Chulalongkorn (TH): Local capabilities and TH-proposed R&D topics

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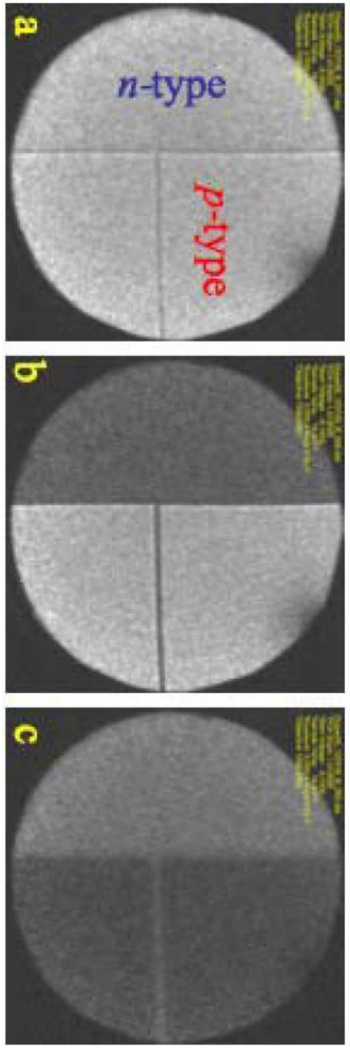
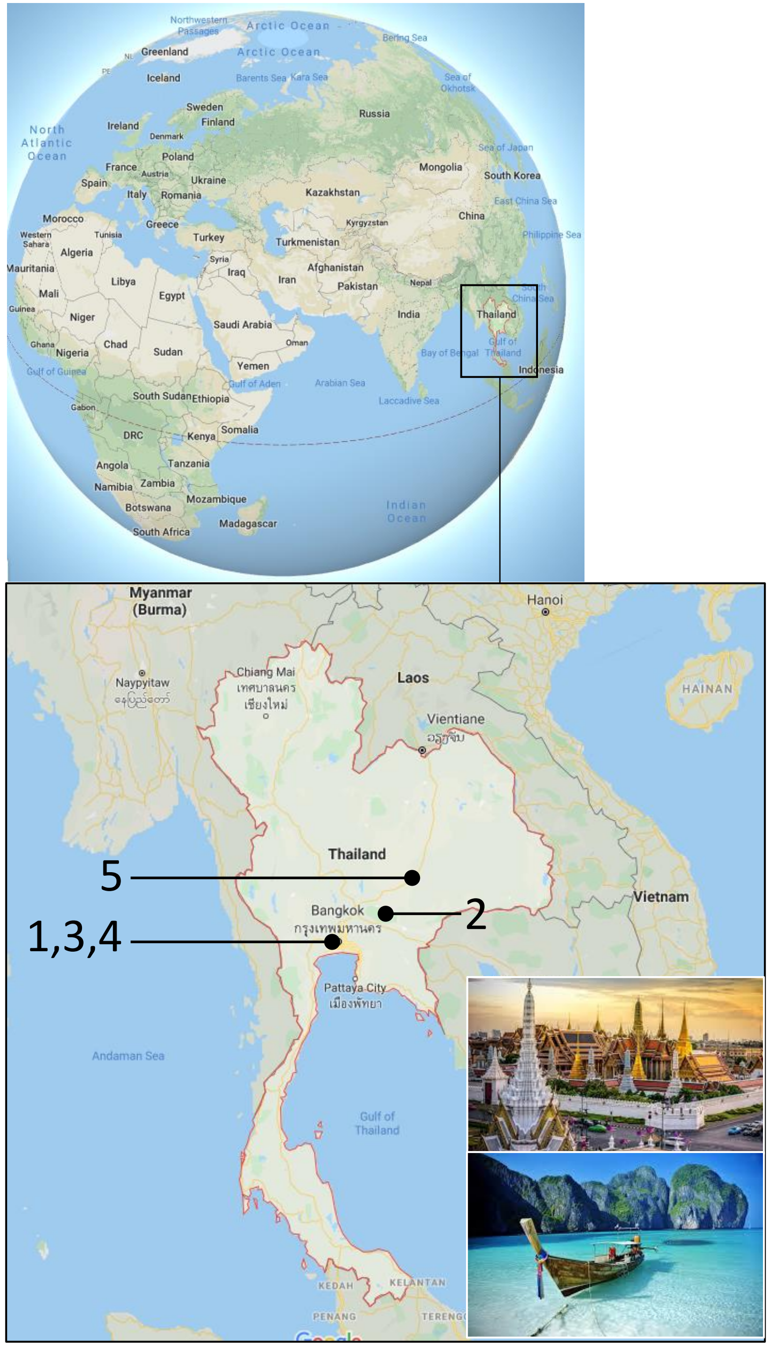


TH capabilities

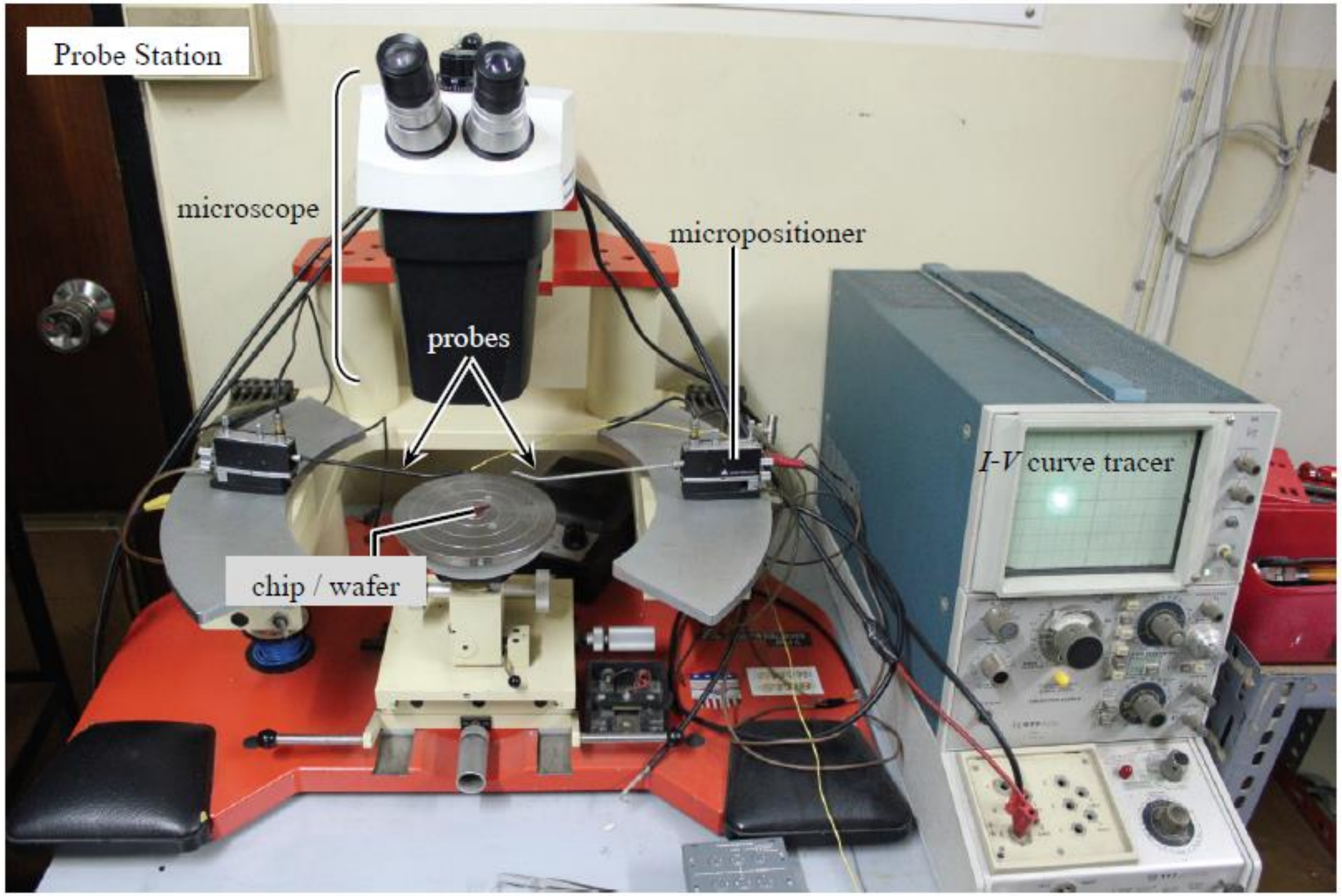
1. Chulalongkorn/Engineering (measurements: I-V, C-V, AFM, PL; crystal growth: MBE)
2. TMEC (Si wafer fab)
3. TINT (irradiation: TRIGA III reactor)
4. NSTDA (bulk: HRXRD, Raman)
5. SLRI (surfaces/interfaces by Synchrotron-based techniques

