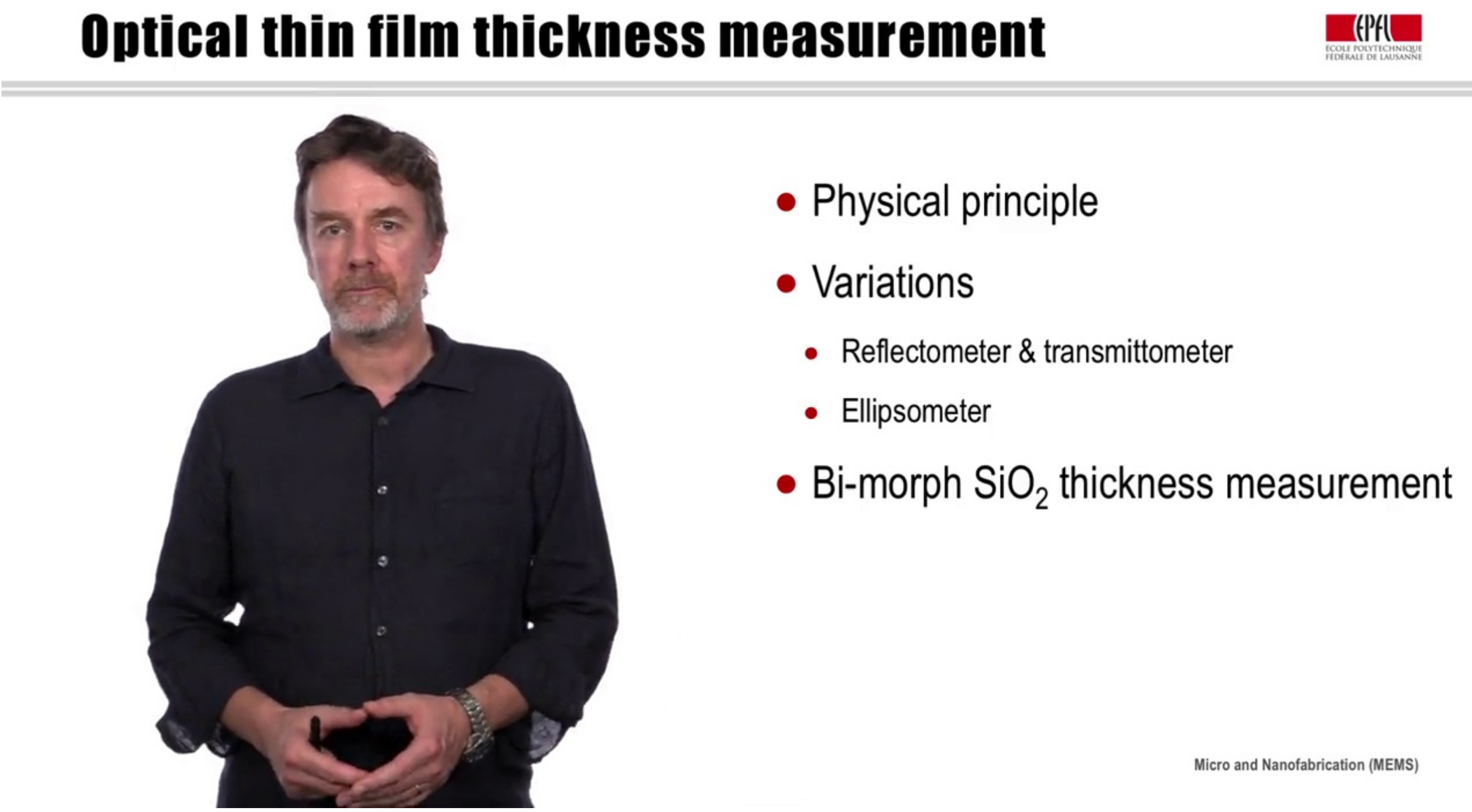
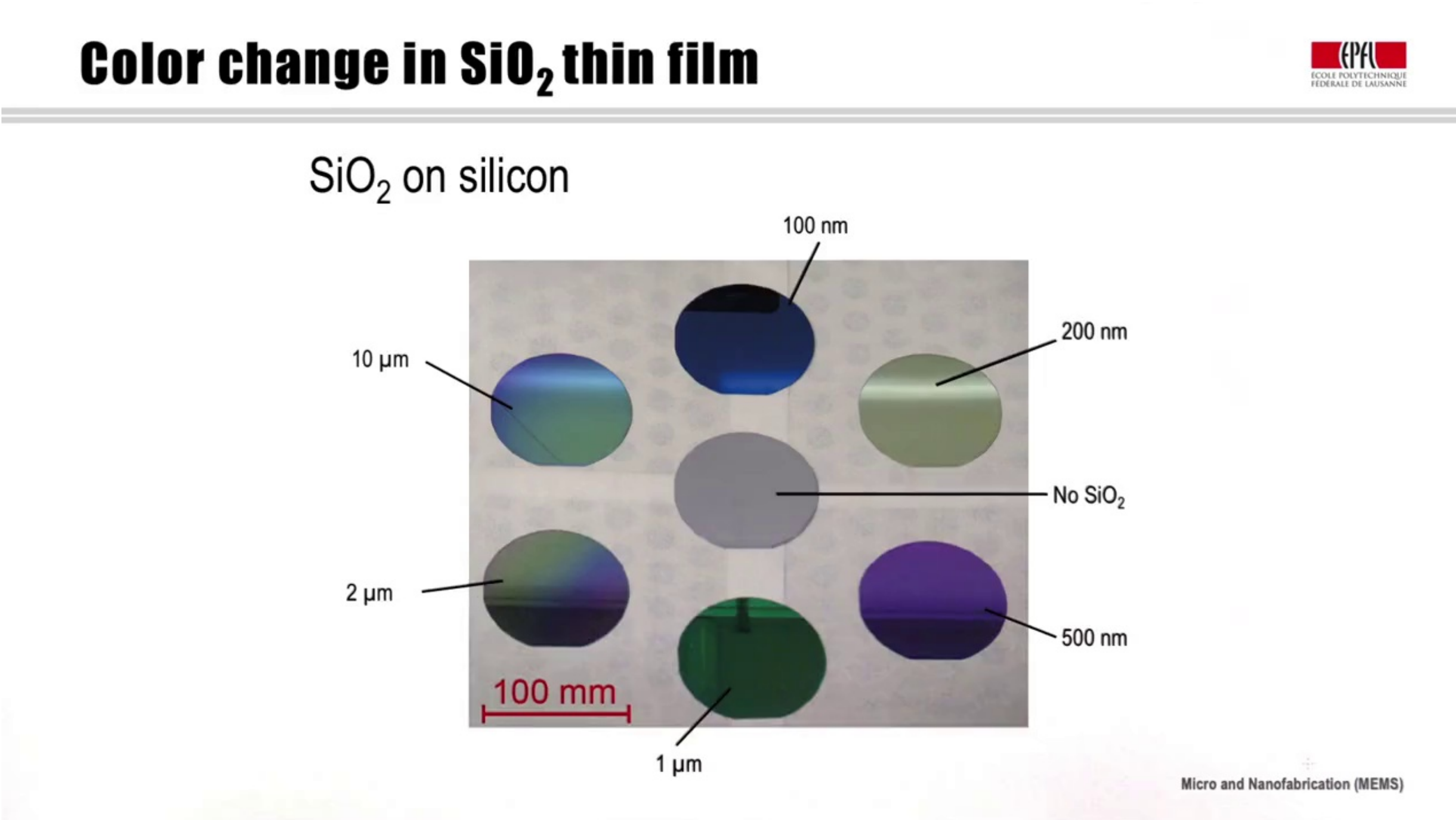
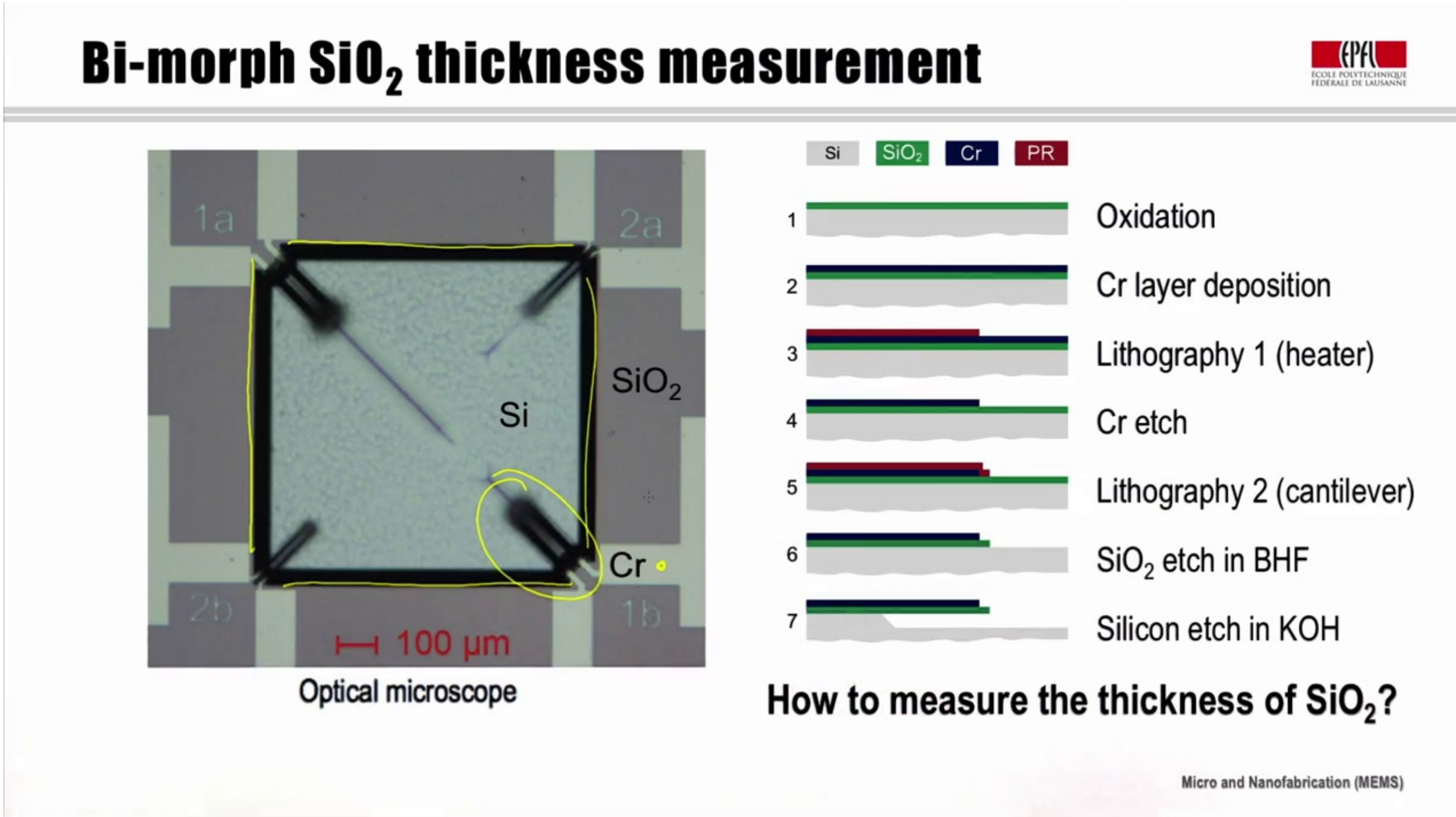


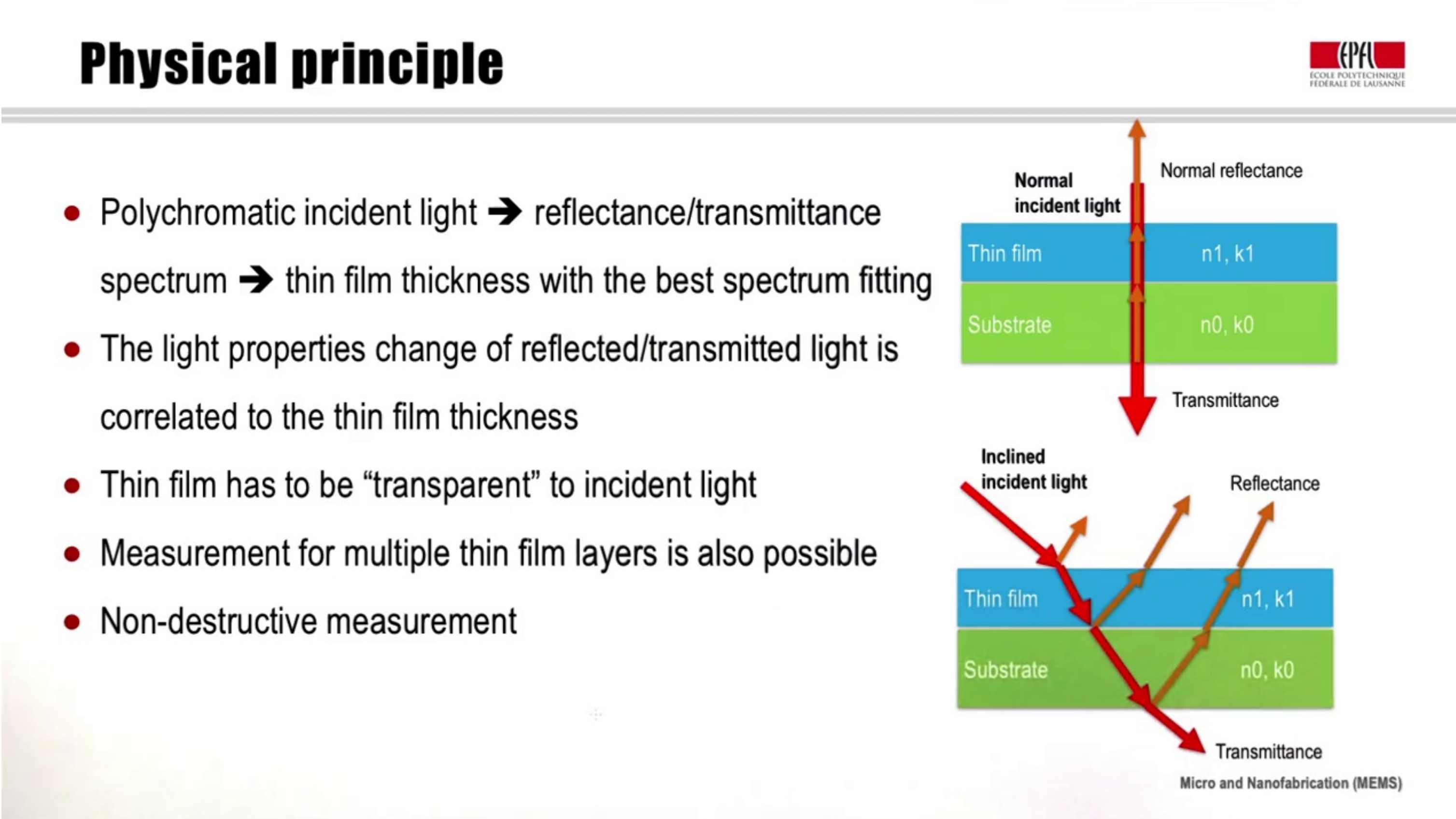
In wafer inspection, metrology and quality control, it is very important to determine the exact thickness of deposited thin films. Here in this lesson, I will show how we can precisely quantify the thickness of transparent films such as silicon dioxide or silicon nitrate using optical methods. We will use again the bi-morph device as an example and determine the SIO2 thickness.



