나노팹 공정 및 테스트베드

- ▣ 나노종합기술원 소개
- ▣ 나노팹 공정 플랫폼
- ▣ 반도체 소부장 테스트베드

양 준 모
나노종합기술원



나노종합기술원(NNFC) 소개

Nanoinfrastructure of Korea

❍ Nanoinfrastructures of Korea were established in provincial cities with a specialized technology.



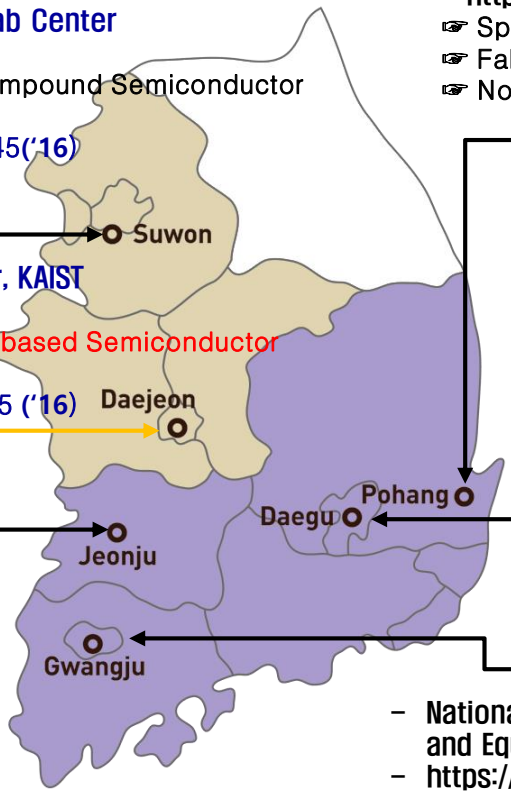
- Korea Advanced Nanofab Center
- http://www.kanc.re.kr
☞ Specialized Tech. : Compound Semiconductor
☞ Fab Size : 3,450m²
☞ No. of Services : 14,145('16)



- National Nanofab Center, KAIST
- http://www.nnfc.re.kr
☞ Specialized Tech. : Si-based Semiconductor
☞ Fab Size : 5,068m²
☞ No. of Services : 19,615 ('16)



- Korea Printed Electronics Center, KETI
- http://www.printedelectronicskorea.org
☞ Specialized Tech. : Printed Electronics
☞ Fab Size : 2,346m²
☞ No. of Services : 5,139('16)



- National Institute for Nanomaterials Technology, Postech
- http://www.nano.or.kr
☞ Specialized Tech. : Power Device
☞ Fab Size : 3,110m²
☞ No. of Services : 11,107('16)



- Nano Convergence Practical Application Center
- http://www.npac.or.kr
☞ Specialized Tech. : Nano Materials
☞ Fab & Open Lab Size : 2,125m²
☞ No. of Services : 1,962('16)



- National Center for Nanoprocess and Equipments, KITECH
- https://ncne.kitech.re.kr
☞ Specialized tech. : Optical device
☞ Fab & open lab size : 1,426m²
☞ No. of Services : 4,540('16)



나노종합기술원(National Nanofab Center) 소개

설립 근거 및 기능

[설립근거] 나노기술개발촉진법 제11조(연구시설 등의 확충)

[주요기능] ① 나노시설·장비의 산학연 공동활용 촉진
② 첨단시설 및 장비를 활용한 전문인력 양성
③ 연구성과의 실용화 및 중소・벤처기업지원





주요 연혁

2002.7	2004.5	2014.1	2019.12
나노종합팹센터 유치	KAIST 부설기관화	과기정통부 직할 출연기관 편입	N-Facility 지정 (반도체 소부장 국가연구시설)

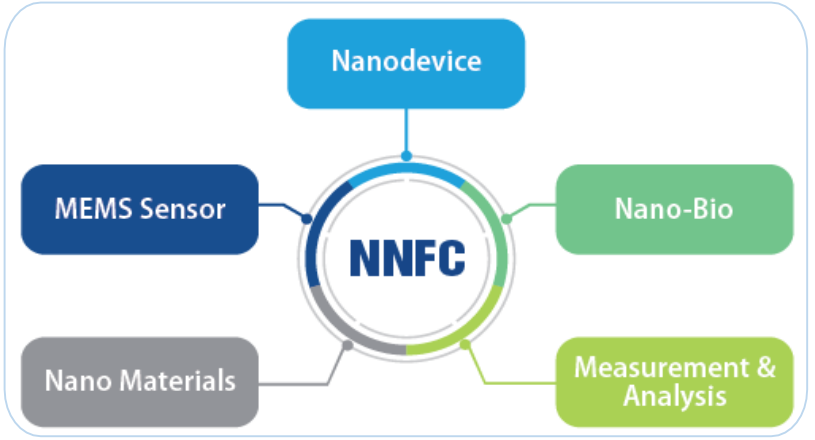


연구장비・시설

[장비] CMOS, MEMS, 바이오, 소재, 측정분석 등 (3,000억원)

[시설] 클린룸(1,530평), 연구동(5,045평) 등 8,000평

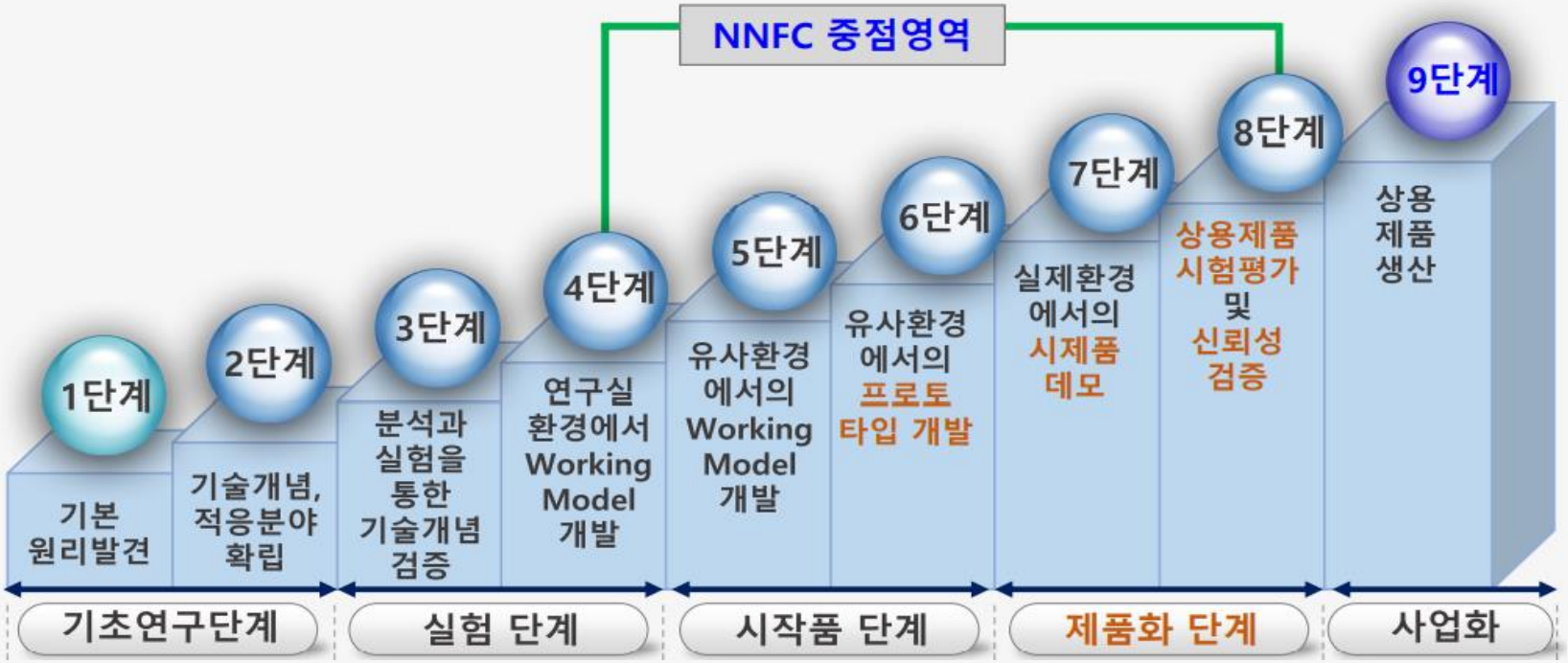




나노종합기술원 기관 역할의 차별성

1) 기초・원천연구를 수행하는 연구목적 기관과 달리 **기업현장의 기술적 애로를 중점지원**하고 서비스 고도화를 위한 연구개발을 보완적 수행

2) 기술 성숙도가 일정수준(TRL : 4 – 8 단계)에 도달한 기업현장의 기술애로(Technology Bottle-neck)를 나노인프라 및 공정기술을 접목하여 **양산 직전의 수준까지 완성도**를 획기적으로 높이는 역할 수행



나노팹 공정 플랫폼

- ❖ CMOS Process Platform
- ❖ MEMS Process Platform
- ❖ Nano-Bio Technology
- ❖ Nanoanalysis Technology

나노팹 공정 플랫폼

❖ CMOS Nanodevice Platform

- 180 nm Standard Process
- Monolithic 3D Integration Process, Neuromorphic Device

❖ MEMS Platform

- Thin MEMS & Thick MEMS Process
- Flexible Hybrid Nanostructure & Process & Device & System
- MEMS-based Photonic/Electronic Convergence Device/Process

