Advancement in 8 inch AlN MEMS line and enabling technologies for productization

氮化铝中试线的先进性和为产品化服务的共性技术研发平台

More than Moore · More than Innovation

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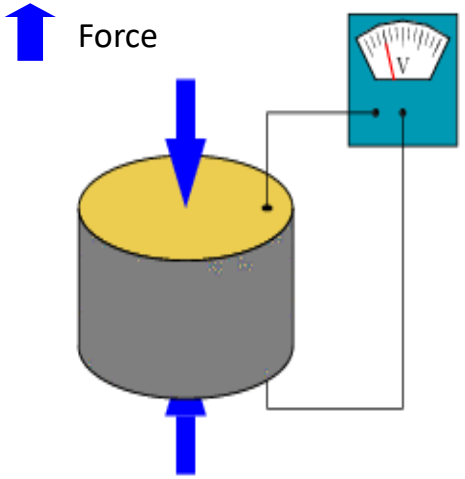
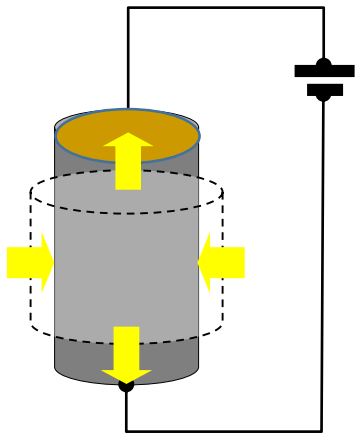
Outlines （目录）

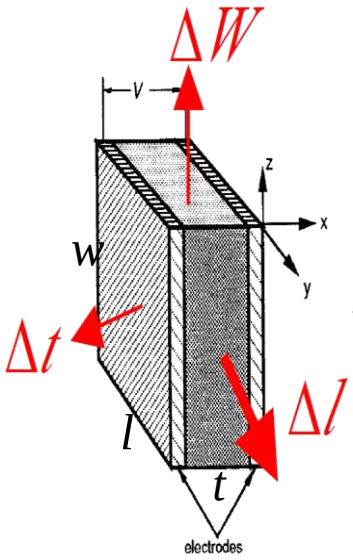
- **Introduction of 8-inch AlN line in SITRI**
  工研院八寸氮化铝中试线的介绍
  - Piezoelectric effect（压电效应简介）
  - Advantages of 8-inch AlN MEMS platform (8寸氮化铝平台的优势)
  - Progressive development of 8-inch AlN platform (8寸氮化铝平台的技术发展规划)
- **Technology development enabled by 8-inch AlN line**
  基于氮化铝平台的技术拓展
  - Technology incubation model & development roadmap (技术孵化和发展路线)
  - Piezoelectric Micro-machined Ultrasonic Transducer (pMUT) (微型超声换能器)
  - Progress updates and demonstration （应用场景演示）
- **Common technology platforms and supports in SITRI**
  共性技术和服务平台
- **Conclusions （小结）**

Piezoelectric effect （压电效应简介）

Piezoelectric effect	Inversed Piezoelectric effect
Force  Electrical charge by Force	Displacement  Displacement by Electric field
Sensing	**Actuation**

$$S = sT + dE$$
$$D = dT + \varepsilon E$$

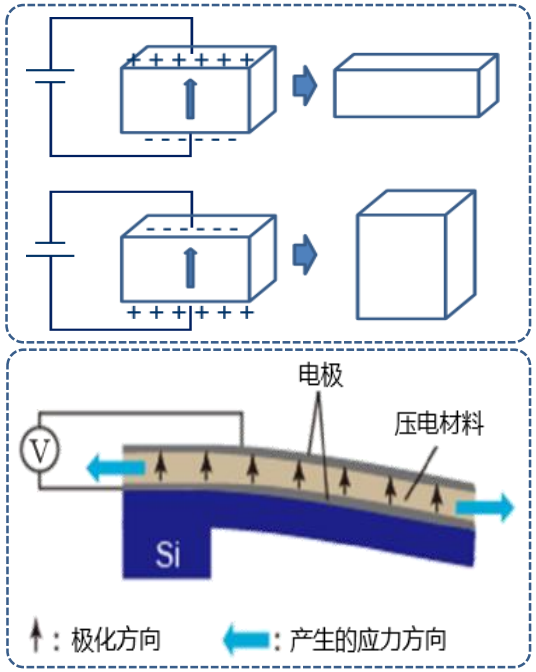
S: Strain **E**: Electric field
T: Stress s: Compliance
d: Piezoelectric strain co-efficient
D: displacement field ε: permittivity



$$\frac{\Delta l}{l} = d_{31}E$$
$$\frac{\Delta w}{w} = d_{32}E$$
$$\frac{\Delta t}{t} = d_{33}E$$

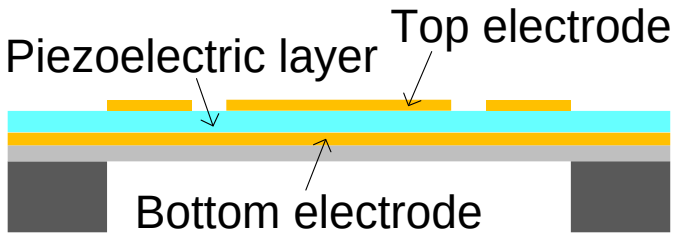
d_{33} 驱动

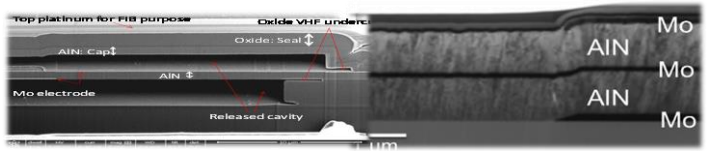
d_{31} 驱动

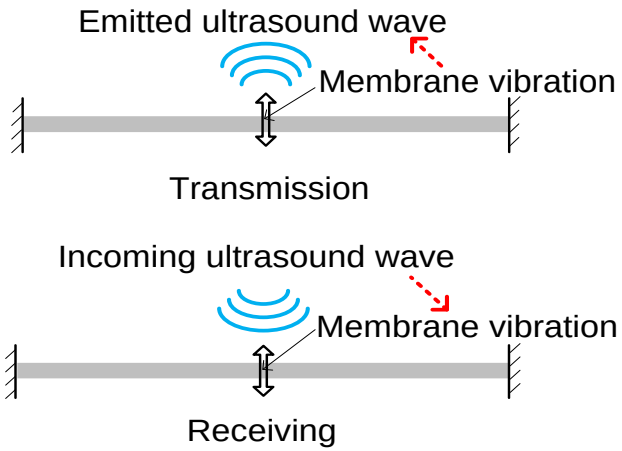


AlN MEMS platform and its advantages (氮化铝MEMS平台及其优势)

