Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

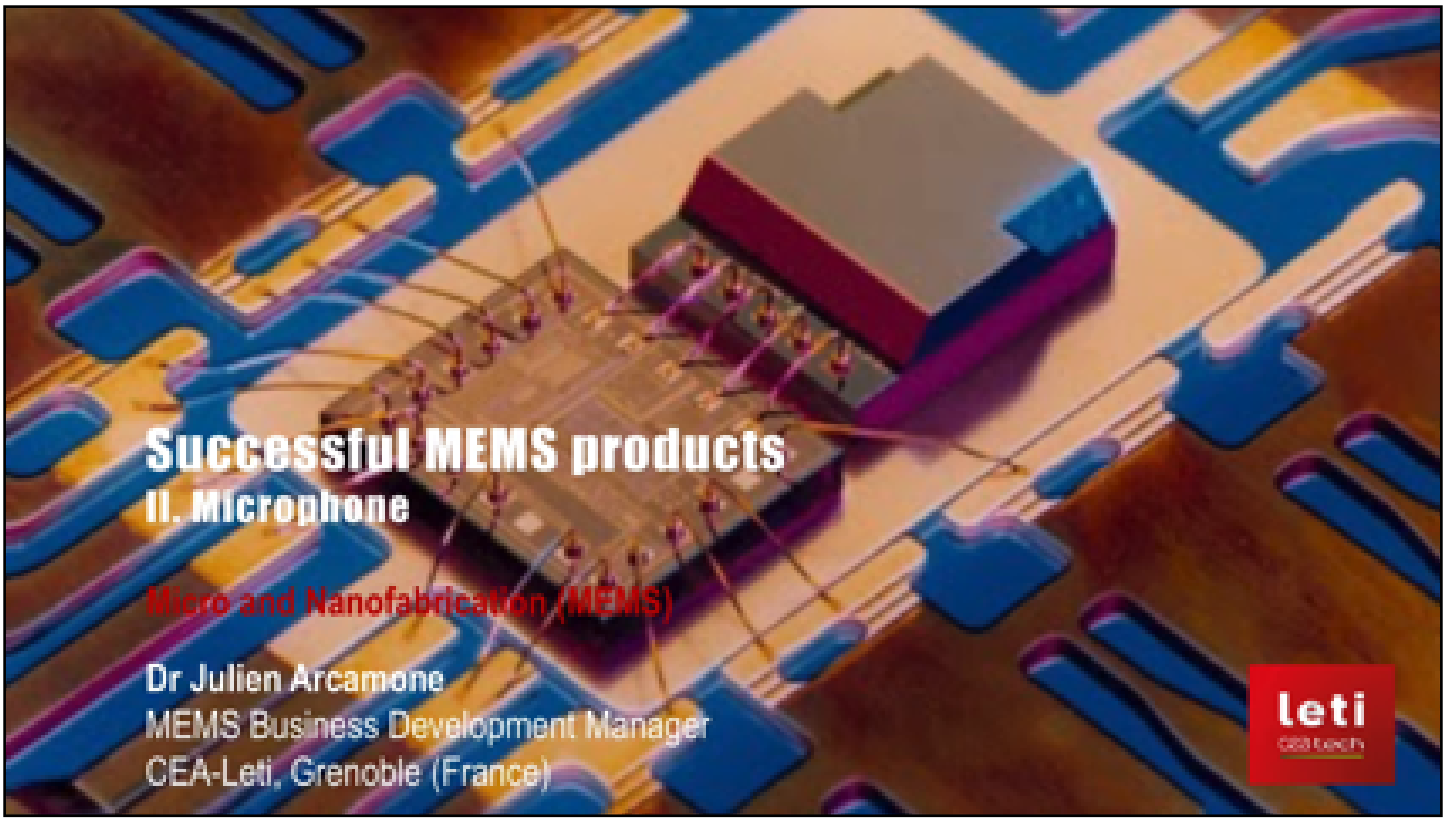
1.2 Successful MEMS products, II Microphone

Concepts (extracted from automatically generated subtitles):

Fabrication process of such sensors. First critical process module. Mems microphone. Moveable membrane. Mix of surface. Second critical process module. Back chamber. Bulk micromachining. Important step. Successive deposition of a thick polysilicon layer. Deposition of the low-stress polysilicon membrane. Fixed back plate. Motion of a moveable membrane. Capacitive detection. Asic readout circuit.

