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# Addressing MEMS development challenges

## Lab-in-Fab approach to accelerate time to volume

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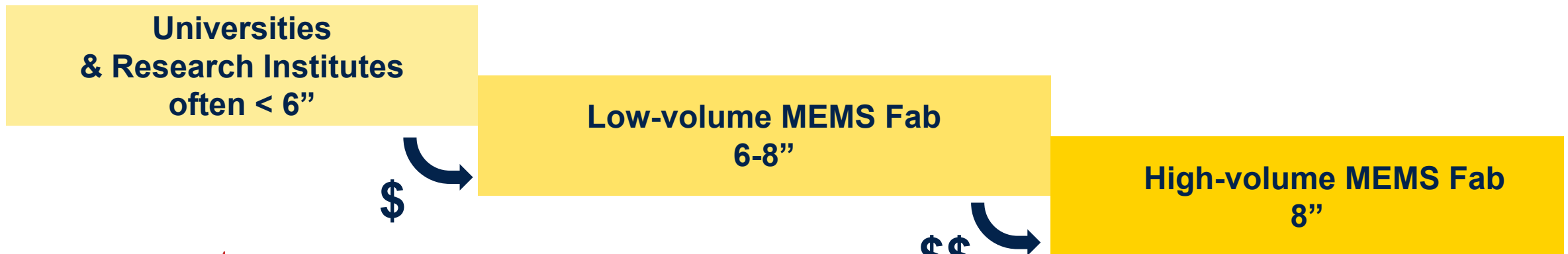
STMicroelectronics

A person wearing a blue cleanroom suit and hood is working in a MEMS fabrication facility. The background shows various pieces of industrial equipment and machinery. A dark blue banner with white text is overlaid on the right side of the image.

**What is the traditional development cycle of state-of-the-art MEMS products?**

# “MEMS development 101”

**“Classical” development cycle**  
Working with multiple players slows down time-to-volume





Can we do better?



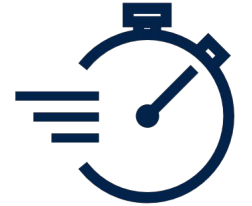
# World's first Lab-in-Fab for Piezoelectric MEMS

ST Techno Park in Ang Mo Kio  
(Singapore)



# Lab-in-Fab: accelerating time to volume

**Lab-in-Fab model: all under one “roof”**  
Combining all phases in the same place



## Your research and industrialization partner

### Our mission

Become the **global leader** in **microsystems research** and **industrialization**, **accelerating** the commercialization of **leading-edge products**

### Our vision

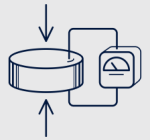
**Support customers** in their journey to the **industrialization** of innovative products using advance **piezoelectric** materials, **sensors & actuators** technology platforms

### How?

By combining **world-class R&D personnel**, key semiconductor equipment and access to the complete **IME & ST development ecosystem**

# Leading-edge competence & access to the global ecosystem

## Rapid product development



**PIEZO MATERIALS**  
AlN, ScAlN, PZT, ...



**MEMS PROCESS & TOOLS**  
8" – "high-volume ready"



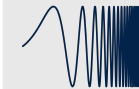
**EWS & DICING**  
Characterization & reliability



**MEMS on top of CMOS**  
Post-CMOS, ...



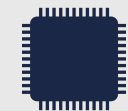
**MEMS & ASIC DESIGN**  
Companion chips, edge AI



**DEVICE ENGINEERING**  
Reference designs



**PROCESS INTEGRATION**  
Packaging, assembly & test



**SYSTEM INTEGRATION**  
Application & system support





# Institute of Microelectronics (IME)



Established in 1991



> 300 highly skilled researchers, scientists, engineers



Leading microelectronics research institute for industrial and academic collaboration

# IME – key expertise

Combining deep expertise with cutting-edge facilities to conduct world-class microelectronics research



**8900 m<sup>2</sup> of cleanroom space Class 1 to 10,000**

**8" piezoelectric specialty at Lab-in-Fab**

**8" Sensor systems**

**8" SiC R&D line**

**8", 12" Photonic systems**

**6" mmWave RF GaN**

**12" Advanced packaging**

# We are creators and makers of technology



One of the world's largest semiconductor companies



Over **50,000** employees  
of which **9,500+** in R&D



**\$17.3 billion** revenues  
in 2023



Over **80** sales & marketing  
offices serving over **200,000**  
customers across the globe