❖ Nano-Bio Chip Design & Fabrication & Characterization

❖ Nanomaterial Synthesis & Characterization

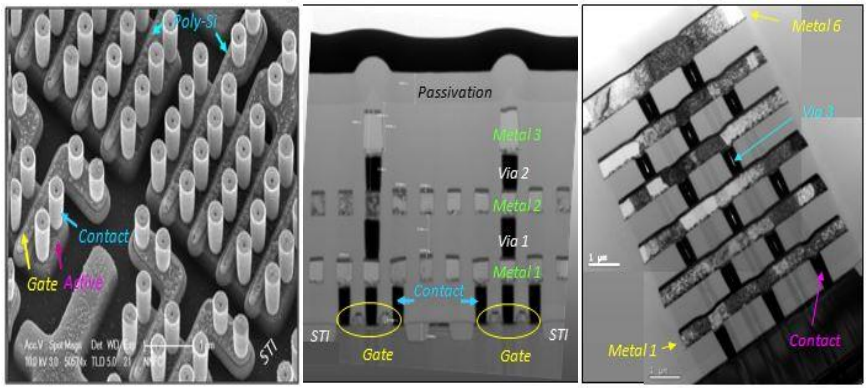
❖ Measurement & Analysis

나노팹 공정 플랫폼

CMOS Process Platform

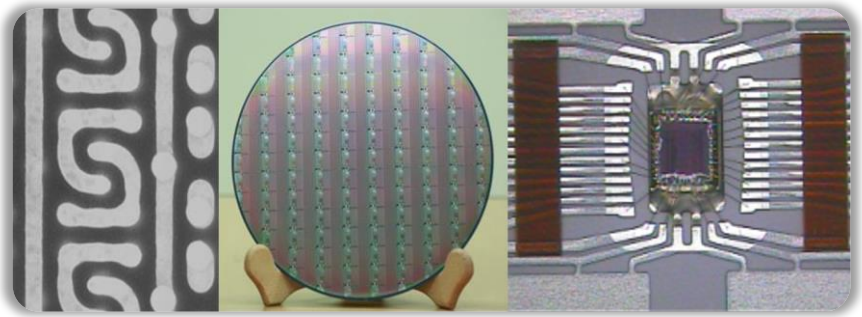
CMOS 플랫폼

180 nm Mixed Signal CMOS Platform

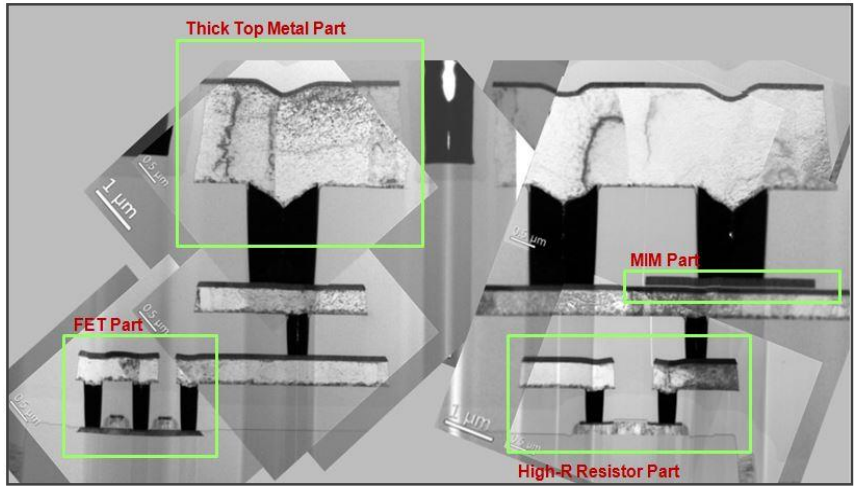


- 180 nm Standard Logic Process
- 1 Poly 6 Metal Structure, TFR, DNW, MIM 제공
- VDD (Core/IO) : 1.8 V/3.3 V

* Verification Device : 256 K SRAM

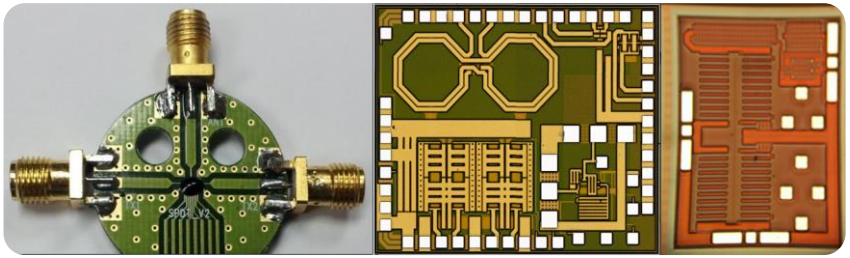


180 nm RF SOI CMOS Platform



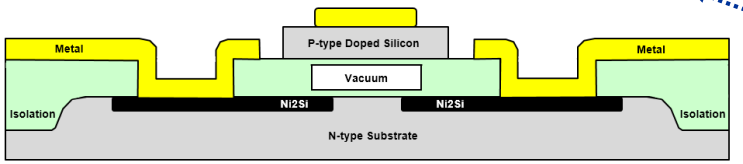
- 180 nm RF SOI Process
- 1 Poly 3 Metal Structure, HR-R, MIM, TKM 제공
- VDD : 2.5 V
- M社 기술이전

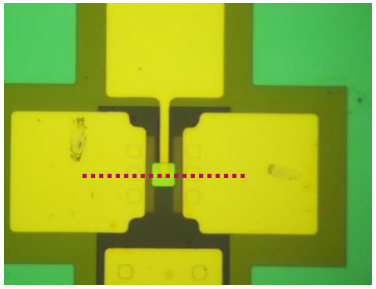
* Verification Device : RF SPDT Antenna Switch



