

CMUT: a versatile and low cost ultrasonic platform

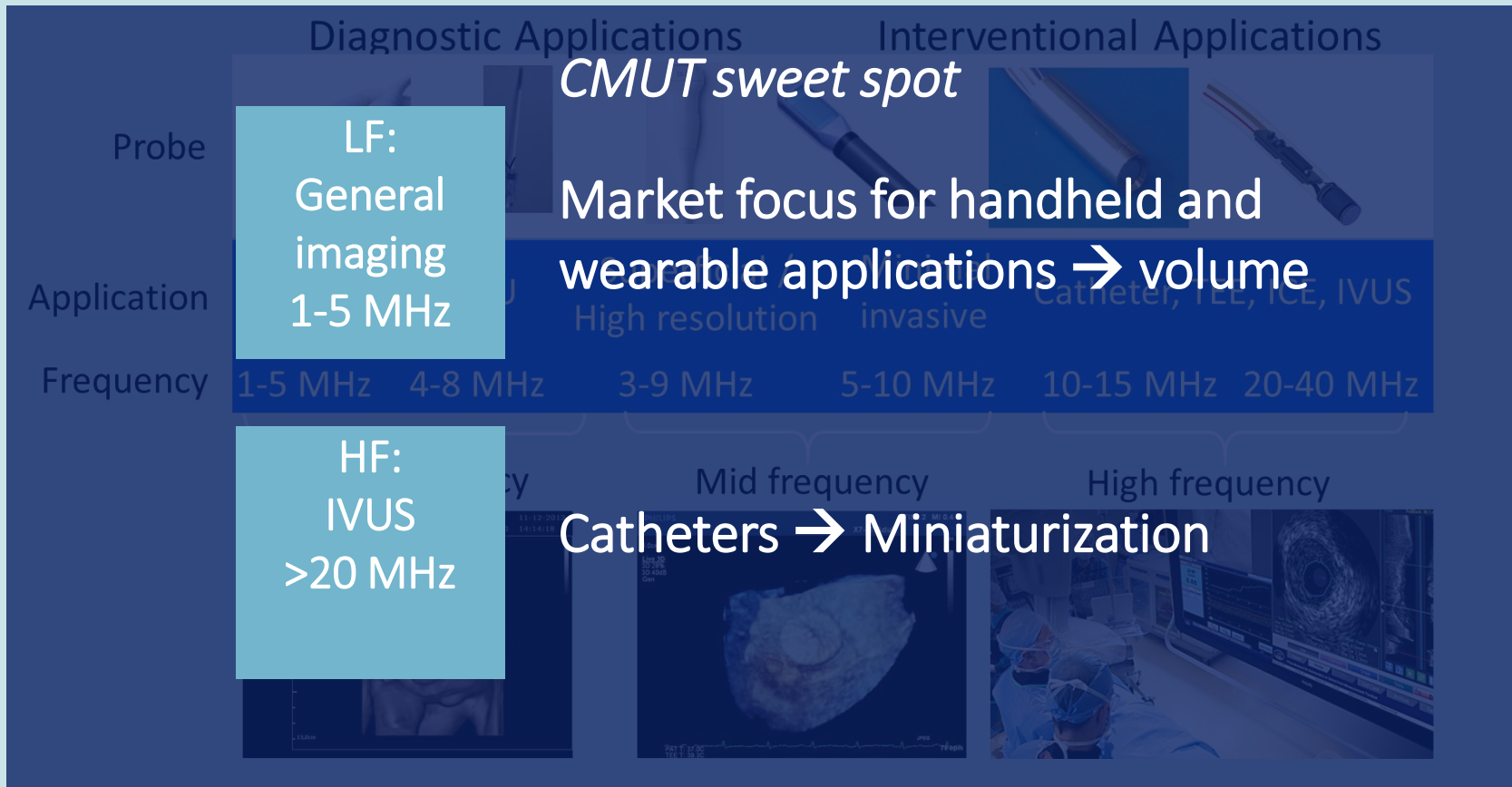
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MEMS & Micro Devices
11-06-2019



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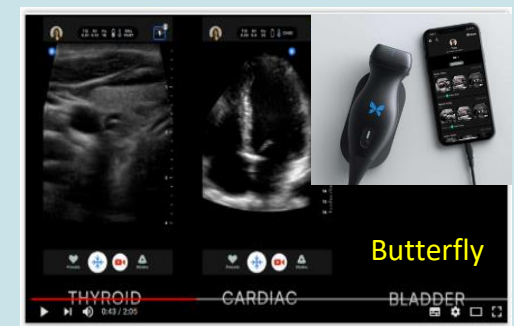
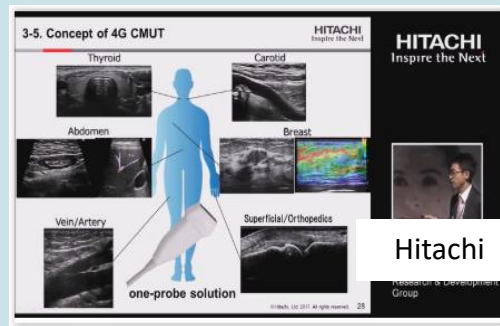
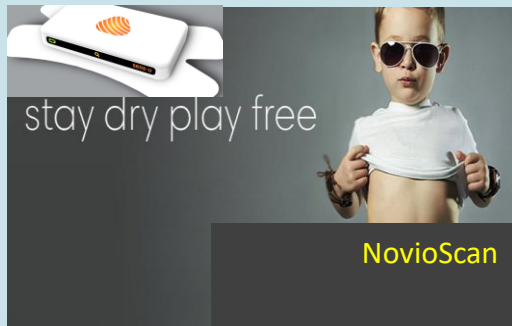
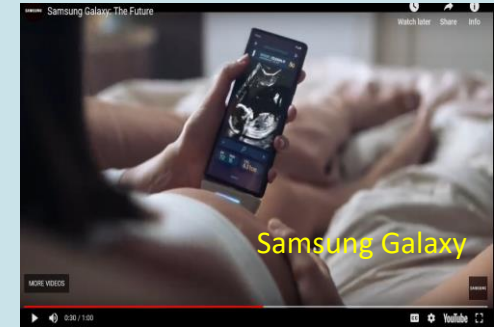
Medical ultrasound application range