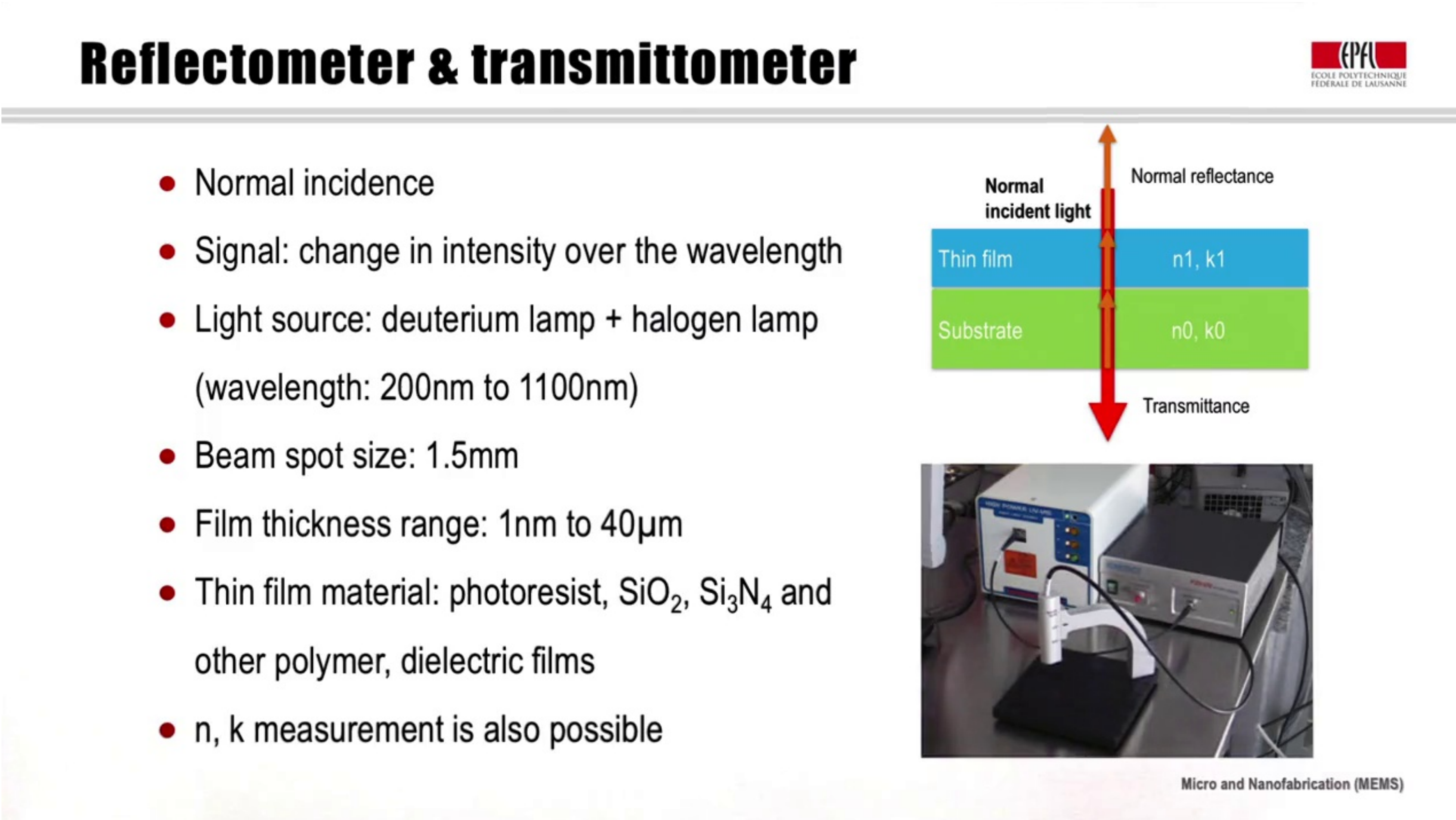
Remember, we have already seen these silicon dioxide coated silicon wafers in an earlier lesson. Pay again attention to the different colors appearance which is a function of the sio2 layer thickness. This effect is due to the interference between the light reflected by the upper and lower boundaries of the transparent thin films. It allows already getting a first estimation of the SIO2 thickness. For more precise value, we need specific tools.