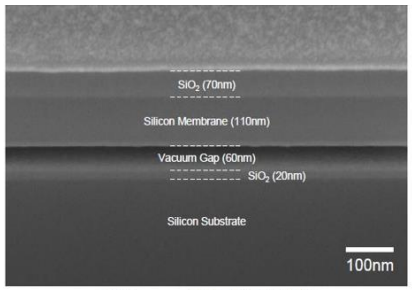
Monolithic 3D 플랫폼

[상부소자] **Membrane Gate FET**

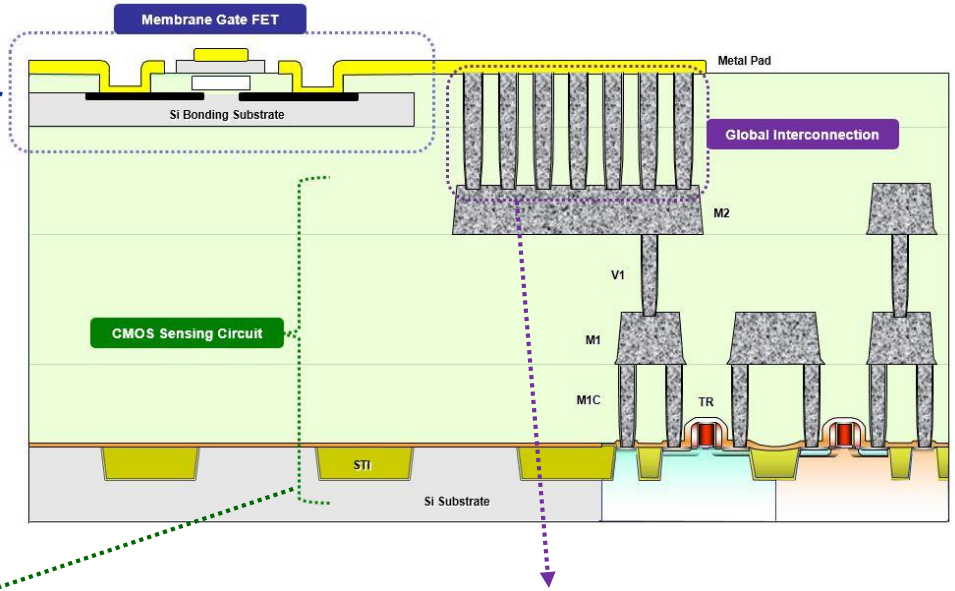




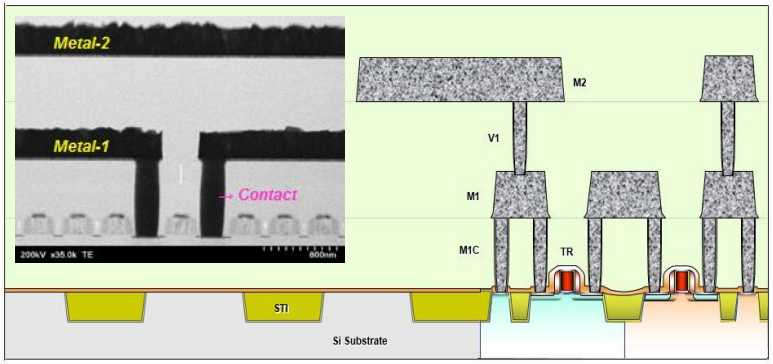
MG-FET 평면 OM 이미지

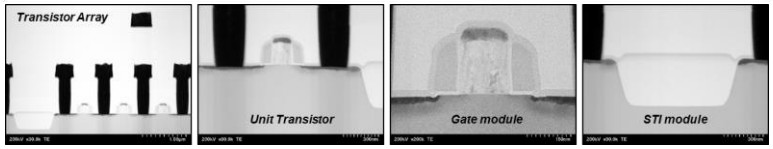


MG-FET 단면 SEM 이미지

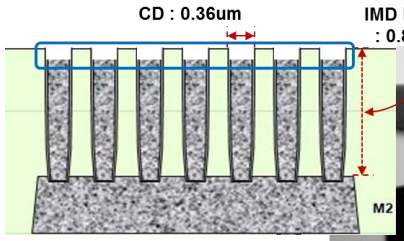


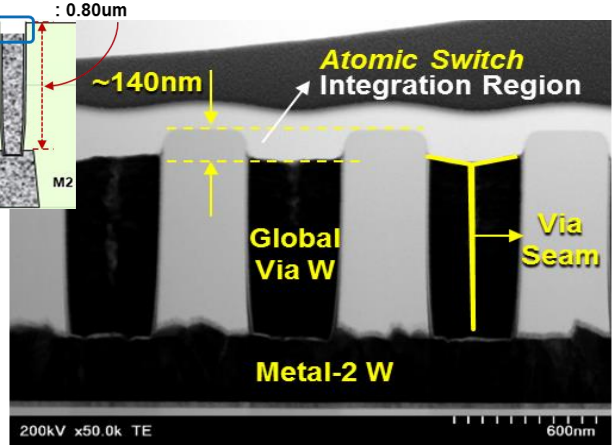
[하부소자] **CMOS Sensing Circuit** 기술





[응용소자] **Global Interconnection & Atomic Switch** 기술

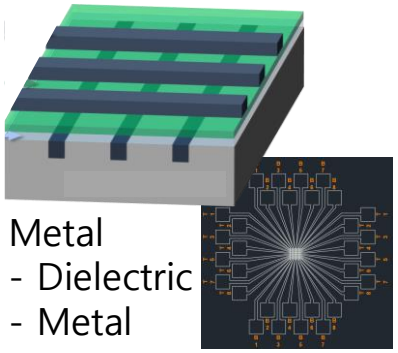




(차세대) 뉴로모픽 디바이스 공정

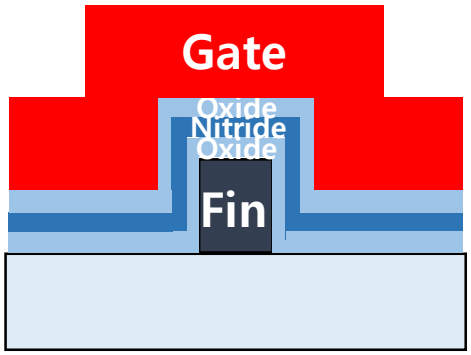
❍ 뉴로모픽 디바이스 공정

2-terminal Synaptic Devices



- Filament-type ReRAM device
- Crossbar array 구조
- ~500nm CD
- 주요 공정장비 : Reactive/RF sputtering

3-terminal Synaptic Devices



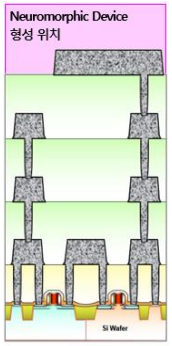
- Charge-trapped device (SONOS형)
- Sub-100nm FIN
- Poly-gate
- 주요공정장비 : ArF scanner, LPCVD

❍ 뉴로모픽 디바이스 기술개발 방향

기반기술 구축

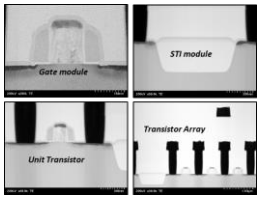
과학기술정보통신부

미래반도체 신소자원천기술개발사업



→ 인공시냅스용 플랫폼 기술 구축

기존 기술 최적화



→ 8인치 기반 180nm CMOS 소자 제작 기술 활용한 인공뉴런용 플랫폼 기술 구축

구축 기술 서비스

인공시냅스/뉴런 플랫폼 기술 산/학/연 공공서비스

나노팹 공정 플랫폼

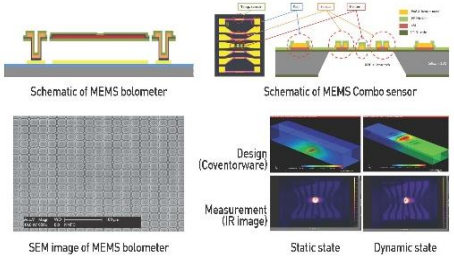
MEMS Process Platform

MEMS 플랫폼

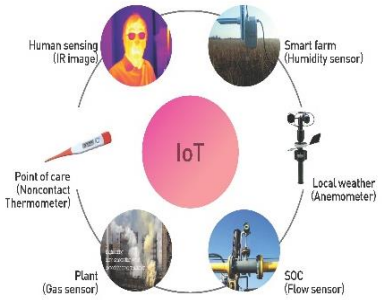
Thin MEMS Platform

Thin MEMS Platform using

– Sacrificial layer process and thin MEMS membrane



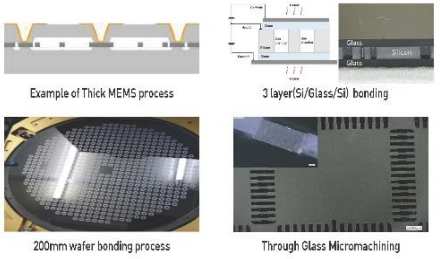
Application



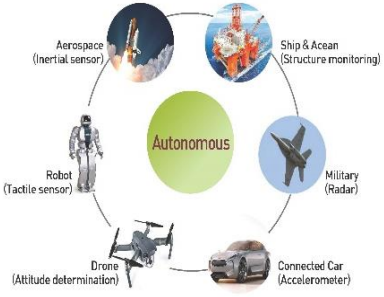
Thick MEMS Platform

Thick MEMS Platform using

– Substrate etching (Si, Glass) and W2W bonding (Eutectic and Anodic bonding)



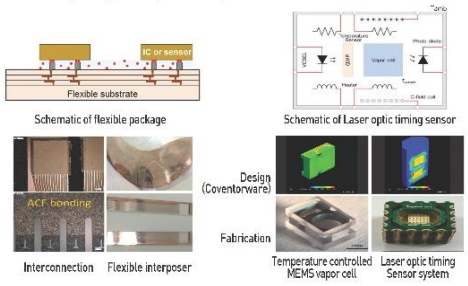
Application



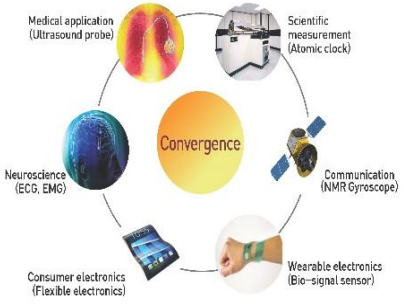
Hybrid Integration

Device and System Package using

– Flexible package and system integration



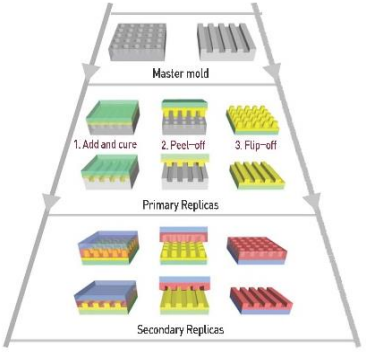
Application



Nanostructure

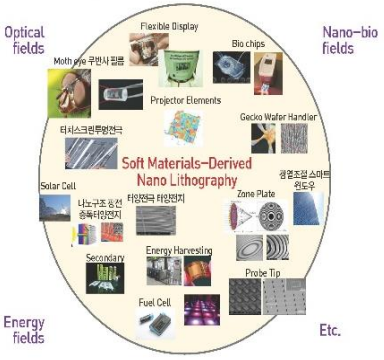
Reversible Replica Molding (RREM)

– Si master mold & polymer replicas



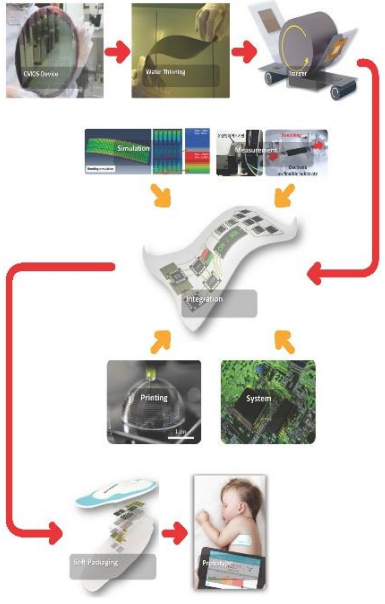
Applicable Industries

– Reversible replication technology



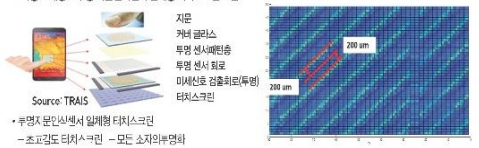
Beyond Silicon

Flexible Hybrid Electronics

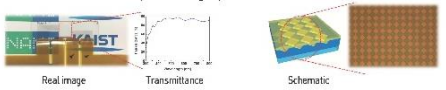


Passive Matrix Transparent Capacitive Fingerprint Sensor

Concept of ultra-thin & high-resolution transparent fingerprint sensor for integration with touchscreen module