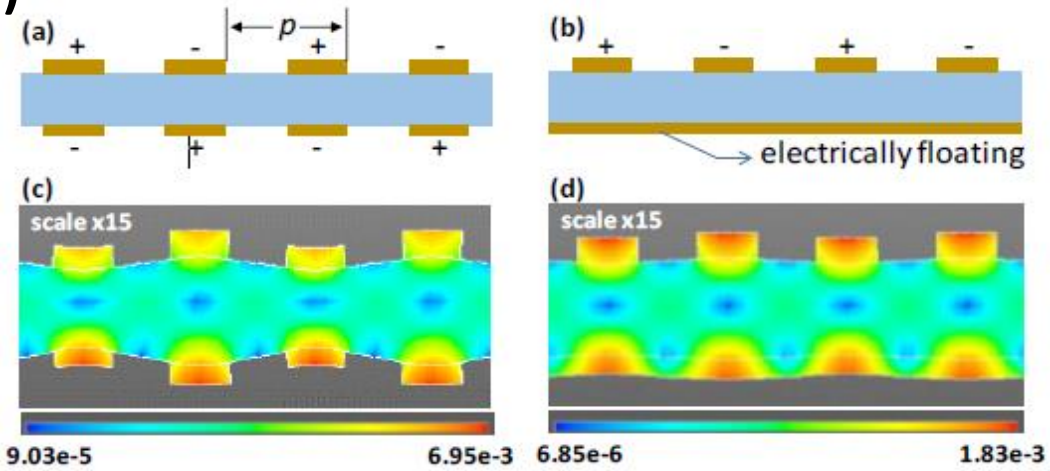
Piezoelectric micro-machined ultrasonic transducer (pMUT)







5G RFFE



Advantages

- ✓ Optimized device performance
- ✓ High yield & Low manufacturing cost

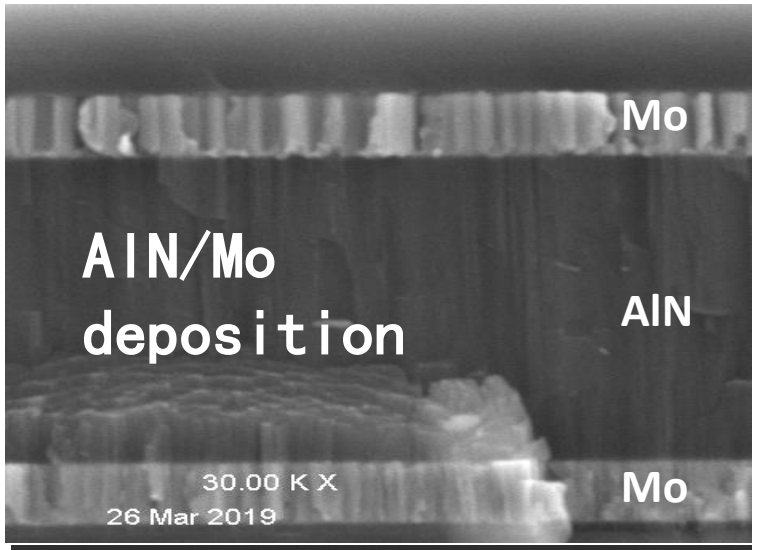
Productization 产品化

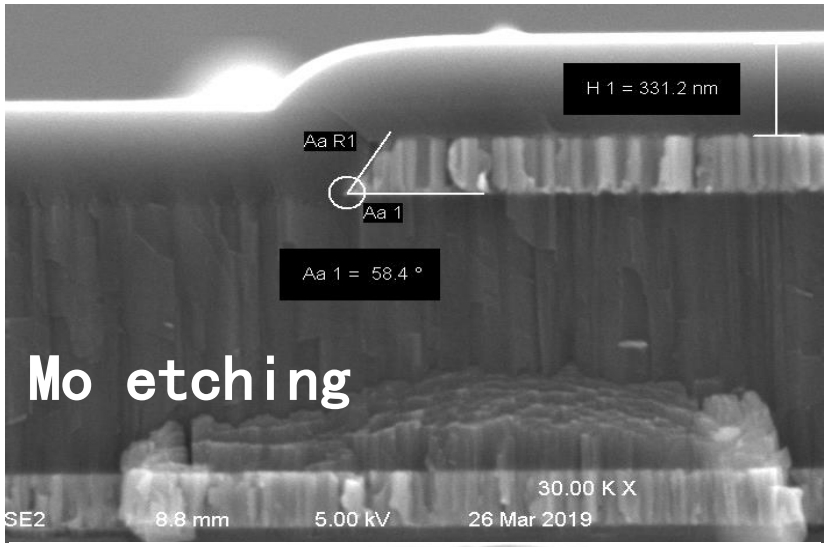
- ✓ Converged integration platform
- ✓ Platform progression

