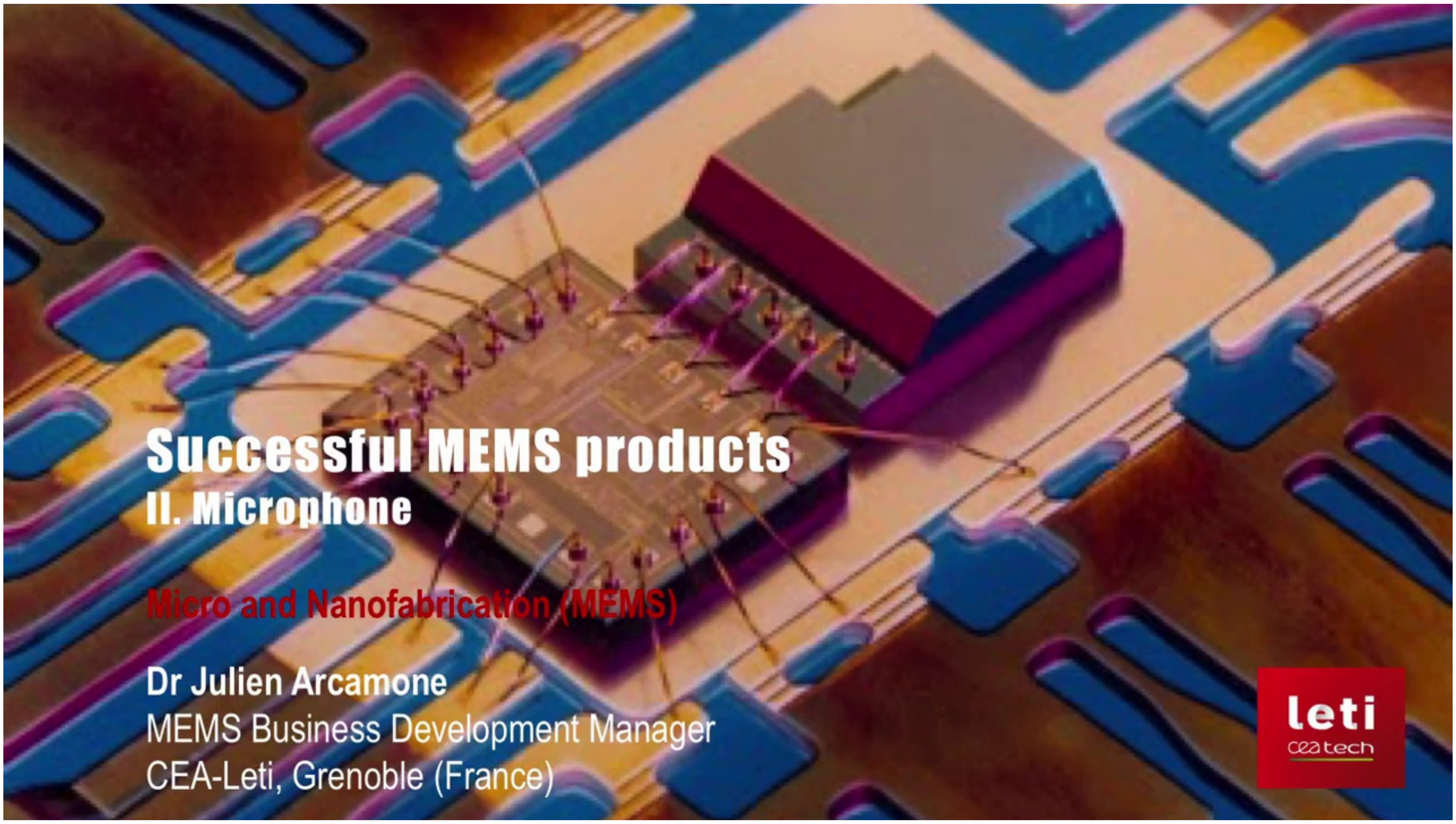
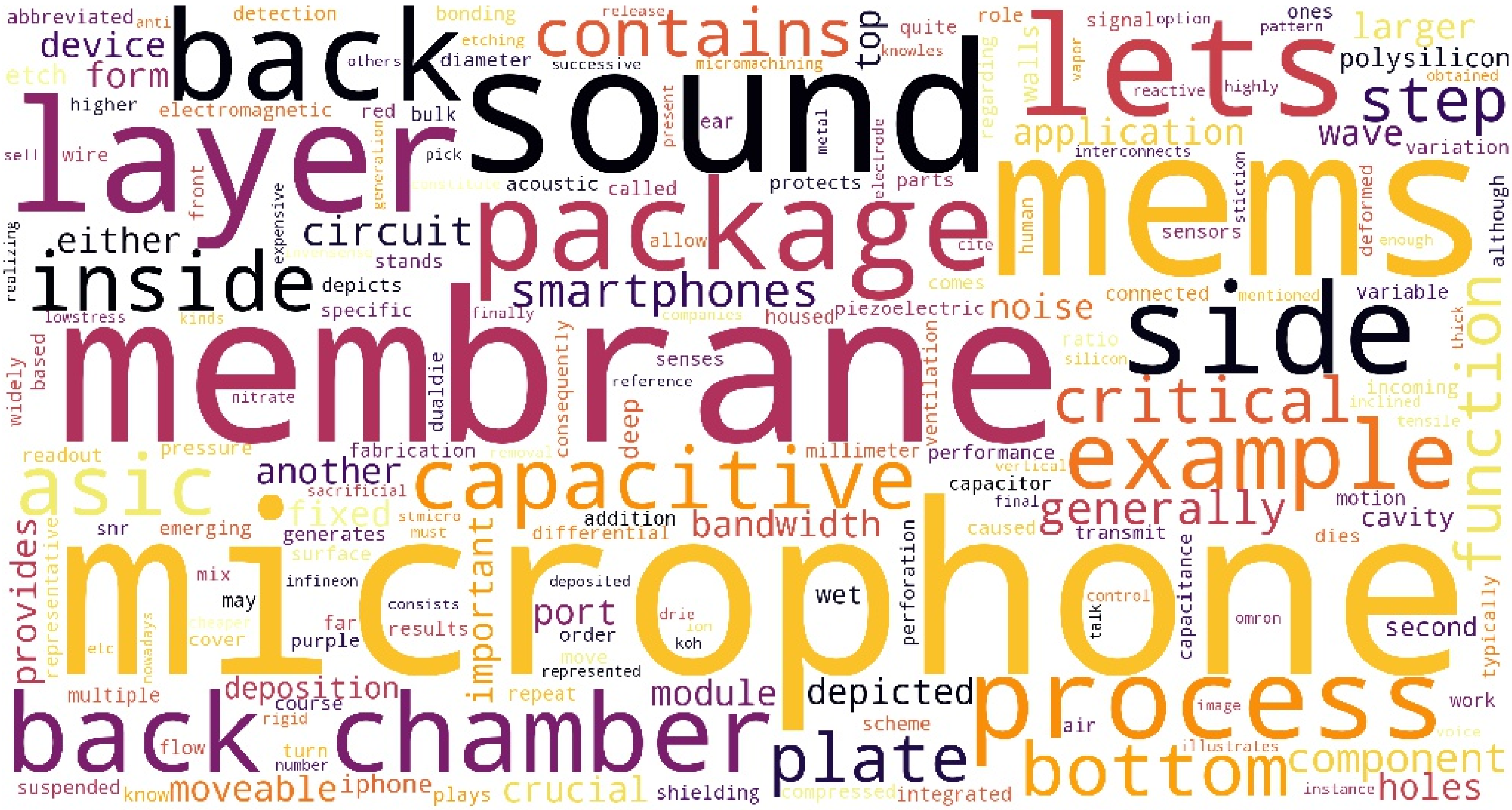