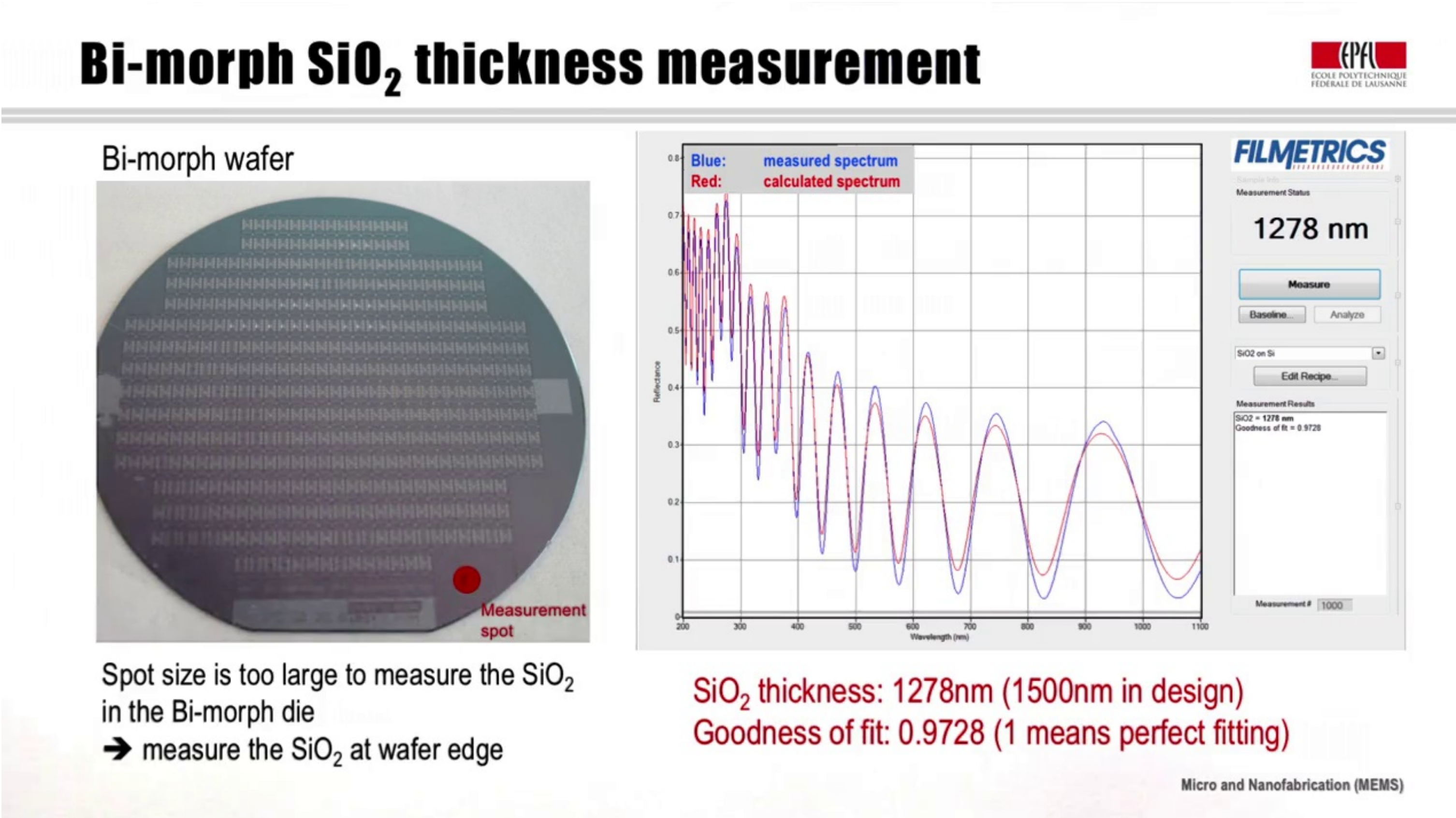
I will now show you how we can determine the SIO2 layer thickness of the bi-morph device shown here again. The SIO2 layer not only defines the mechanical properties of the free standing bi-morph cantilever, over here, but it also delineates the mask layer for the KOH etching like here, here , here and here. Finally, the SIO2 layer also serves as an electrical isolation between the conducting chrome wires and the underlying silicon substrate.



