

# laboratoire de Génie électrique et électronique de Paris (GeePs)



José Alvarez

jose.alvarez@geeps.centralesupelec.fr

- UMR8507 : CNRS, CentraSupélec, Univ. Paris-Saclay et Sorbonne Univ.
- Sections: 8 CNRS, 63 CNU

- Permanent : 129  
CNRS (20); CS,Psaclay, SUniv (109)  
Non permanent : 112  
Doct.(95), Post-doc (15), Apprentis (2)

## AXE

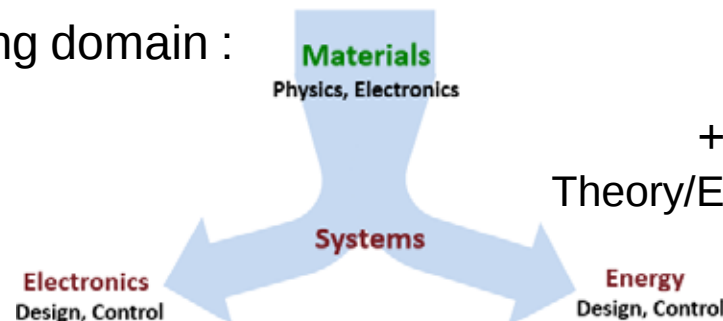
Élaboration

Mesures de propriétés

Mesures de performances de dispositif

Simulations/Théorie

- Electrical Engineering domain :



+ threefold approach :  
Theory/Experiment/Numerical modelling

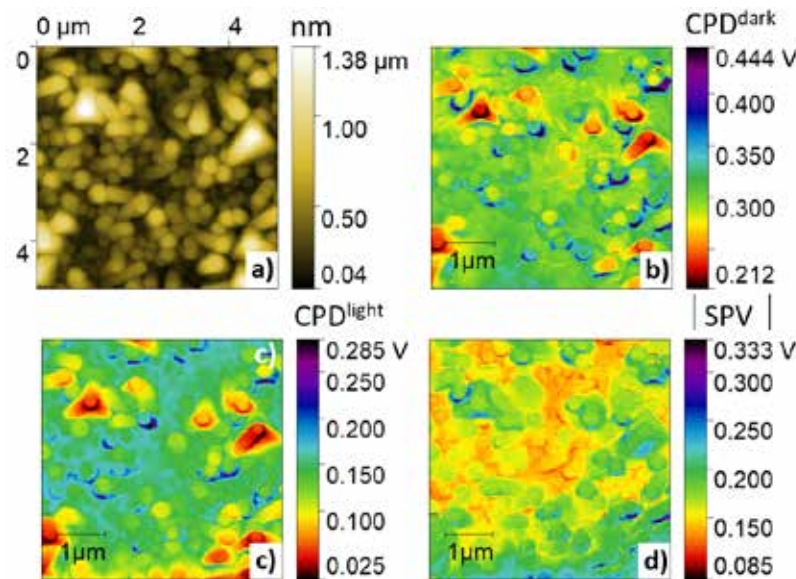
# Electric, Optoelectronic and Structural characterizations from nano to macro scales

- Experimental platforms with associated instrumental developments and expertise applied to :

## - Photovoltaics nanostructures or nanoscale building blocks

Nanowires solar cells, heterointerfaces c-Si/a-Si:H and poly-Si/SiOx/c-Si

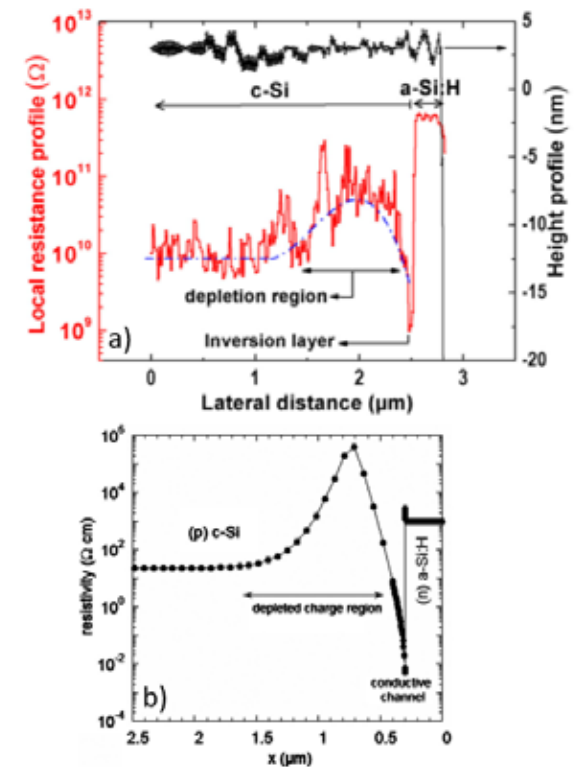
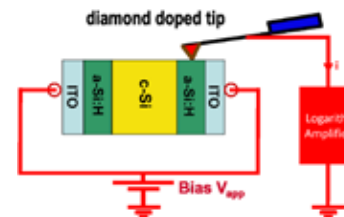
Local VOC Measurements by Kelvin Probe Force Microscopy Applied on P-I-N Radial Junction Si Nanowires, C. Marchat et al., *Nanoscale Research Letters*, 14 (2019), 398.