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

to video



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notes

summary

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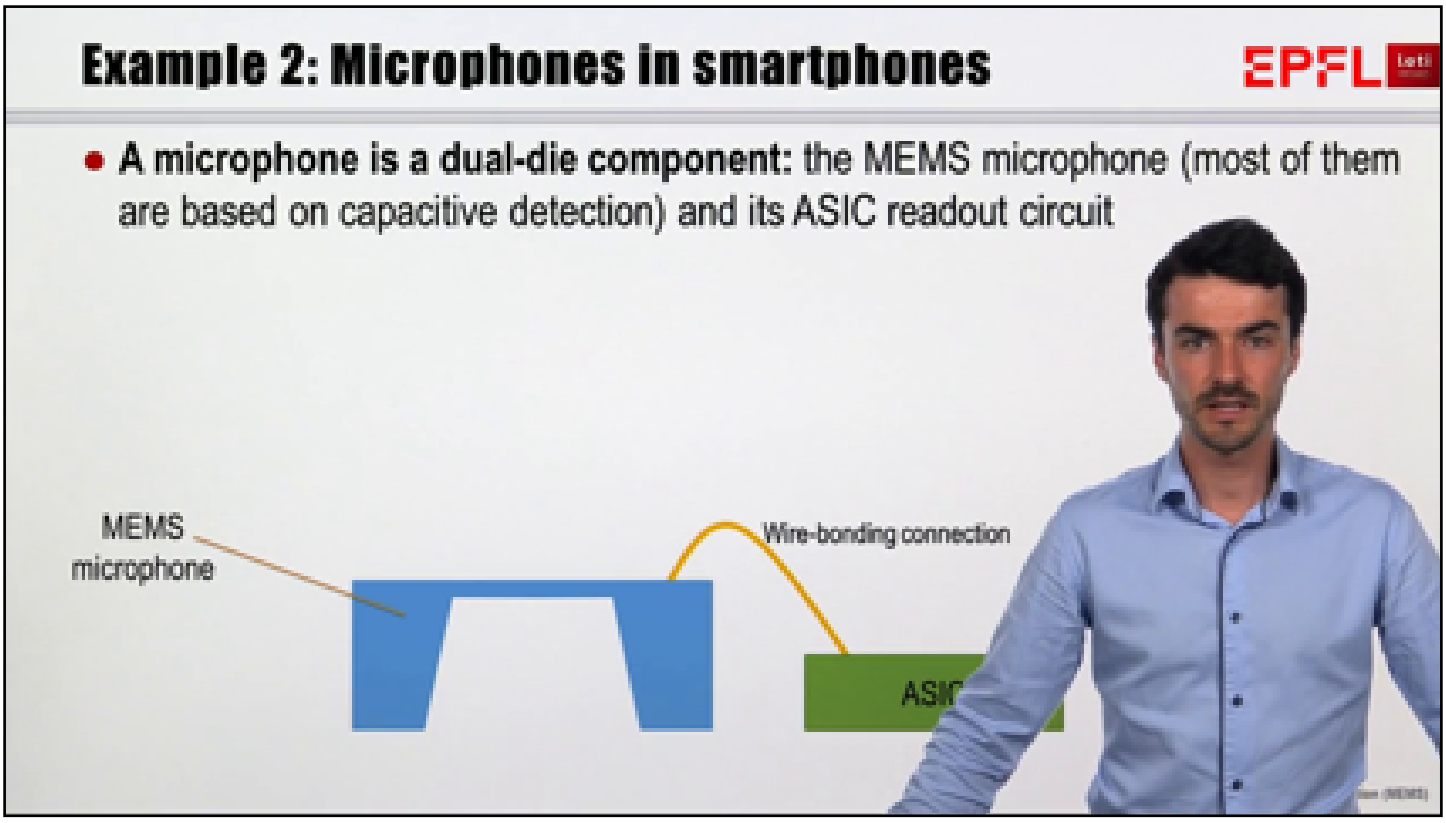


Let's move to example 2 :