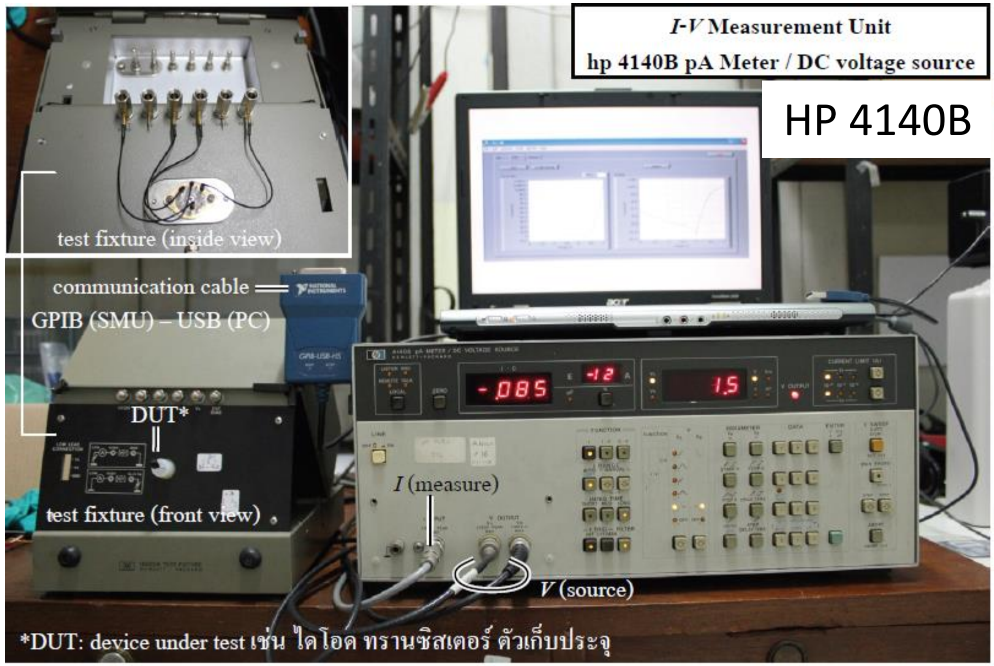
+ (Chulalongkorn/Physics, Burin's HEP group, CMS)