**14** main manufacturing  
sites



Signatory of the United Nations Global Compact (UNGC)  
Member of the Responsible Business Alliance (RBA)

# ST's global ecosystem

**9,500+ people working  
in R&D and product design**

**Advanced R&D centers around  
the globe**

**A unique portfolio of specialized  
technologies**

**Cooperations is a core  
fundamental of ST's DNA**



**14 manufacturing sites**

- 7 Front-End sites
- 7 Back-End sites

Offering quality, flexibility,  
and supply security

More than **30 years**  
of expertise in advanced  
semiconductors

More than **20 years** in  
MEMS

Supporting customers in  
advanced R&D

# ST Singapore campus

Ang Mo Kio



**1<sup>st</sup> semiconductor front-end plant in Singapore (1984)**

**> 51,200 m<sup>2</sup> combined cleanroom**

**6" and 8" production areas**

**~ 4,500 employees**

## Large mix of technologies

MEMS & microfluidics, Bipolar, power MOSFET, BCD & advanced BCD, EEPROM, smartcard, CMOS logic & BiCMOS, SiC diode & MOSFET

# ST Singapore/Italy virtual FAB



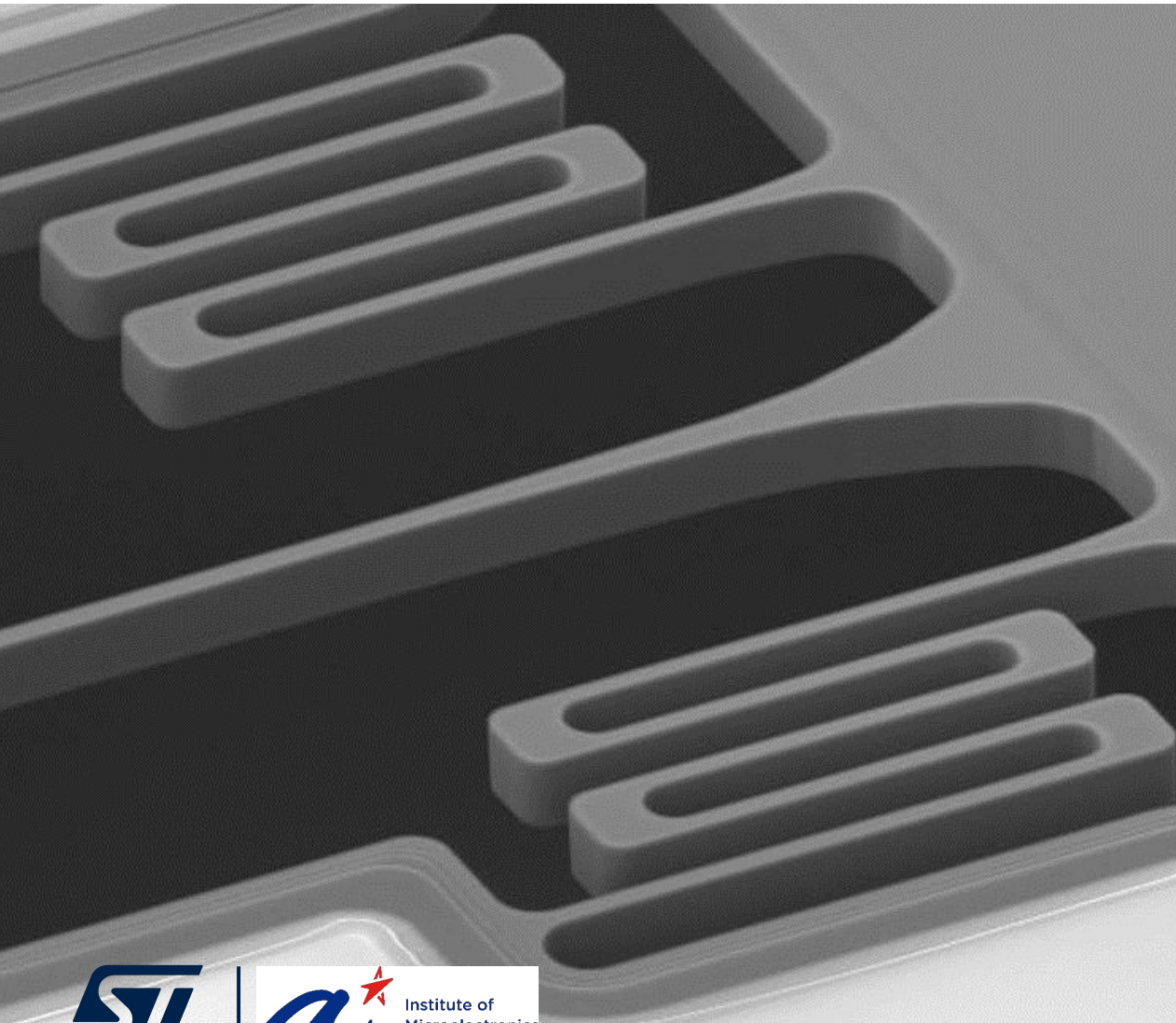
**two physical locations = one functional FAB**