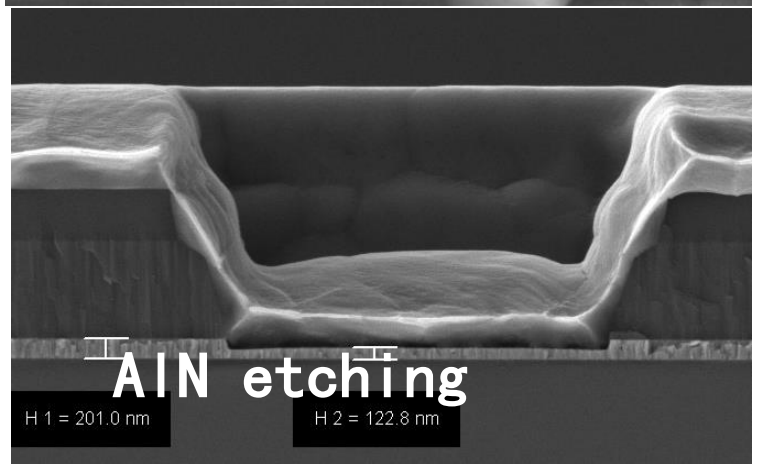
More than Moore 超越摩尔平台

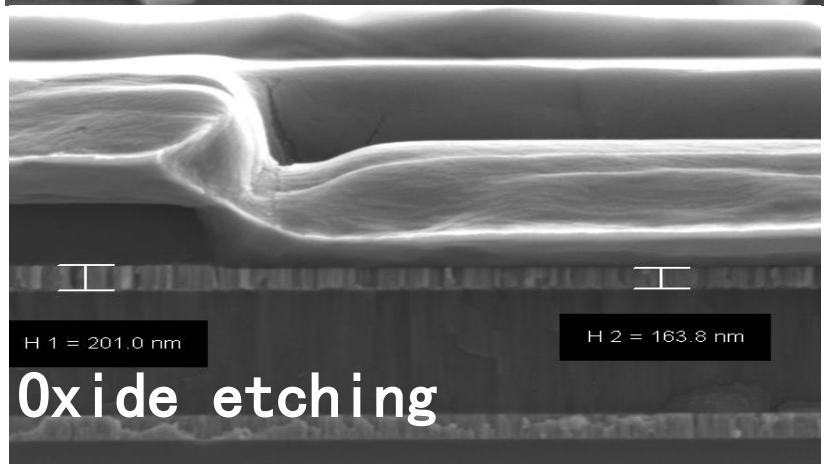
8-inch AlN platform（8寸线氮化铝MEMS平台简介）

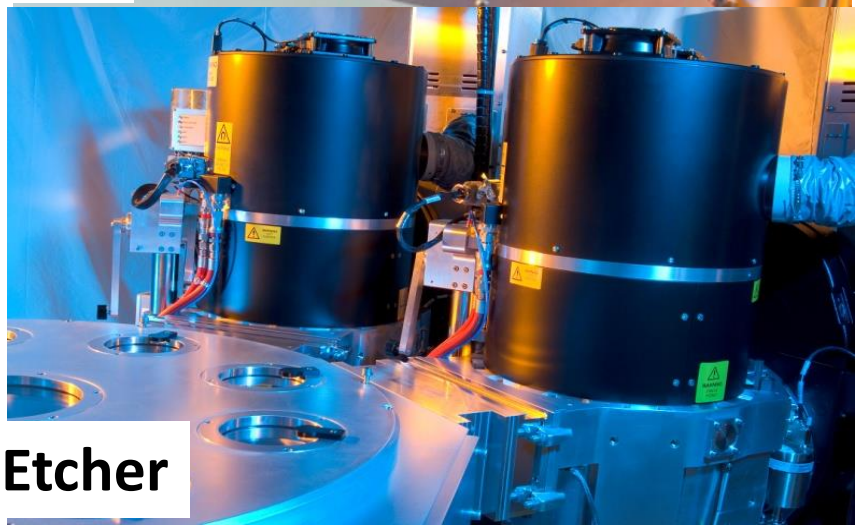
- Both PVD and thin-film deposition tools have be installed. Overall investment > ￥50 million
- Collaboration with SPTS for a continuous improvement of technology advancement and competitiveness