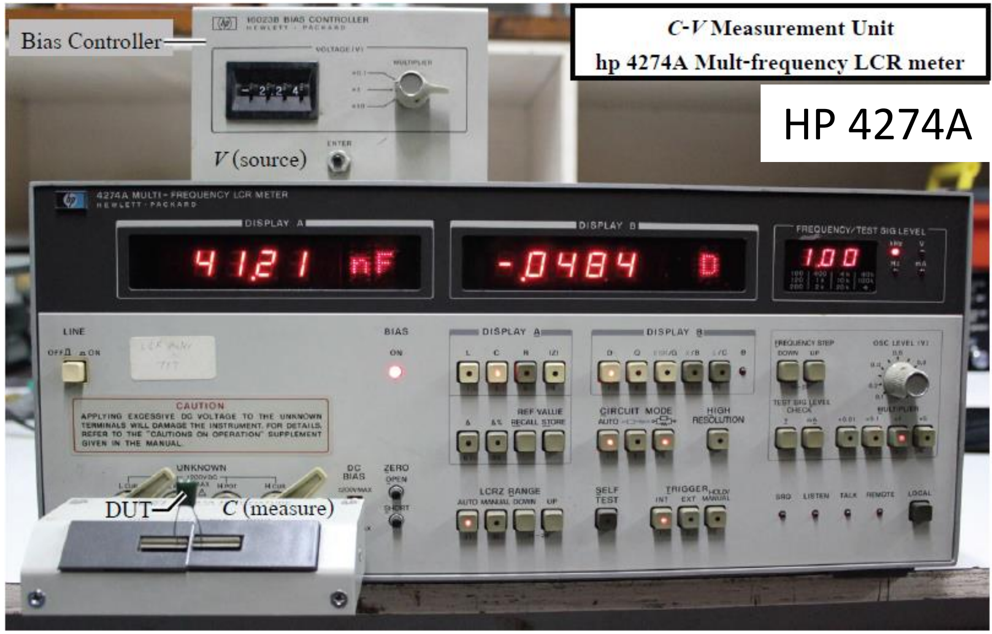


TH capabilities

1. Chulalongkorn/Engineering (measurements: I-V, C-V, AFM, PL)

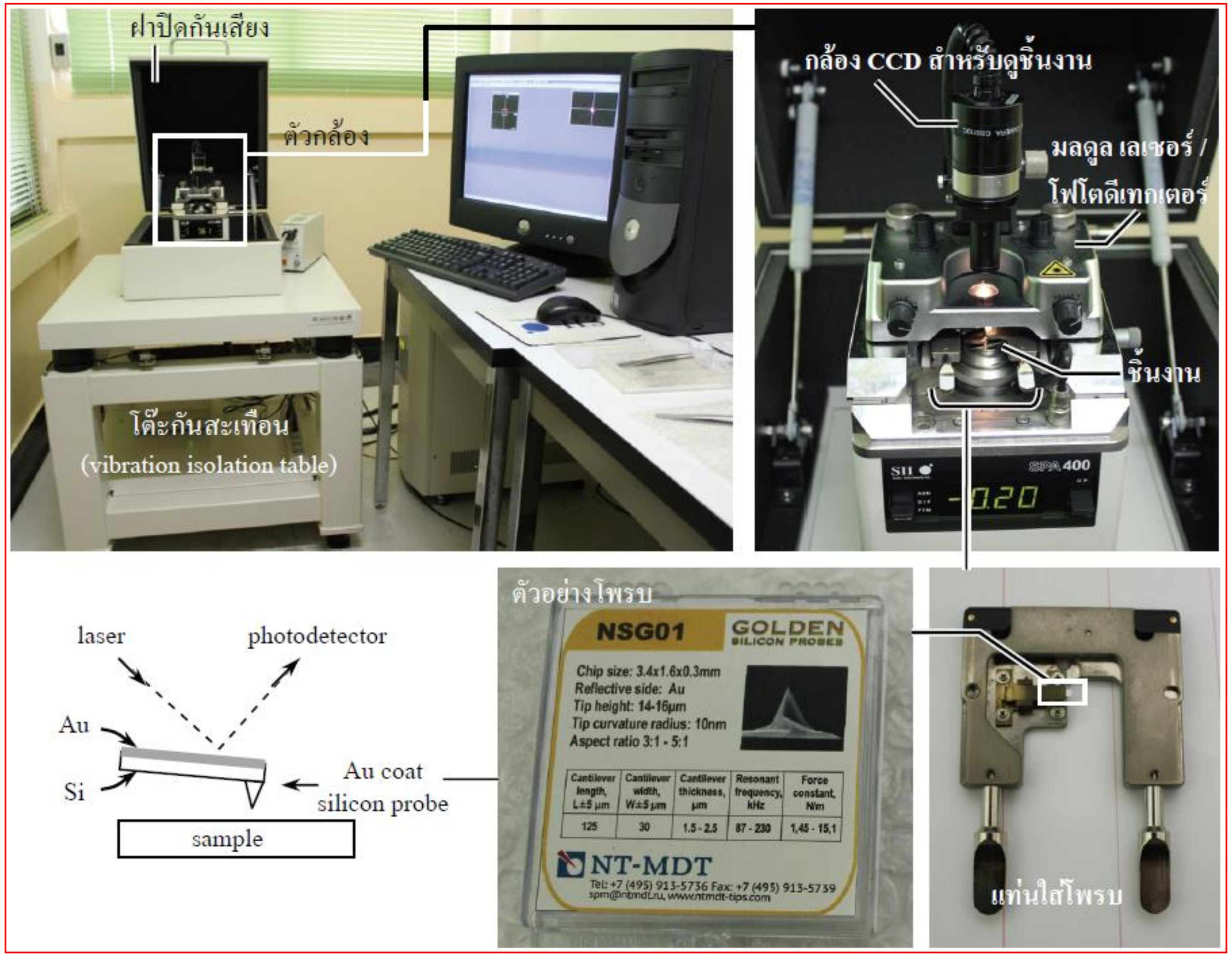




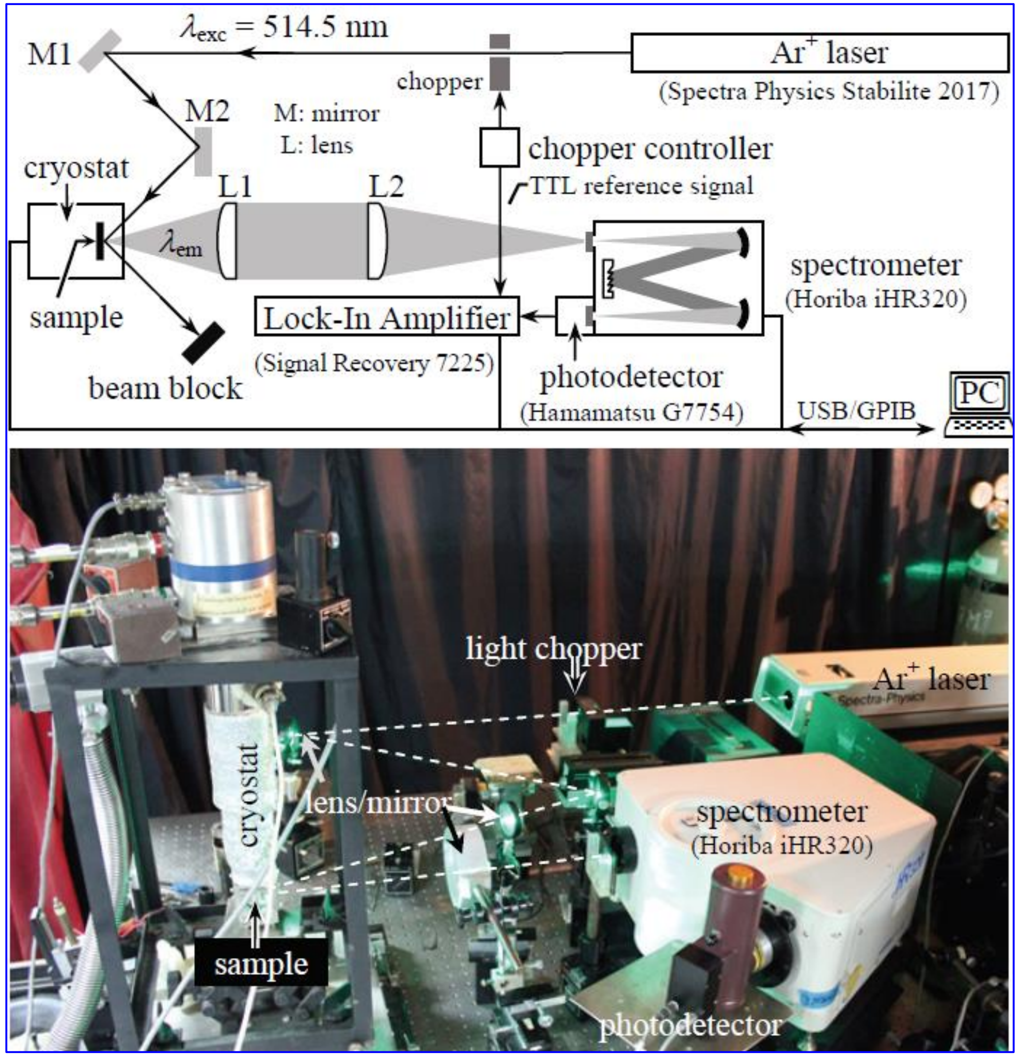


Karl Suss PM5 probe station. I-V by HP4140B pA meter/DC voltage source. C-V by HP4274A LCR meter.

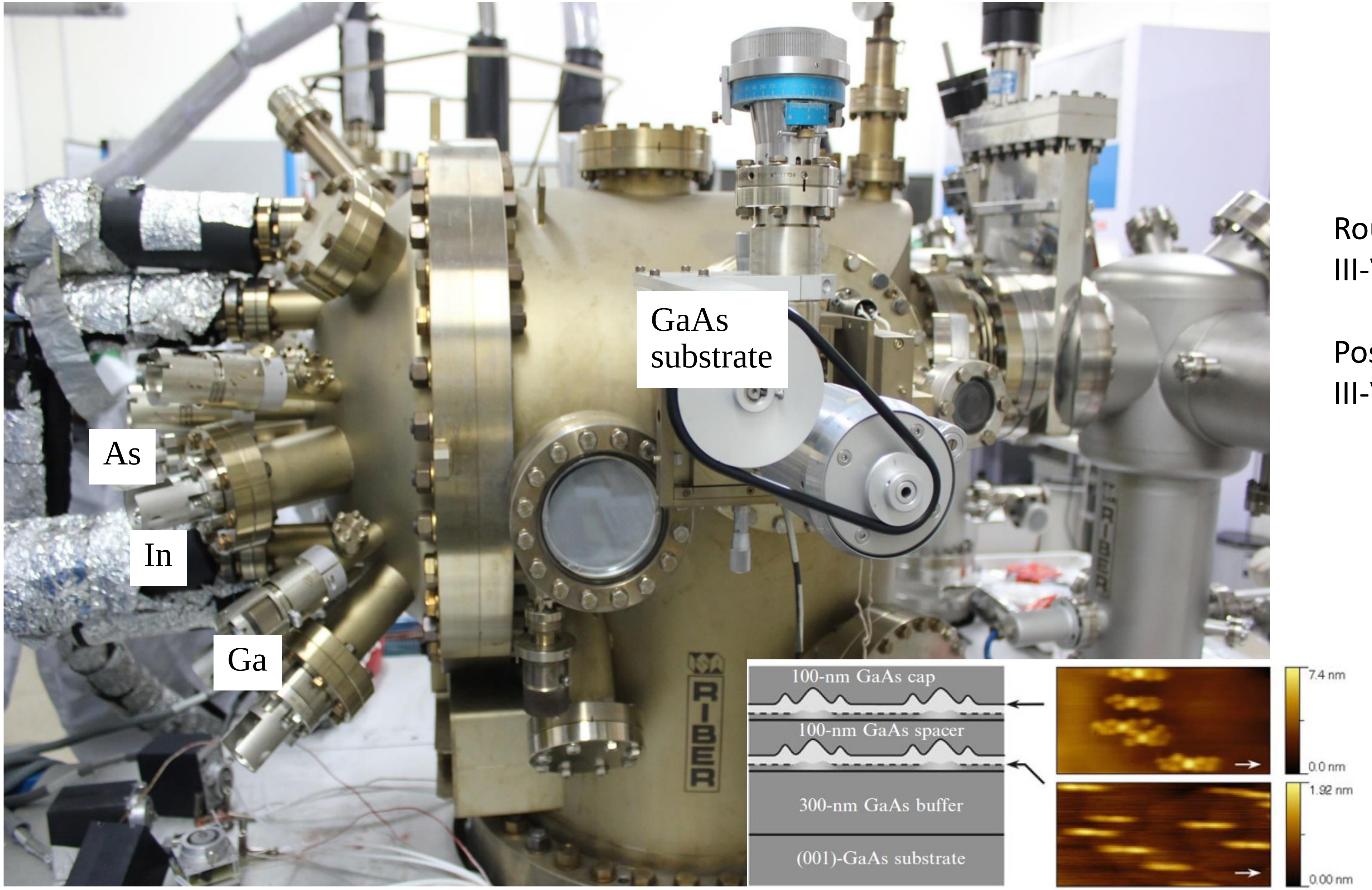
AFM (Atomic force microscope)



PL (Photoluminescence spectroscopy)



AFM Seiko Instrument (SII) SPA400. PL setup with closed-cycle He cryostat, laser excitation, grating spectrometer (Horiba iHR320) and photodetector (Hamamatsu G7754)

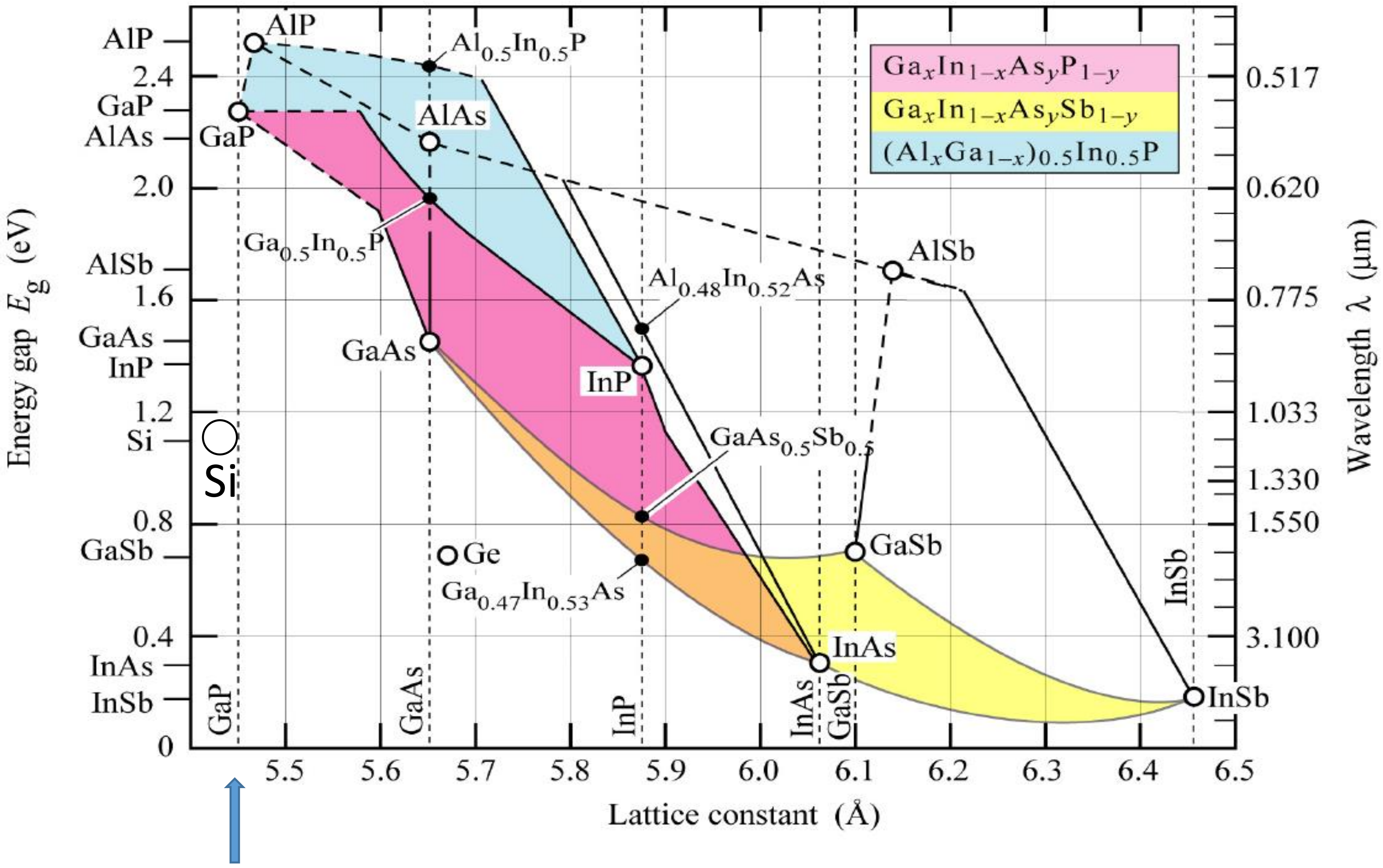


Routine:
III-V on III-V

Possible:
III-V on Si

Crystal growth (III-V Semiconductors): molecular beam epitaxy (MBE), quantum dots, solar cells