Successful MEMS products

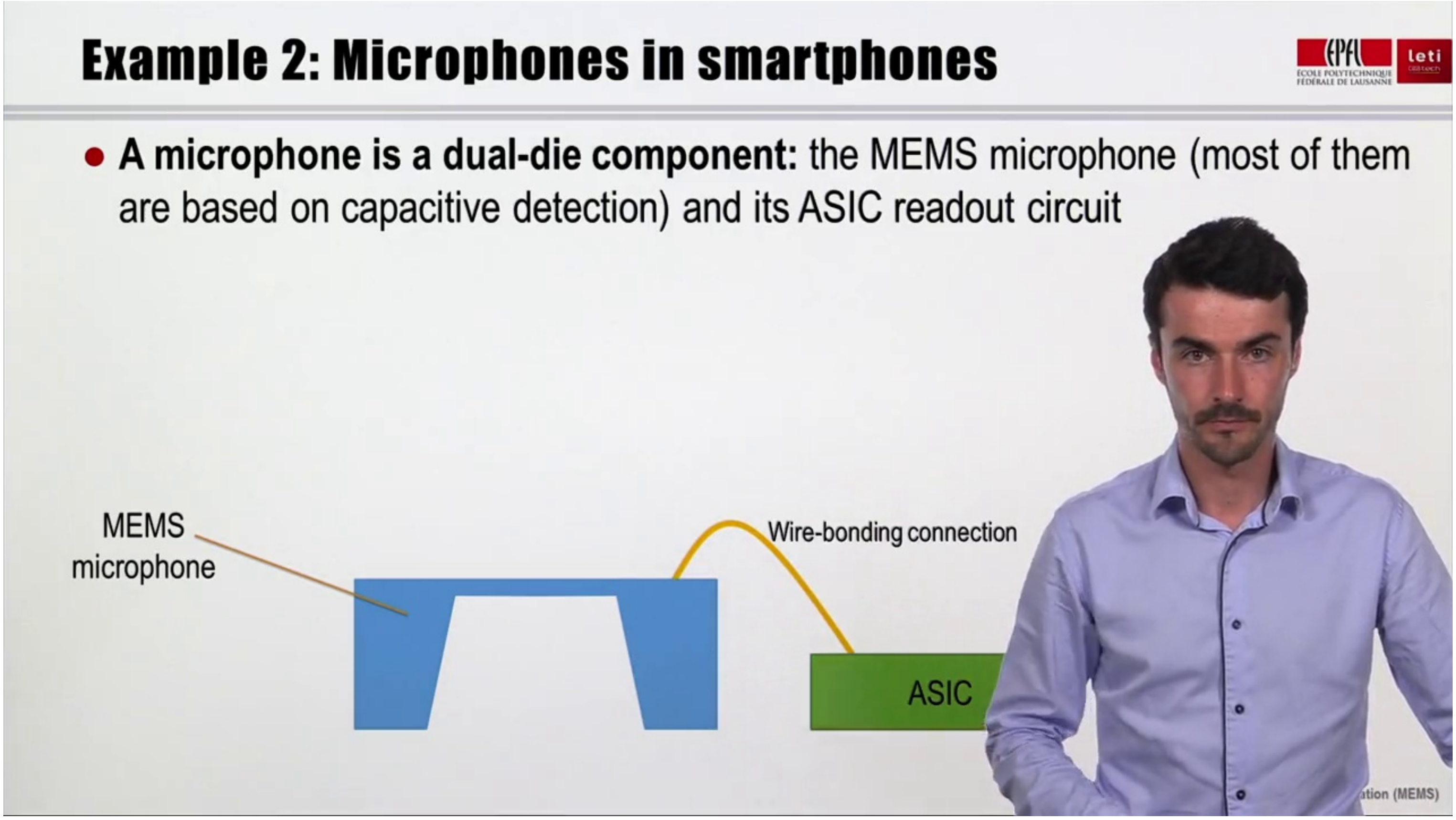
II. Microphone

Micro and Nanofabrication (MEMS)

Dr Julien Arcamone
MEMS Business Development Manager
CEA-Leti, Grenoble (France)



Aperçu une erreur ? Envoyez-nous votre commentaire !
Spotted an error? Send us your comment!
https://forms.gle/hYPC8Auh6a4q52qT7