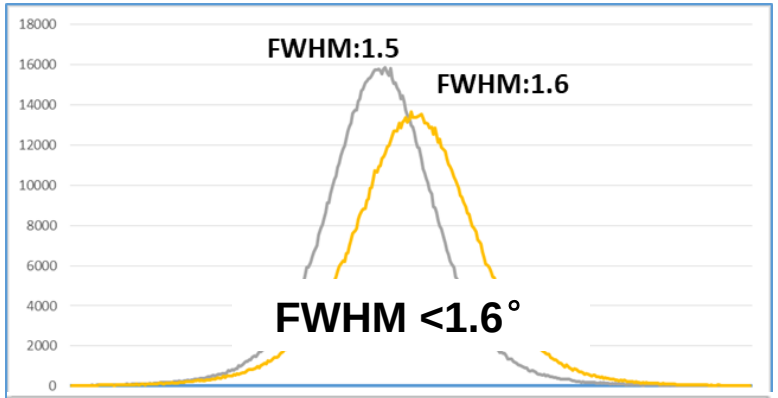


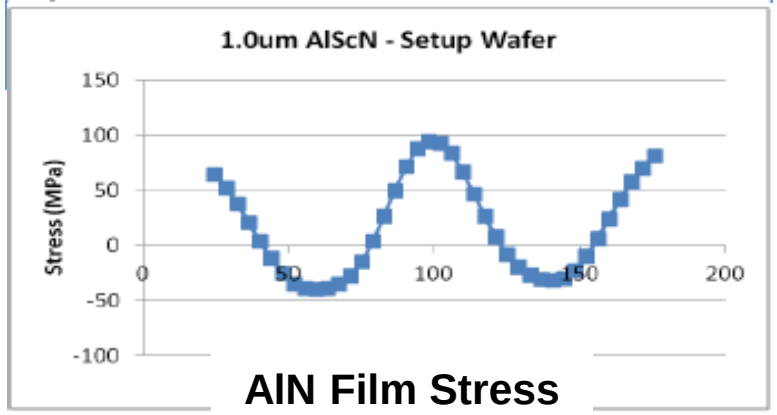




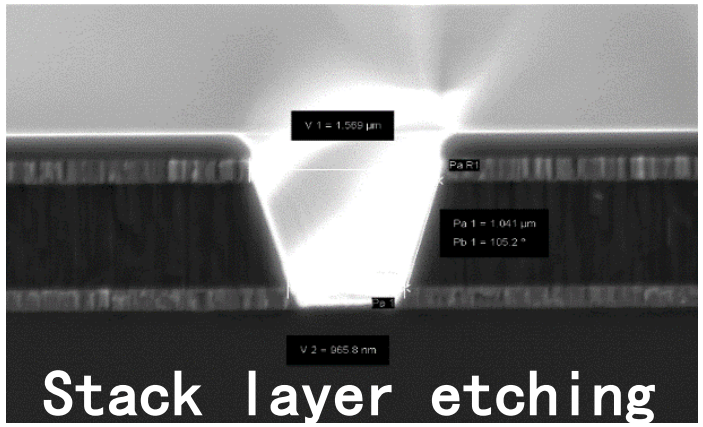


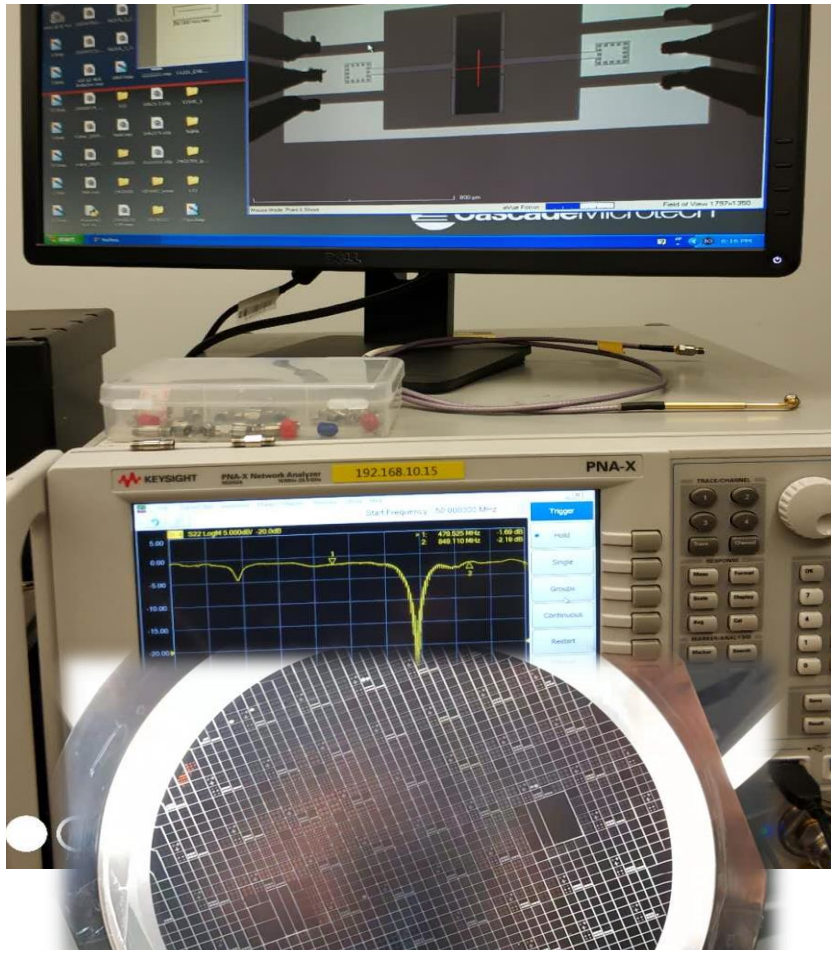
8-inch AlN platform （8寸线氮化铝MEMS平台简介）





Mean Stress: 17 MPa
WIW Stress: 135 MPa



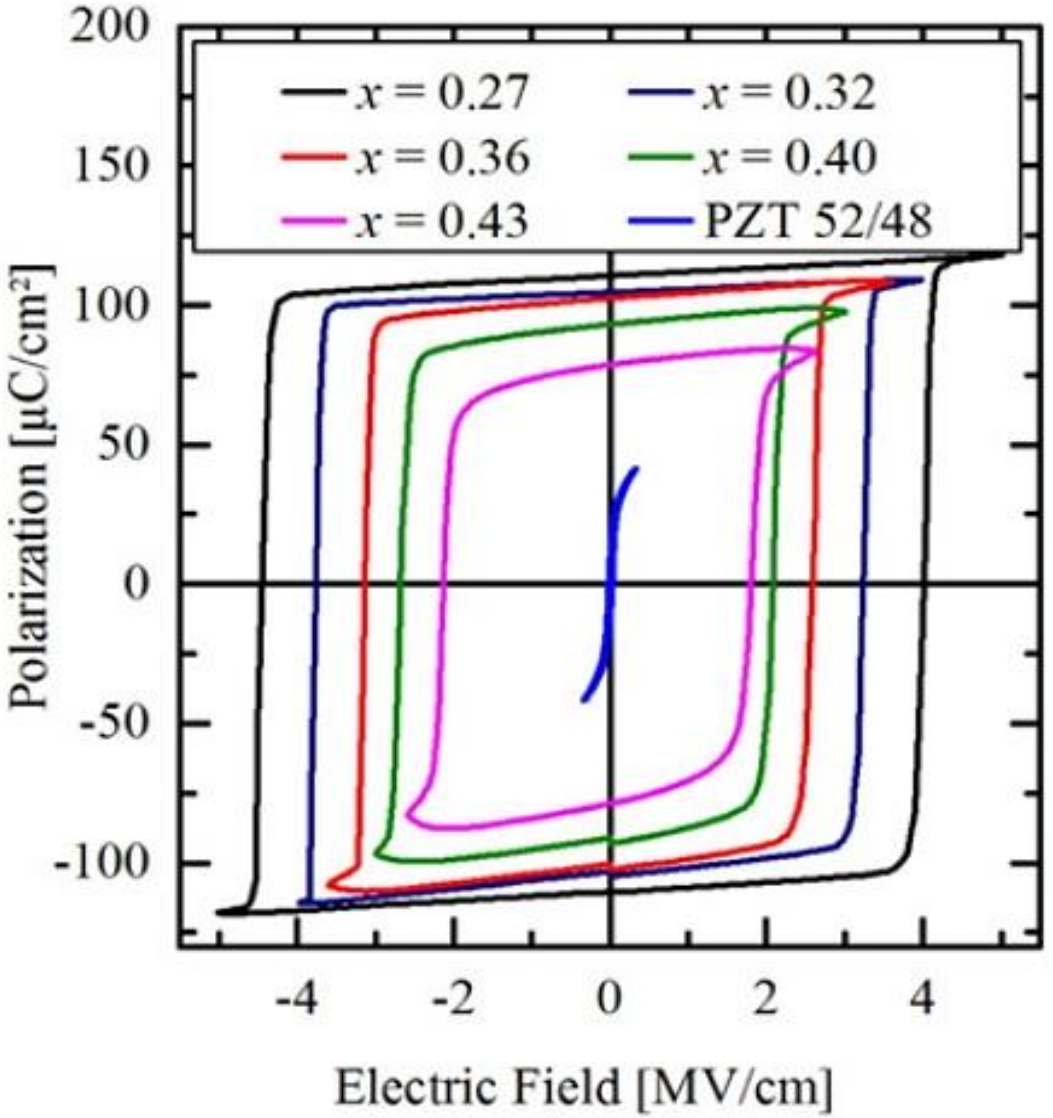


- **Serval iterations with different MEMS designs have been successfully fab-out.**

平台可靠性已经多次流片验证

- ***We are now open for Multi-project-wafer (MPW) run*!**

What's new in the next… (氮化铝平台下接来可能的发展方向)



- **Ferroelectric behavior for highly doped ScAlN (doping>22%)**
- **Even larger polarization capacity (>100 μC/cm2) than PZT material**

Opportunity for a new generation of lead-free piezoelectricity!
新一代无铅压电材料！

Simon Fichtner et. al., *J. Appl. Phys.*, Vol 125, p114103, 2019

Technology incubation model（技术孵化模式）

Model

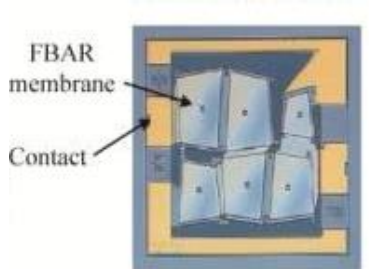
MEMS module

RF MEMS | Acoustic MEMS | Optical MEMS | Flexible Electronics | Other MEMS Devices