Proposal: GaP/Si heterostructure particle detectors



Rationale:

- Lattice matching
- Large bandgap
- Radiation hard(er)?
- Band engineering (≈MJ solar cells)

E_G (eV), T_m , T_C (°C)

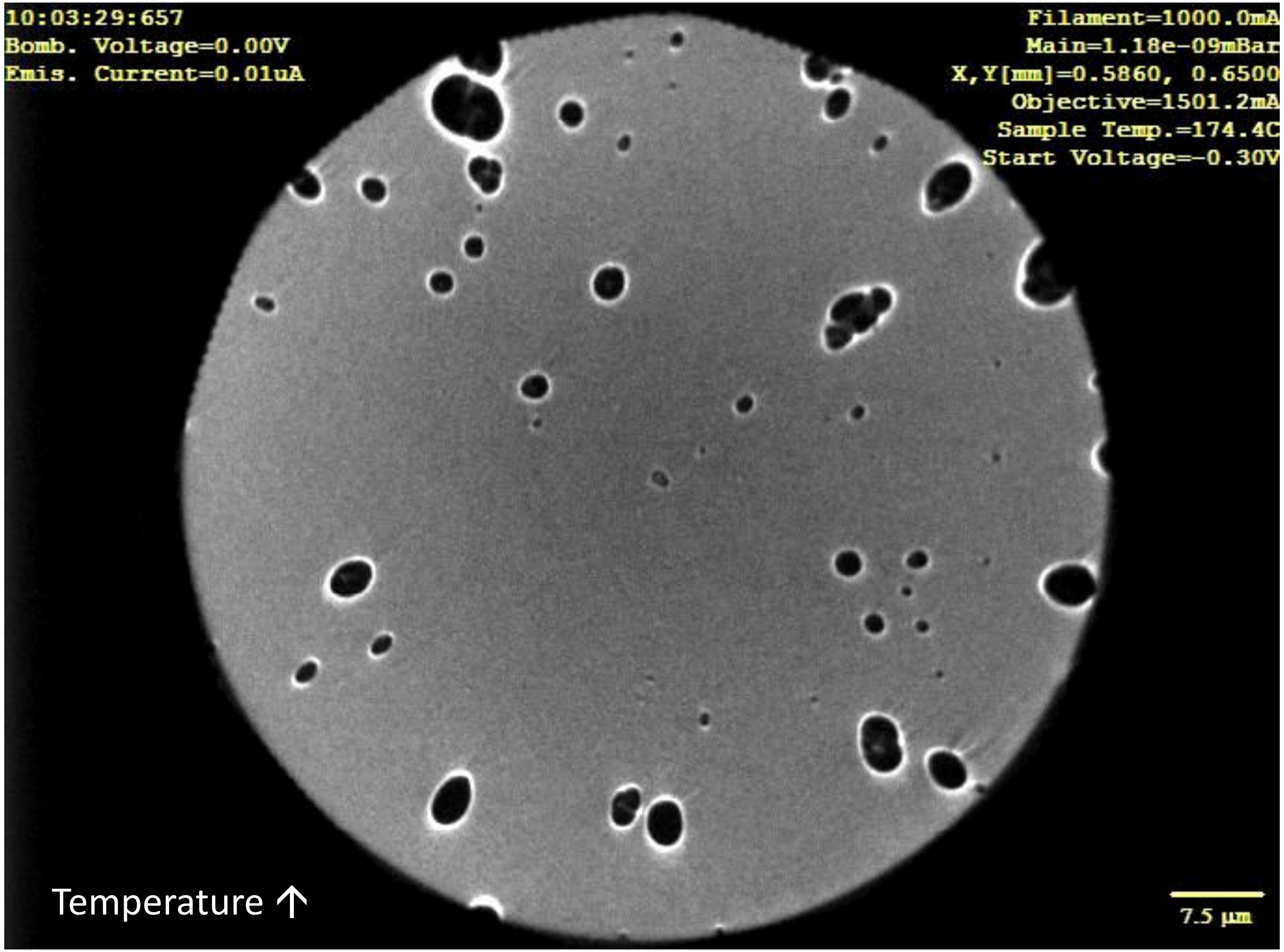
Si, 1.1, 1412, -

GaAs, 1.4, 1238, 625

GaP, 2.2, 1457, >750?

SiC (4H), 3.2, 2730, ?

Au/GaAs



- LEEM vdo / surface signal
- native oxide evaporating
- droplet etching (Au etches GaAs)
- droplet running (AuGa, Ga)

- Post-annealed XRD, FWHM unchanged
- Message: surface stability may be limiting factors

"Au-catalyzed desorption of **GaAs** oxides“
Nanotechnology 30 (2019) 215703

TH capabilities

2. Thai Microelectronic Center

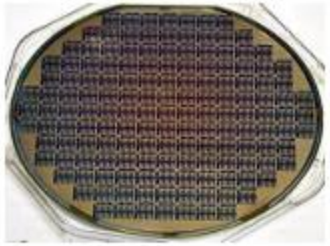
Si wafer fabrication: 0.5 μm CMOS process, currently involved with ALICE/ITS upgrade, resistivity profiling of high ρ Si substrates

Core Technology

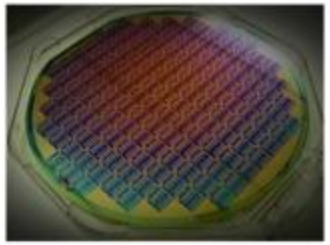
TMEC
Thai Microelectronics Center

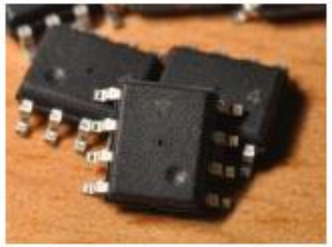
1. Semiconductor process technology
2. Si sensor fabrication technology
3. MEMS technologies
4. ISFET platform
5. Device Design, Modelling, Simulation
6. Si mold fabrication and Casting technology through Soft-lithography
7. Microfluidic devices for lab on chip and on disc

Humidity Sensor

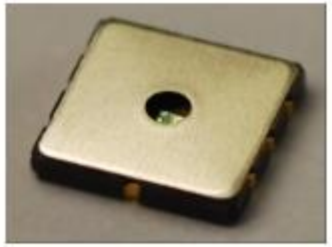


Solar Tracker Sensor





ISFET (ion-sensitive)



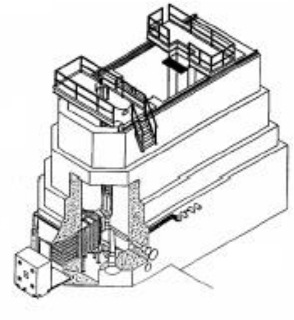
Pressure Sensor

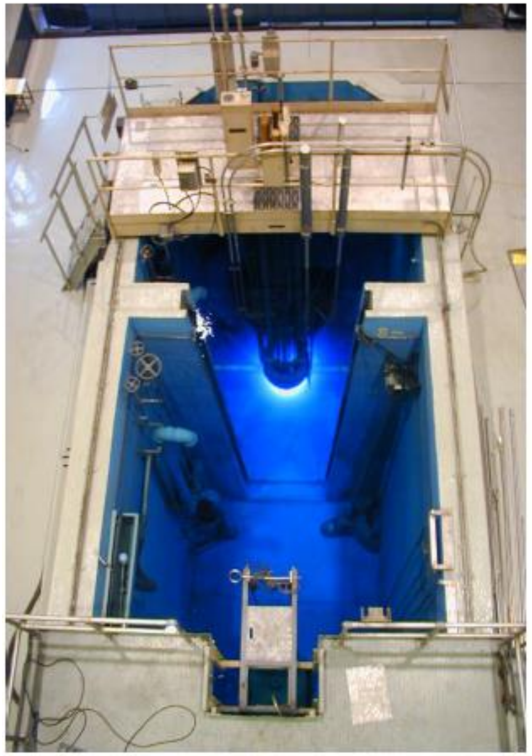
TH capabilities

3. TINT (irradiation: TRIGA III reactor)

สถาบันเทคโนโลยีนิวเคลียร์แห่งชาติ สทน
Thailand Institute of Nuclear Technology TINT