## Technology platforms

# Key process modules



**W2W bonding**

**Dry etching**

**Piezo  
materials  
PZT and  
ScAlN**

**Metrology**

**Surface  
preparation**



# Lab-in-Fab capabilities

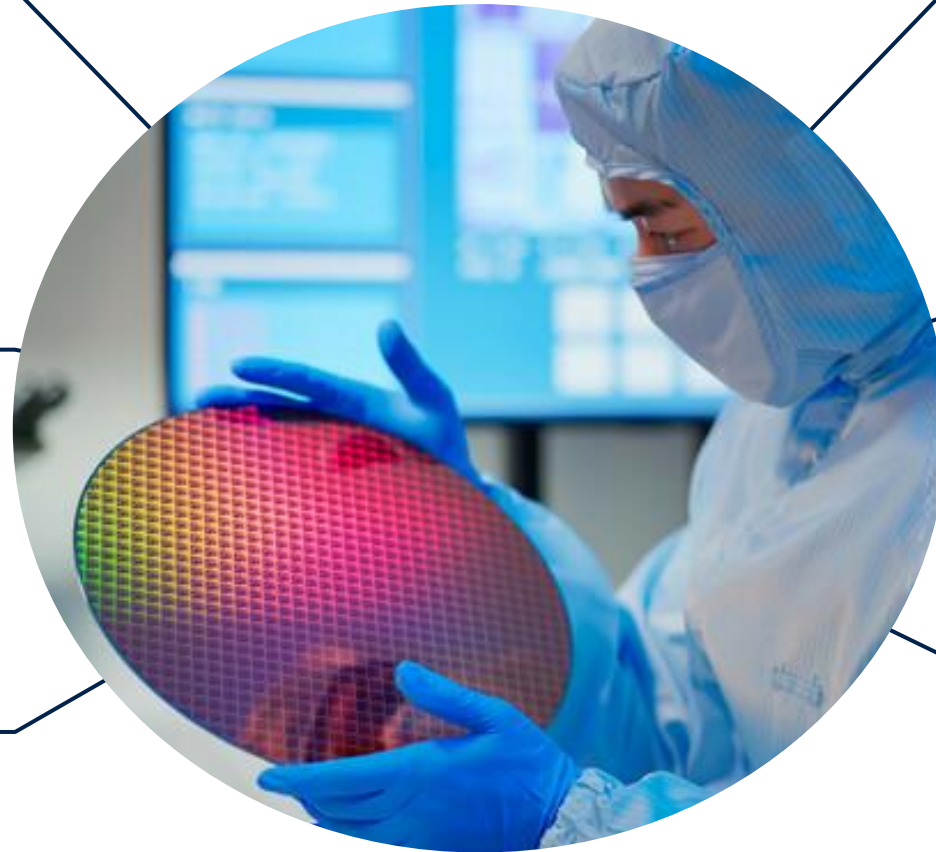
## Wet and other etchings:

silicon oxide, quartz-glass, polymer, and sacrificial layer removal

## Piezo, metal, and protective layer depositions:

AlN, ScAlN, PZT, Al, TiW, AlCu, Ti, AlO, Pt, SiN, ...