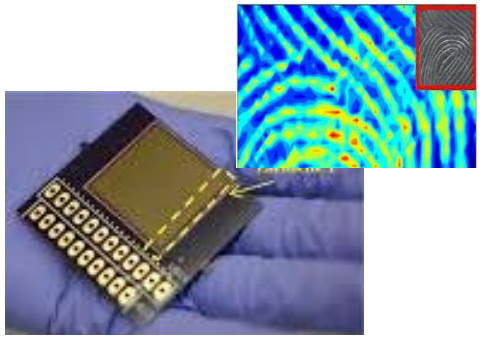
Analog & Mixed Signal IC

Special Processes & Integration

Modules



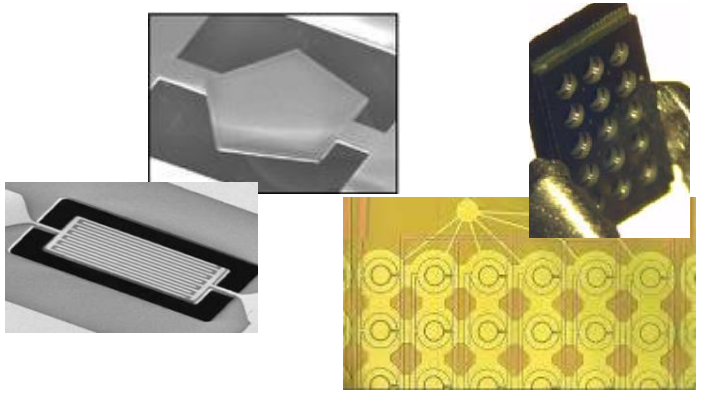
4G/5G RF Filters

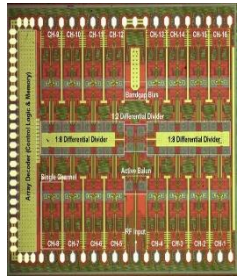


Fingerprint

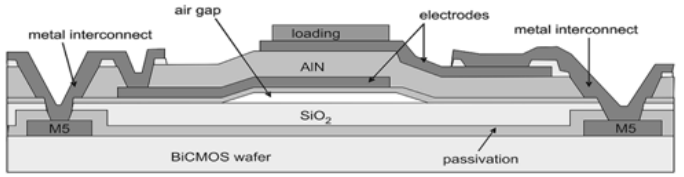
Speakers/uphone

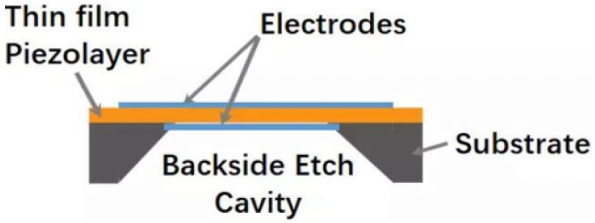
Devices





Process

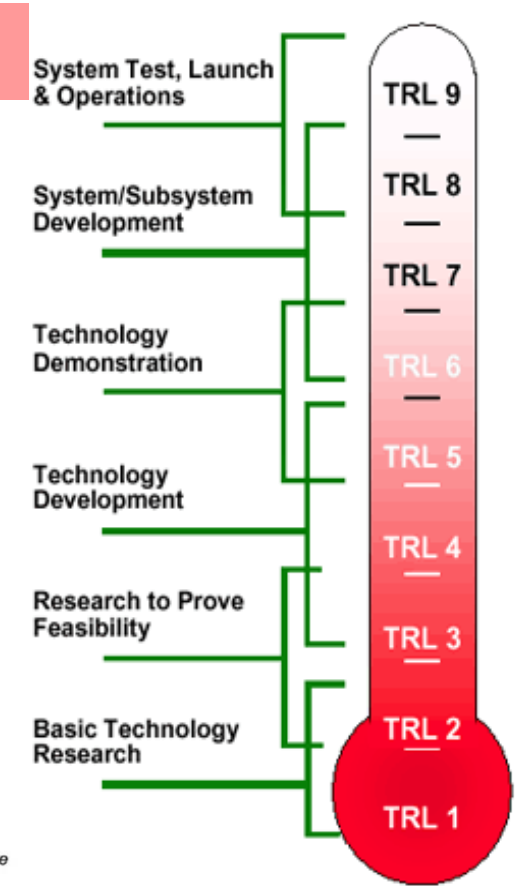




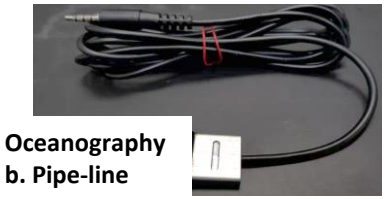
Technology convergence for product / module development!

Roadmap for development of acoustic sensors (声学设计平台发展方向)

TRL (Technology Readiness Level)



1. Hydrophone --TRL 7



a. Oceanography
b. b. Pipe-line

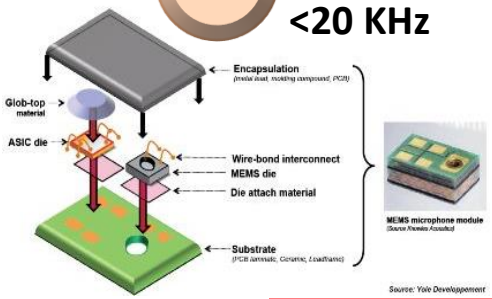
10 Hz – 10 KHz

3. pMUT --TRL 7

< 300 KHz

5. Fingerprint sensor --TRL 6

1 - 50 MHz



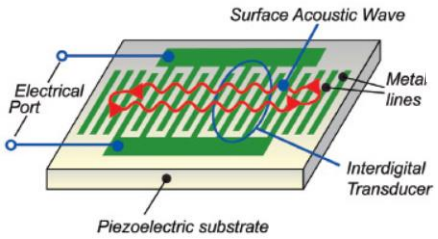
<20 KHz

2. Piezoelectric microphone --TRL 4

200 KHz- 10 MHz

4. Ultrasound flow meter --TRL 6

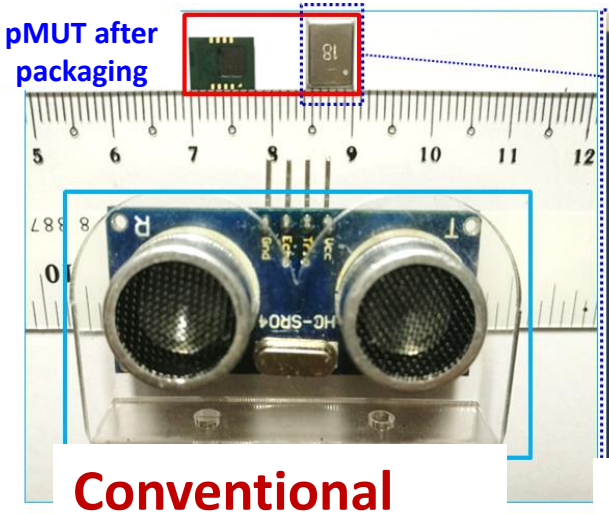
300 - 600MHz



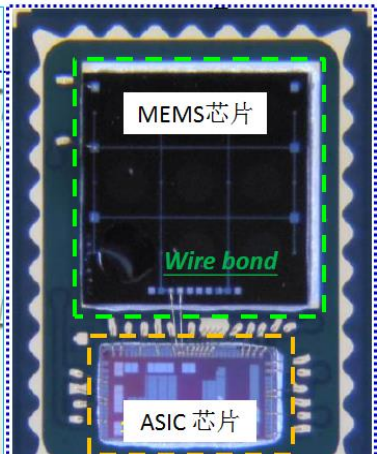
6. SAW temperature sensor --TRL 4

pMUT （微型超声换能器）– TRL 7

			
材料	PZT 陶瓷	PZT 陶瓷	氮化铝薄膜 (MEMS)
尺寸(毫米)	10x10x10	5.2×5.2 (封装后，不含电路)	4×4 (封装前) 4.5x4.5（预计封装后，不含电路）
应用	测距	测距	手势
工作距离 (厘米)	150~200	未知	70
频率(千赫兹)	40	40	105
分辨率（毫米）	10	---	<3
可以波束成形	不可以	不可以	可以
可以进一步微型化	很难	几乎不可以	可以