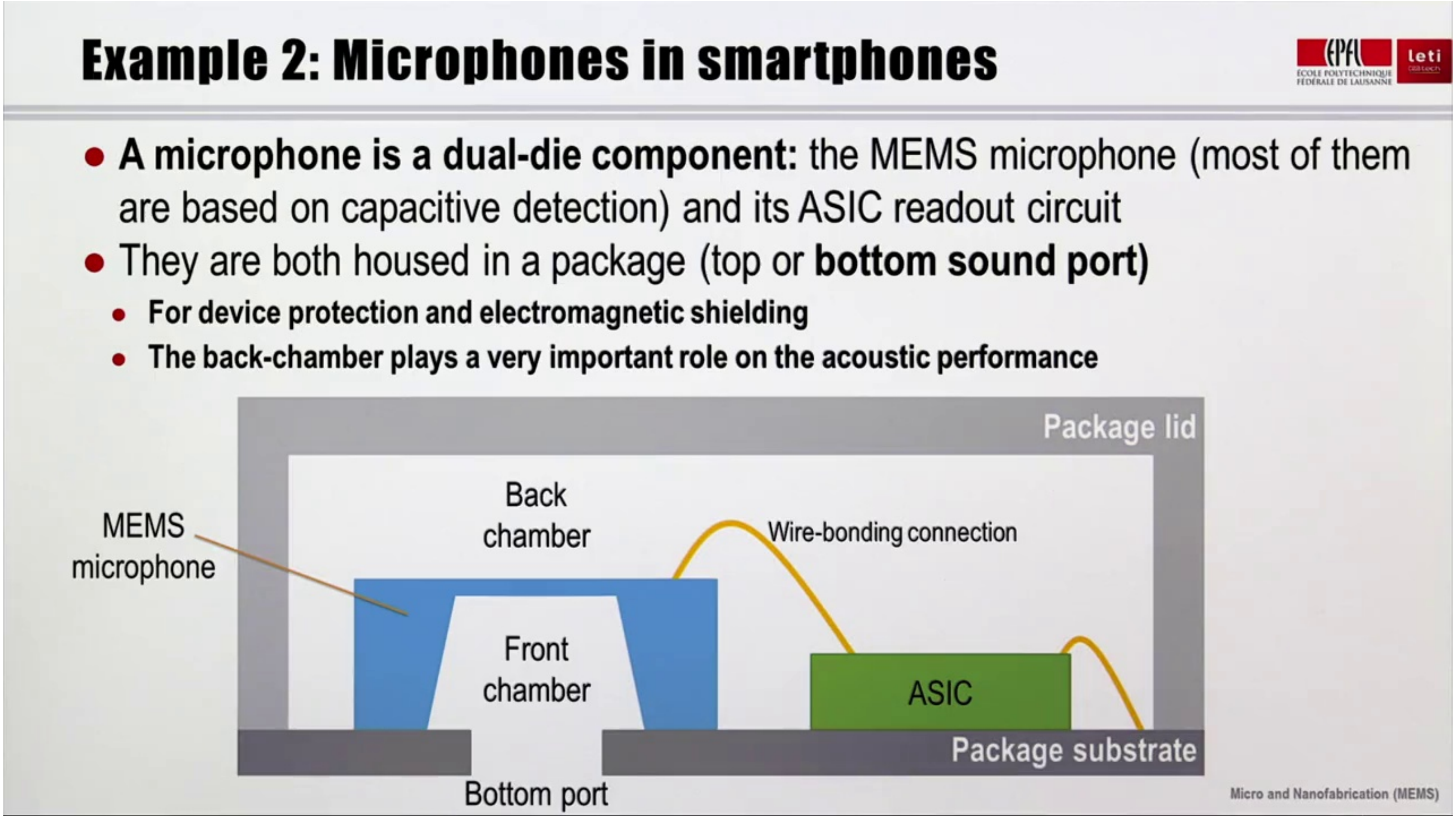


Example 2: Microphones in smartphones

- **A microphone is a dual-die component:** the MEMS microphone (most of them are based on capacitive detection) and its ASIC readout circuit

---

Let’s move to example 2 : microphones in smartphones. Generally, what is called a MEMS microphone is a dual-die component. The MEMS microphone itself most of them are based on capacitive detection and its ASIC readout circuit. ASIC as you may know stands for Application Specific Integrated Circuit. They are connected to one another by wire bonding.