**Dry etching:** silicon, silicon oxide, metal, piezo, photoresist stripping



**Metrology:** defectivity, ellipsometry, stress, SEM/EDX, metal sheet res, topography, infrared

**Wafer-to-wafer bonding:** metallic, fusion, organic, temporary bonding

**Lithography:** MEMS stepper with resolution of 0.4  $\mu\text{m}$ , double side alignment accuracy of  $\pm 0.1 \mu\text{m}$

# Lab-in-Fab 8" tool-set in details (1/2)

## Photolithography



- Steppers and mask aligner (1x)
- Front to back alignment
- Up to 0.4 um resolution
- Thick and thin resist
- Screen printing

## Thin-film



- Oxide and SiN CVD
- AlO and HfO ALD
- Metals and barriers
- Piezo layers
  - PZT, ScAlN
  - ...

## Etch



- Metallic etch
- Dielectric etch
- Silicon etch
- PZT and ScAlN etch
- XeF2 Si etch

## Wafer bonding



- Fusion bonding
- Eutectic bonding
- Polymer bonding
- Temporary bonding
- Back grinding and edge trimming

# Lab-in-Fab 8" tool-set in details (2/2)

## Metrology



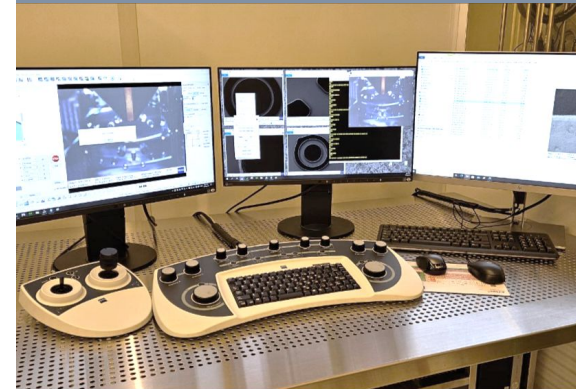
- Film thickness
- Film stress
- Resistivity
- Alignment and CD
- XRD
- DBLI

## Wet and Cleaning



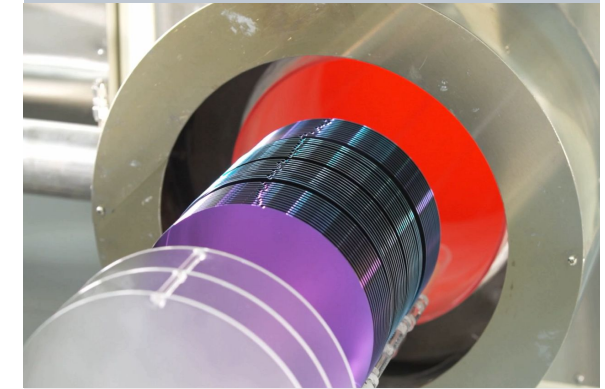
- Front and back scrub
- Wet etches, cleanings and polymer removal
- Backside decon.
- Wet resist strip
- Vapor HF release