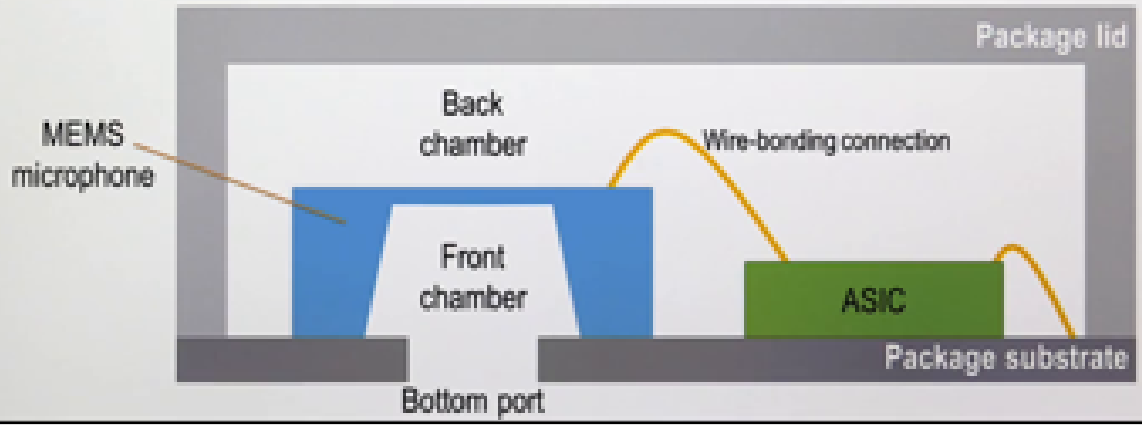
notes

summary

0m 1s

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**

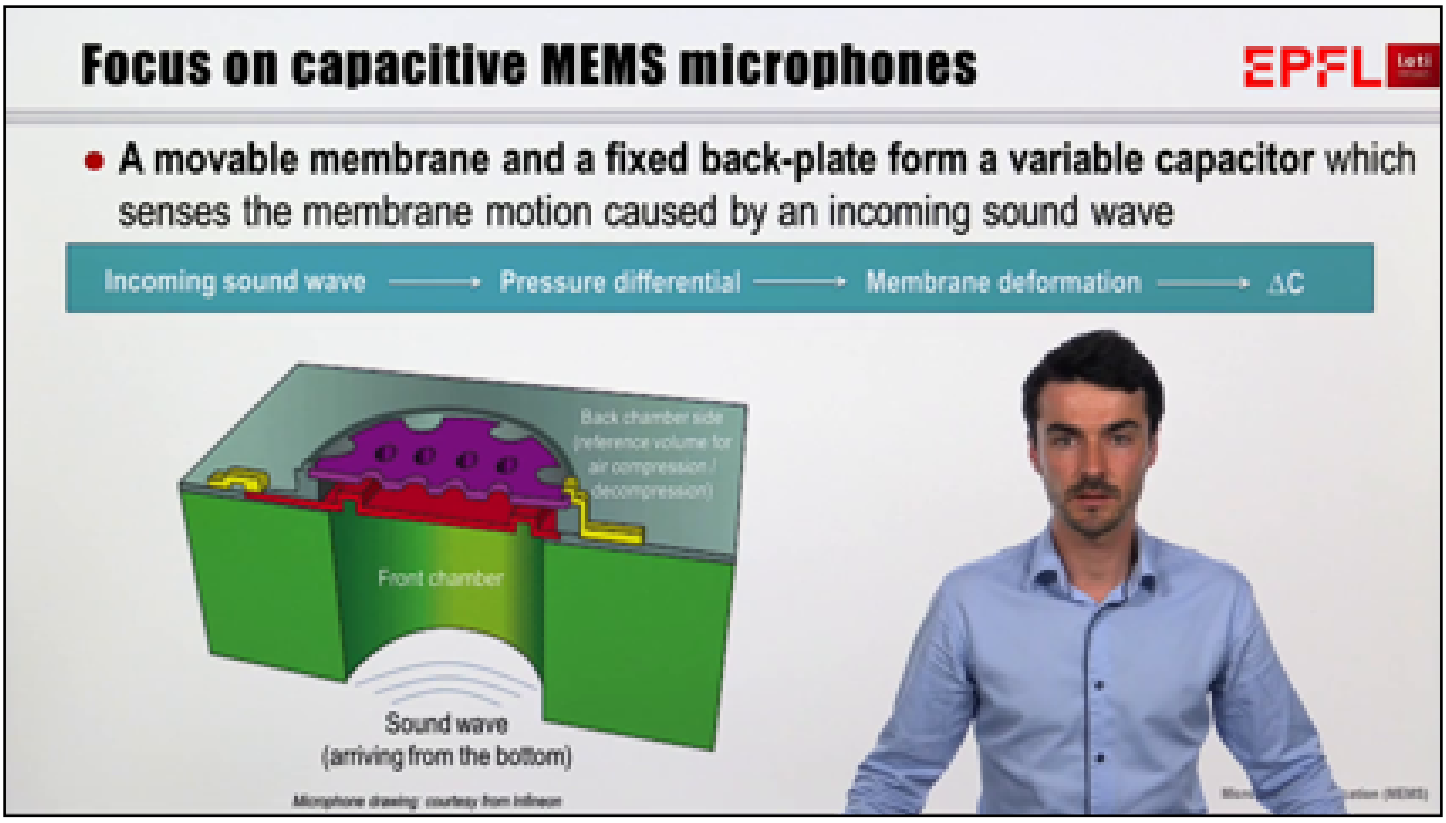


microphones in smartphones. Generally, what is called a MEMS microphone is a dual-die component. The MEMS microphone itself most of them are based on capacitive detection and its ASIC readout circuit. ASIC as you may know stands for Application Specific Integrated Circuit. They are connected to one another by wire bonding. MEMS and ASIC dies are both housed inside a package which has