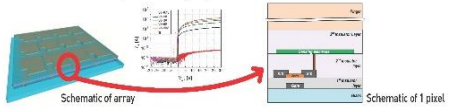


Demonstration of transparent fingerprint sensor

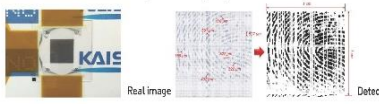


Active Matrix Self-type Capacitive Fingerprint Sensor

Oxide TFT-based capacitive fingerprint sensor

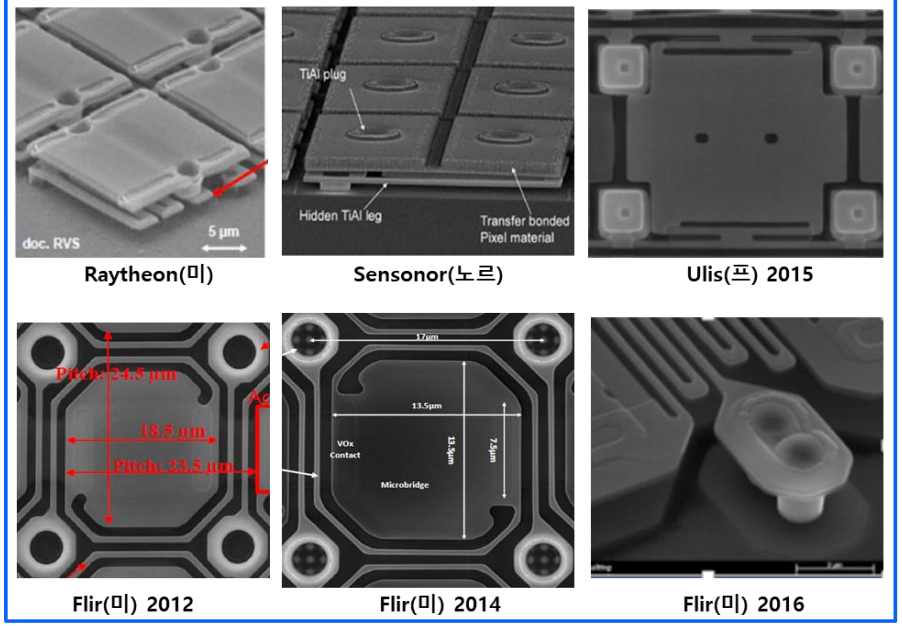


Demonstration of transparent fingerprint sensor



비냉각 적외선 열영상 센서 공정

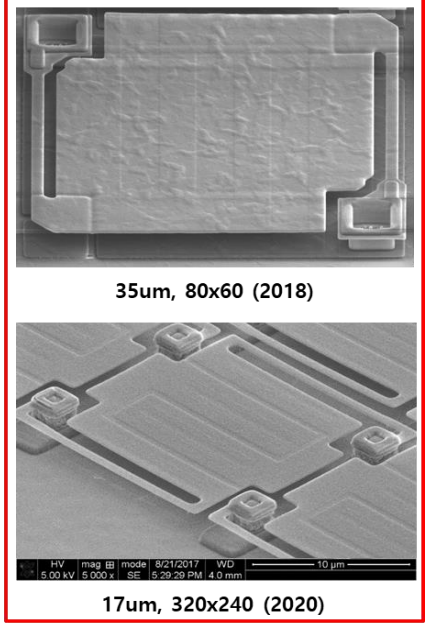
Mircrobolometer Platform



Raytheon(미) Sensonor(노르) Ulis(프) 2015

Flir(미) 2012 Flir(미) 2014 Flir(미) 2016

MOx/폴리머 희생층/세라믹패키징



35um, 80x60 (2018)

17um, 320x240 (2020)

a-Si/CMOS공정/WLP

➢ 소재 & 공정 혁신

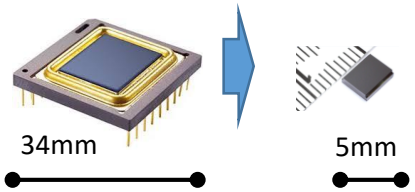
① CMOS 반도체 호환공정

② 감지물질 : 비정질 실리콘

- 미국 Honeywell 특허 회피
- 세계 3번째, 국내 최초

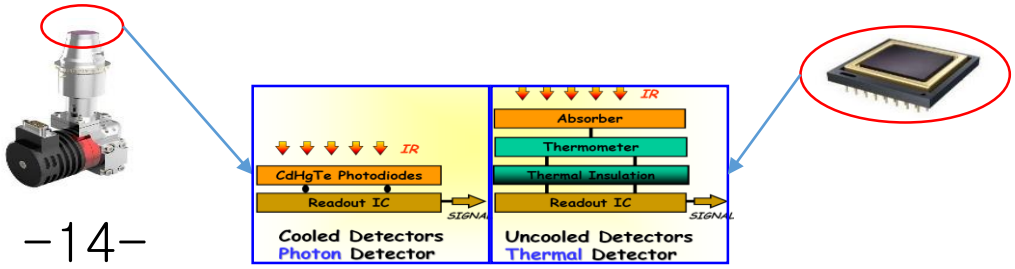
③ 웨이퍼레벨 패키징

- 세라믹 패키징 대비 1/6

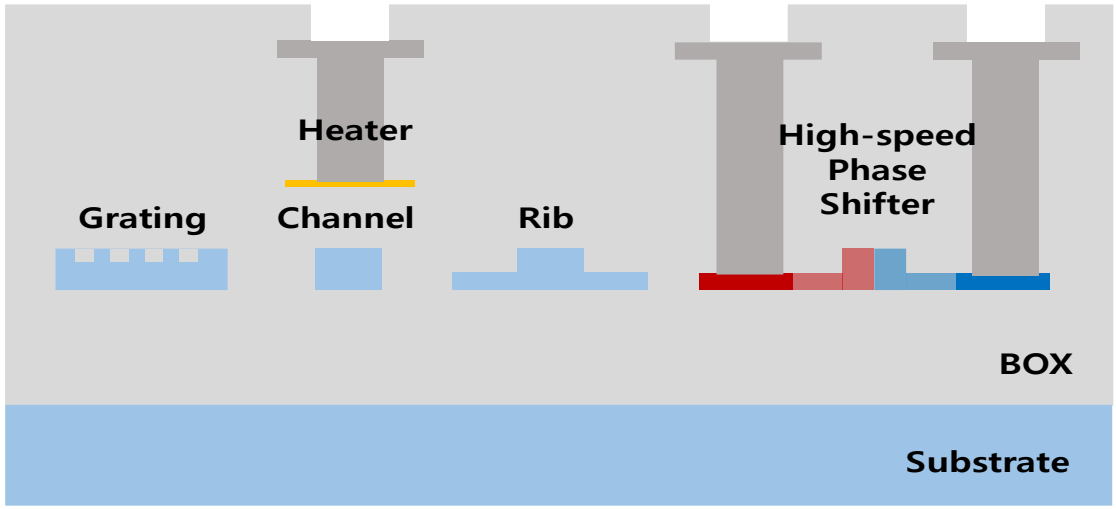


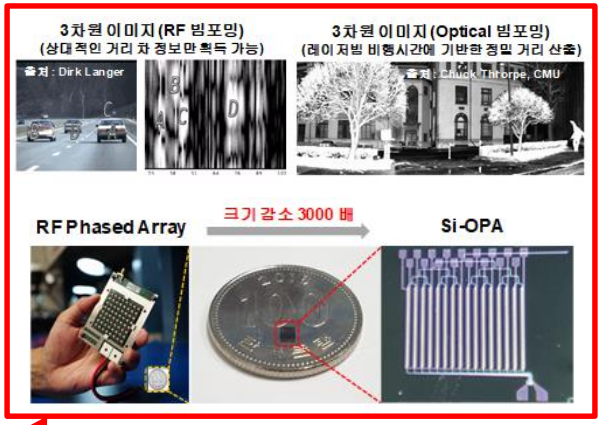
- ❖ 저화소(35um, 80x60 array)
- ❖ 중화소(17um, 320x240 array) 개발 (2021)

냉각형 >> 비냉각형(크기, 가격)