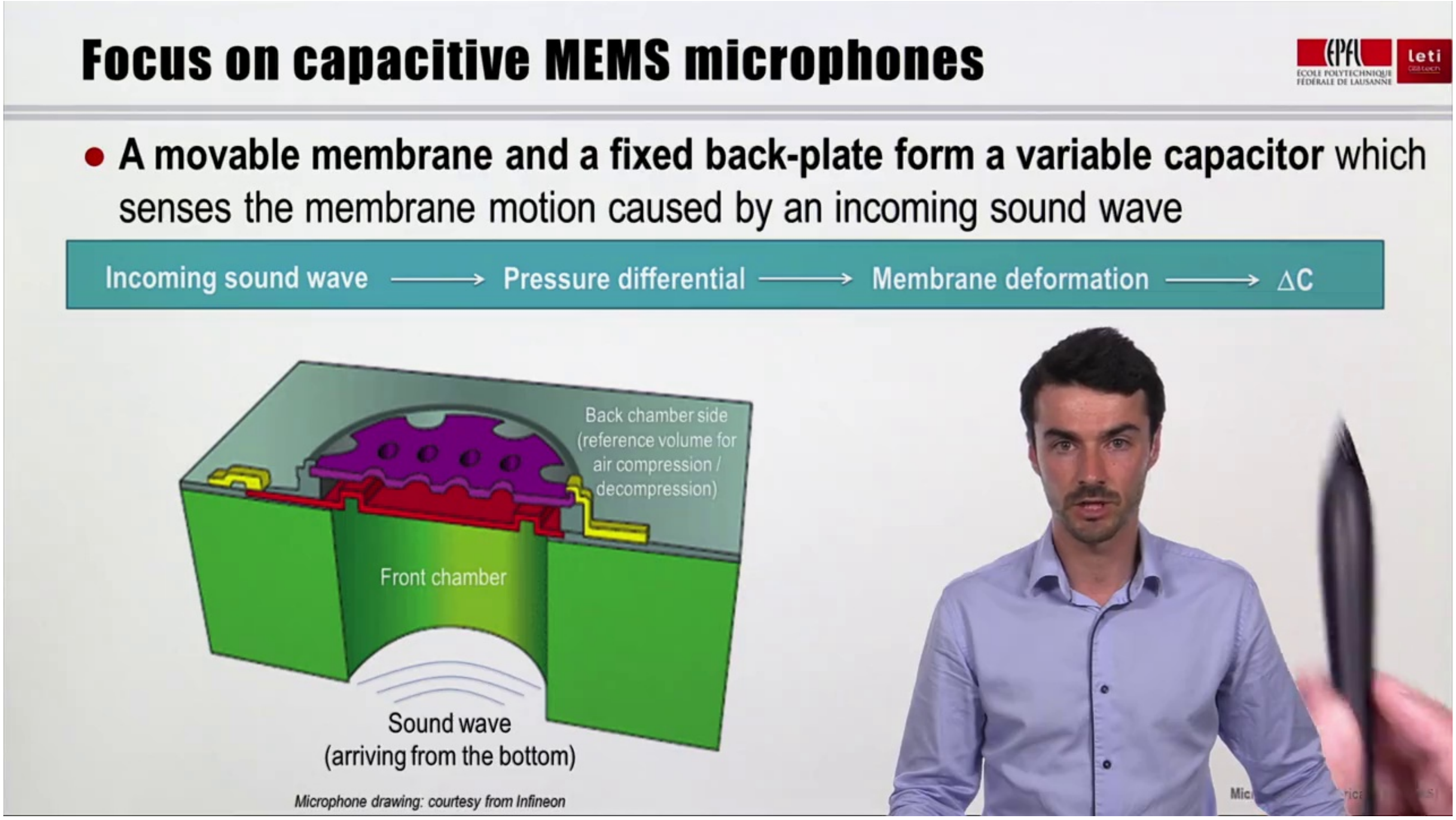


Example 2: Microphones in smartphones

- **A microphone is a dual-die component:** the MEMS microphone (most of them are based on capacitive detection) and its ASIC readout circuit
- They are both housed in a package (top or **bottom sound port)**
  - **For device protection and electromagnetic shielding**
  - **The back-chamber plays a very important role on the acoustic performance**

Micro and Nanofabrication (MEMS)

MEMS and ASIC dies are both housed inside a package which has a sound port, either on the top side or at the bottom of the package. This scheme depicts a bottom port component. The package has multiple functions of course, as in all MEMS. It protects the device and provides a crucial electromagnetic shielding. In addition to that, the back chamber plays a very important role on the acoustic performance. The larger it is, the higher the signal to noise ratio, abbreviated as SNR.



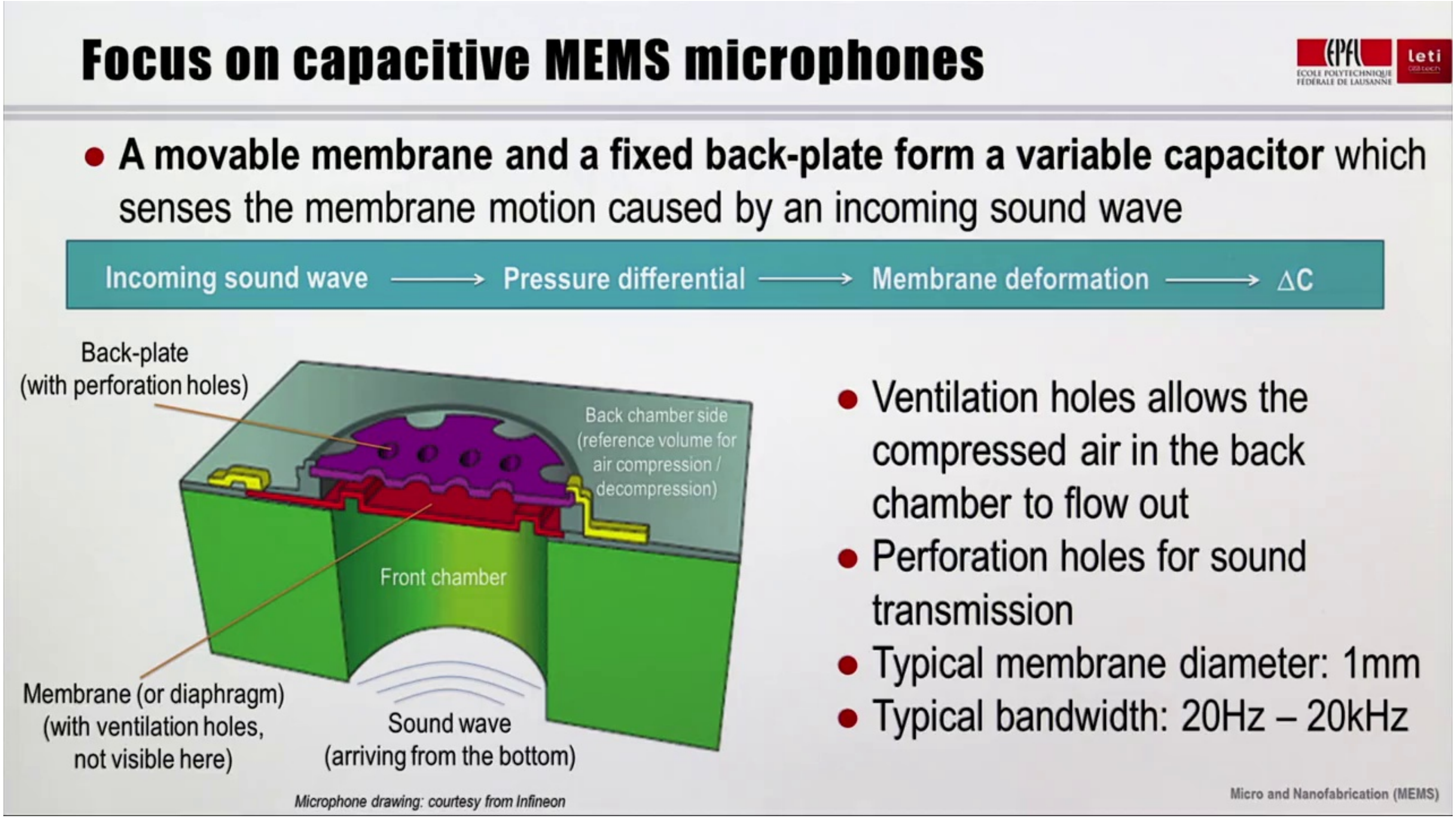
Focus on capacitive MEMS microphones

- **A movable membrane and a fixed back-plate form a variable capacitor** which senses the membrane motion caused by an incoming sound wave