Descriptions of TRR-1/M1

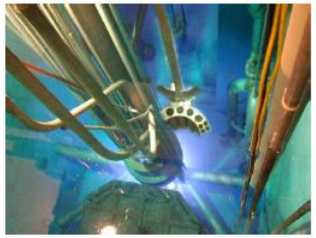




- TRIGA Mark III
- First Critical July 1977
- Max. Power: 2 MW
- Nominal Operation: 1.2 MW
- Flux $3x10^{13}$ cm^{-2}.sec^{-1}
- Coolant water

Fuel Elements

- 20% TRIGA rod



- **Control Rods**
- 4 FFCR
- 1 AFCR
- B^{4}C

Activities:
Gems irradiation (neutron, gamma)
Isotopes production (^{131}I, ^{153}Sm, ^{32}P, ^{177}Lu…)
Neutron computed tomography

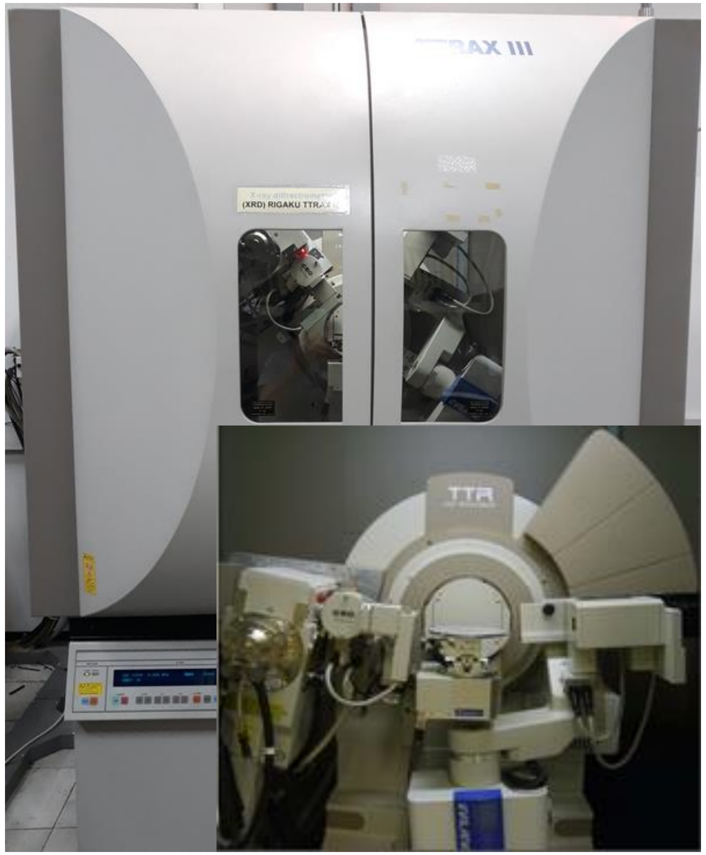
TRIGA reactor operated by TINT, in full working order. Research collaboration with Chulalongkorn.

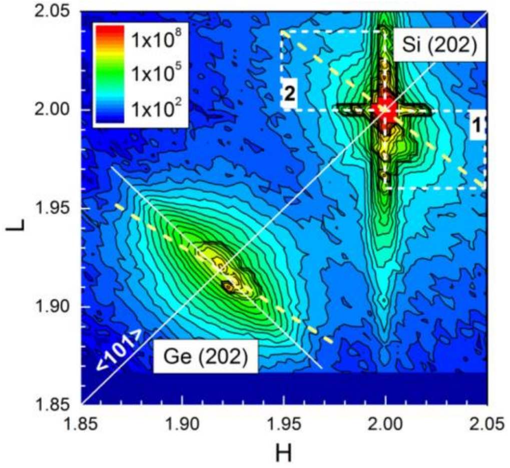
TH capabilities

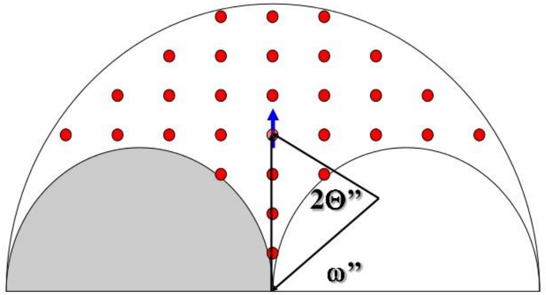
4. NSTDA (bulk: HRXRD, Raman)

National Science and Technology Development Agency

Rigaku X-ray diffractometer (HR-XRD)







Renishaw Raman spectrometer

Single crystals and dislocation densities can be studied/quantified by the full width at half maxima (FWHM) of related Bragg's peaks (HR-XRD) in reciprocal space maps (RSM), as well as FHWM of Raman peaks.

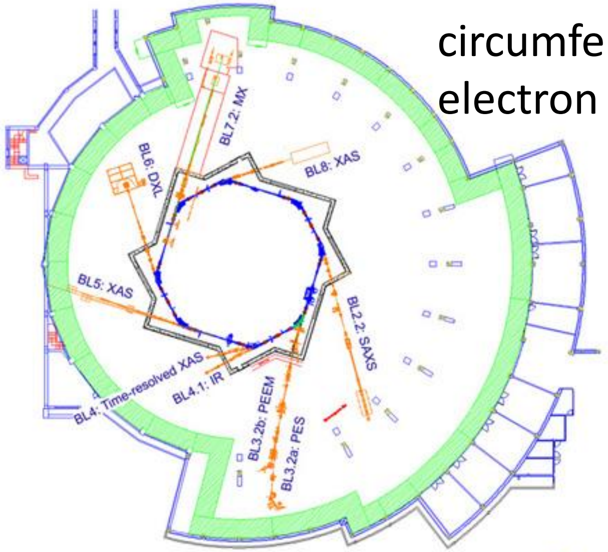
TH capabilities

SYNCHROTRON THAILAND CENTRAL LAB

5. SLRI (surfaces/interfaces by Synchrotron-based techniques: XAS, XPS, LEEM/PEEM)

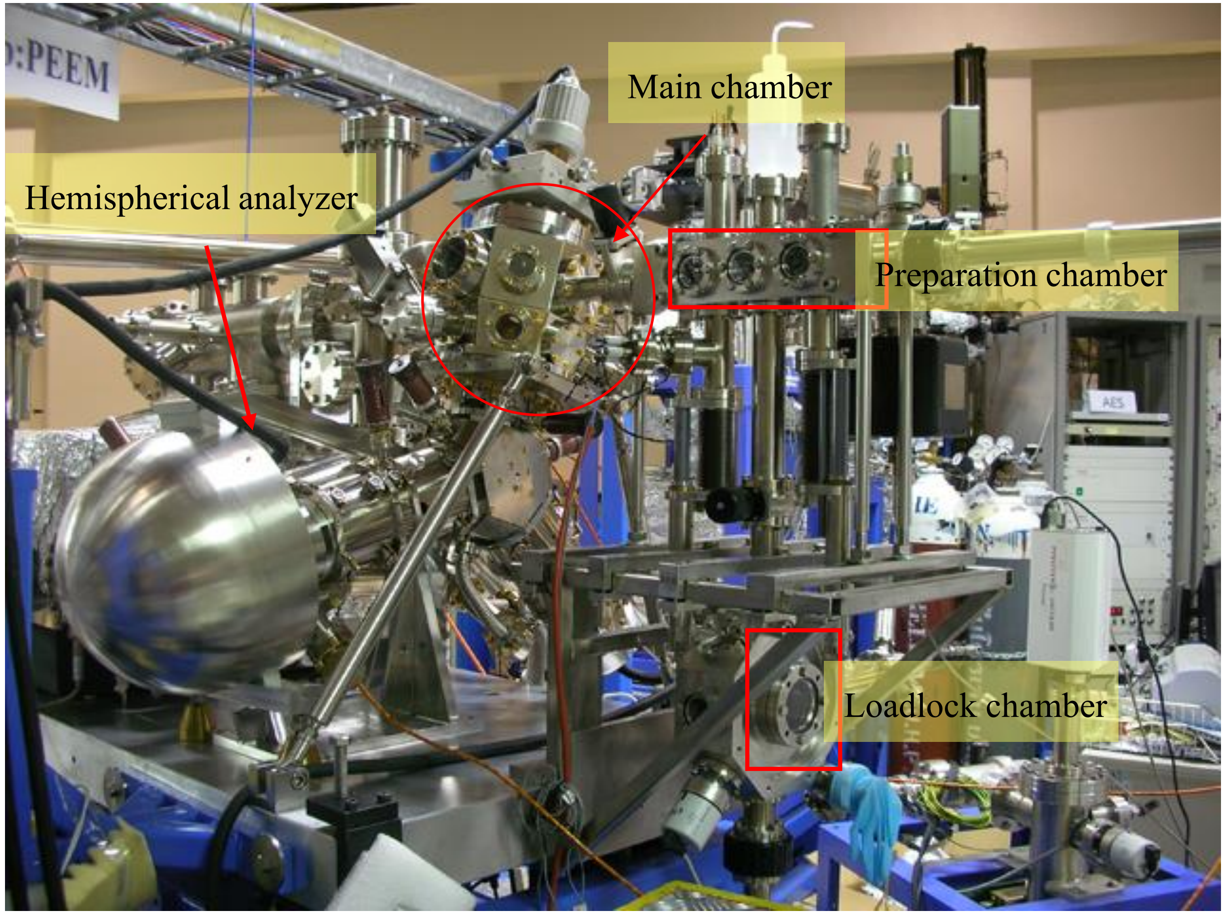
Beamline	Technique
BL2.2: SAXS	Small Angle X-ray Scattering
BL3.2a: PES	Angle-resolved Photoemission Spectroscopy (ARPES) Ultraviolet Photoelectron Spectroscopy (UPS) X-ray Photoelectron Spectroscopy (XPS) X-ray Absorption Spectroscopy (XAS)
BL3.2b: PEEM	Photoemission Electron Microscopy Imaging/Micro XPS Imaging/Nano XAS
BL4.1: IR Spectroscopy and Imaging	Infrared Spectroscopy and Imaging
BL4: Time-resolved XAS (Bonn-SUT-SLRI)	Time-resolved X-ray Absorption Spectroscopy
BL5: XAS (SUT-NANOTECH-SLRI)	X-ray Absorption Spectroscopy
BL6: DXL	Deep X-ray Lithography
BL7.2: MX	Macromolecular Crystallography
BL8: XAS	X-ray Absorption Spectroscopy