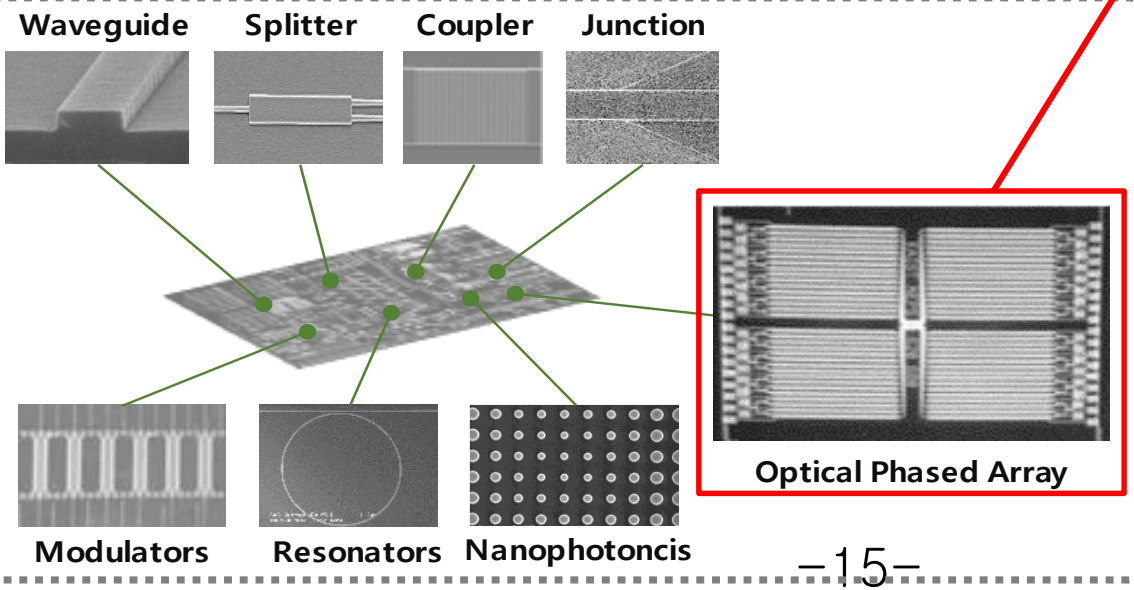


Si Photonics 소자 공정



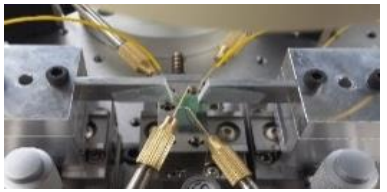


다양한 Si Phtonics 광소자/광집적회로 개발



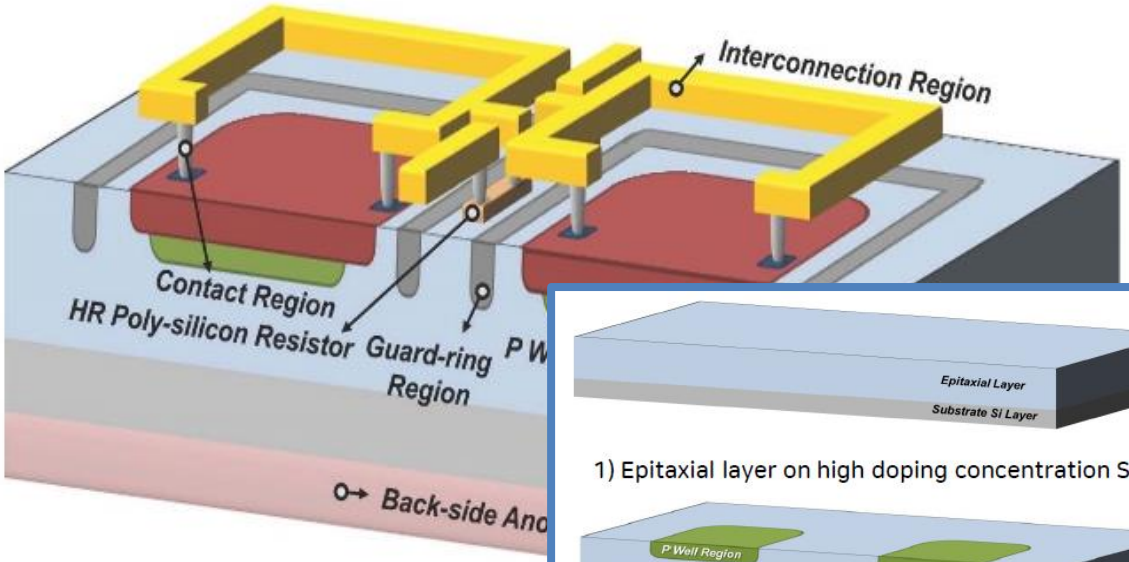
성능 시험평가 플랫폼

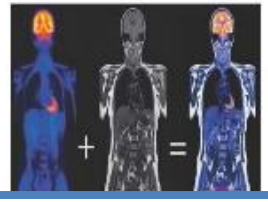




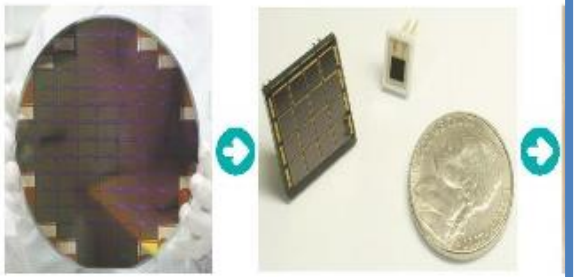
SiPM 소자 공정

SiPM(Silicon Photomultiplier, 실리콘 광증배센서) 소자 기술

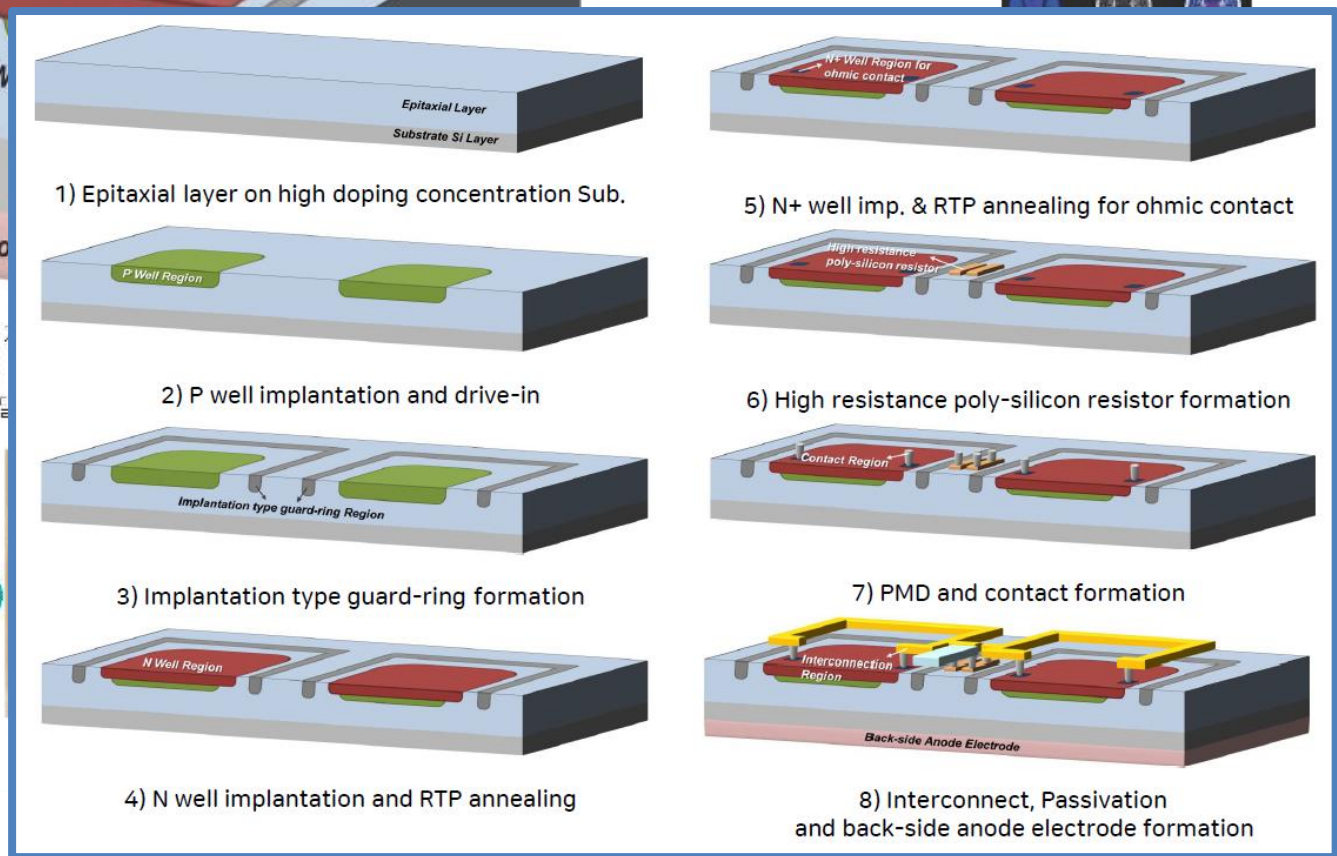




- 소자 내부에서 100만배까지 신호 증폭 → 단일광자 측정이
- 국내 최초 차세대 융합 의료영상기기 PET-MRI 공동 개발
  임 종양 및 알츠하이머 치매, 파킨슨병 등 다양한 질환의 정밀