## Inspection and Engineering

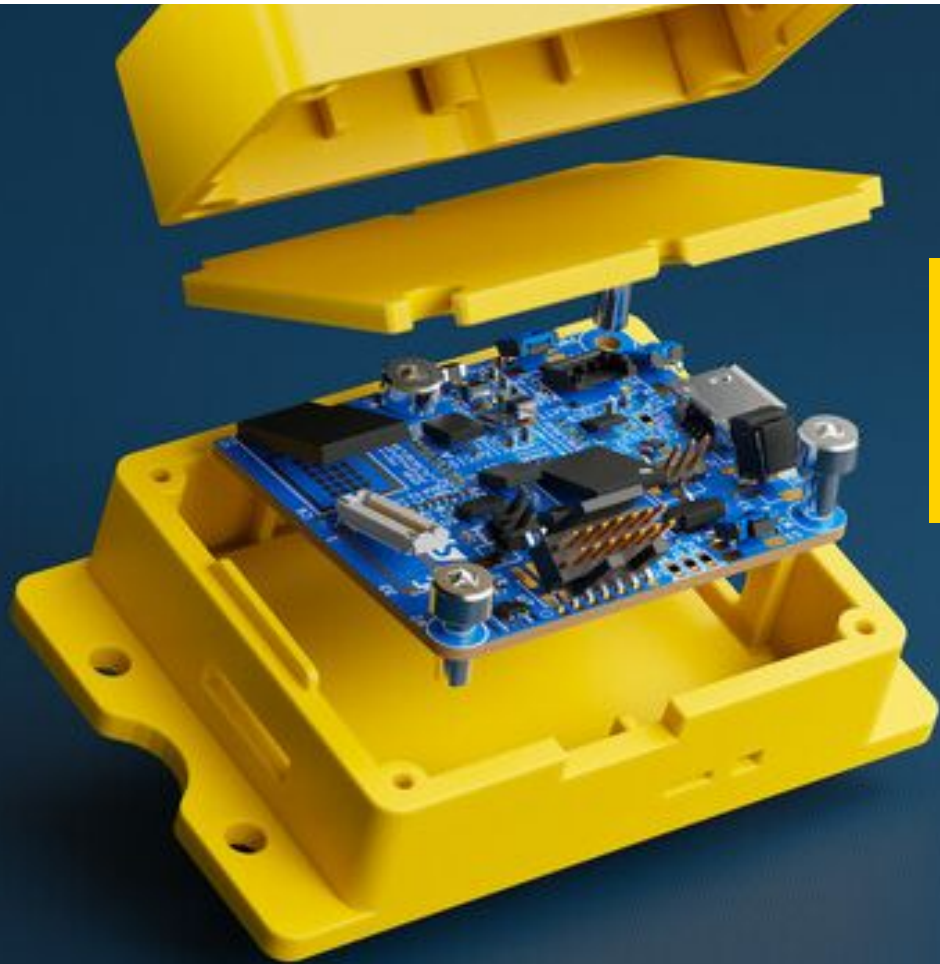


- Defectivity scan
- Defect review
- Inspection SEM
- EDX
- IR Inspection
- Microscope

## Others

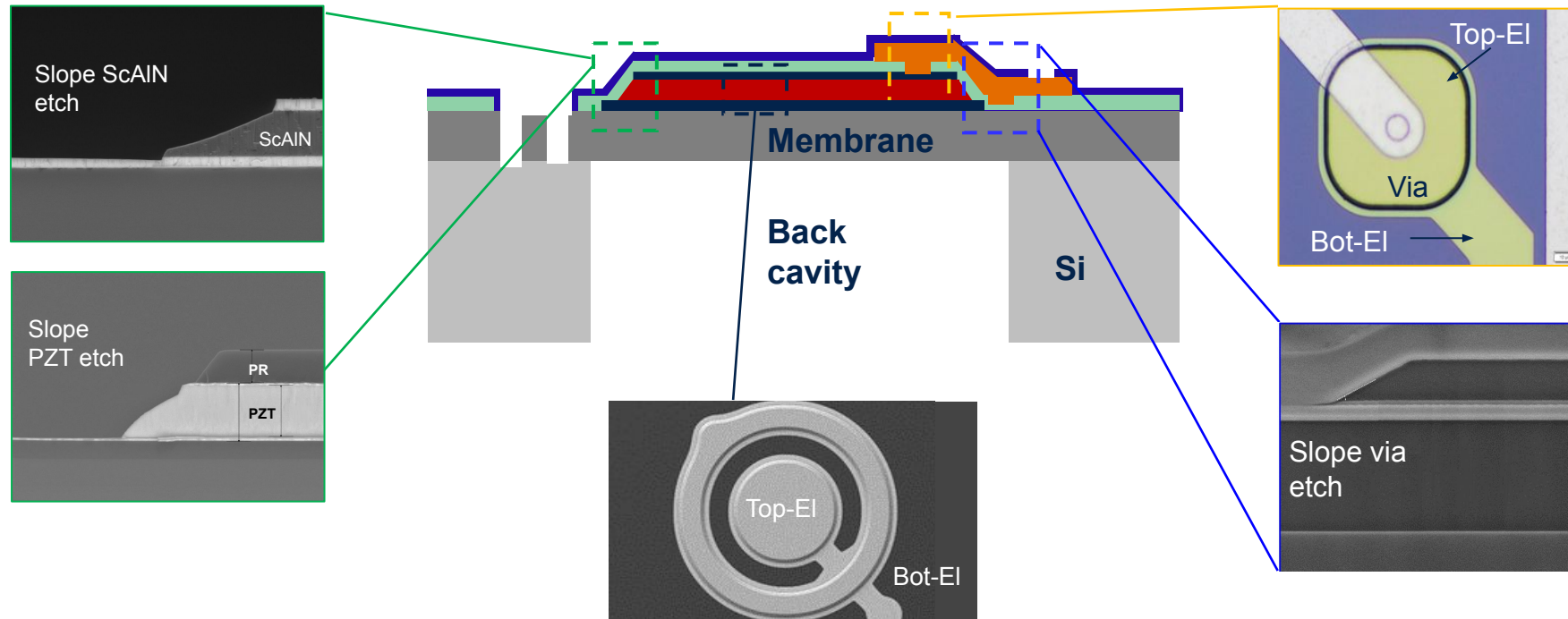


- CMP
- Anti stiction coating
- Thermal oxidation
- POCL doping
- Dry resist strip
- Descum