notes

summary

0m 5s

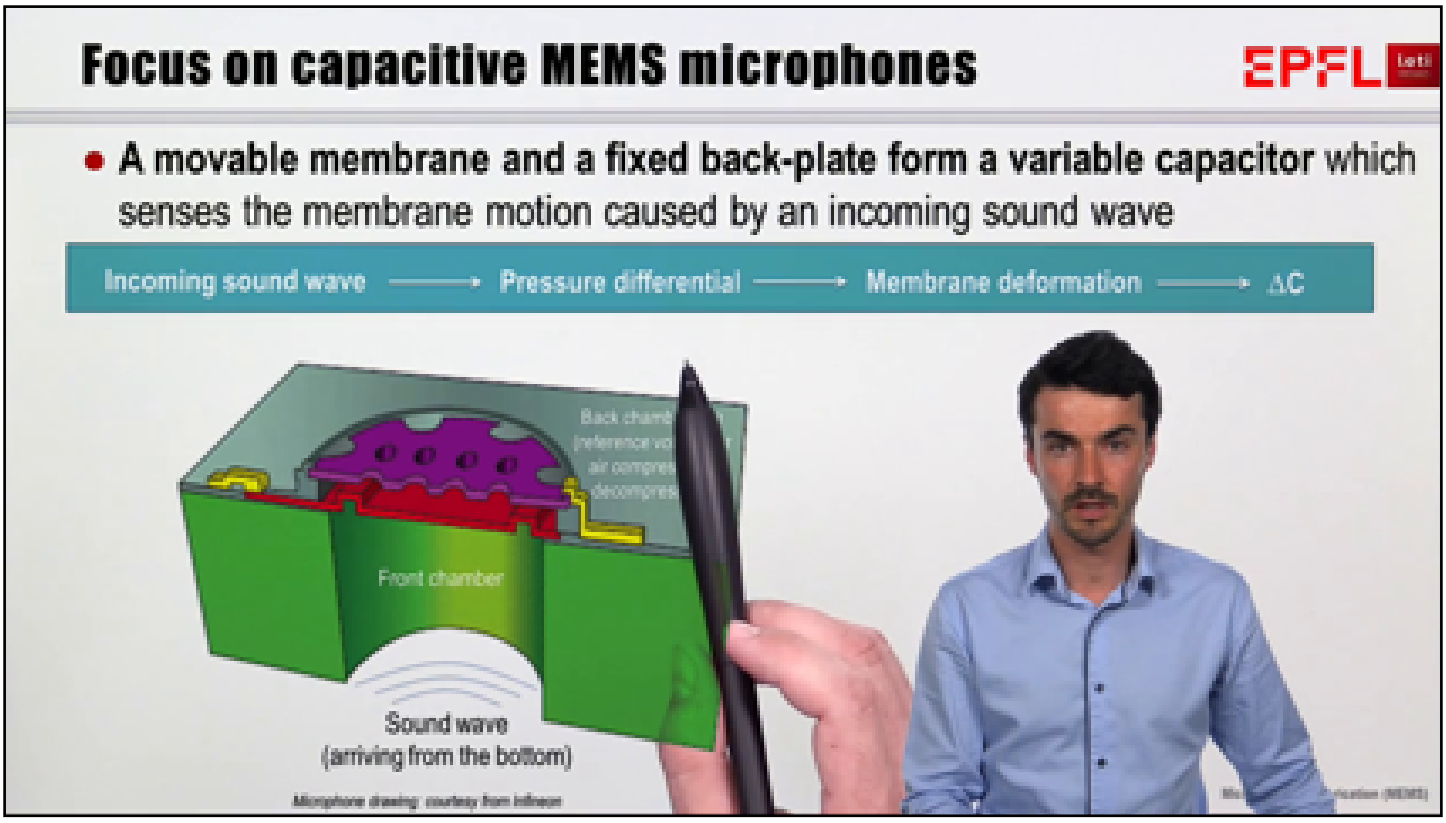


a sound port, either on the top side or at the bottom of the package. This scheme depicts a bottom port component. The package has multiple functions of course, as in all MEMS. It protects the device and provides a crucial electromagnetic shielding. In addition to that, the back chamber plays a very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

notes

summary

0m 37s



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,

notes

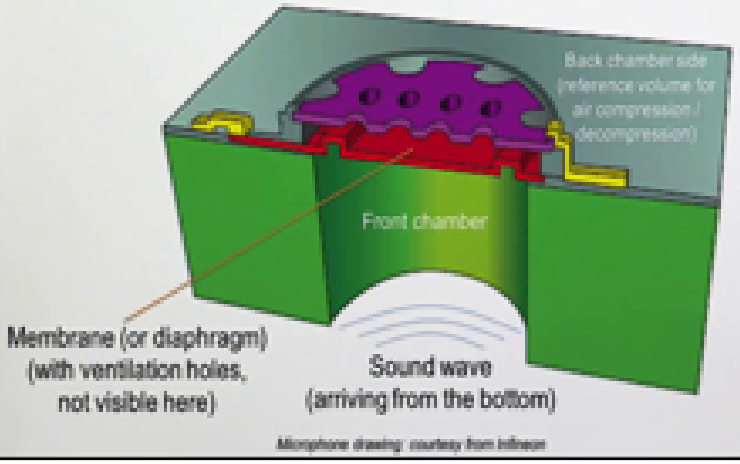
summary

1m 13s

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

- Ventilation holes allows the compressed air in the back chamber to flow out

consequently the membrane is deformed and this results in a capacitance variation.