Handheld and wearable ultrasound



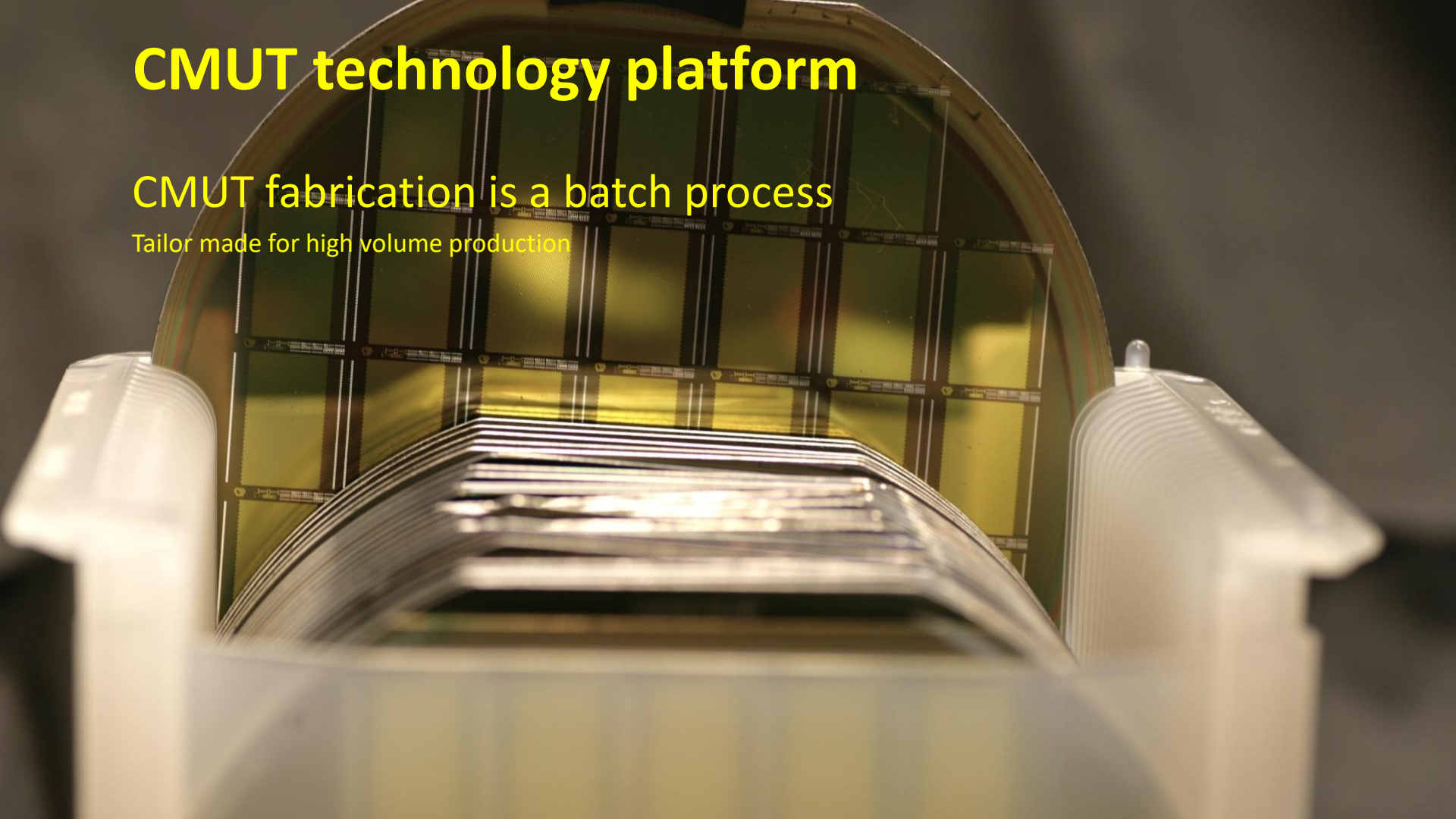
Keywords: Consumer Ultrasound, High volume, Pregnancy, Bladder, Medical and non-medical applications



CMUT technology platform

CMUT fabrication is a batch process

Tailor made for high volume production



CMUT

Capacitive Micromachined Ultrasound Transducer

A replacement for piezo-based ultrasound in the medical domain

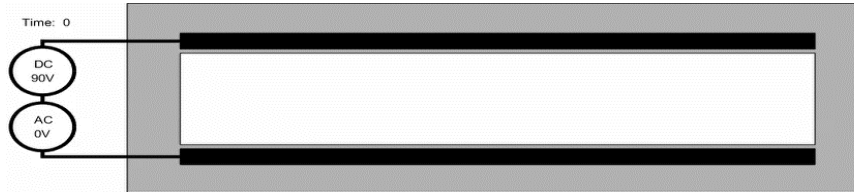
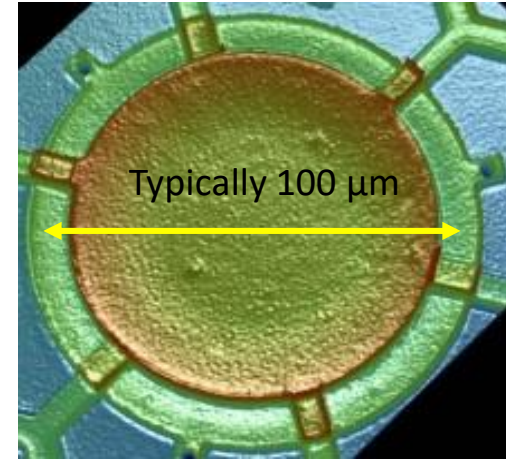
CMUT is fabricated by IC technology

Parallel plate capacitor on membrane

Transmits and receives ultrasound at 1 - 50MHz

Collapse mode: the membrane touches the cavity bottom

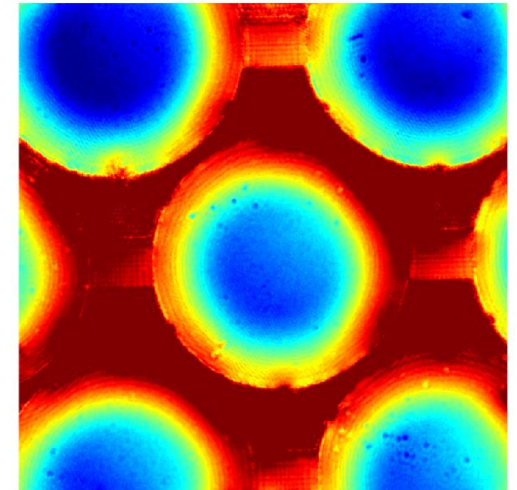
An RF-voltage makes the membrane vibrate



Advantages:






Robust design, large volume & low cost, high level of integration

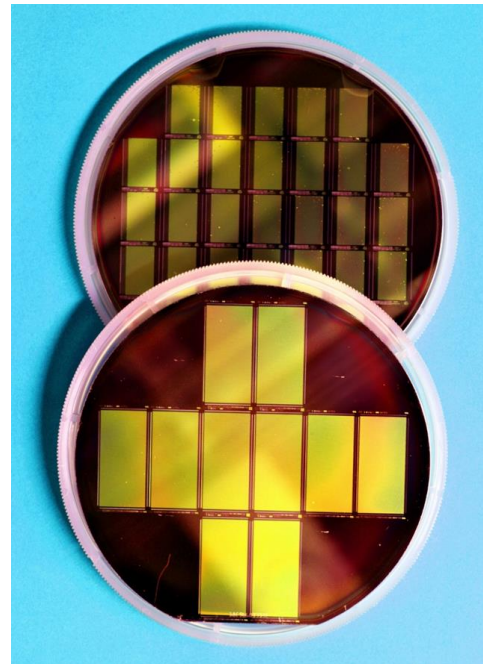
Miniaturization & high frequency, lead free for disposable applications