## Example of applications

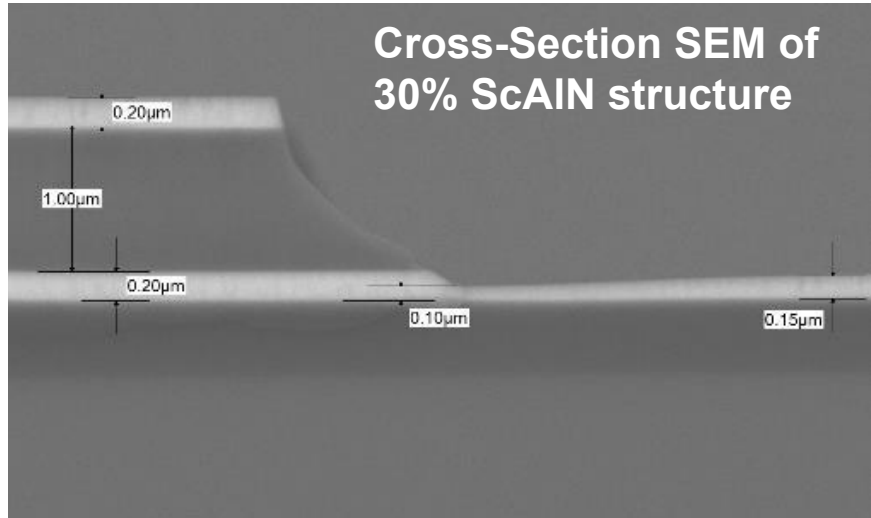
## PVD PZT & ScAlN platforms



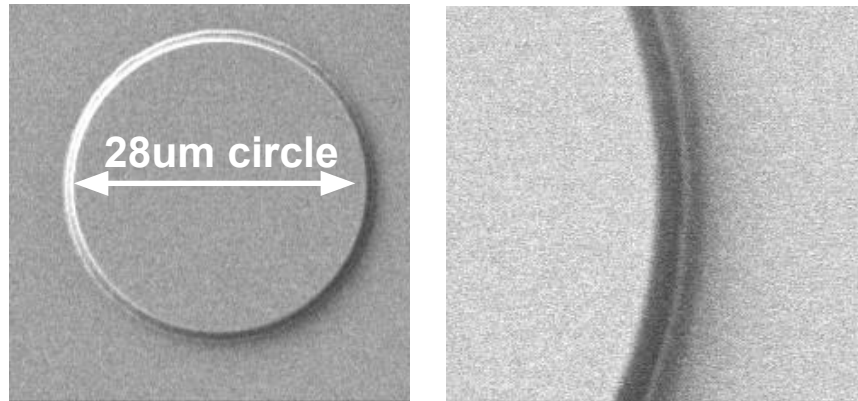
### Key applications

- PMUT
- Microphone, micro speaker
- RF resonators
- Other custom designs compatible with proposed process platforms