notes

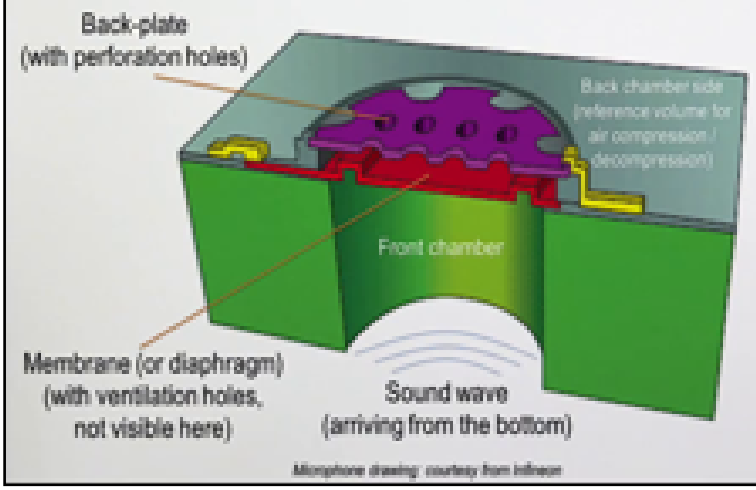
summary

1m 49s

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

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.

notes

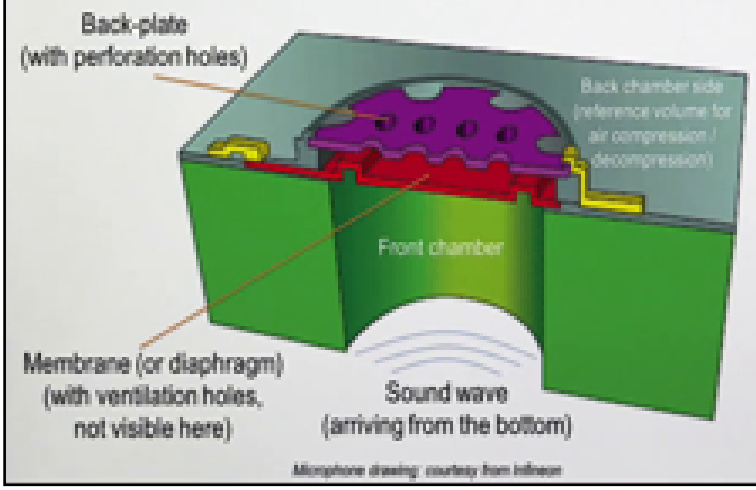
summary

1m 57s

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

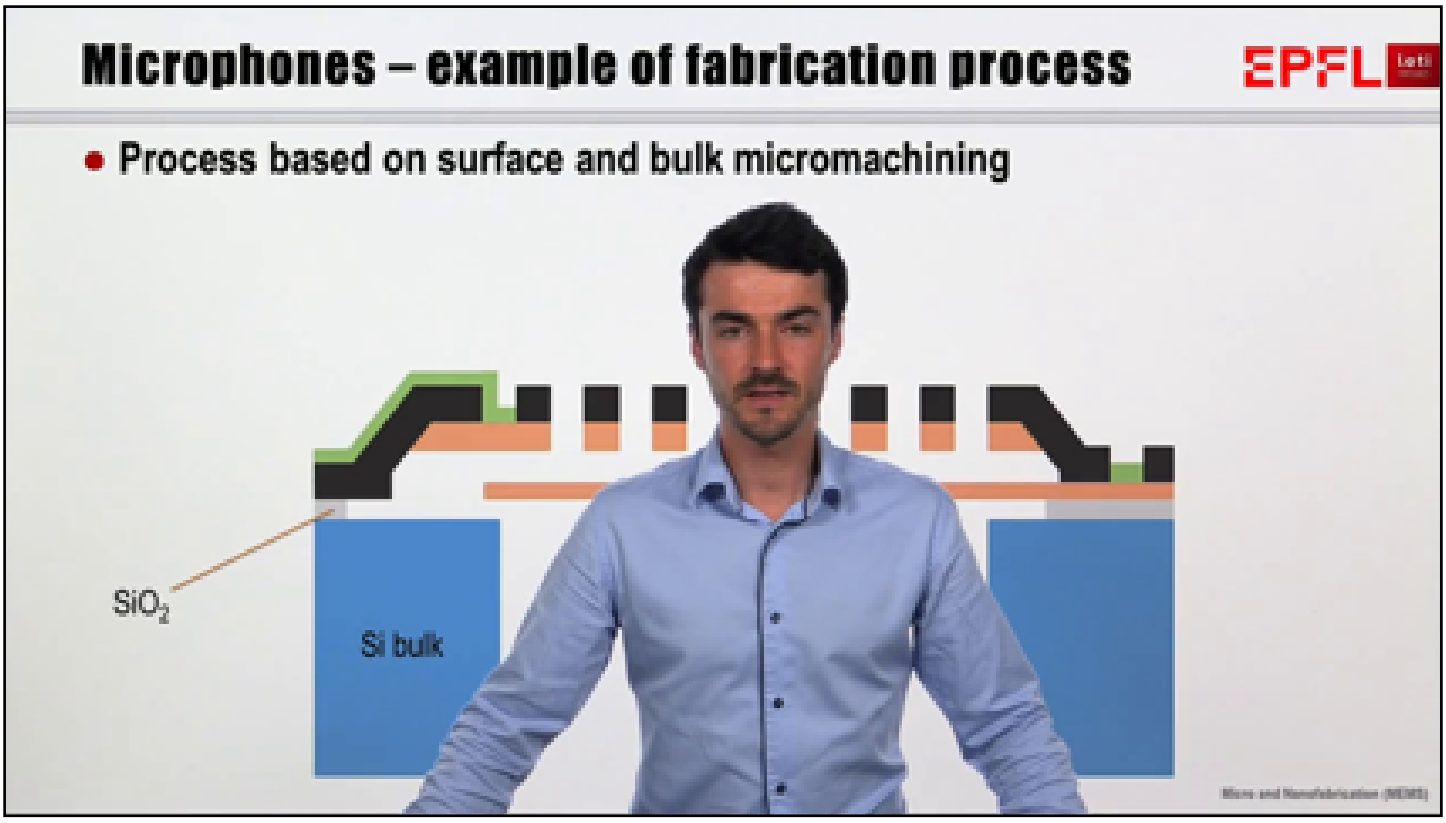
- Ventilation holes allows the compressed air in the back chamber to flow out