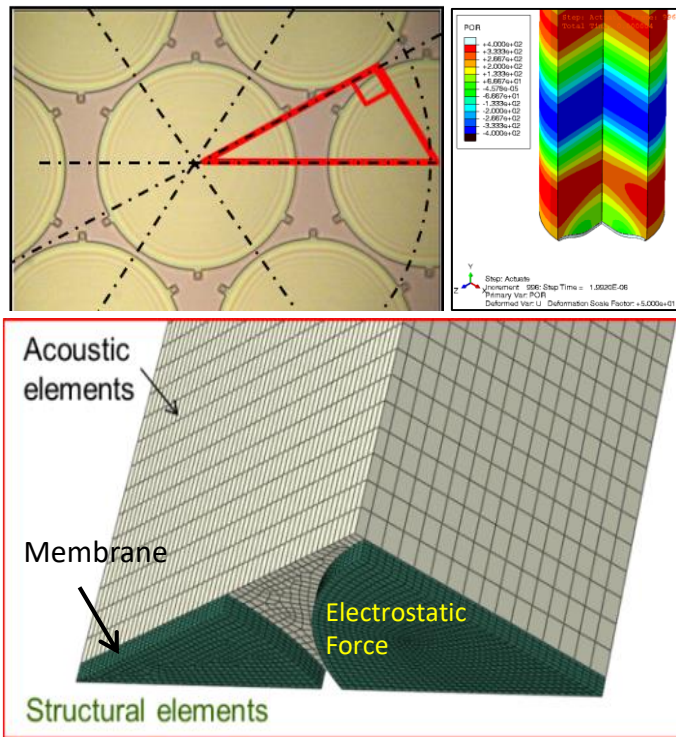
CMUT modular technology platform

CMUT offers a lot of **design freedom**

Wafer		150mm	200mm
Substrate		Bare Si	ASIC
# cMUTs / die		Variable	
Membrane / cavity	Diameter	< 500 μm	
	Pitch	Variable	
	Membrane thickness	< 5 μm	
	Gap height	< 1 μm	
	Dielectric	SiO ₂	SiN



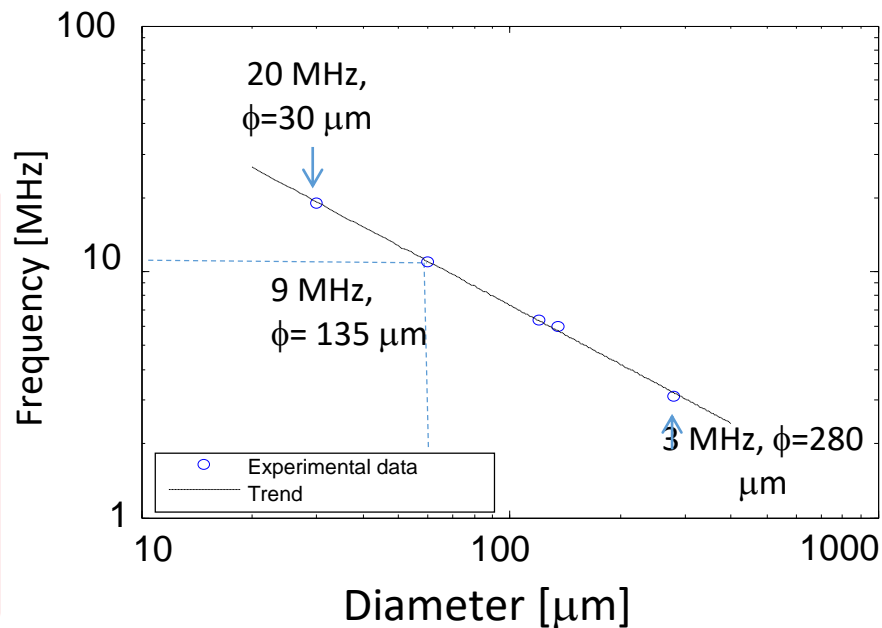
CMUT design



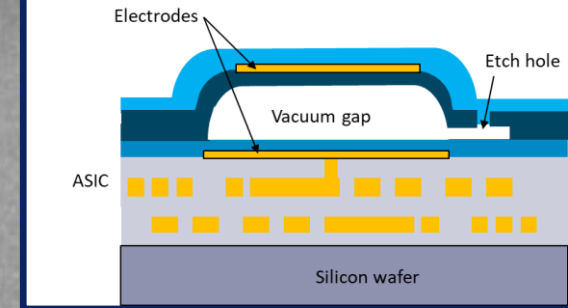
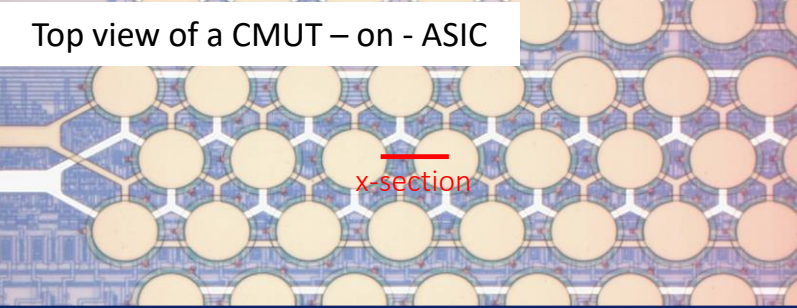
FEM and analytical model

Validated for a wide range of frequencies

Frequency vs diameter



Top view of a CMUT – on - ASIC



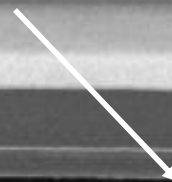
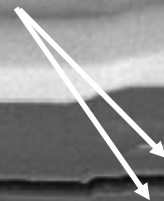
Membrane

Etch hole
(sealed)



Electrodes

Vacuum gap



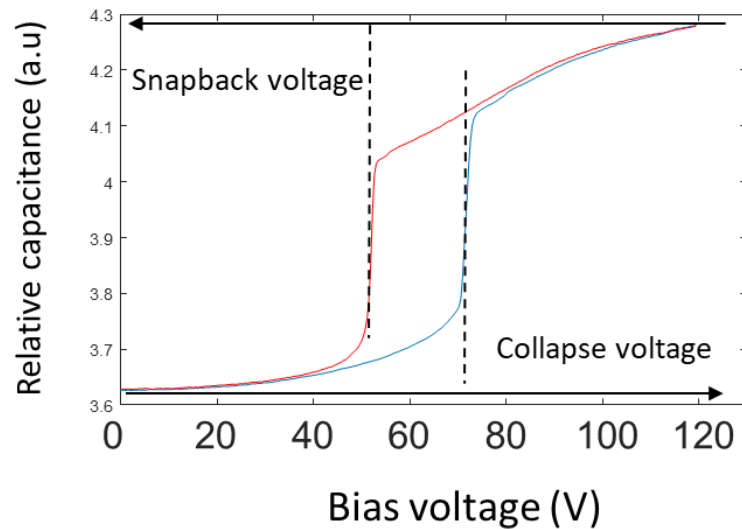
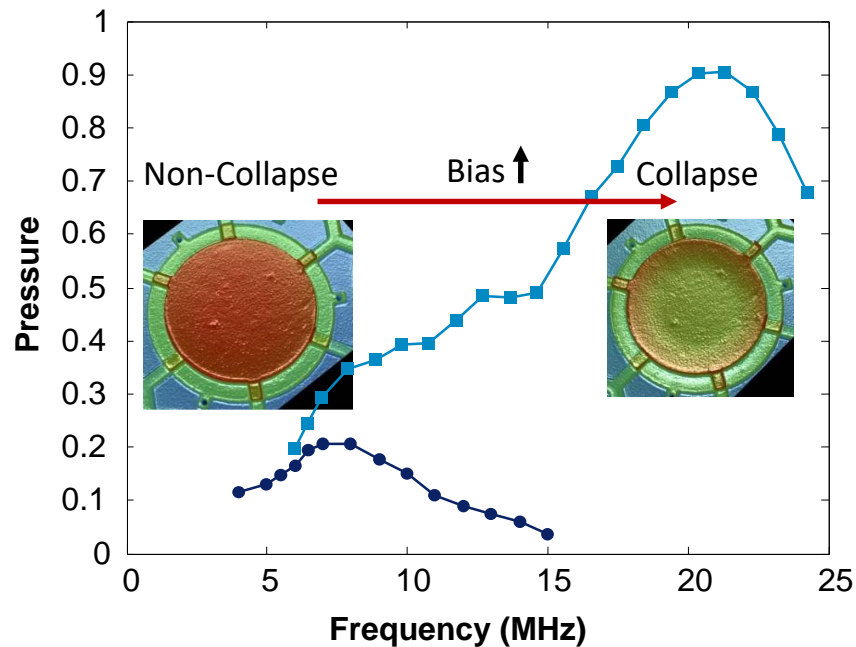
Planarization layer