ANR SOLARIUM (2014-2018)

Nanowires EMPIR 19ENG05 (EURAMET; 2020-2023)

Recent Progress in Understanding the Properties of the Amorphous Silicon/Crystalline Silicon Interface, J.-P. Kleider et al., *Physica Status Solidi A* 216, (2019) 1800877.

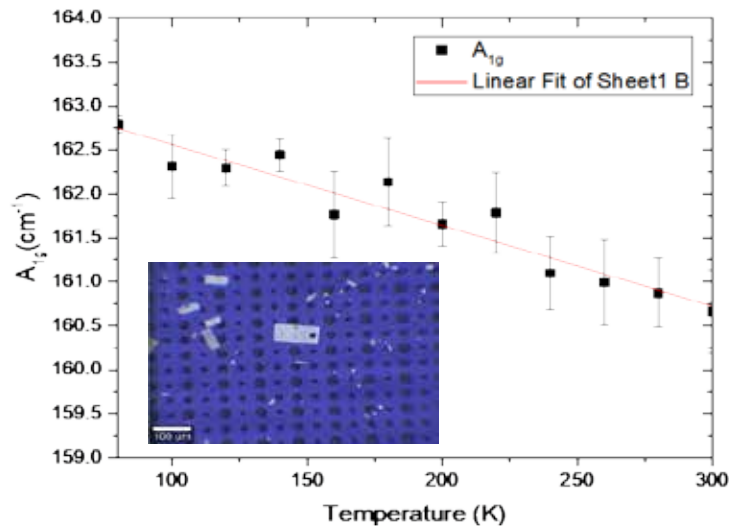


Involved researchers : J. Alvarez, J.-P. Kleider  
Collaborations : LPICM, INES, LNE

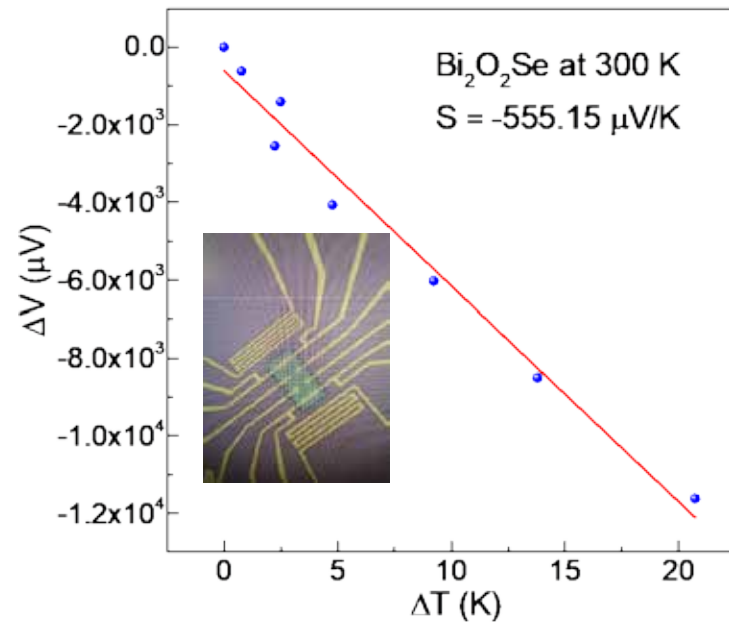
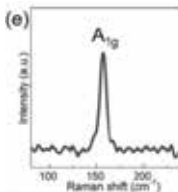
# Electric, Optoelectronic and Structural characterizations from nano to macro scales

## - Thermoelectric properties

2D layers: graphene, oxy-chalcogenide ( $\text{Bi}_2\text{O}_2\text{Se}$ ), 2D BiTe crystals