Incoming sound wave ⟶ Pressure differential ⟶ Membrane deformation ⟶ ΔC

Microphone drawing: courtesy from Infineon

Although piezoelectric microphones are emerging, capacitive ones are by far the most widely used. How do they work? Basically there are 2 suspended parts : a moveable membrane, here in red, and a fixed back plate, here in purple. Both form a variable capacitor which senses the motion of a moveable membrane caused by any incoming sound wave. In this example the sound comes from the bottom and the package is not depicted. To repeat again, the sound wave generates a pressure differential between the front and back chamber, consequently the membrane is deformed and this results in a capacitance variation.



Focus on capacitive MEMS microphones

- **A movable membrane and a fixed back-plate form a variable capacitor** which senses the membrane motion caused by an incoming sound wave

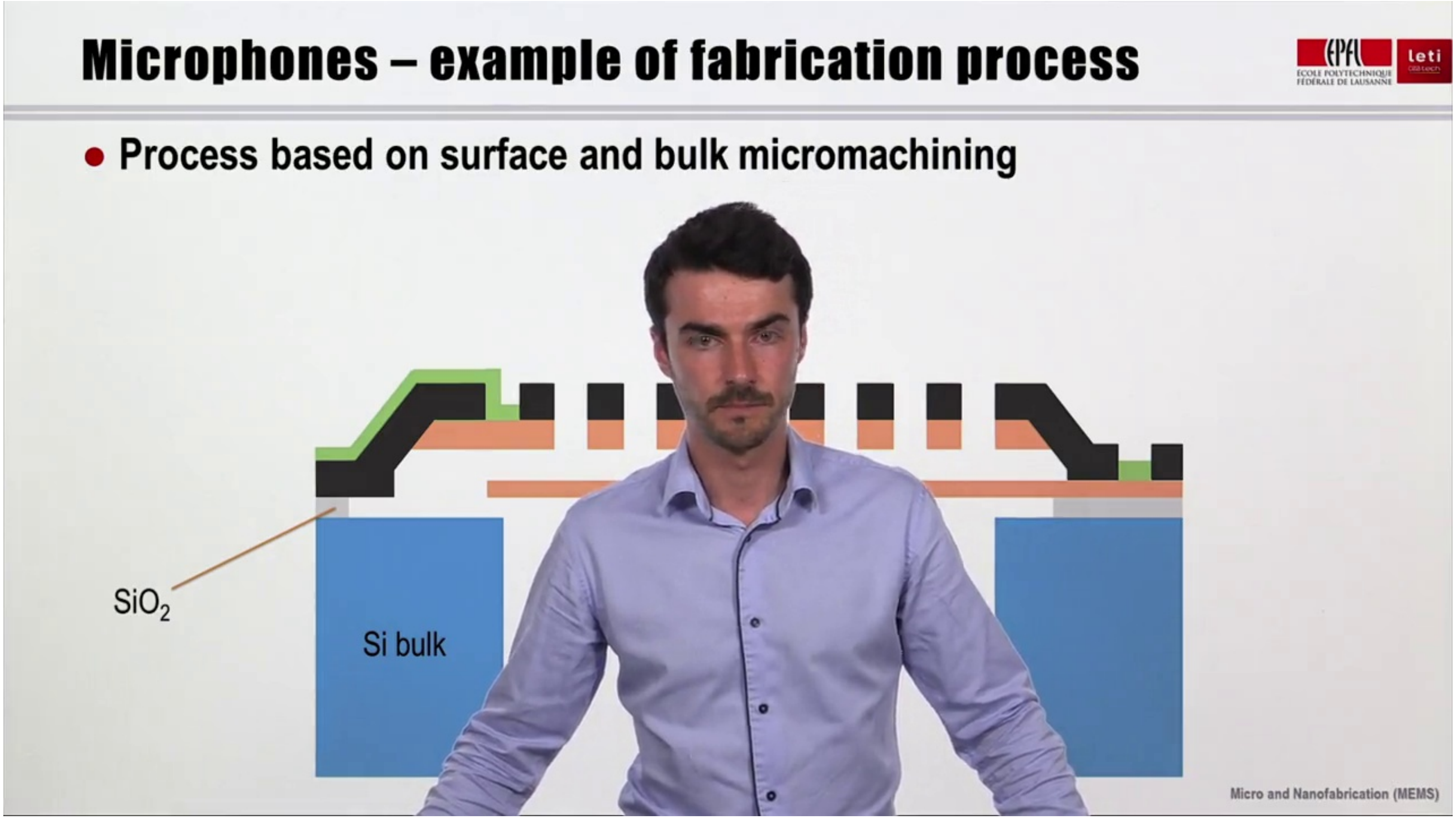
Incoming sound wave ⟶ Pressure differential ⟶ Membrane deformation ⟶ ΔC

- Ventilation holes allows the compressed air in the back chamber to flow out
- Perforation holes for sound transmission
- Typical membrane diameter: 1mm
- Typical bandwidth: 20Hz – 20kHz

Microphone drawing: courtesy from Infineon

Micro and Nanofabrication (MEMS)