PET-MRI용 SiPM 저소



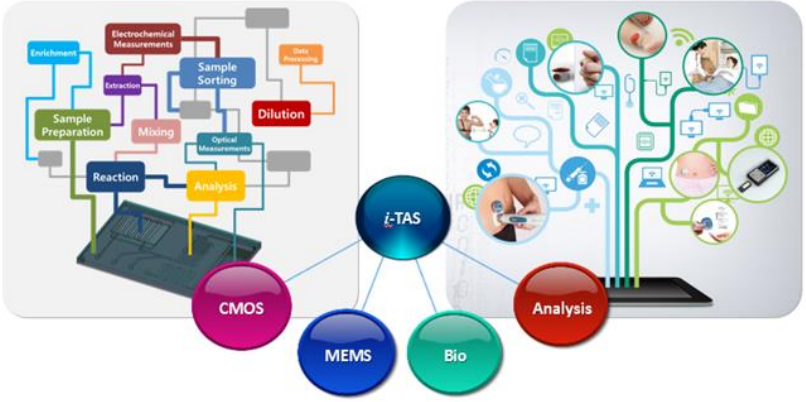
나노팹 공정 플랫폼

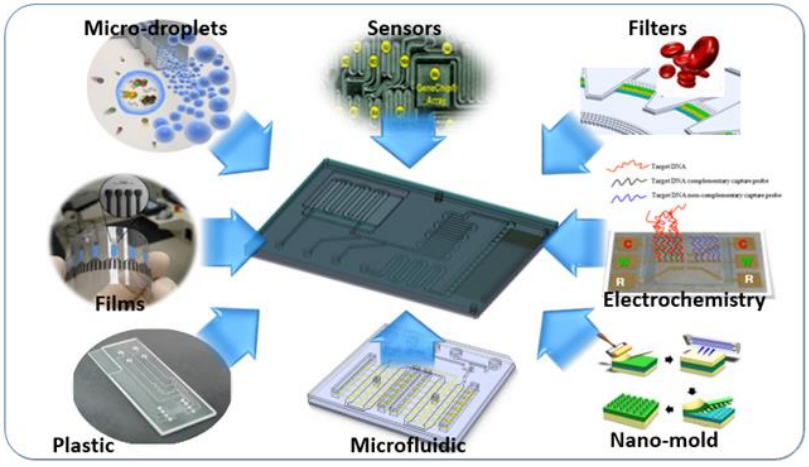
Nano-Bio Technology

나노바이오 플랫폼

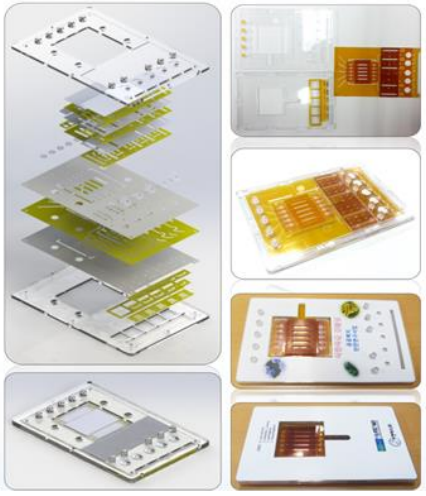
i-TAS Platform

Integrative Total Analysis System (i-TAS) **is a device that integrates one or several laboratory functions on a single chip of only millimeters to a few square centimeters in size.**



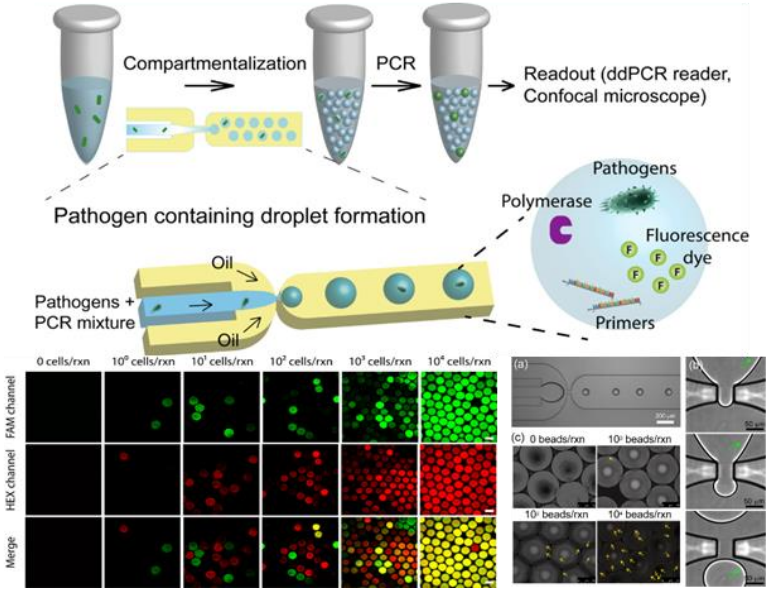


Bio chip and System Platform for Diagnosis

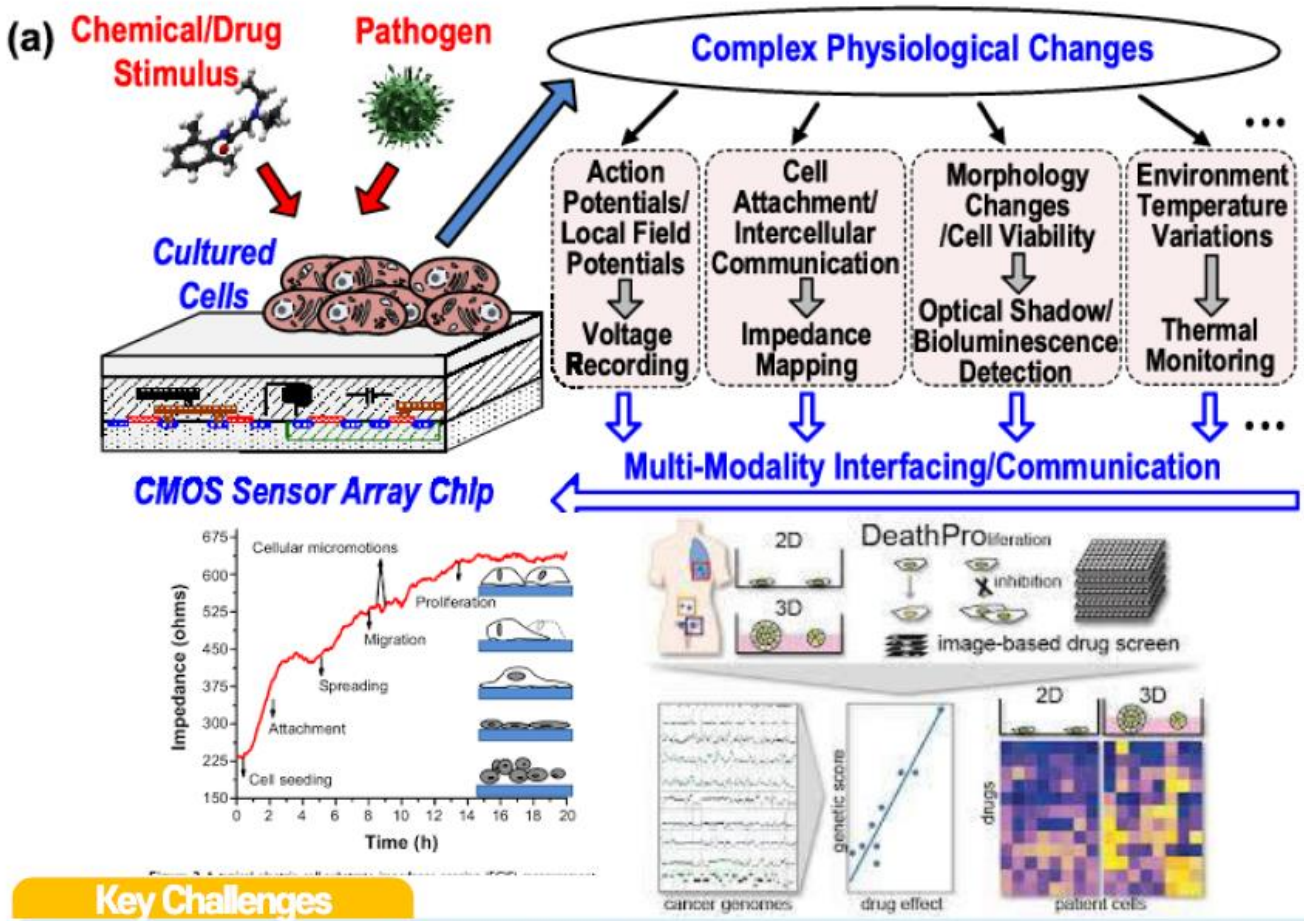


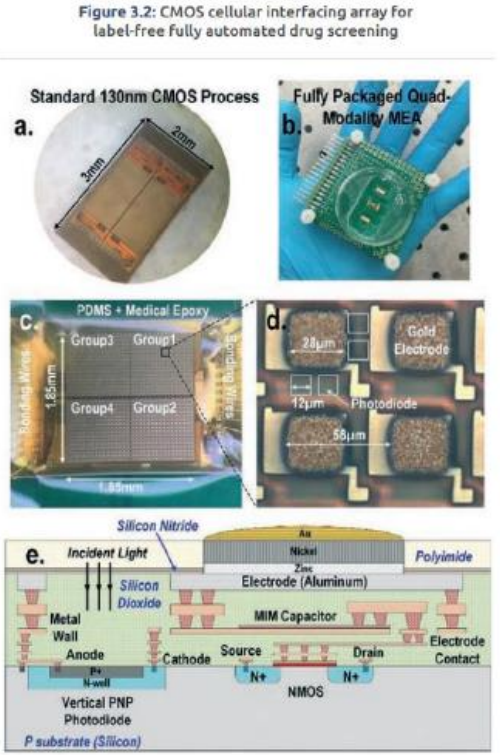


Droplet digital PCR Platform



(차세대) 반도체 공정기반 나노메디컬 디바이스





Key Challenges

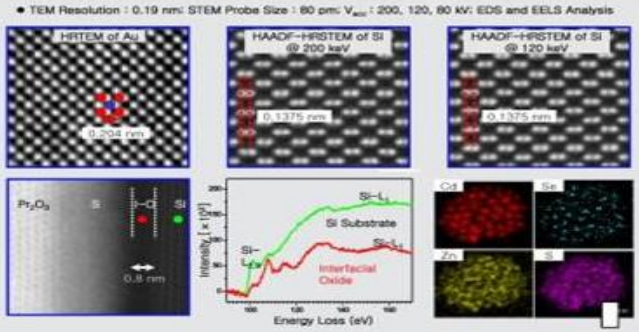
Scalability issues : SNR trade-off for electrical modalities, yield and packaging, etc.
Maintaining long-term cell viability on semiconductor substrate
Energy issues : Ultra-low-power circuit interface to in vitro or in vivo cell sensors