Conventional Low frequency ultrasonic device



Low frequency MEMS pMUT

Able to be embedded into portable system like ***smartphone, tablet!***

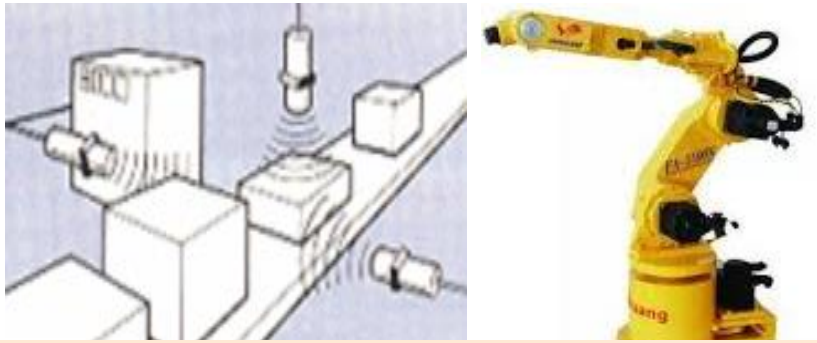
- **System integration has been completed (device + circuit + algorithm + prototype packaging)**

测距系统集成现已完成，正在和客户密切接触，准确定义产品推向市场

- **Customer engagement for product optimization & customization**

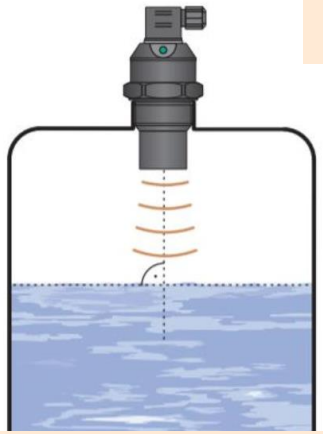
pMUT: Application scenarios and advantages
(微型超声换能器的可能应用场景和优势)

Consumer electronics



Industrial applications

Smart home & infotainment



Water-level

Automotive industry

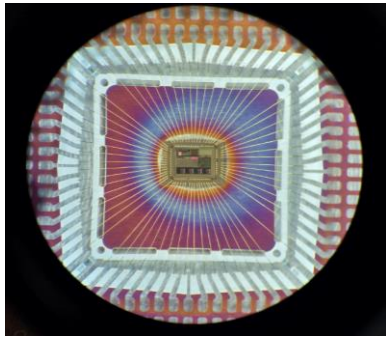
Insensitive to material properties
对反射材料(如玻璃)要求低

Small footprint for system integration
小型化便于和大系统集成

Low power + low development cost
低功耗、低开发成本

Progress updates and demonstration
（应用场景演示）

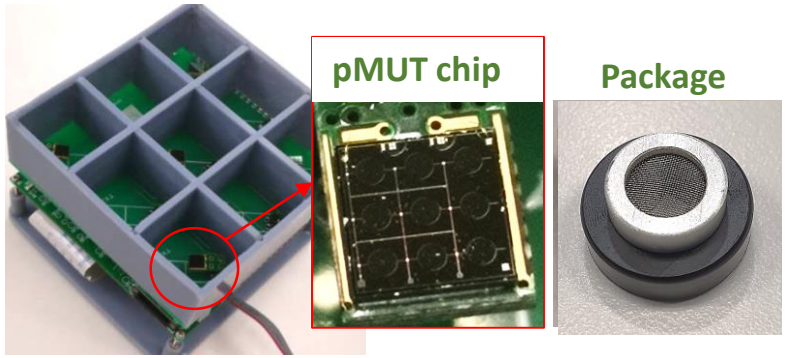
Interface IC for ultrasound ranging
超声器件接口电路