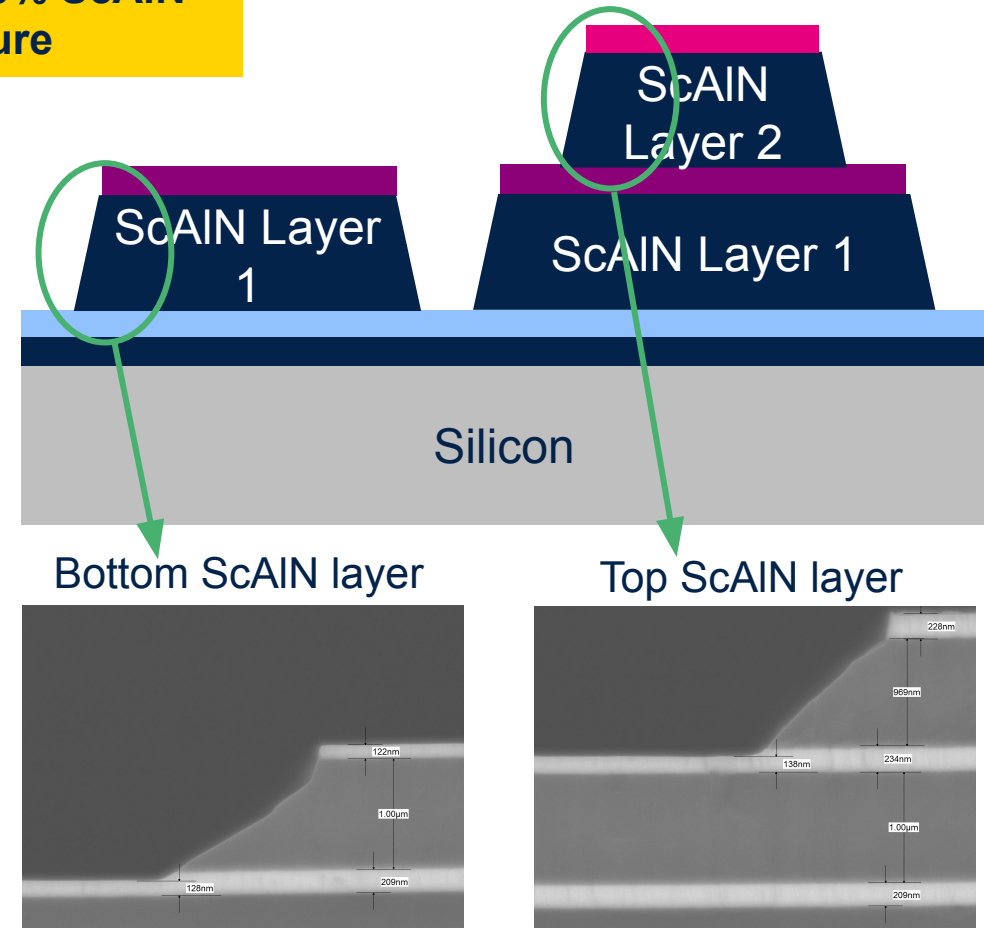
# Multilayer ScAlN MEMS



SEM top views

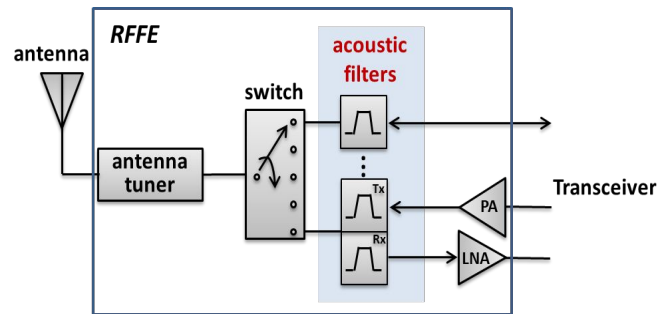


Schematic of 20% ScAlN bimorph structure



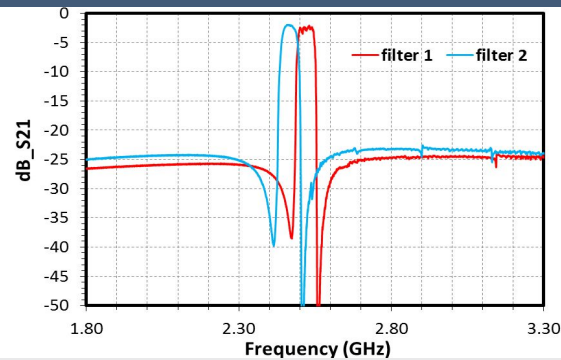
# RF MEMS platform

## Acoustic filters for RF front-end systems



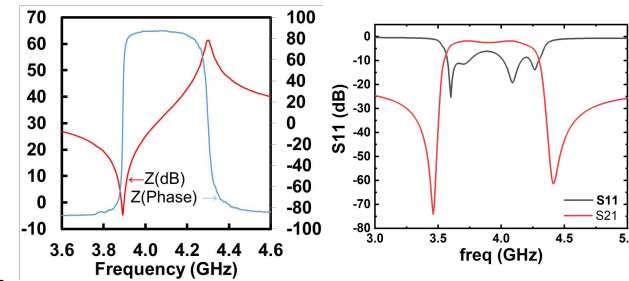
- Addressing RF front end (RFFE) using high performance MEMS technology
- Acoustic filters
- Frequency reference for oscillators