ASIC



Collapse mode operation

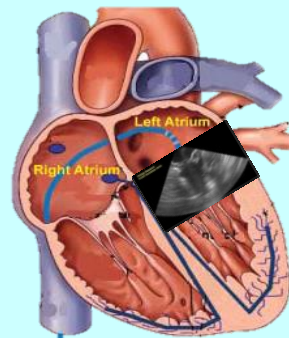
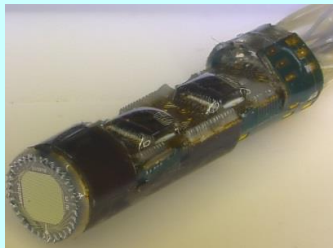


Collapse mode: frequency agility

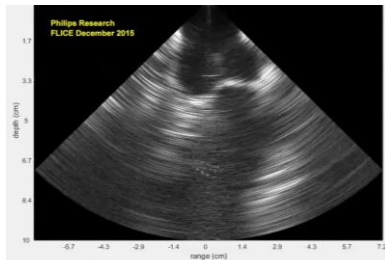
Example: cMUT based Forward Looking Inter Cardiac Echo (FLICE)

- Image from inside the heart (aortic valve)
- cMUT frequency tuning 6 \rightarrow 14 MHz enables zooming

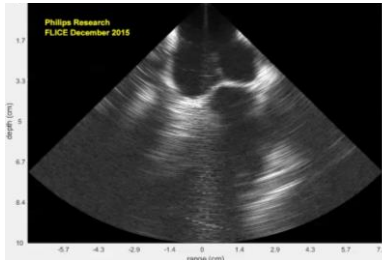
2x2 mm
aperture \rightarrow



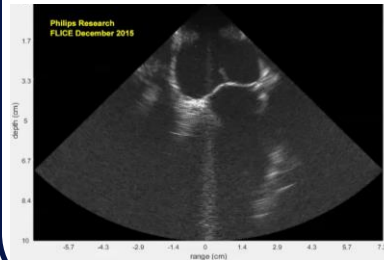
Penetration mode
Bias low \rightarrow 6MHz



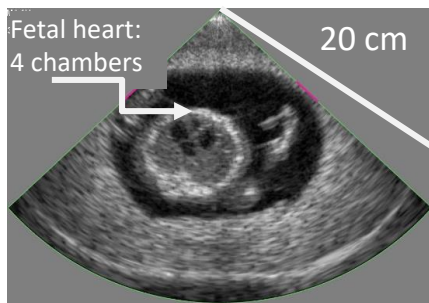
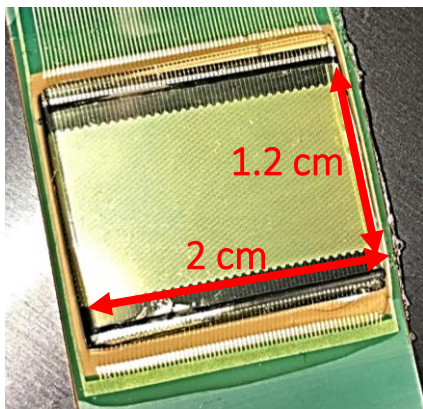
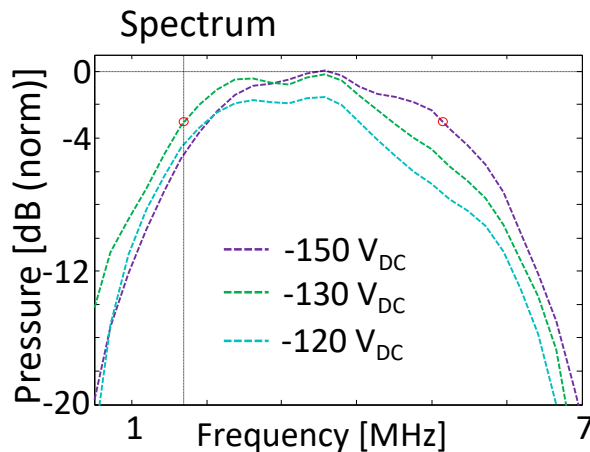
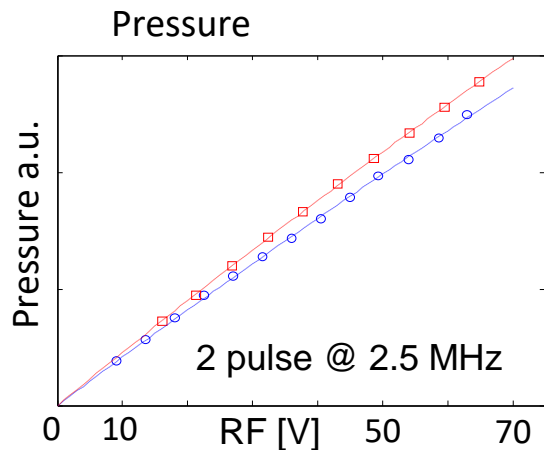
General mode
Bias nominal \rightarrow 10MHz



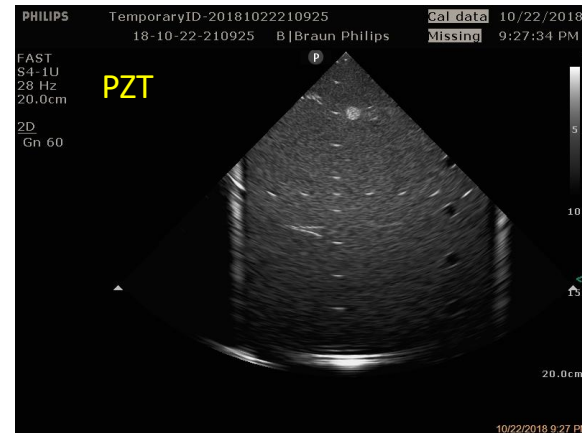
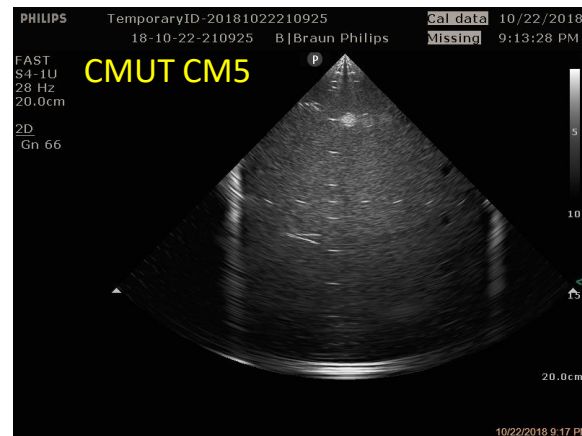
Resolution mode
Bias high \rightarrow 14MHz