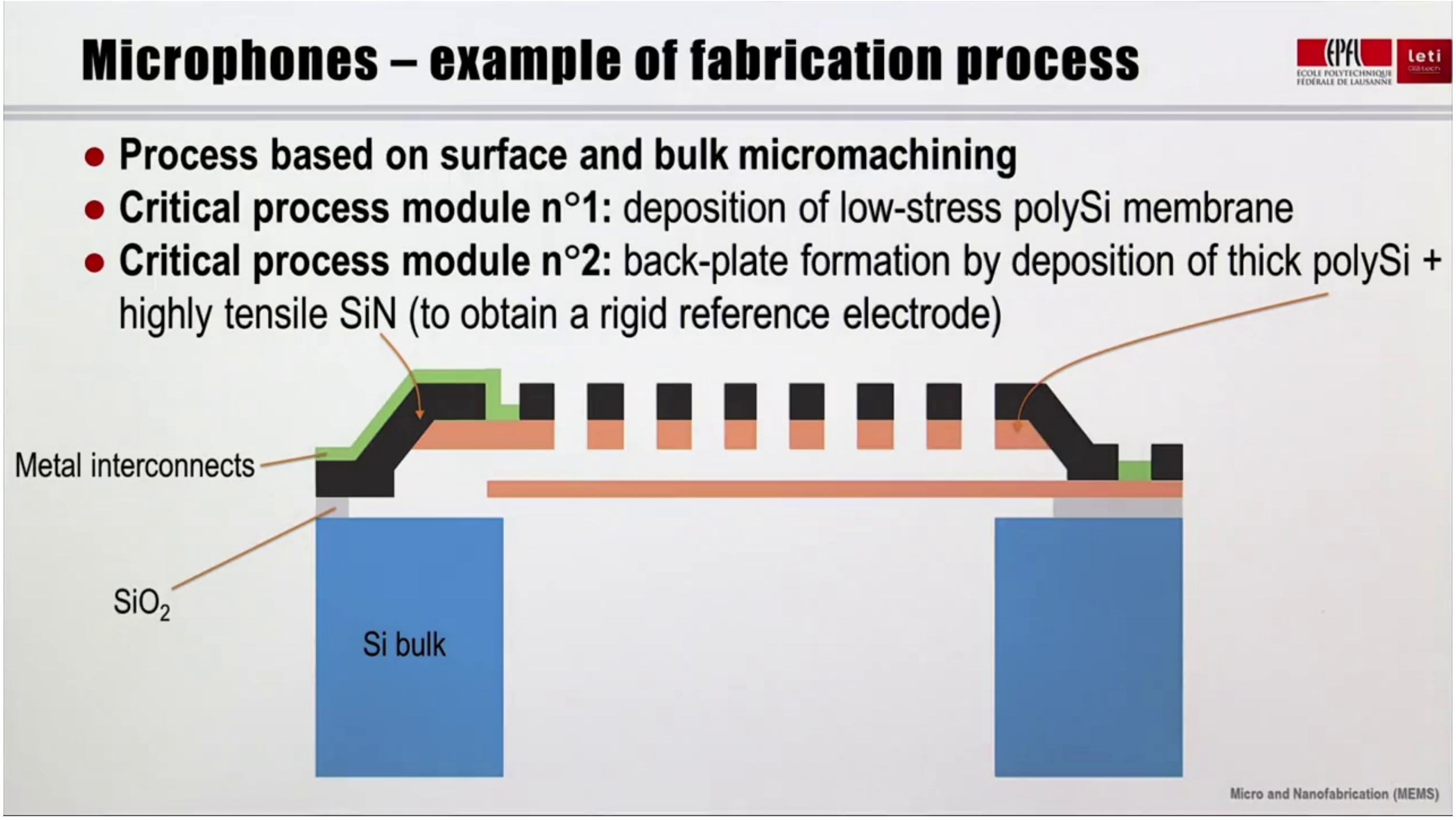
The membrane contains ventilation holes, not depicted here, to allow the compressed air of the back chamber to flow out. The back plate contains perforation holes basically to transmit the sound to the back chamber. The membrane diameter is typically in the order of 1 millimeter. Regarding the microphone bandwidth, it has to cover the human ear bandwidth, so from 20Hz up to 20KHz.



Microphones – example of fabrication process

- Process based on surface and bulk micromachining

Let’s turn to the fabrication process of such sensors. This example is quite representative of all capacitive MEMS microphones. Generally the process is a mix of surface and bulk micromachining,