## Lamb wave resonator technology



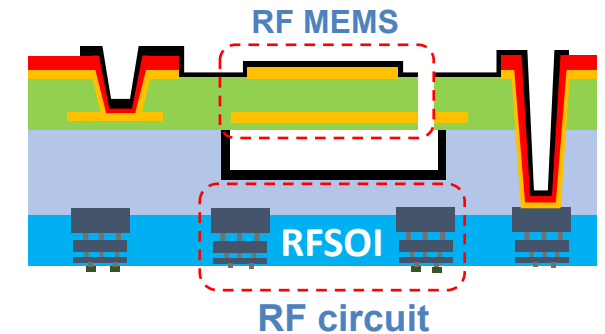
- Lithographic frequency tunability
- Multiple frequencies on one wafer
- Fab cost reduction

## Bulk acoustic wave (BAW) technology



- Various Sc% doping for customized design
- Frequency ranging from 700 MHz to 15 GHz
- High quality factor and high bandwidth filter

## Monolithic integration technology



- Acoustic filter monolithically integrated with CMOS circuits
- Minimize the footprint of RF module
- Parasitic reduction



## Engagement models



# Lab-in-Fab engagement model



## Phase 1

### First level assessment no NDA required

- Assess alignment with Lab-in-Fab technology roadmap, Fab toolset and capability

Within 4 weeks from first contact



## Phase 2

### In-depth assessment under NDA

- **Technical:** feasibility of process flow, rough estimate of resources needed, high level schedule
- **Business:** estimate of development cost, high level IP alignment

Within 3 months from first contact



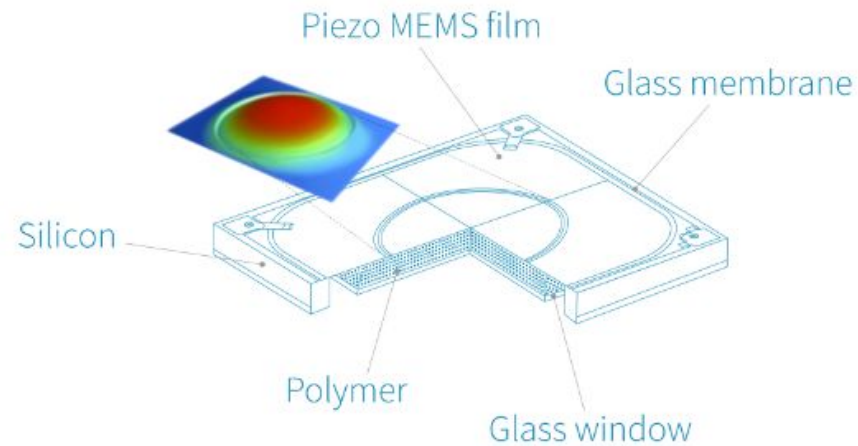
## Phase 3

### Contractual agreement SOW or development agreement, signed

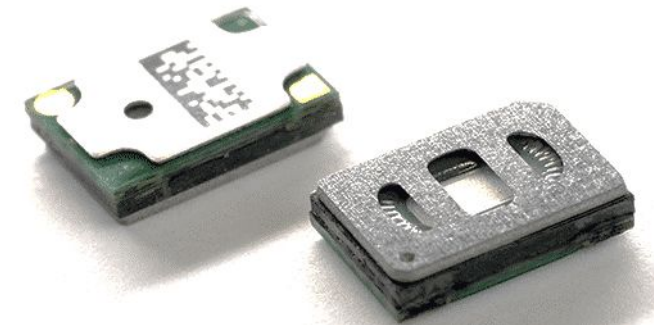
- Covering all technical and business aspects
- Technical activity can start in parallel

6 months from Phase 2

# Examples of third-party collaborations



**U))) SOUND**



# Lab-in-Fab

**Want to know more?**

Contact us at

**[Lab\\_in\\_Fab\\_List@list.st.com](mailto:Lab_in_Fab_List@list.st.com)**



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# Our technology starts with You



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