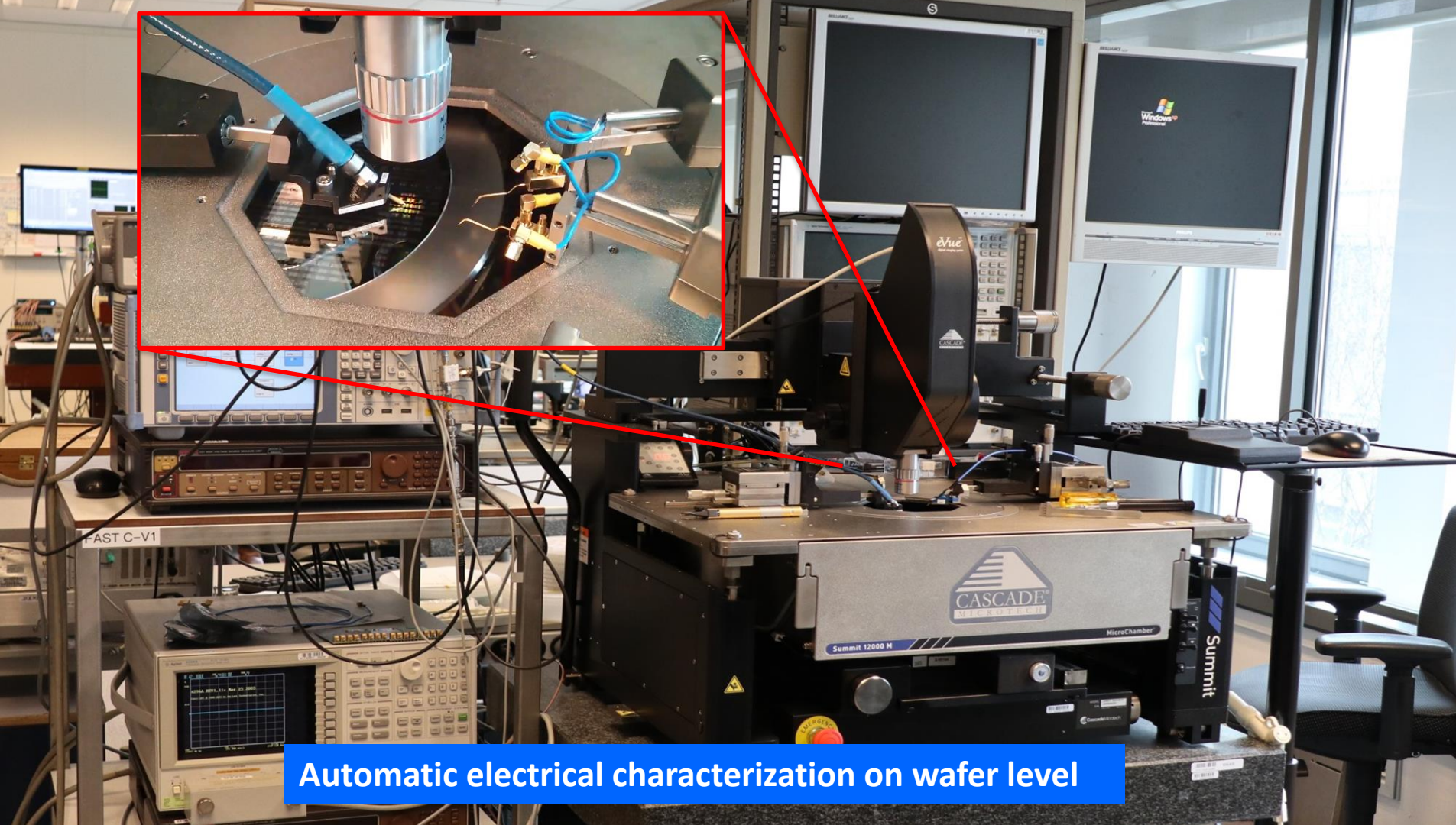


Low frequency example: CMUT imaging probe



- fetal imaging, 24 weeks phantom
- 20 cm penetration

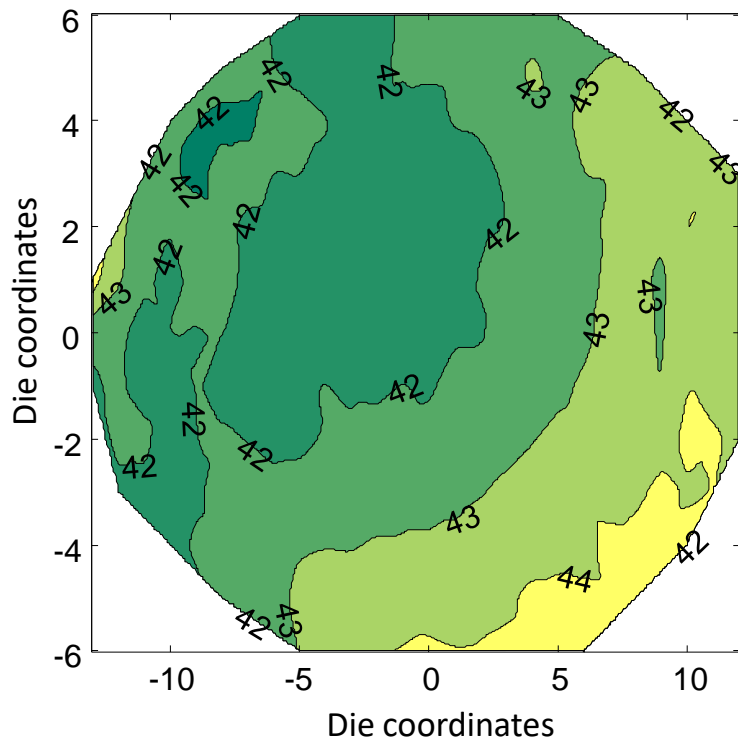




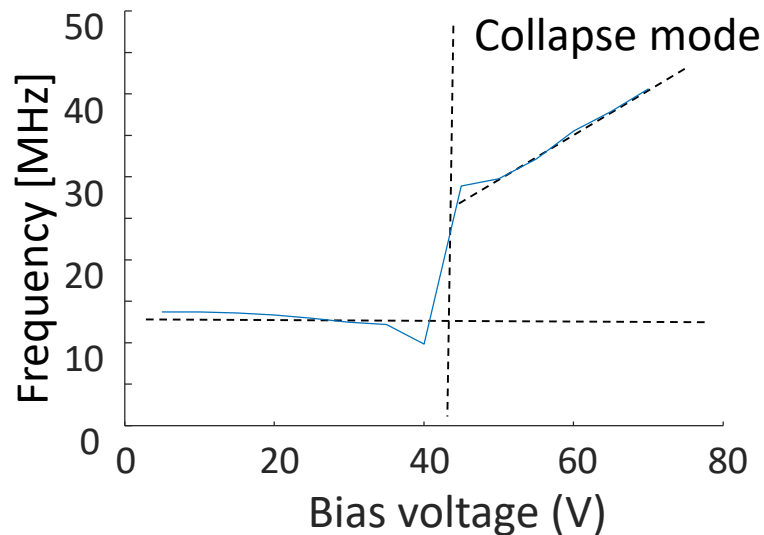
Automatic electrical characterization on wafer level