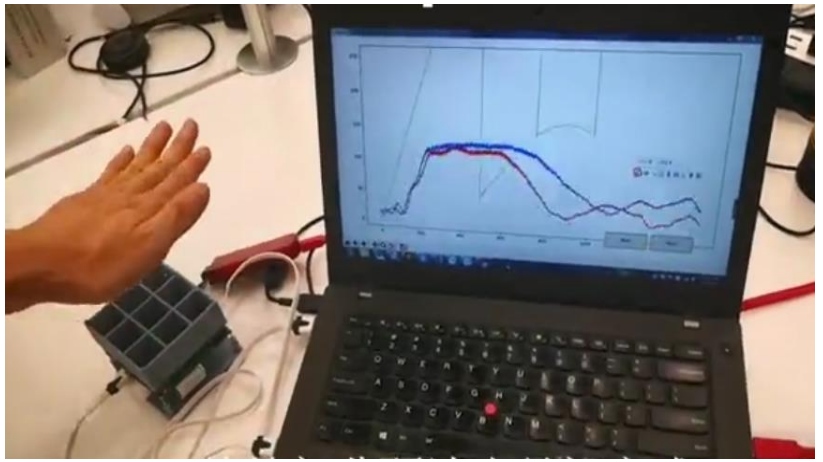


Analog + ADC

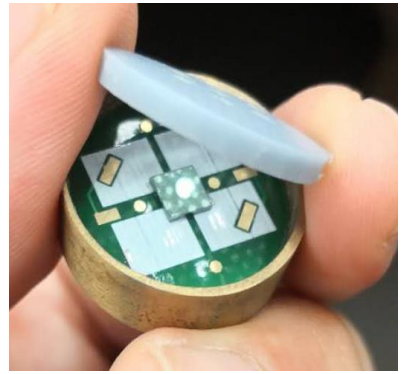
After AFE packaging

Gesture recognition algorithm
手势算法开发



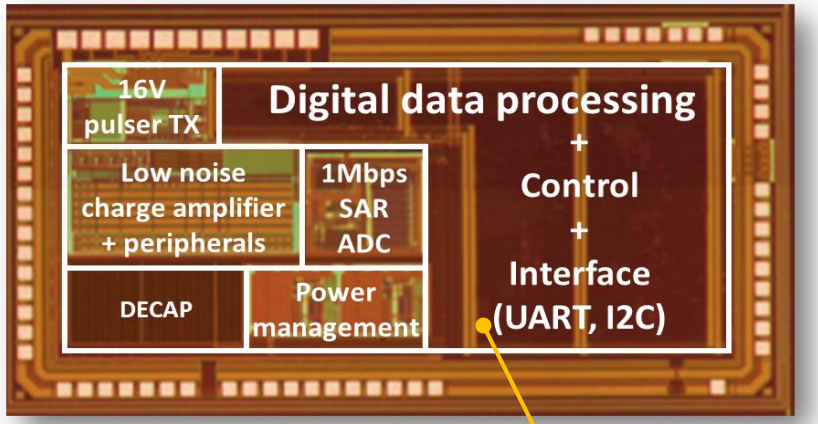


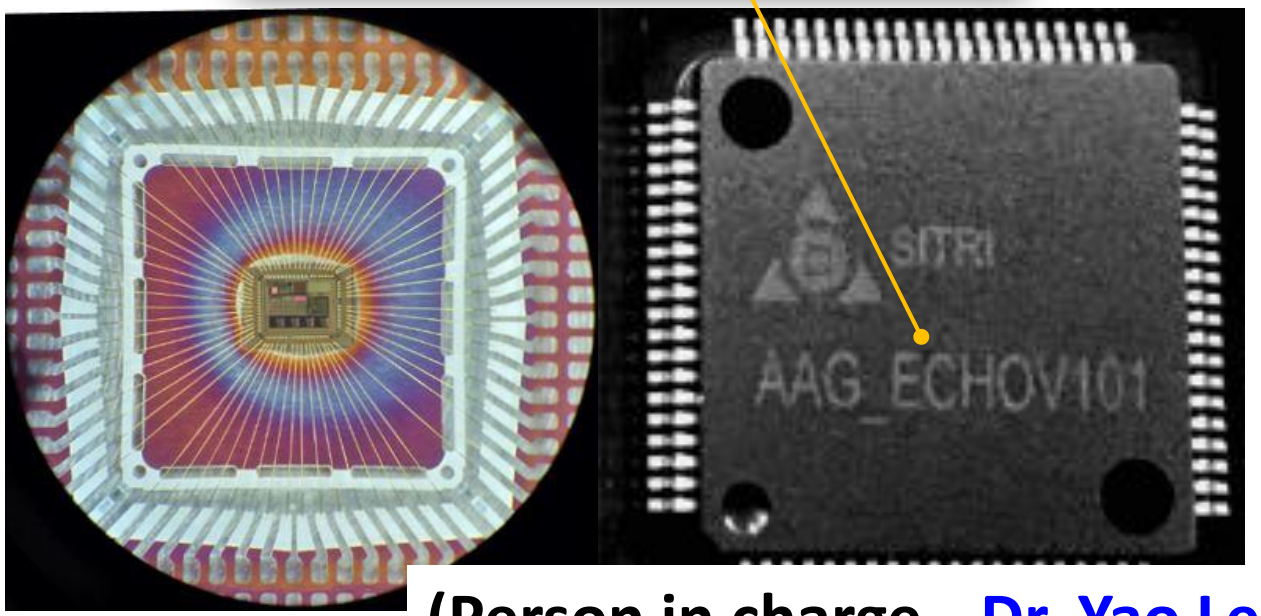
Simulated testing environment
模拟测试环境搭建



SITRI

Circuit platform – Device interface design (集成电路设计平台)





pMUT interface ASIC（*ECHO1*）：

2.7mm x 1.9mm, SMIC018 GE process
Ultra low power 16V 100kHz TX
Low power RX with 15nV/√Hz @ 100k Hz
Flexible TRX configuration (TX/RX/TRX mode)
Standard UART/I2C interface
On chip data processing
On chip 1.5mV/K temperature sensor

Capability of circuit platform：

- 中低频段低噪声放大器
- 高压（>20V）传感器驱动电路
- 高精度低功耗ADC/DAC
- 高速低抖动PLL
- 电源管理电路LDO、DC/DC、AC/DC
- 时钟发生电路RC/Ring/Crystal OSC
- 周边电路Bandgap、POR、temperature sensor等

(Person in charge --Dr. Yao Lei; Lei.Yao@sitrigroup.com)

SITRI

8 inch AlN process integration platform
(8 寸氮化铝中试线的工艺模块、集成平台)

SN		Name of the Key Processes (Tool)
1	Available Processes	Mo/AlN/Mo deposition (SPTS)
2		Mo/AlN/Mo etching process (SPTS)
3		Dielectric deposition: oxide, nitride, SiON (AMAT CENTURA)
4		Metal deposition: Au, Pt, AlCu (AMAT ENDURA)
5		Litho (Nikon i-line Stepper and Suss g-line Aligner)
6		Wafer Bonding (Suss)
7		Thin films (TEL ALPHA)
A	*Process development in progress*	*Film thickness trimming (SCIA or TEL)*
B		*Sacrificial layer release (SPTS)*
C		*Sacrificial layer CMP (AMAT or Ebara)*
D		*Wafer Thinning (Disco or Okamoto)*

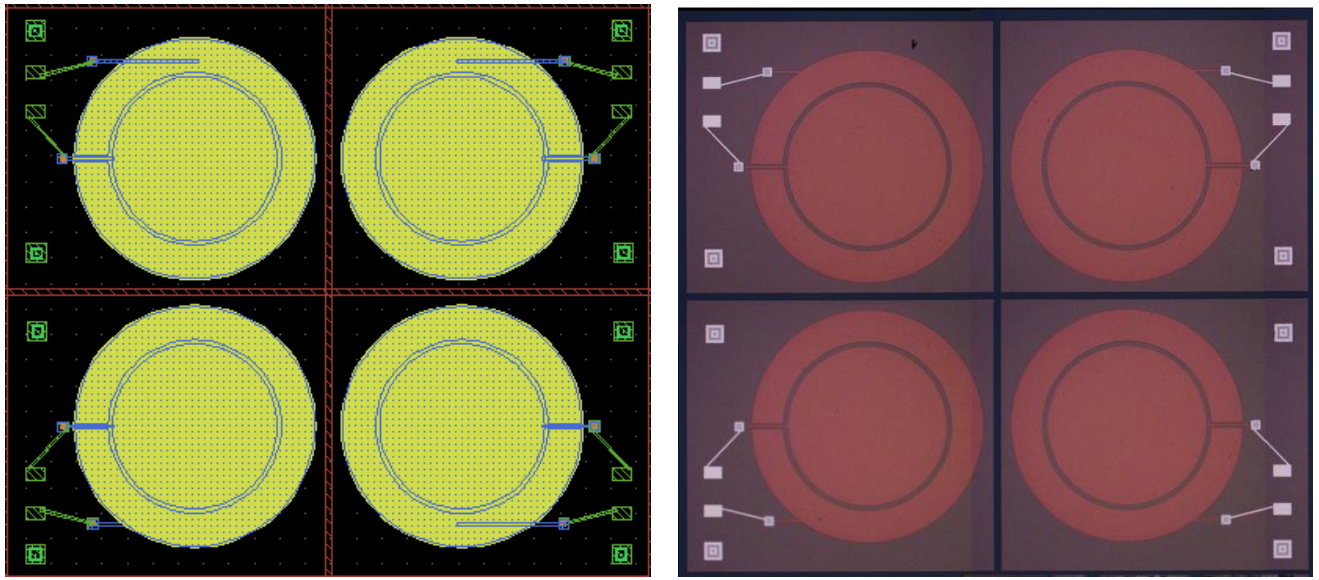
(Person in charge--Dr. Lin Huamao; *Huamao.Lin@sitrigroup.com*)