나노팹 공정 플랫폼

Nanoanalysis Technology

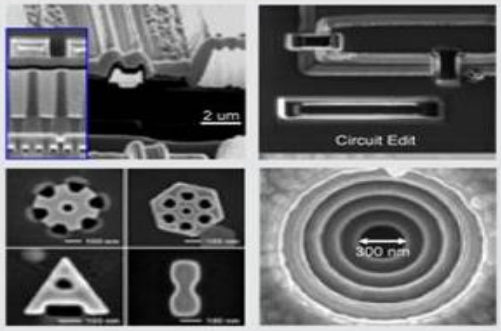
나노분석 기술

Structure Analysis Technology

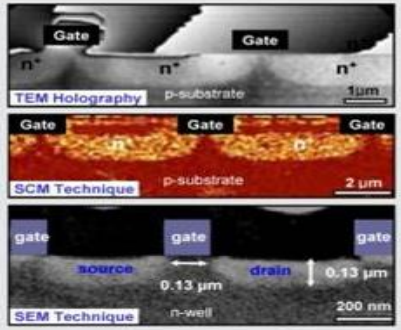


Atomic Scale Analysis :
HRSTEM-EELS spectrum

EDS Map of QDs
(CdSe/ZnS)

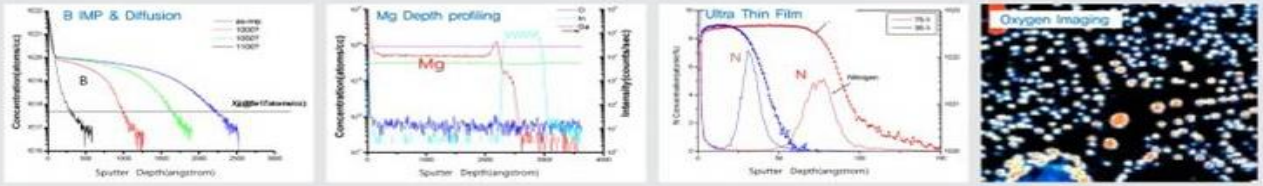


Dual-beam FIB Techniques

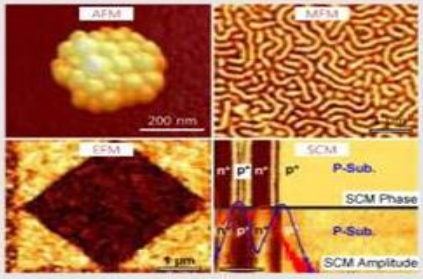


2D Dopant Profiling Techniques

Surface Analysis Technology

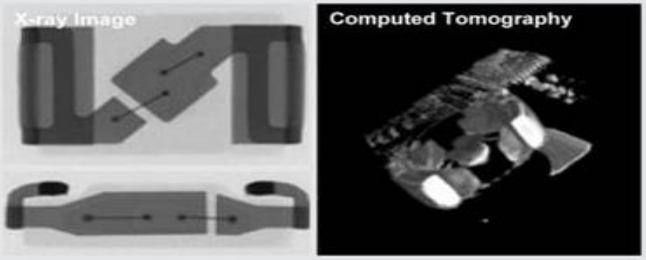


M-SIMS Techniques

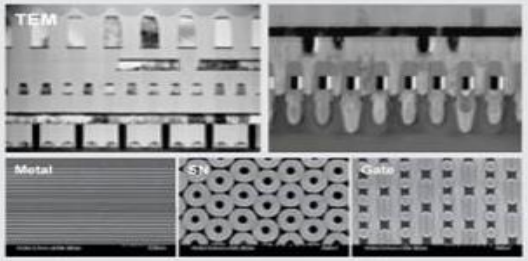


SPM Techniques

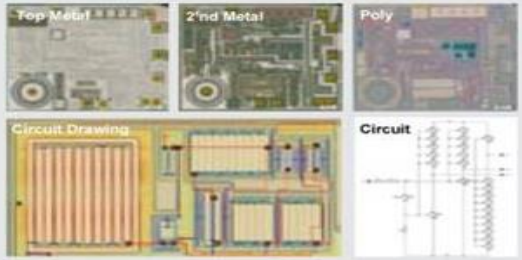
Device & Process Analysis Technology



Nondestructive Inspection



Process Analysis

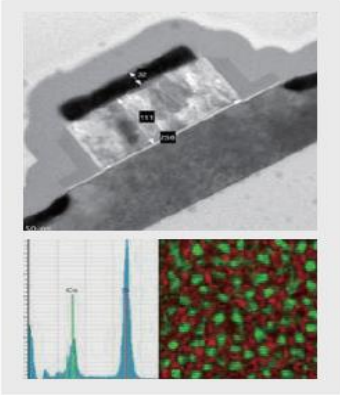


Circuit Extraction

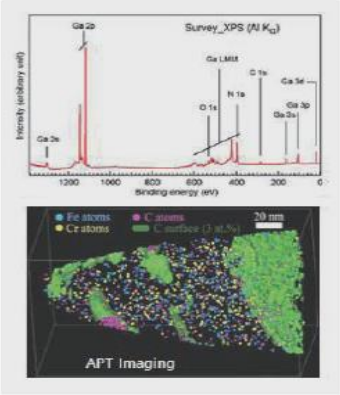
나노분석 보유장비

구조분석	표면분석	전기적 특성 측정	In-line 공정 측정	소자 불량분석
• FE-(S)TEM [2대]	• M-SIMS • TOF-SIMS • APT	• Parameter Analyzer	• Ellipsometer	• X-ray Microscope
• Cs-corrected STEM	• SPM [2대]	- Manual P/S	• Reflectometer	• Reactive Ion Etcher [2대]
• 3D FE-STEM	• FT-IR Spectrometer	- Semi-auto P/S	• Surface Profiler	• Wet Station
• In-situ TEM	• Raman Spectrometer	- Auto P/S	• Optical Profiler	• Polisher • Cross-section Polisher
• UHR FE-SEM • FE-SEM [3대]	• Nano-indenter	• Power Device Analyzer	• Stress Gauge	• Auto Microscope
• DB-FIB [2대]	• X-ray Photoelectron Spectrometer		• 4-point Probe	• Laser Decapper
• SB-FIB	• X-ray Diffractometer			• Scaning Acoustic Microscope

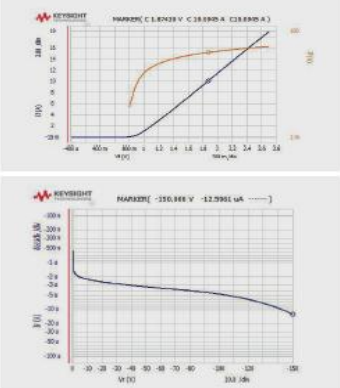
미세구조 및 성분분포



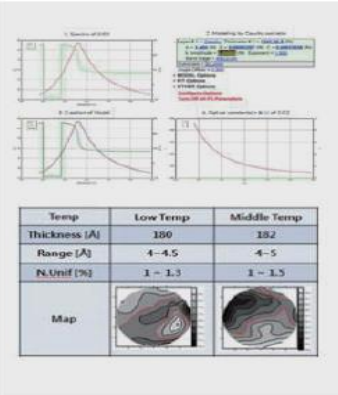
성분분석 및 3차원 분포



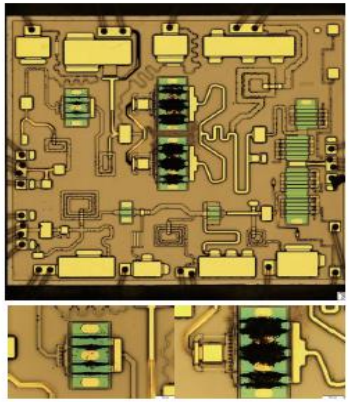
전력반도체 특성측정결과



SiO2 광학적 특성 및 두께 map

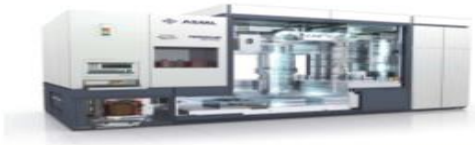
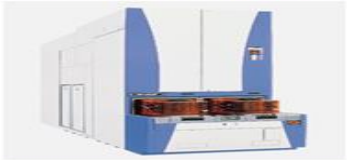


불량분석결과



12인치 반도체 소부장 테스트베드

반도체 테스트베드 : 12인치 구축 장비

ArF Immersion Scanner	Track System	CD-SEM
		
ArF Photo Resist 평가 - 40nm급 패턴 구현	감광제(PR) Coat/Dev Thermal Baking, ARC coating	미세패턴 선폭 측정, 패턴 형상 확인
Wet Single Cleaner	**PECVD**	**Conducting & Dielectric Dry Etcher**
		
Wafer표면의 화학적, 물리적 잔류물 제거 - SC-1, DHF, LAL, O3 water 등	PE Oxide/Nitride 박막, PETEOS 박막 Hradmask용 ACL 박막	Dielectric Layer 및 Conduct 박막 선택적 식각
Thermal Oxidation	**LPCVD System**	**Thickness Measurement system**
		