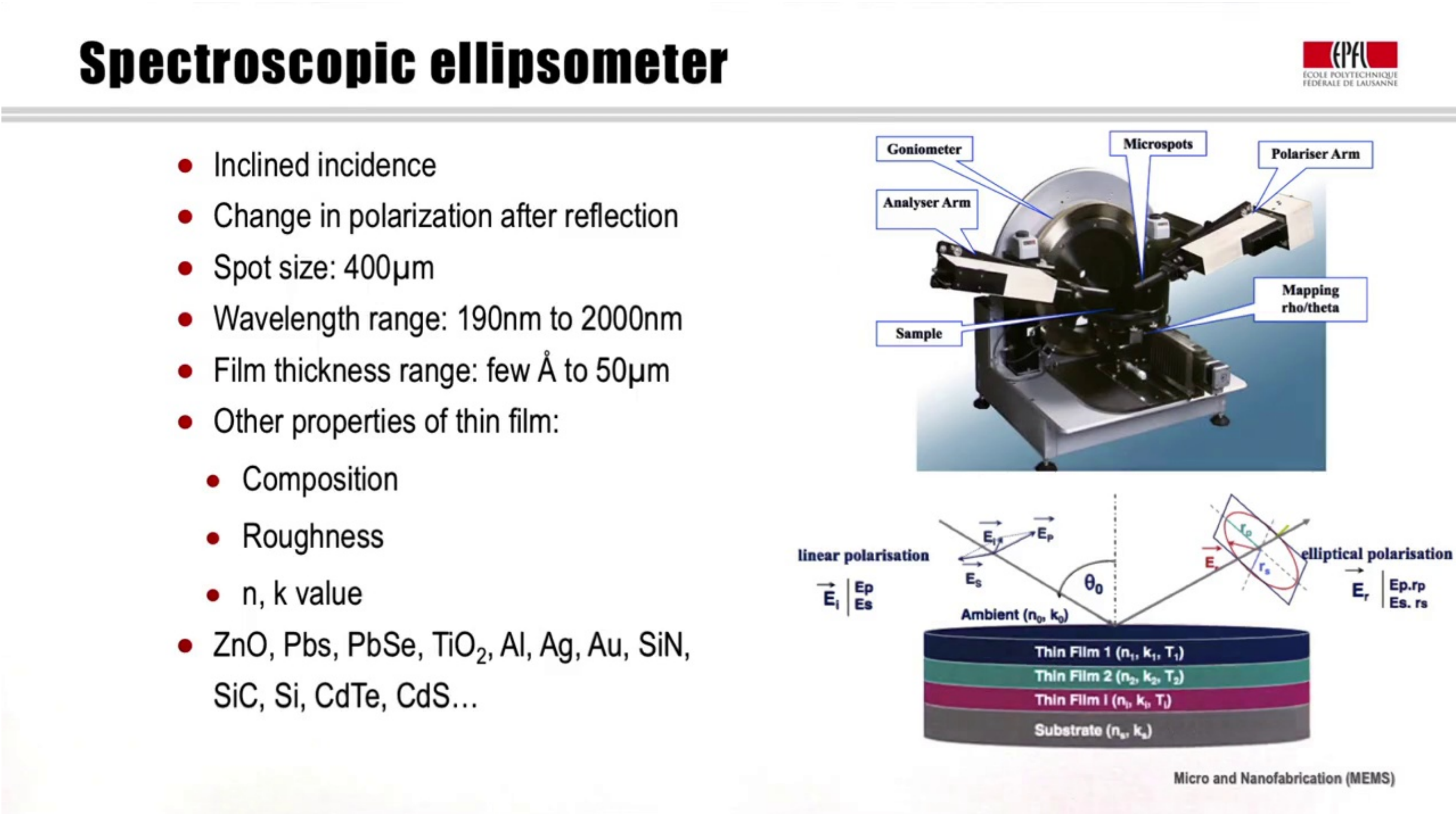
There are 2 ways to perform optical measurements shown here and that use polychromatic light that is incident to the surface either normal or under an angle. The light is then reflected back to the instrument and by measuring intensity wavelength, or polarization of the reflected light, one can compute the thin film properties. For instance by knowing the film parameters of ”n” and ”k”, where ”n” is the refractive index, and ”k” is the extension coefficient respectively, one can precisely determine the SIO2 layer thickness. It is also possible to measure multiple thin films. These techniques are entirely non-destructive to the sample.