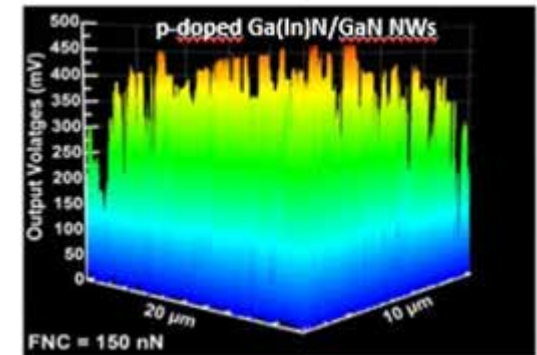
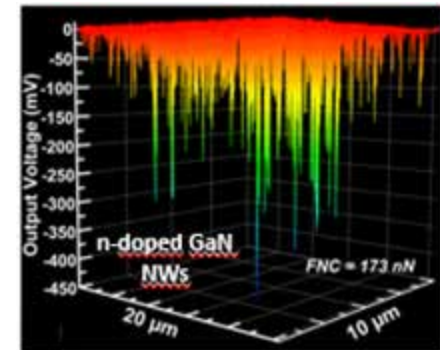
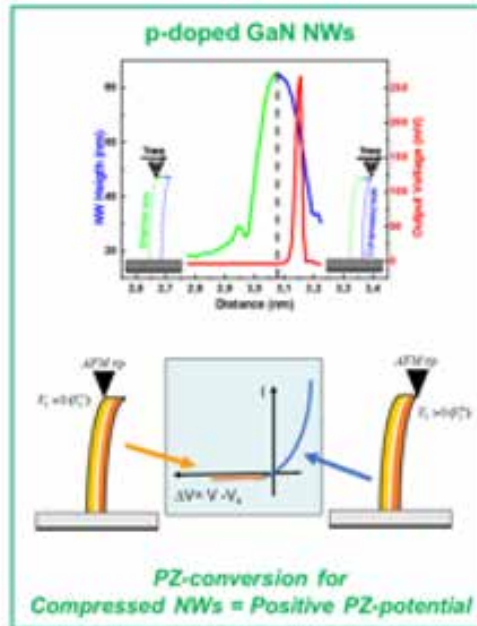
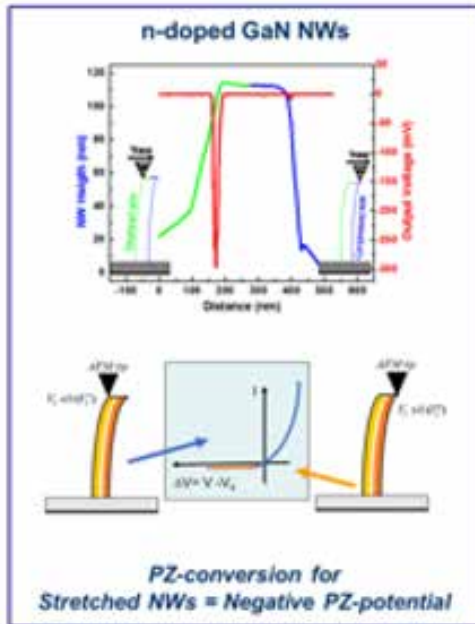
- suspended sample i.e. well defined membrane
- fit using FE modelling
- $20 \text{ Wm}^{-1}\text{K}^{-1}$



Thermoelectric power measurements

# Electric, Optoelectronic and Structural characterizations from nano to macro scales

## - Piezoelectric properties : GaN and GaInN/GaN Nanowires



Strong correlation deformation, NW properties and piezoelectric potential in NWs

3D-mapping piezo-conversion by Resiscope module

ANR SCENIC 2021-  
Nanowires EMPIR 19ENG05 (EURAMET; 2020-2023)

Involved researchers : P. Chrétien, F. Houzé  
Collaborations : GeePs-C2N

## Scanning Probe, Raman and Photoluminescence Microscopies; Electrical and Photoemission spectroscopies

- **Scanning Probe Microscopy** tools :

- 7 AFM : Bruker (multimode, enviroscope), Keysight (5500, Picomaps), CSI(Nanoobserver), Nanosurf (DriveAFM), Witec and AIST-NT (Trios)

Analysis modes : Résiscope contact/intermittent, KPFM (single or dual pass, peakForce, LFM/EFM/MFM); Scan size max : XY: 150 $\mu$ m x 150 $\mu$ m, Z: 5 $\mu$ m