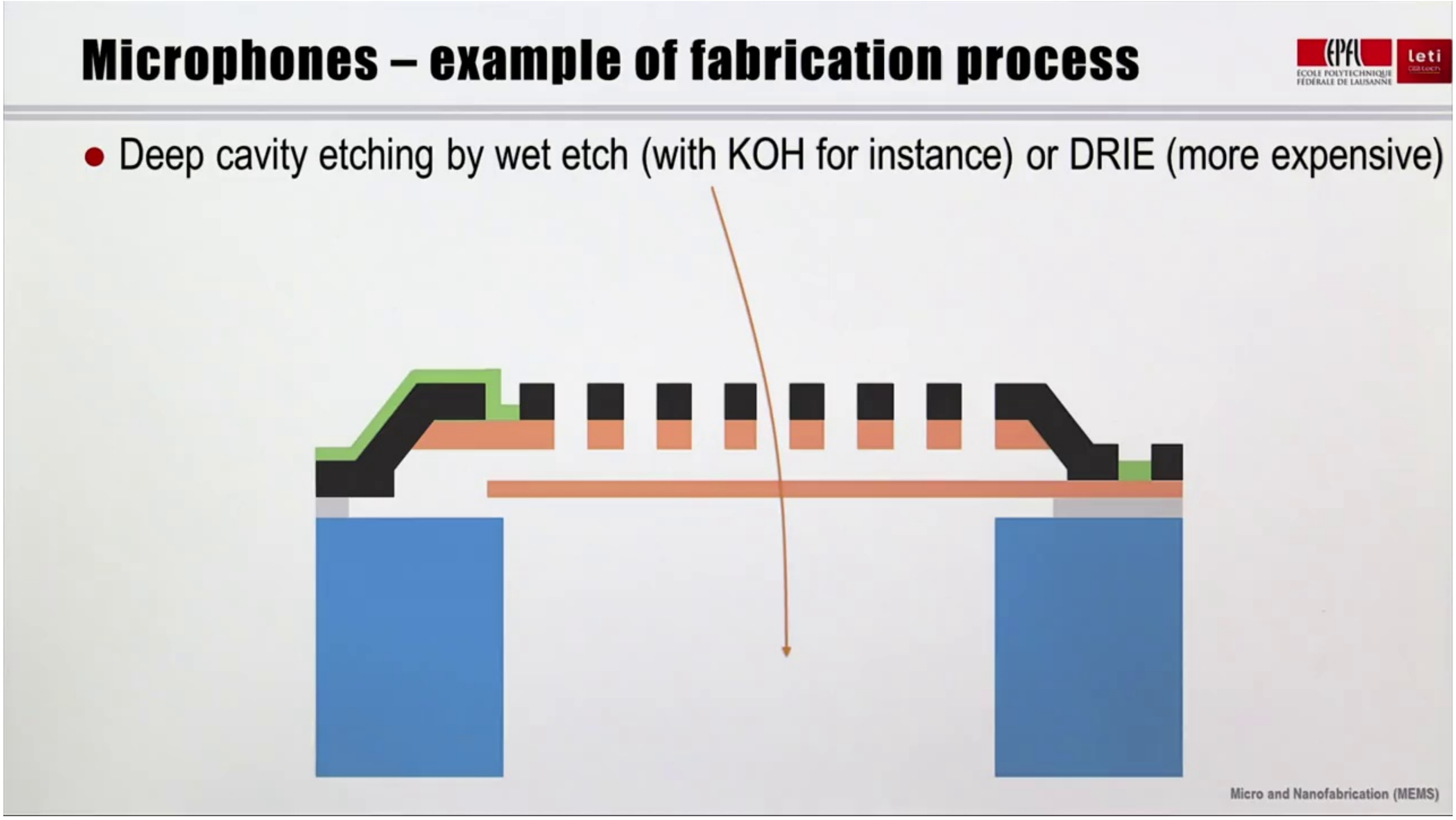


Microphones – example of fabrication process

- **Process based on surface and bulk micromachining**
- **Critical process module n°1:** deposition of low-stress polySi membrane
- **Critical process module n°2:** back-plate formation by deposition of thick polySi + highly tensile SiN (to obtain a rigid reference electrode)

Micro and Nanofabrication (MEMS)

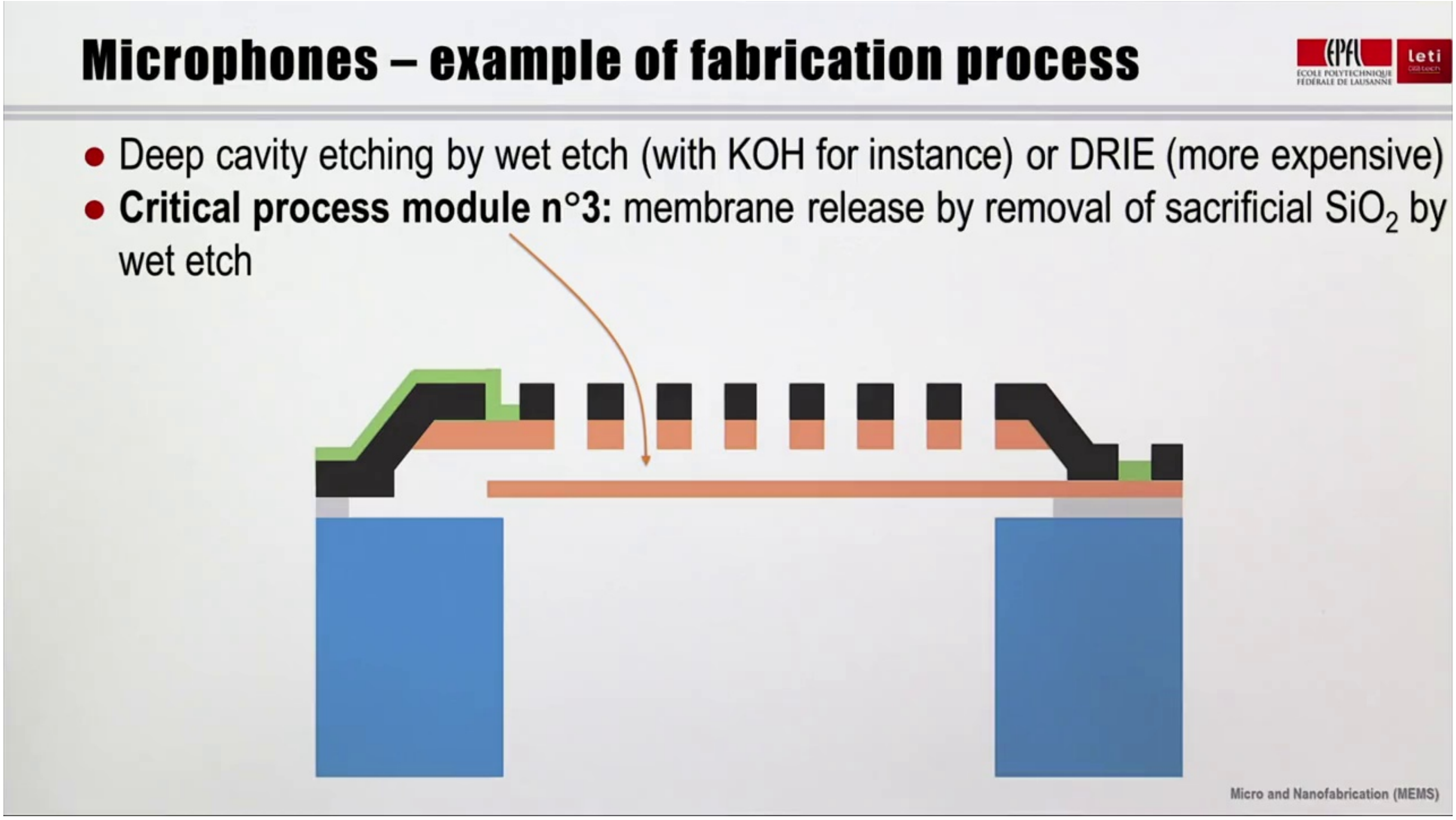
The first critical process module is a deposition of the low-stress polysilicon membrane on top of a SiO2 layer. The second critical process module is a successive deposition of a thick polysilicon layer and of a highly tensile silicon nitrate layer. These 2 layers form the back plate, which must be rigid enough to constitute a fixed reference electrode. Finally, metal interconnects are deposited in pattern.