The Thai Synchrotron lab operates 8 beamlines. Of most relevance to the studies of p-n junctions of Si detectors is BL3.2b (SPELEEM)



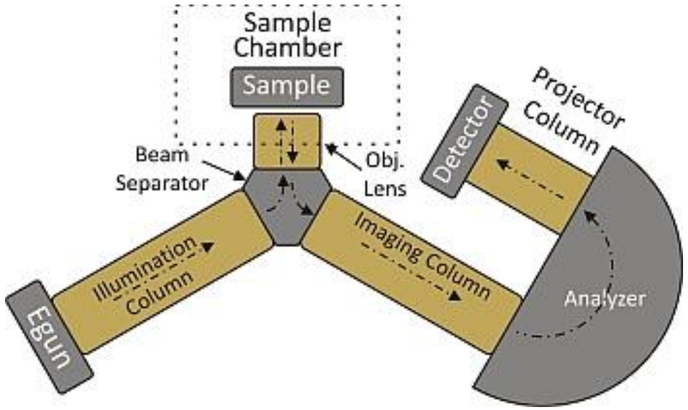
circumference 81.3 m
electron energy 1.2 GeV

BL3.2b SPEctroscopic Low-Energy Electron Microscopy (SPELEEM), commercial system (Elmitec LEEM III) coupled with Synchrotron



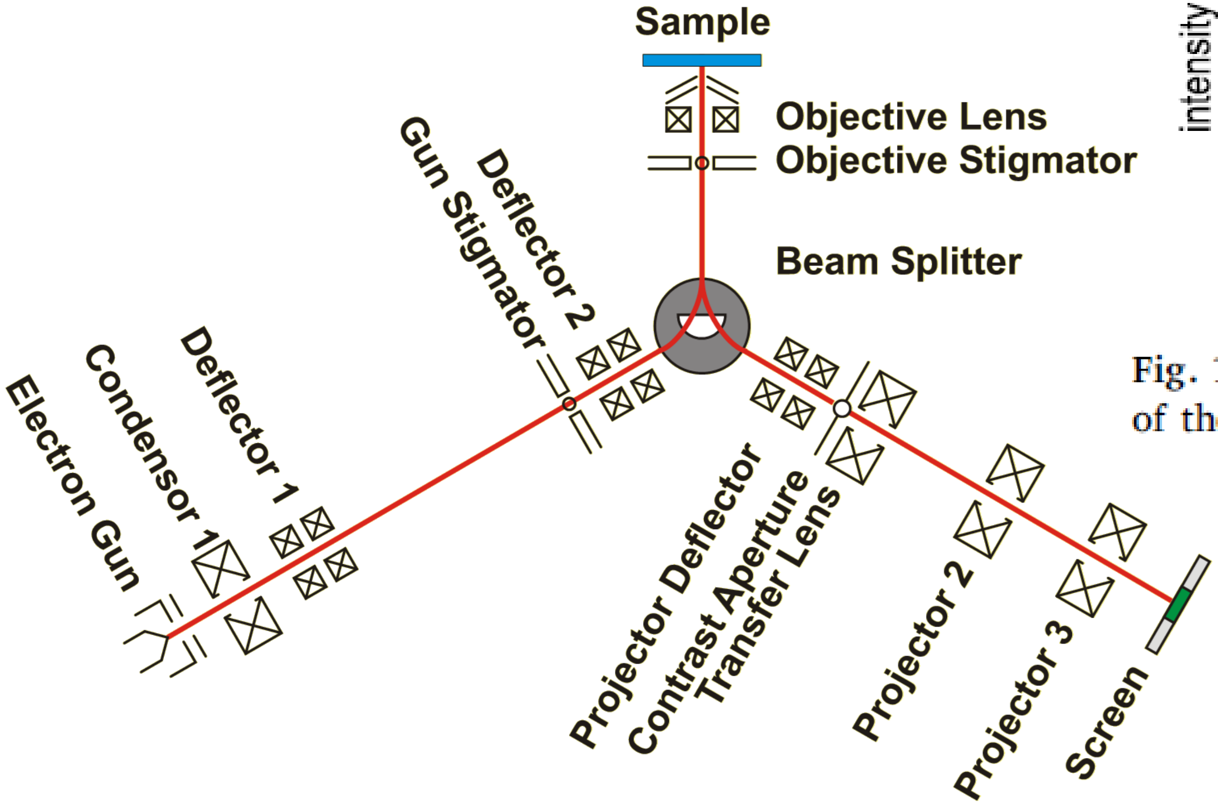
ELMITEC

Imaging/Spectroscopy modes:
- PEEM: Photoemission electron microscopy
- XPEEM: X-ray Photoemission electron microscopy
- LEEM: Low-energy electron microscopy
- MEM: Mirror electron microscopy



SPELEEM has been used to study dynamical events on Si and compound semiconductor surfaces, including dislocation decoration by liquid droplets, desorption of surface oxides, work-function contrast imaging (p-n junctions)

low-energy electron microscopy (LEEM)



workfunction contrast

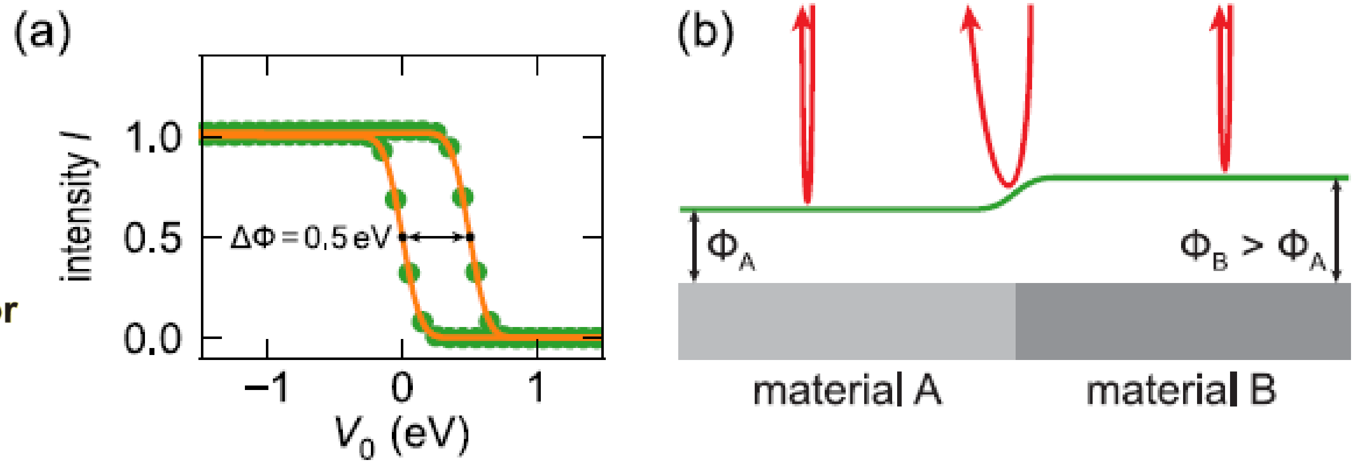


Fig. 1. Sketch of the canonical way to determine $\Delta\Phi$ from LEEM IV-curves and of the problem with WF-induced, in-plane fields. (a) The start voltage V_0 at

Ultramicroscopy 200 (2019) 43–49

Imaging Oxide-Covered Doped Silicon Structures Using Low-Energy Electron Microscopy