Wafer level electrical characterization

Wafer map of collapse voltage



- Capacitance
- Resonance frequency
- Element uniformity
- Frequency tuneability & linearity
- Model verification (FEM & analytical)

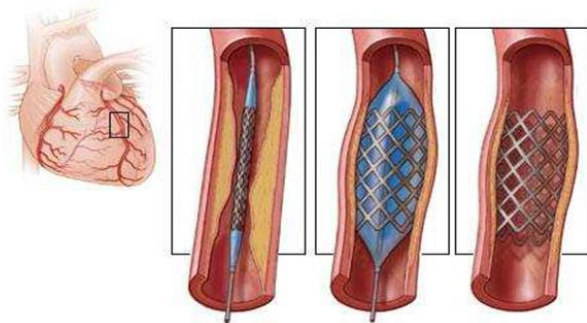
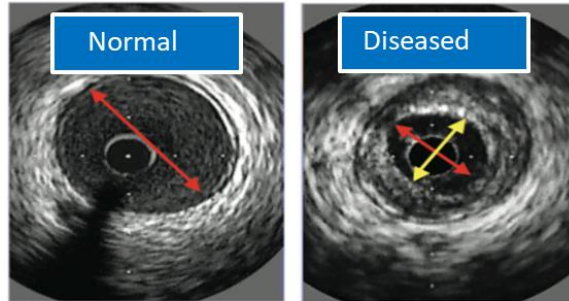


Miniaturization challenge:
smart catheters

IVUS: Intravascular ultrasound

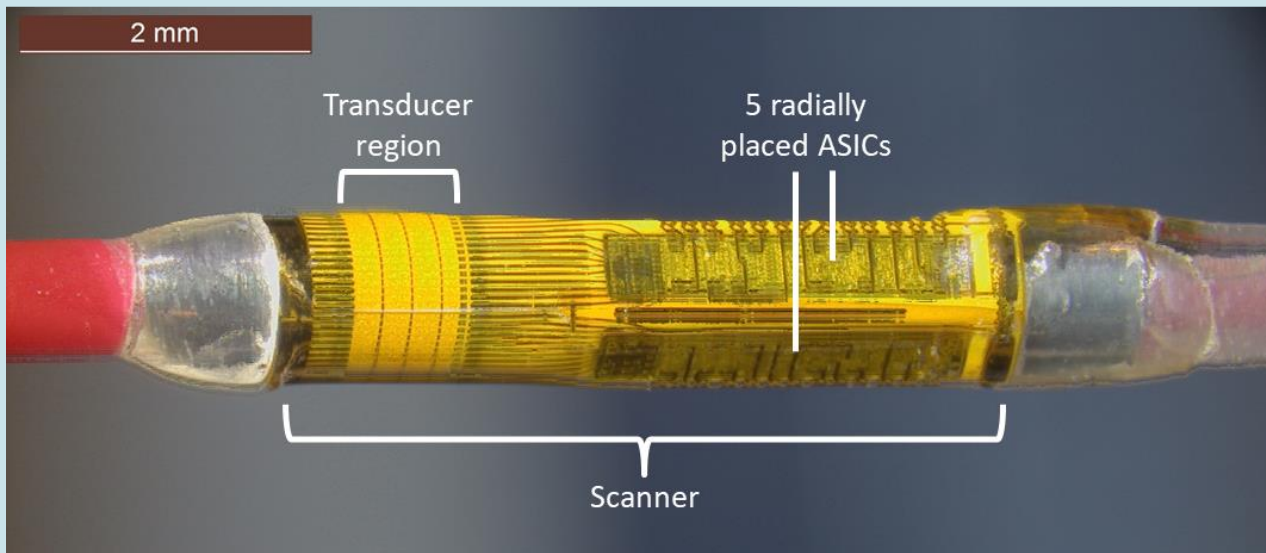


IVUS for stent sizing & deployment verification



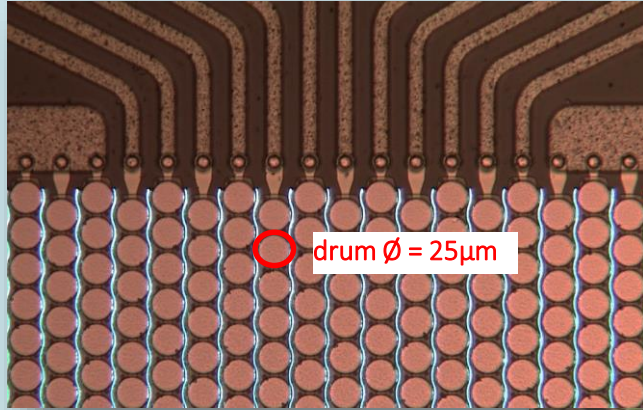
State-of-art: Volcano Eagle Eye IVUS catheter

Ø 1.2 mm catheter, 64 piezo elements around circumference



- 3.5 French (Ø 1.2 mm)
- 7 mm rigid tip length
- 5 ASICs in distal tip
- 64 Piezo elements
- 20 MHz phased array

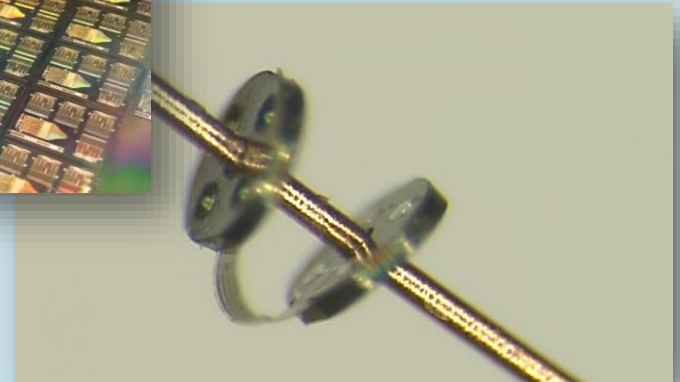
Micro fabrication platform technology



HF CMUT array



Flex-to-Rigid (F2R)



F2R Fundamentals

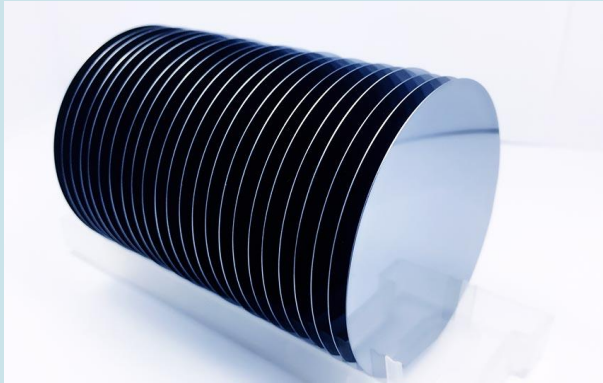
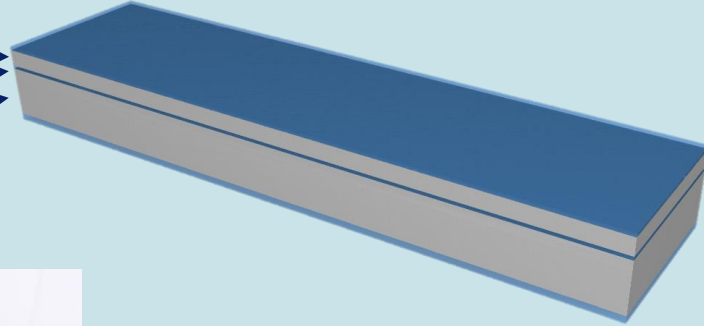