Microphones – example of fabrication process

- Deep cavity etching by wet etch (with KOH for instance) or DRIE (more expensive)

Another important step consists in realizing a deep cavity from the back side. It is obtained either by wet etch, for instance with KOH, or DRIE. The first option is cheaper but side walls are inclined. The second one, with deep reactive ion etching, represented here is more expensive, but side walls are vertical, which provides a larger cavity.



Microphones – example of fabrication process

- Deep cavity etching by wet etch (with KOH for instance) or DRIE (more expensive)
- **Critical process module n°3:** membrane release by removal of sacrificial SiO_2 by wet etch

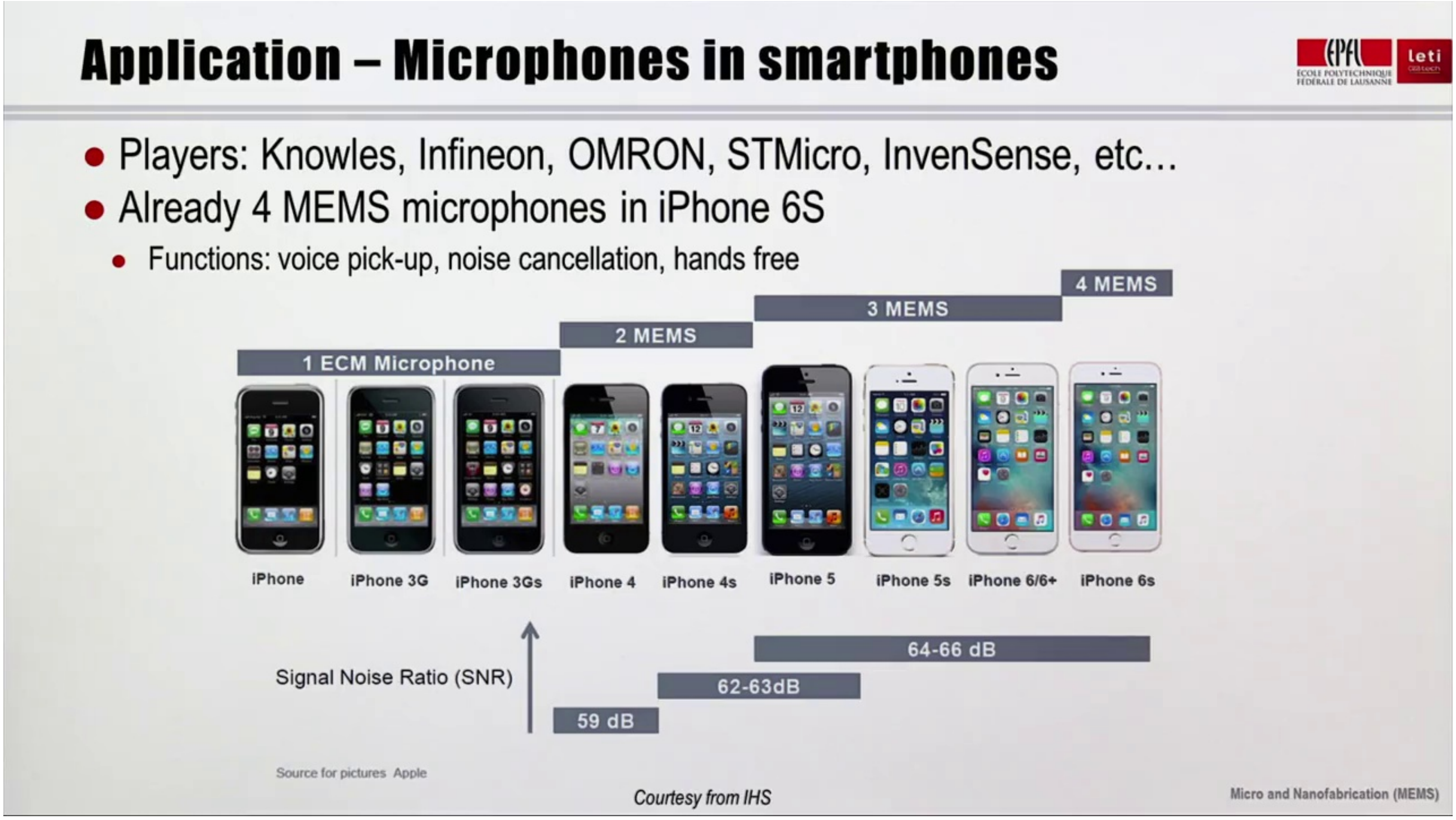
Micro and Nanofabrication (MEMS)

The final critical step is a membrane release by removal of a sacrificial SiO2 layer by wet or vapor etch. Anti stiction control is crucial during this step.

Application – Microphones in smartphones

- Players: Knowles, Infineon, OMRON, STMicro, InvenSense, etc…
- Already 4 MEMS microphones in iPhone 6S
  - Functions: voice pick-up, noise cancellation, hands free

So let's talk about application now. First, which MEMS companies sell these kinds of devices? Let's cite Knowles, Infineon, OMRON, STMicro, InvenSense, etc.. As I mentioned before, microphones are present inside smartphones.



Application – Microphones in smartphones

- Players: Knowles, Infineon, OMRON, STMicro, InvenSense, etc…
- Already 4 MEMS microphones in iPhone 6S
  - Functions: voice pick-up, noise cancellation, hands free

Source for pictures Apple

Courtesy from IHS

Micro and Nanofabrication (MEMS)

The image below illustrates the number of MEMS microphones inside the iPhone as a function of its generation. Nowadays, the iPhone 6 contains 4 microphones. Some are used to pick up the voice, others for the cancellation of surrounding parasitic noise and the least main function is for the hands-free kit.