LEEM

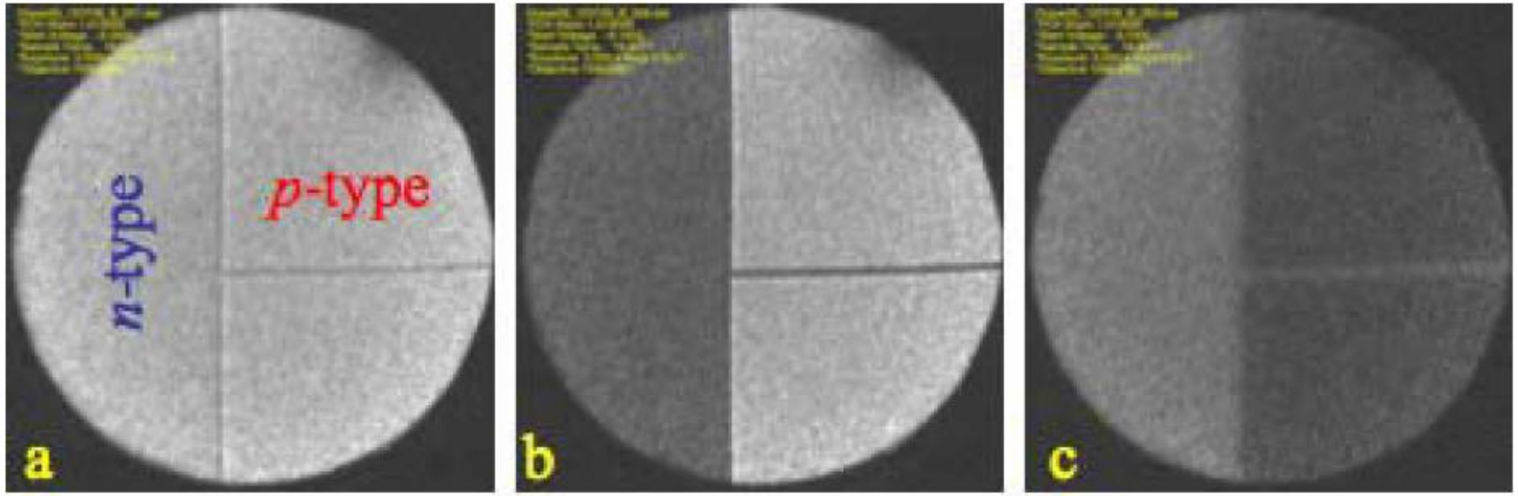


Figure 4. LEEM images of 0.5 µm *n*-type line at start voltages of a) -2.0 V, b) -0.15 V, 0.7 V, 50 µm field of view.

reflectivity contrast
(due to ΔWF)

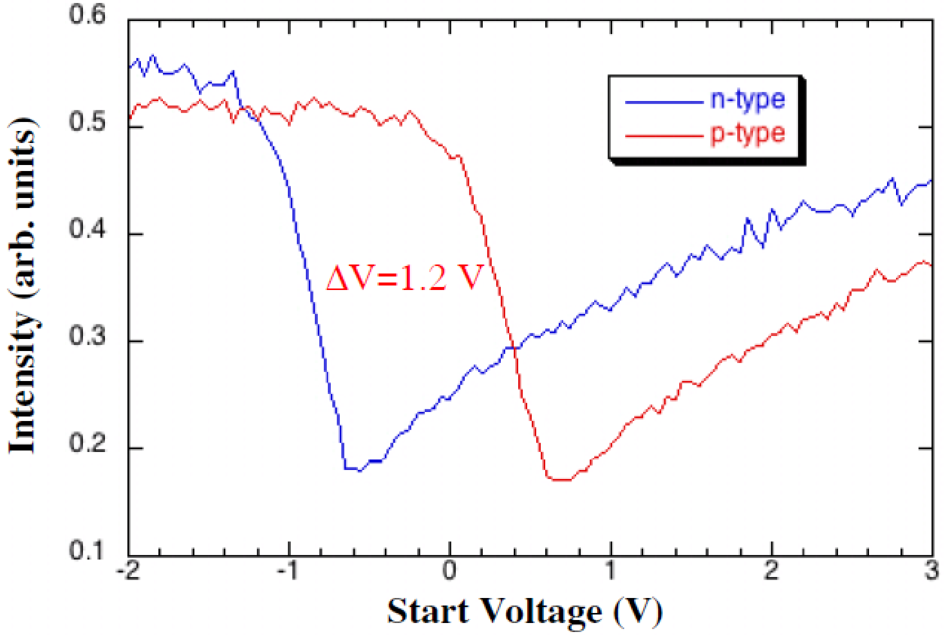


Figure 5. Reflectivity curves for *n*- and *p*-type Si regions of test structures.

Mater. Res. Soc. Symp. Proc. Vol. 1026 © 2008 Materials Research Society 1026-C15-03

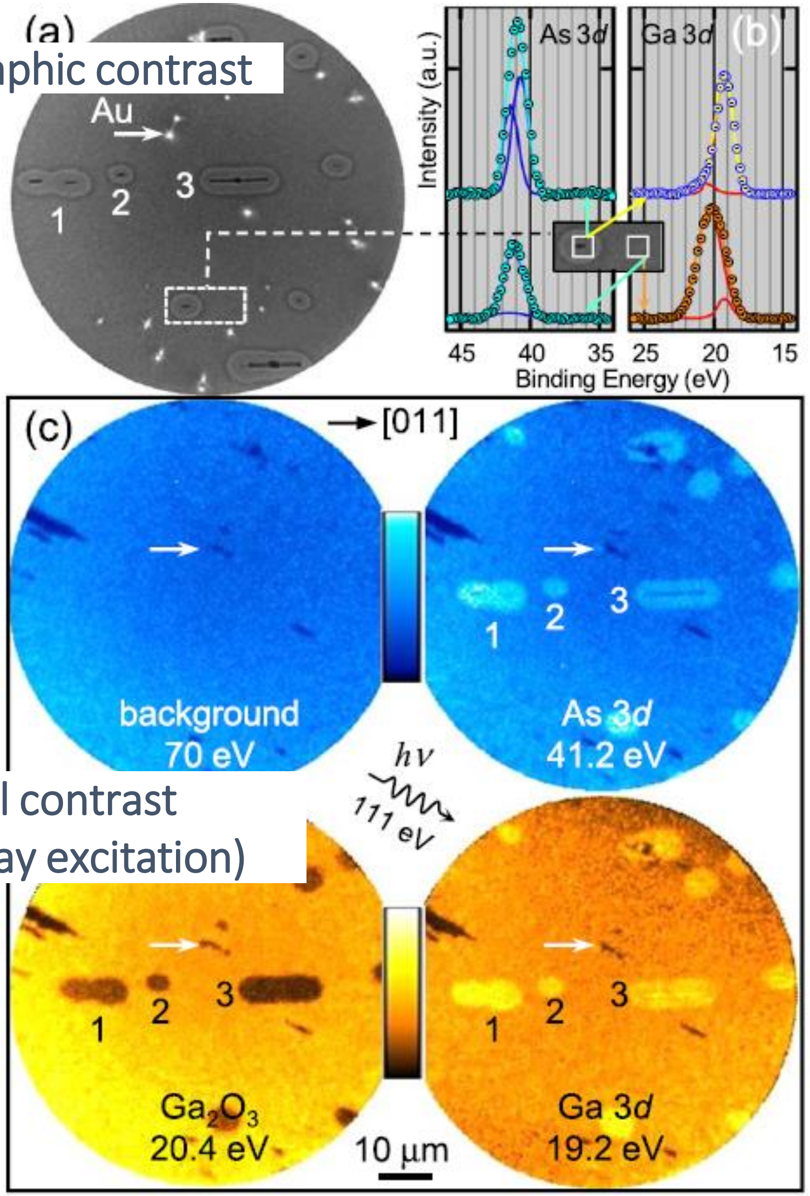
"Au-catalyzed desorption of **GaAs** oxides"
Nanotechnology 30 (2019) 215703

topographic contrast

LEEM

XPEEM

chemical contrast
(soft X-ray excitation)



"Profiling n-type dopants in **Silicon**"
Materials Transactions 51 (2010) 237

workfunction contrast
(UV excitation)