C-SOI MPW （基于Cavity SOI多项目晶圆平台）

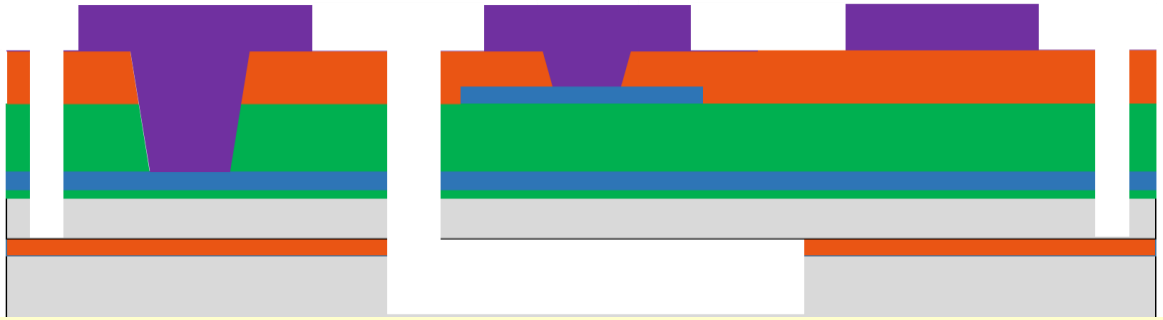
- Devices design successfully fab-out:

SAW device； pMUT device

- Both film stress and piezoelectric performance have been verified
- Overall process flow has been re-fined to minimize the lead-time。



PMUT fabricated on C-SOI substrates



Call for C-SOI AlN MPW run (Dec. 2019) !

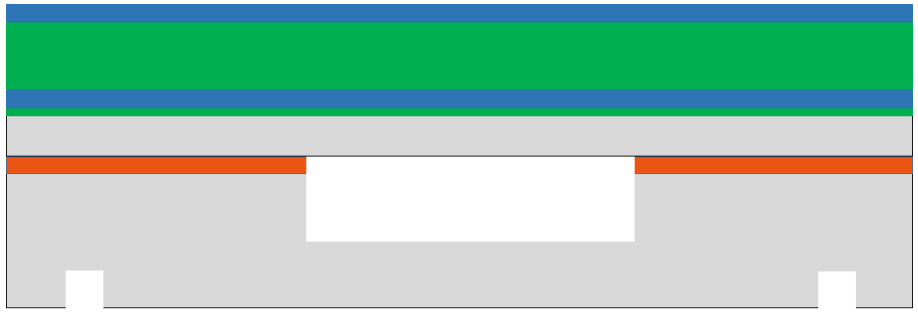
多项目晶圆平台计划于2019年底开放!

Pls contact Dr. Lin for details

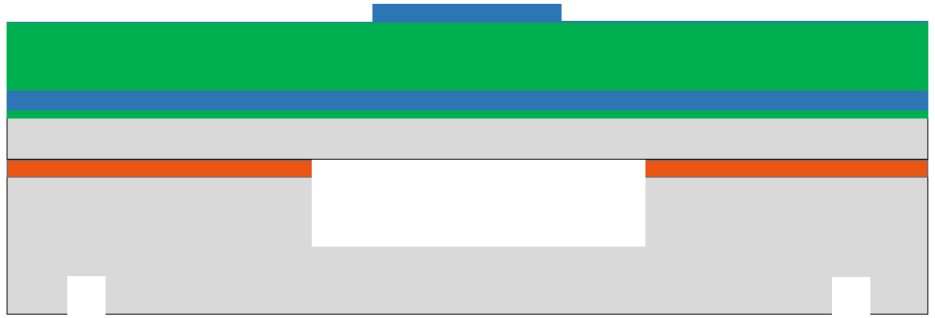
MPW process flow

Mask- 1 (BSA) & 2

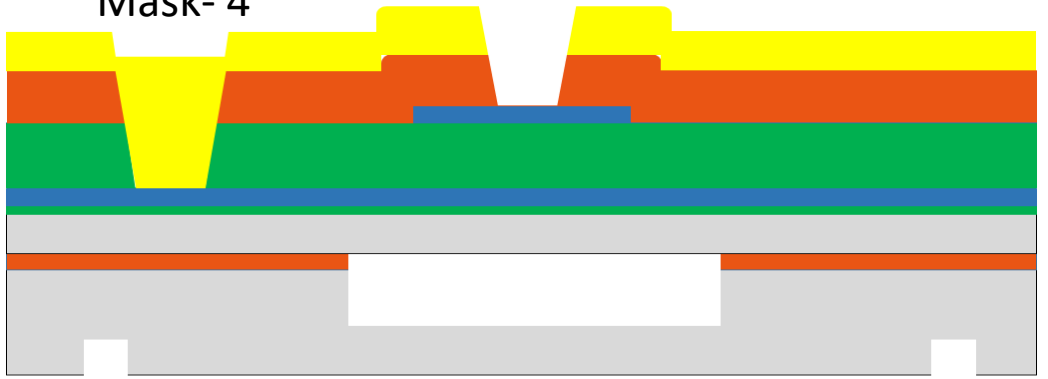
CSOI bonding
+ Piezo stacks



Mask - 3

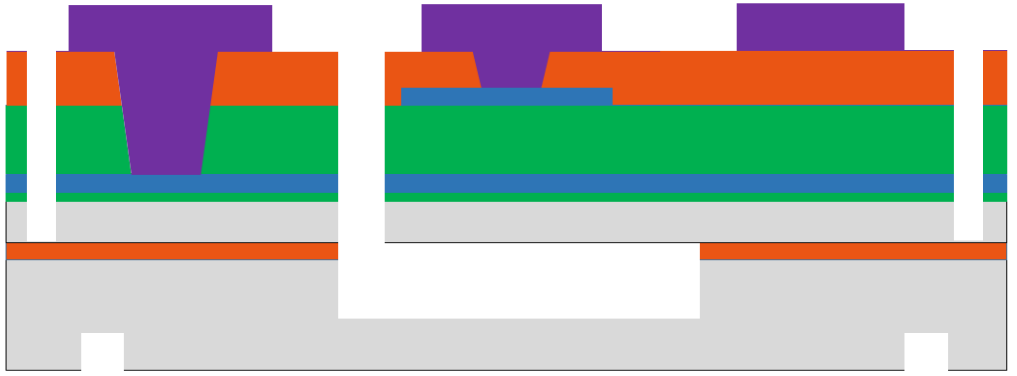


Mask- 4



Mask- 5

Mask- 6



Si SiO2 PR Mo AlN Al

Conclusions （小结）

- **Well-established 8-inch AlN MEMS line open for collaboration (*MPW in Dec 2019*)**
- **Model of technology incubation based on interactive technology platforms**
- **Technology supports & platform service from SITRI**

OPEN R&D platforms

（开放的研发平台）

Technology support at different level

（提供多方位的技术支持）

SITRI

THANKYOU

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SITRI

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