Thermal Dry/Wet Oxidation N2 Anneal	Silicon Nitride 박막	초박막 두께 측정, RI 및 Stress 측정

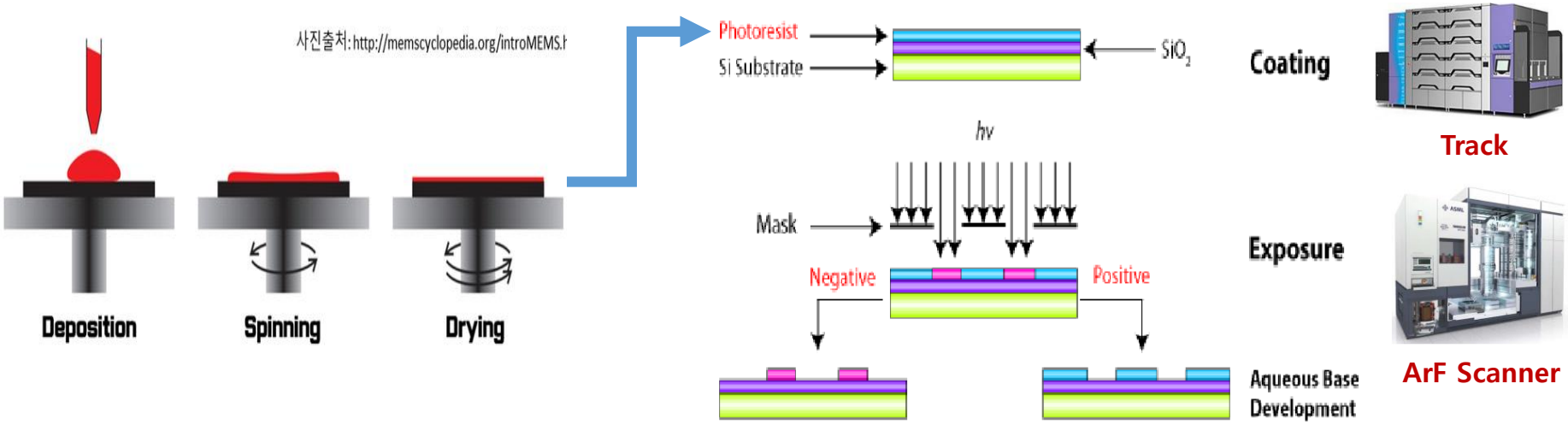


반도체 테스트베드 : 반도체 소재 평가

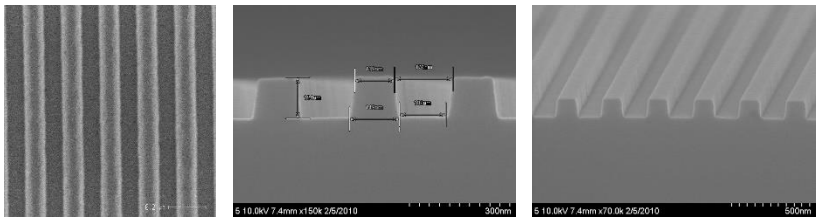
감광제(PR) 평가

PR 평가의뢰 → 소재 수령 → 패턴 형성 → CD 측정 → 의뢰처 제공

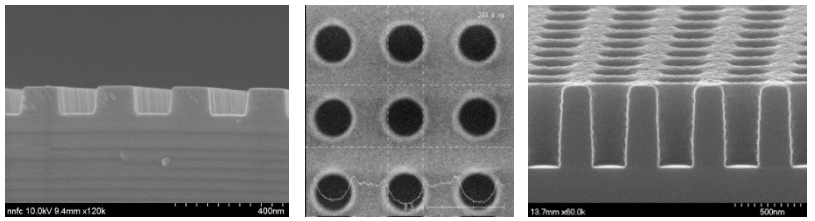
- ✓ PR 평가의뢰 업체에서 제공하는 PR과 공정조건을 기준으로 패턴을 제작하여 업체에 제공
- ✓ Track system을 활용하여 300mm 웨이퍼에서의 Photo Resist Thickness, Uniformity, Defect 등 평가



PR Coating Uniformity & Pattern Profile Evaluation



Etch Pattern Profile & Selectivity Evaluation



반도체 테스트베드 : 반도체 소재 평가

전구체, Chemical, Gas 평가

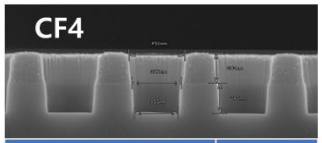
평가의뢰 → 조건 검토 → 평가방법 검토 → 평가수행 → Data 취합 → 의뢰처 제공

- ✓ Chemical : 제공된 Material(박막, SOC 등)의 Wet etching 특성 평가, 불량상태/Etch rate/Film uniformity 데이터 제공
- ✓ Gas : 제공된 Etching gas의 Etch rate, Etch uniformity, Etch profile 등 평가 데이터 분석 및 제공

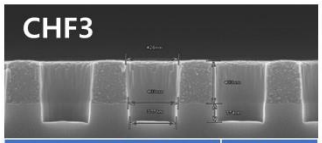
식각 Gas 평가 장비



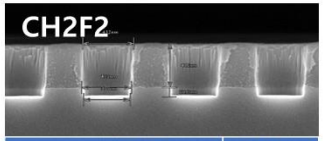
Oxide Etch Profile Test



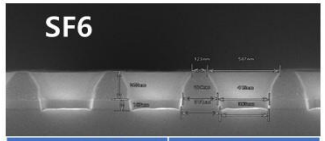
remain PR	282nm
Oxide depth	285nm



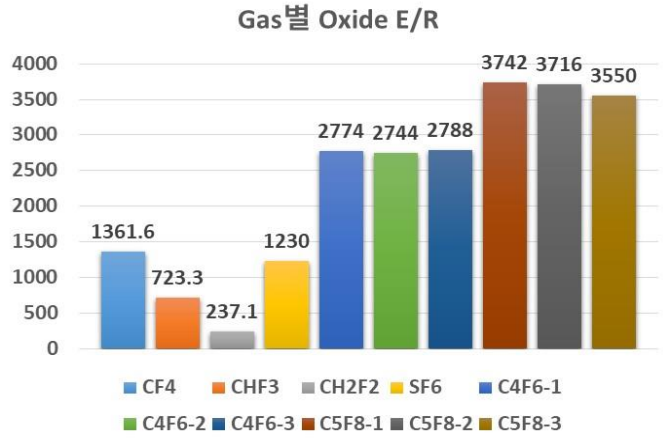
remain PR	403nm
Oxide depth	174nm

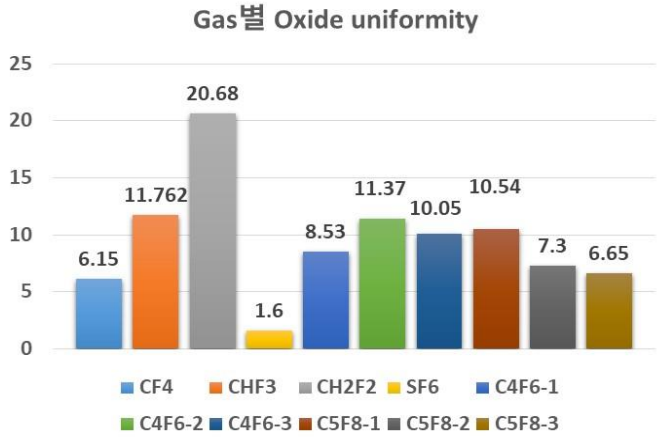


remain PR	415nm
Oxide depth	88nm



remain PR	123nm
Oxide depth	214nm





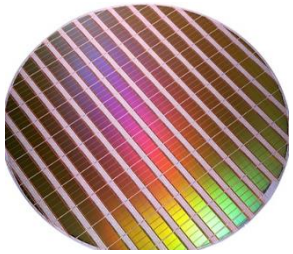
반도체 테스트베드 : 패턴 웨이퍼 제작

패턴 웨이퍼 제작

공정상담 → 조건 검토 → 평가용 웨이퍼 제작 → 자체 측정 → 의뢰처 제공



평판 웨이퍼



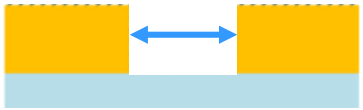
패턴 웨이퍼

(테스트베드)

패턴 웨이퍼 제작 지원

40nm급

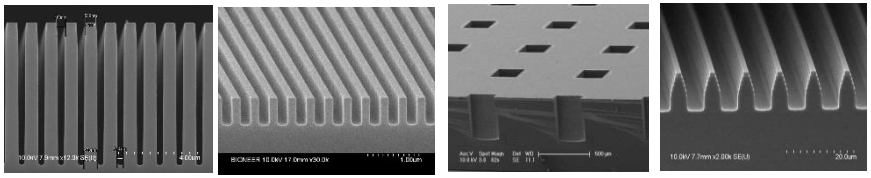
20nm급



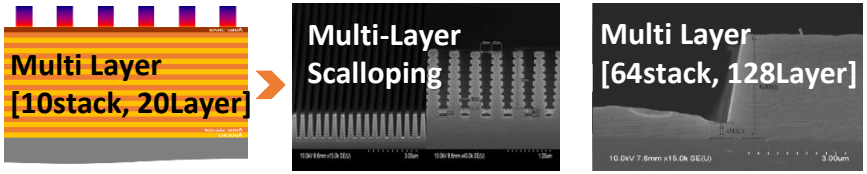
증착공정 테스트



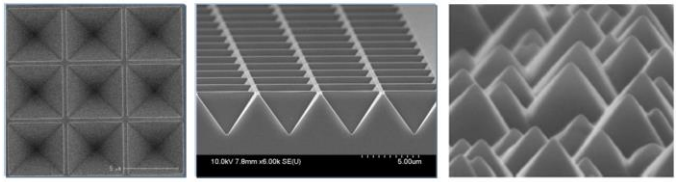
Various Line/Space/Hole Pattern



Vertical-Stacked Pattern @ 3D-VNAND



Si Texturing Wet Etch @ KOH



Si Sigma Shape Wet Etch @ NH4OH