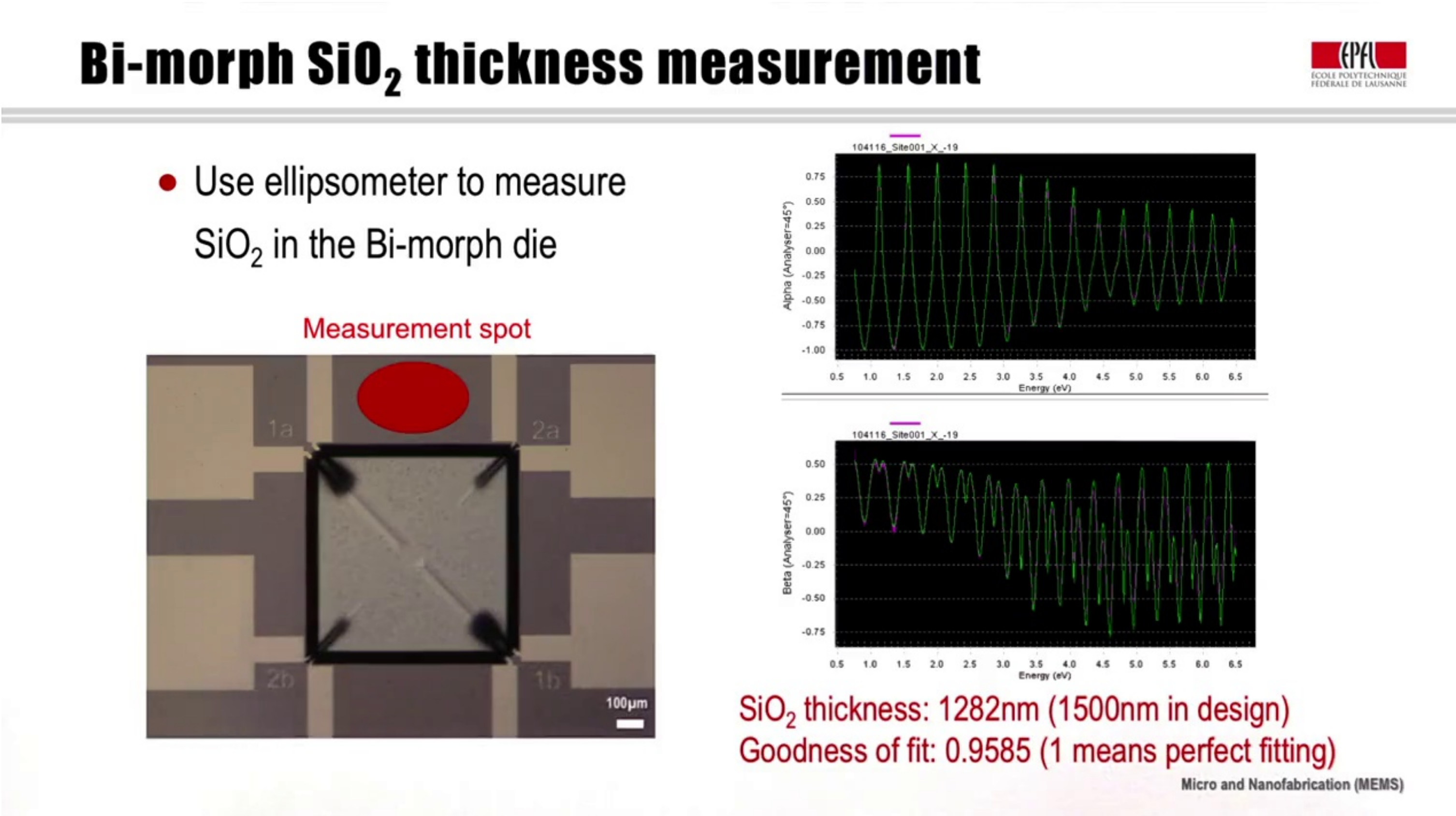
An equipment to measure the layer thickness of thin films using the normal incidence mode is called reflectometer or transmitometer as shown here on the right side. It is based on illumining the surface with polychromatic light of wavelength between 200 and 1100nm. The reflectometer detects the change in intensity of the reflected light over the light source spectrum. Intensity variations are due to thin film interferences. The illumination spot is in the order of 1.5 mm as a consequence, only large film samples can be measured. The range of thickness measurement is between 1 nm and 40 um. This is quite a wide range. This method is often used on photoresists, SIO2, silicon nitrate, glass, and polymer samples. It also allows determining ”n” and ”k” values, in case the thickness is already known. Please consult accompanying documents for more physics background of this measurement.