- Perforation holes for sound transmission
- Typical membrane diameter: 1mm
- Typical bandwidth: 20Hz – 20kHz

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.

notes

summary

2m 11s



Let's turn to the fabrication process of such sensors.

notes

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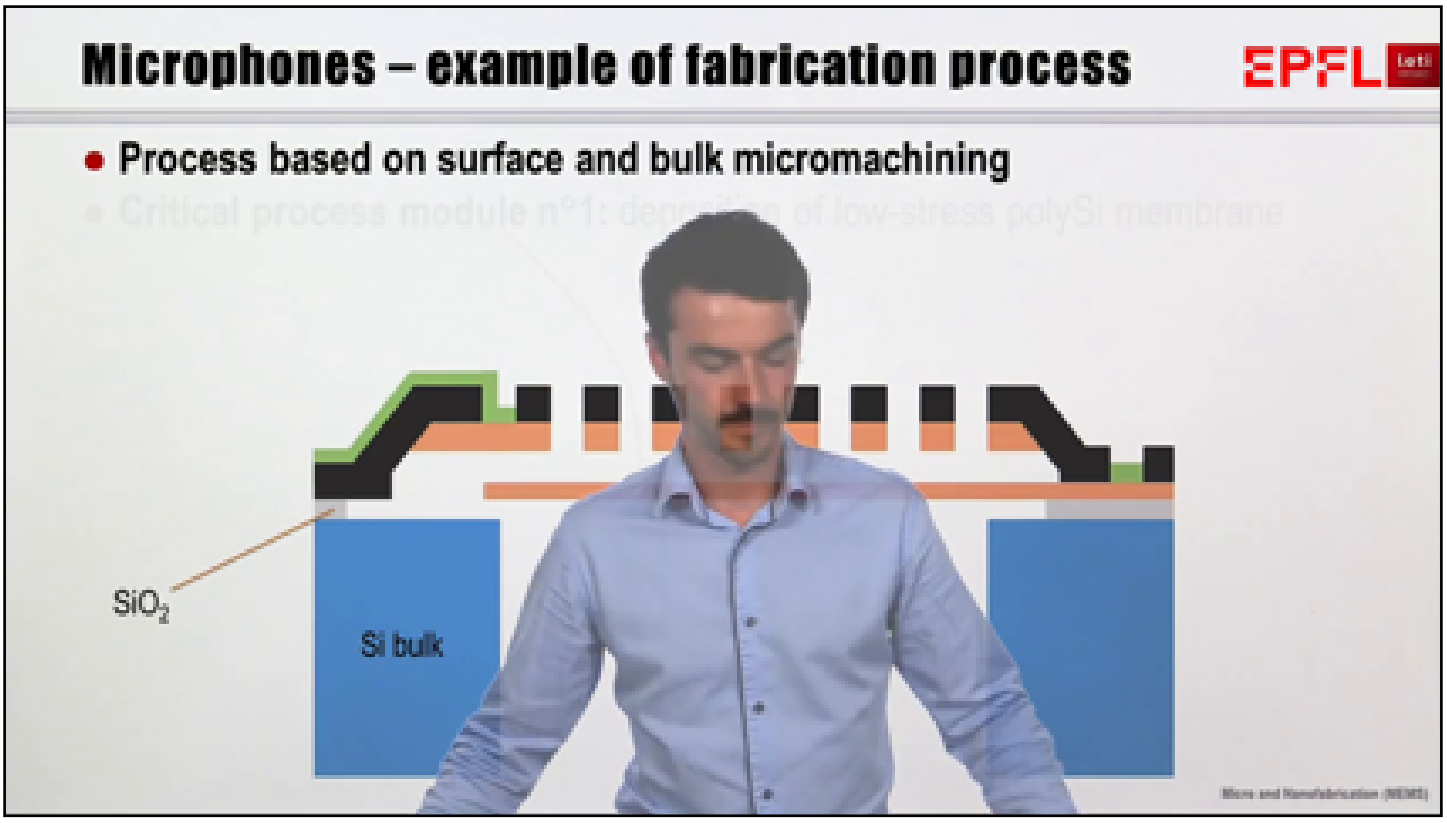
2m 25s