PEEM

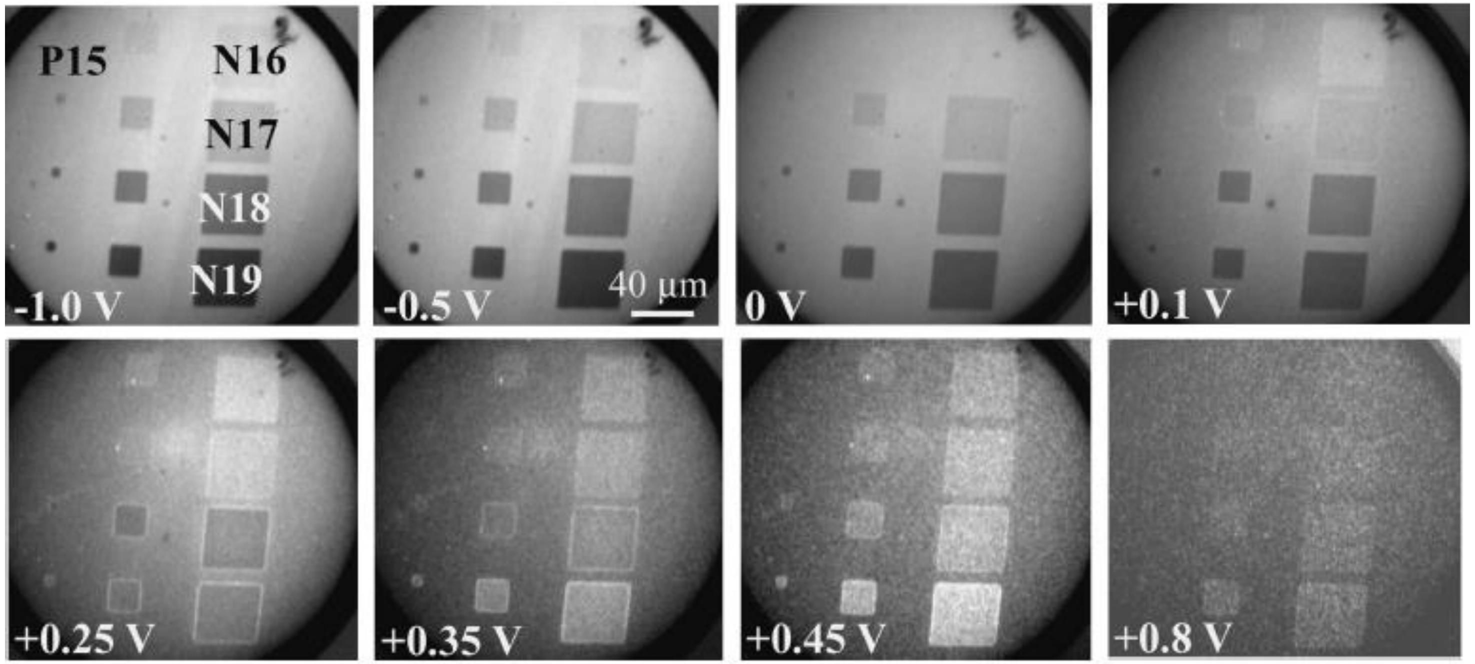
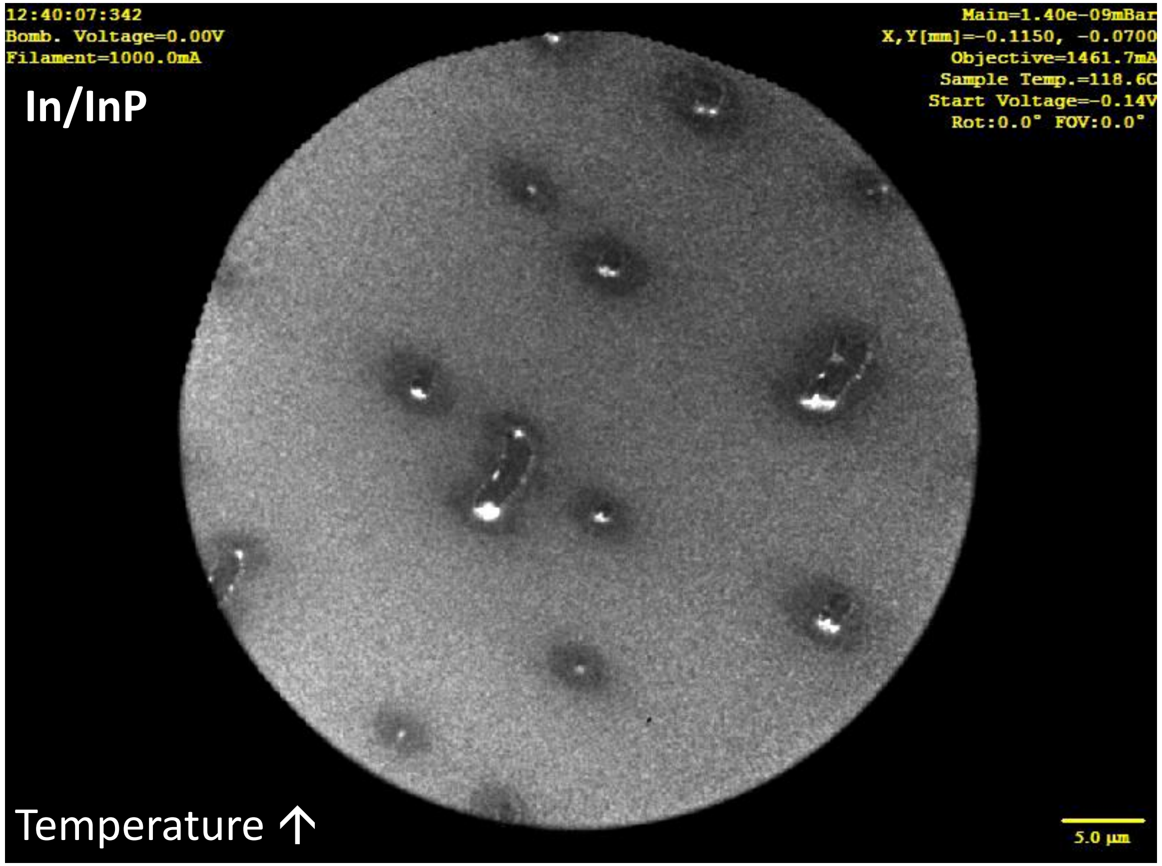


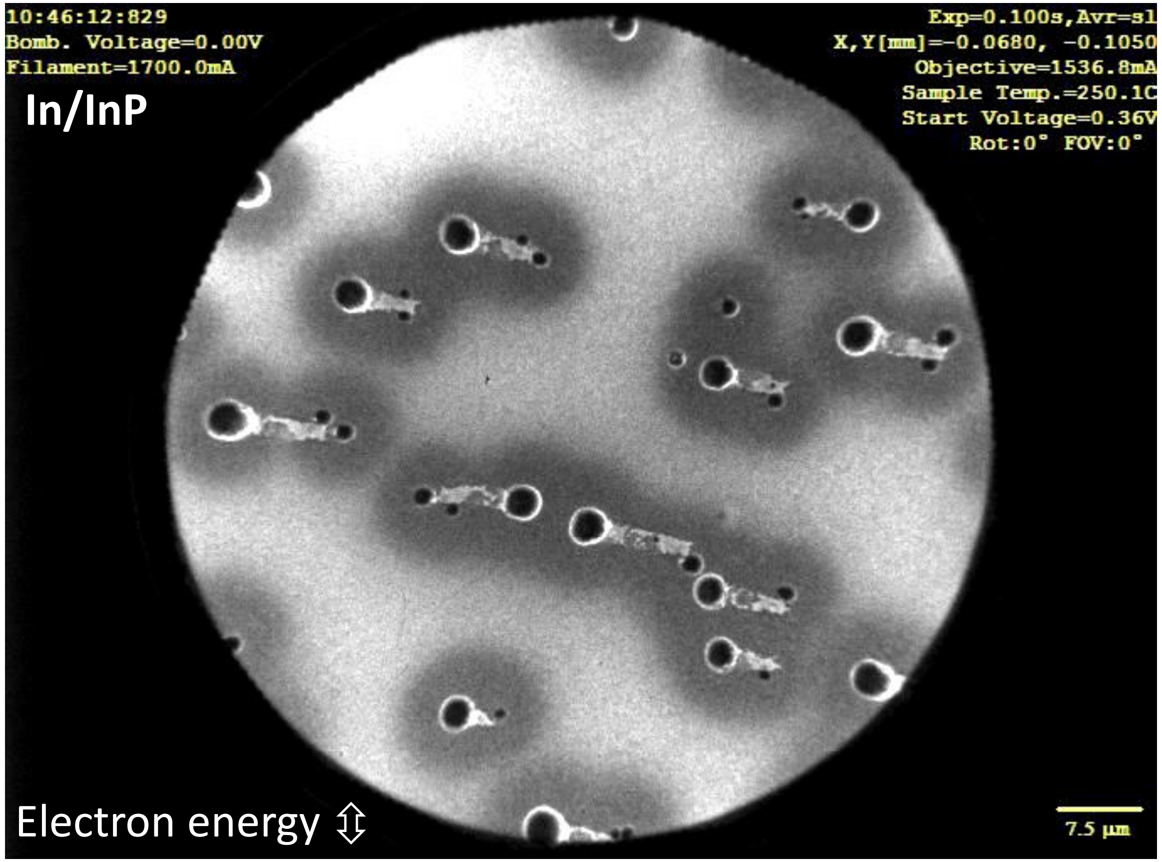
Fig. 1 PEEM micrographs taken under mercury lamp illumination for various retarding voltages (indicated in the left bottom corner of the micrographs) applied on the sample. The doping level in n-type squares varies from $1.5 * 10^{16}$ cm^{-3} (N16) to $1.5 * 10^{19}$ cm^{-3} (N19) while the p-type substrate is doped to $1.9 * 10^{15}$ cm^{-3} (P15). The negative retarding voltages correspond to the full photoemission imaging while with increasing voltage the slowest photoelectrons are filtered off.

In-situ VDOs showing WF+step contrasts

wetting



contrast reversal



TH capabilities

Summary

1. can measure electrical properties of Si detector diodes: I-V, C-V; as well as surface & optical properties: AFM, PL
2. III-V semiconductors growth, 0.35-μm Si CMOS process
3. can irradiate (neutron) TRIGA III reactor
4. can measure changes in bulk defects density (HRXRD, Raman peaks broadening)
5. can probe surfaces/interfaces/junctions properties (donor/acceptor profiles by SPELEEM, PEEM)

TH-proposed R&D topics

A) Spectromicroscopy of p-n junctions. Direct visualization/parameterization of

- type inversion, donor & acceptor removal effects in irradiated Si detectors
- donor & acceptor "reactivation" (holder has integrated resistive heater)
- junction position/abruptness/profiles

B) Growth and investigation of radiation hardness of GaP on Si

? Displacement/lattice damage by local probe LEED, PEEM/LEEM

? Investigations of annealing effects in irradiated samples by time-resolved X-ray absorption spectroscopy (TRXAS)

- <u>Materials Request</u> (A): Si test structures, LGAD, unirradiated & irradiated, ...

THANK YOU