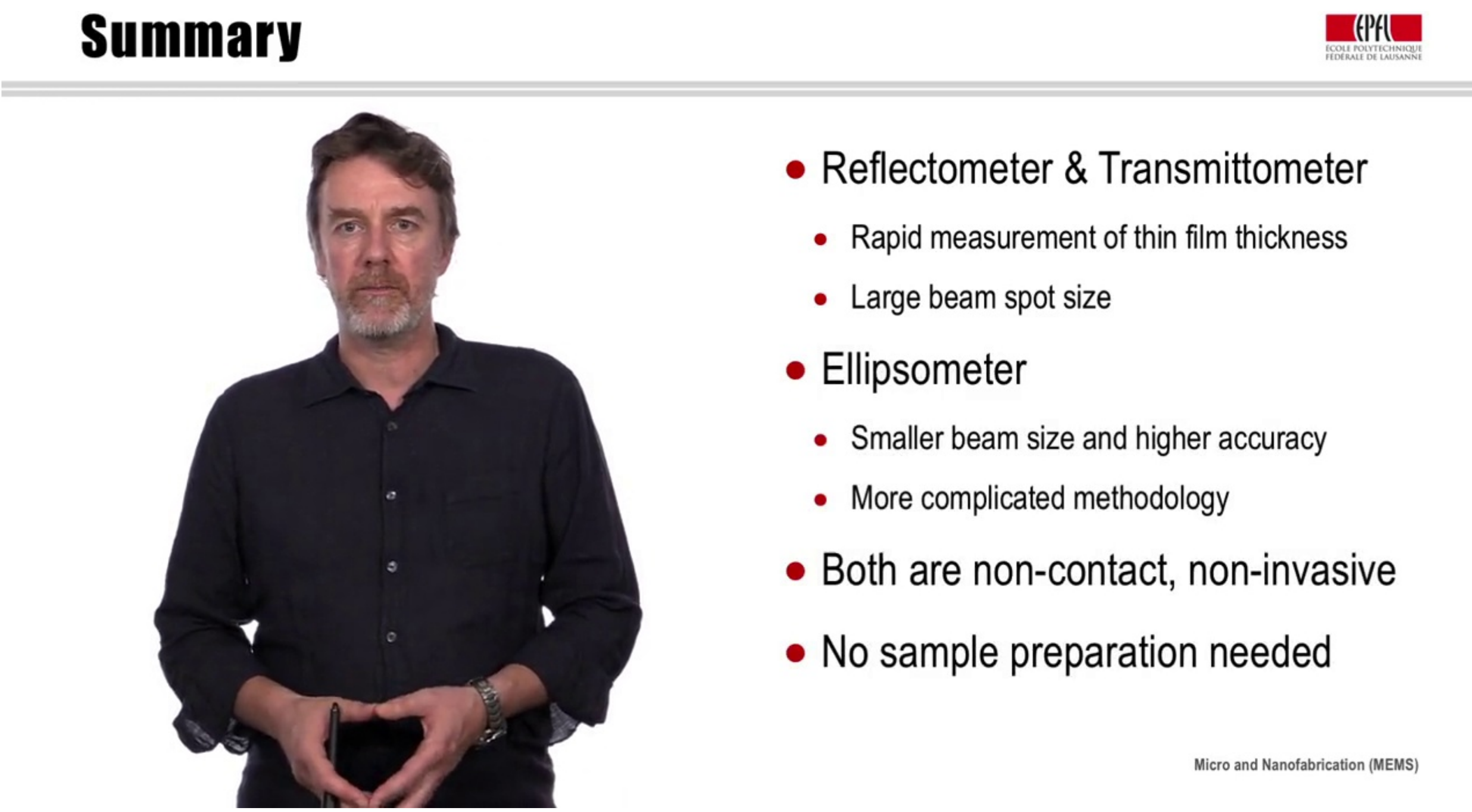
Let us take again the wafer in process for the bi-morph device, shown here. you apply this method at the border of the wafer, here, where there is a large enough surface area to place the measurement spot. In this particular case, we measure the SIO2 layer thickness after the KOH etching. Remember that the target value for the SIO2 layer is 1.5 um. We also know that the SIO2 serves as a mask for the KOH etching. But that the SIO2 is also etched slowly in the KOH etch part. Hence, we expect to see a reduced thickness of the SIO2. Let's now verify this here. The curve here, shows the reflectance on the "y" axis as a function of the wavelength on the "x" axis. This spectrum shows a wavy curve as shown here, which is then fitted mathematically to determine the SIO2 thickness. In our case, we get 1.278 um which is with the goodness of fit of nearly 1. As expected, the thickness of SIO2 has been reduced from our initial value of 1.5 um to 1.278 um. The 200 nm difference obtained is expected and is due to the loss of SIO2 during the KOH silicon etch.



Another often used tool is the spectroscopic ellipsometer. Here, the angle of light incident is inclined which induces a polarization change after the reflection. The linear polarization of the incoming light is changed to elliptical polarization for the reflected light. The spot size of the light is in the order of 400 um. And can be aligned to a microstructure if needed. The wavelengths can be varied between 190 nm and 2000 nm, which allows measuring film thickness from a few Amstrongs up to 50 um thickness. The tool also allows determining to some extent the composition roughness and ”n” and ”k” values, where ”n” is a real, and ”k” is the imaginary part of the refractive index. It can be applied to a variety of dielectric optically transparent thin films, and even some metal thin films. Please consult the study material for further data on the basics behind this method.



As before, I show you now how to use the ellipsometer to measure SIO2 layer thickness in the bi-morph ship area. The spot size is small enough to measure the SIO2 thickness at the border of the device like shown here. The two curves here, showing the "y" axis, the "Alpha" and the "Beta" parameter, for an angle of 45 degree and as a function of wavelength here shown in eV units. The parameters alpha and beta in y axis of the spectrum are called ellipse parameters. They are composed of the incident angle and some geometric factors that describe the shape of eliptically polarized light after the reflection. The measurement here results in 1282 nm, which agrees very well the data obtained from the reflectometer.



In this module, I have introduced 2 optical techniques to determine the thin film thickness. The reflectomer allows us a quick and simple measurement. For more precise measurement, it is advised to use the ellipsometer. Both of them do not touch and damage the sample, and no sample preparation is required.