Starting material SOI wafer:

40 μm device layer

0.5 μm BOX

380 μm handle



F2R Fundamentals

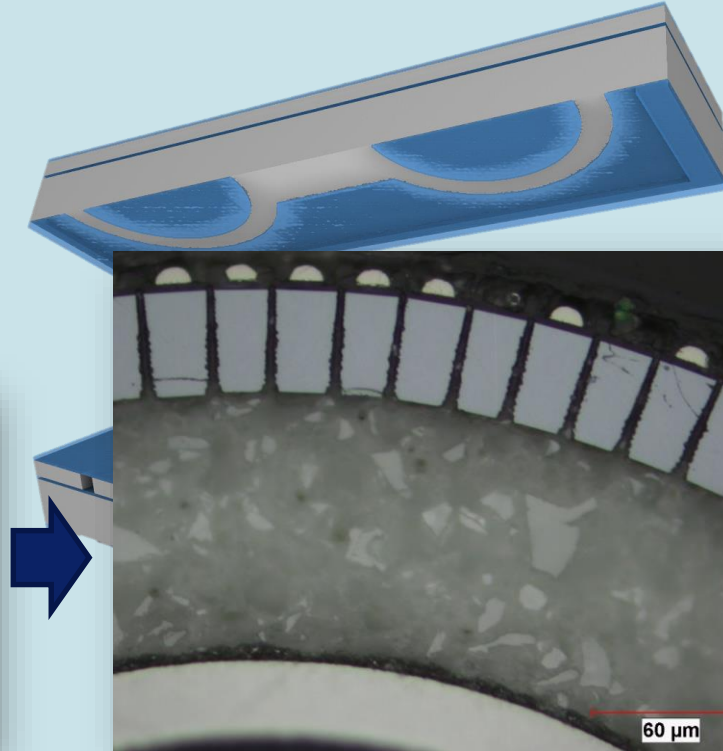
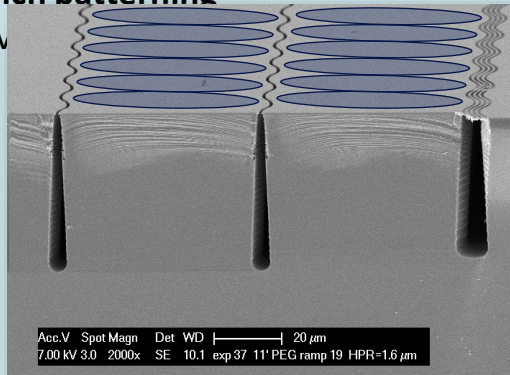
Pre-cMUT F2R process

Backside patterning

Defines where the wafer is thinned down

Buried trench patterning

Defines dev



F2R Fundamentals

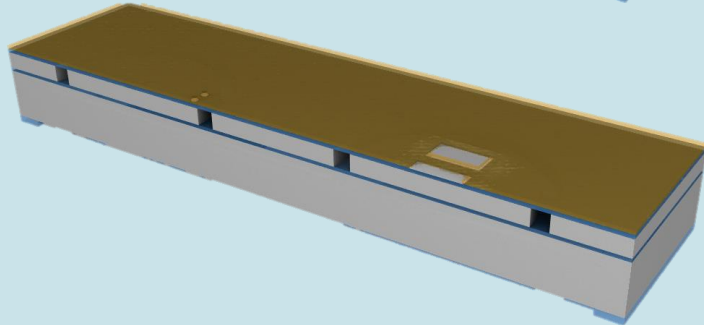
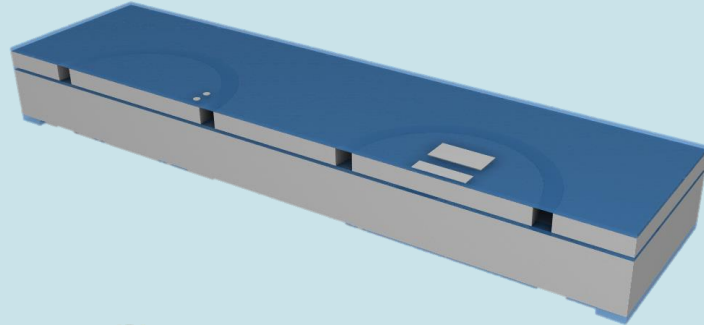
Post CMUT processing