This example is quite representative of all capacitive MEMS microphones.
Generally the process is a mix of surface and bulk micromachining,

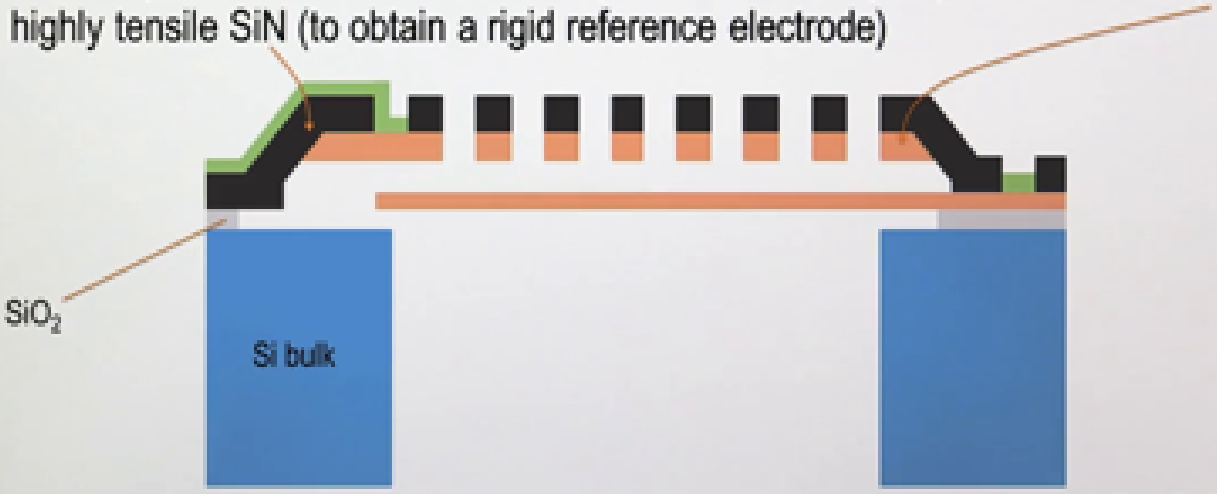
notes

summary

2m 27s

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)



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.