Metal 1

Contacts CMUT electrodes and is used to route on silicon islands

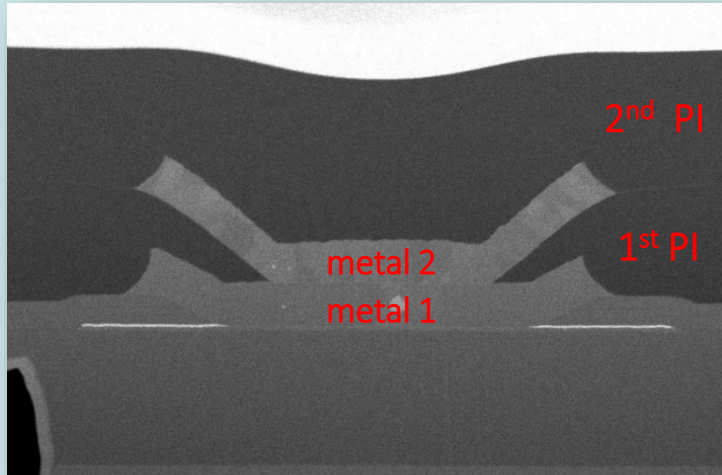
Polyimide deposition and VIA etching

Defines where Metal 1 and Metal 2 are connected



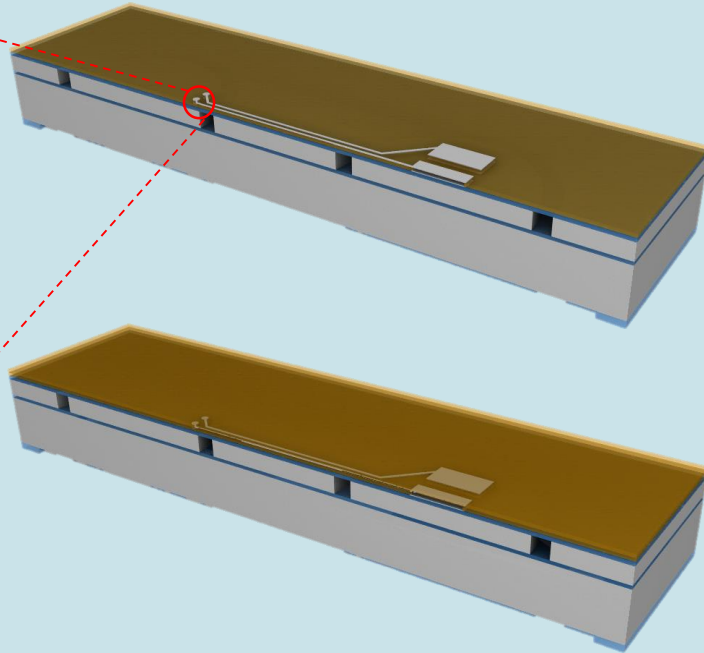
F2R Fundamentals

Post CMUT processing



Second Polyimide is deposited

Layer is completely covering wafer and
Metal 2 is now embedded



F2R Fundamentals

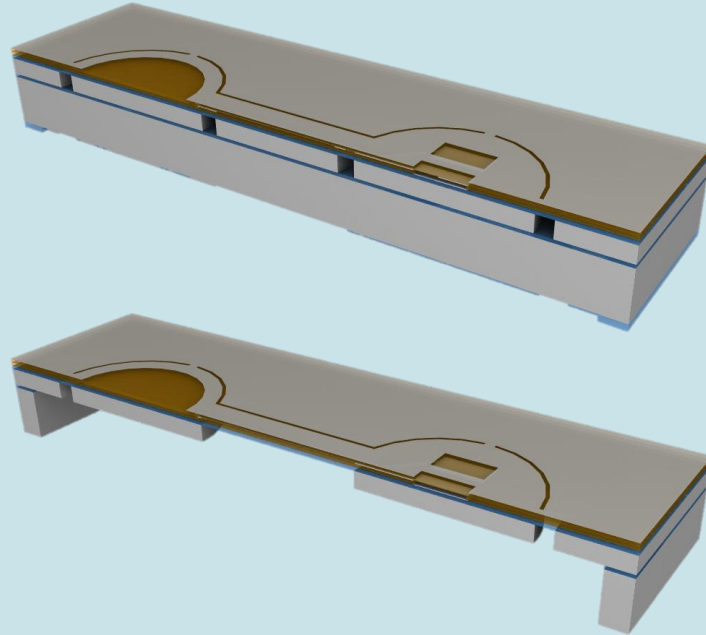
Post CMUT processing

Hard etch mask

Defines where Polyimide is removed after backside etching.

Backside etching

The wafer is thinned down to obtain a device thickness of $40\mu\text{m}$

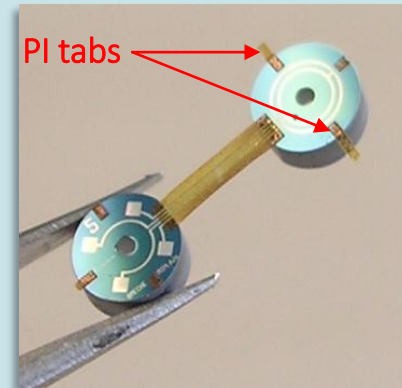
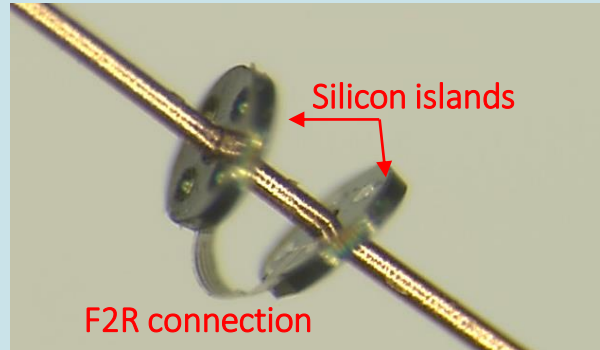
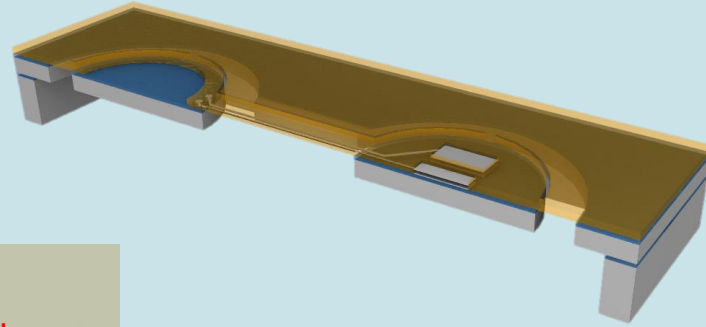


F2R Fundamentals

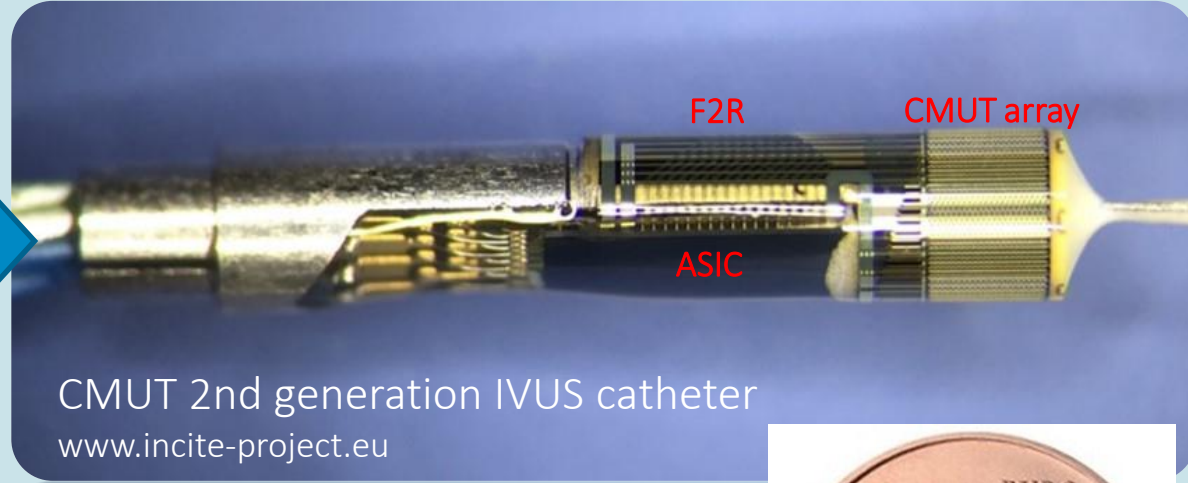
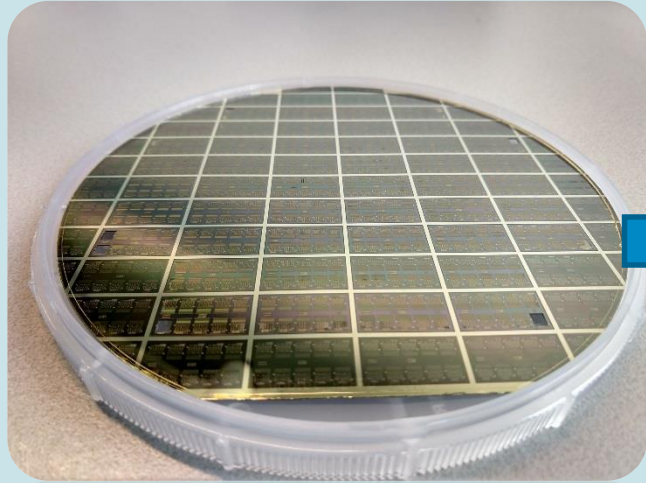
Post CMUT processing

Polyimide etching

Device is now suspended in the wafer by Polyimide tabs



Micro assembly imaging core for catheter



- Complexity of assembly is in the scale of the parts
- General micro-assembly with industrialized/mature techniques



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Thank you for your attention!

Questions?



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POSITION II



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