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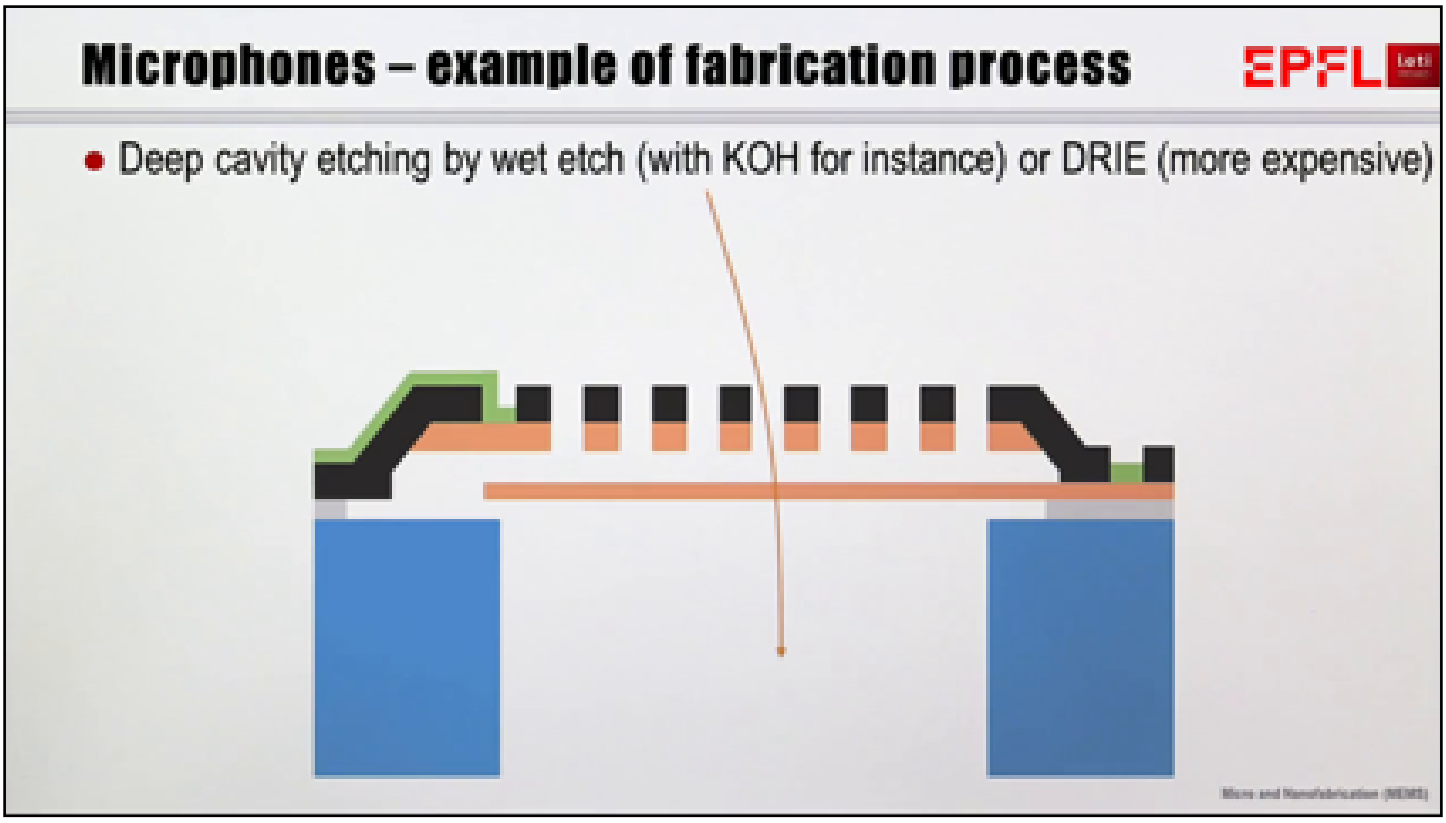
2m 41s



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. 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.

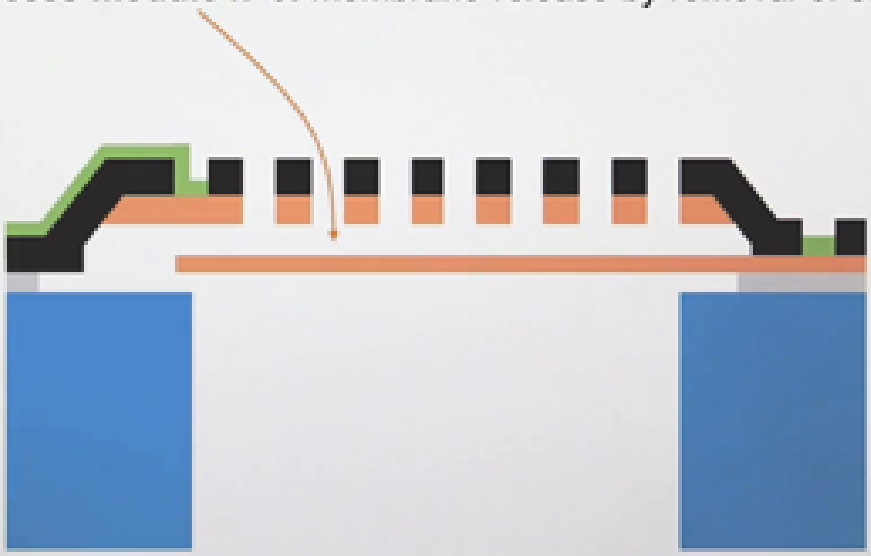
notes

summary

3m 1s

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



The second one, with deep reactive ion etching, represented here is more expensive, but side walls are vertical, which provides a larger cavity.

notes

summary

3m 37s

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.

notes

summary

3m 46s

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..

notes

summary

4m 0s

As I mentioned before, microphones are present inside smartphones. 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.

notes

summary

4m 13s