- **Raman** (405, 532 nm) and **PL** (785, 532 nm) Witec **confocal microscopy** :

Spectral resolution (1 cm<sup>-1</sup> for Raman), spatial resolution (200-300 nm). PL: visible and near-IR imaging spectrometer ; transient PL (ps resolution); two-photons PL; mini cryostat (80-550 K)

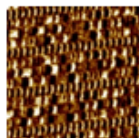
- **Photoemission spectroscopy** analysis (XPS/UPS PHI 5000 VersaProbe) :

Physico-chemical study of materials (micro-analysis: 10 $\mu$ m/100nm); valence band and work function measurements; depth profiling (Ar/C60); preparation chamber

- **Capacitance and Admittance spectroscopy** (70-350K; 1-100 MHz)



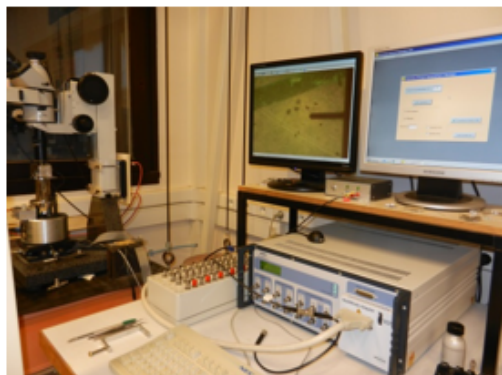
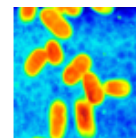
# PLATEFORME Microscopie AFM



5500 (Keysight)

7 AFMs

NanoObserver (CSI)



**AFM Multimode** (Bruker)

**- AFM Haute résolution:**

Tailles de scan maxi :

XY: 150 $\mu$ m x 150 $\mu$ m, Z: 5 $\mu$ m

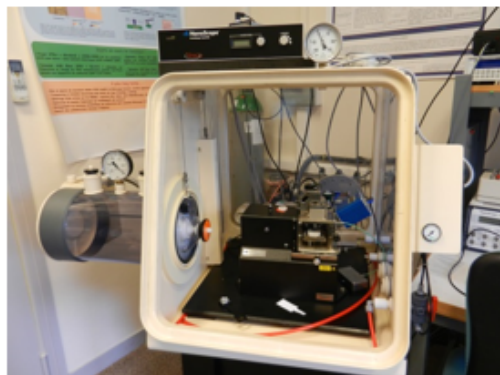
XY: 10 $\mu$ m x 10 $\mu$ m, Z: 2,5 $\mu$ m

Type de mesure (Mode):

- Contact
- Tapping
- LFM/EFM/MFM/KFM (double pass)
- Mesures en milieu liquide

**- Peak Force Tapping (Intermittent)**

**- Mesure Electrique AFM/Résiscope mode contact & Intermittent**



**AFM Enviroscope** (Bruker)

- AFM avec chambre environnementale et vide ( $\rightarrow$  10<sup>-3</sup> Torr) & Boite à gants**
- Mesures en température ( $\rightarrow$  250°C).**

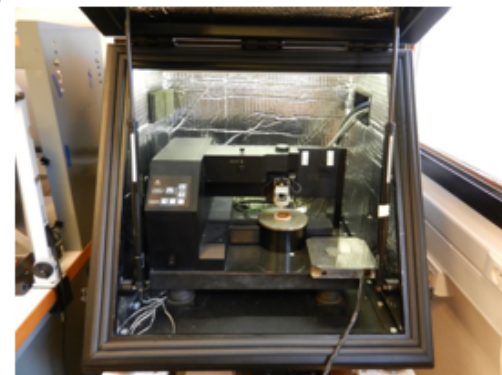
Taille de scan maxi :

XY: 90 $\mu$ m x 90 $\mu$ m, Z: 5 $\mu$ m

Type de mesure (Mode):

- Contact
- Tapping
- LFM/EFM/MFM/KFM (double pass)

**- Mesure Electrique AFM/Résiscope mode contact**



**AFM PicoMaps** (keysight)

- AFM dédié aux grands échantillons**
- Platine XYZ optionnelle permettant de très larges scans**

Tailles de scan maxi :

- Conventionnel :

XY: 100 $\mu$ m x 100 $\mu$ m, Z: 8 $\mu$ m

- **Sur platine large scans (nPoint) :**

**XY: 600 $\mu$ m x 600 $\mu$ m, hauteur Z: 70 $\mu$ m**

Types de mesure (Mode):

- Mode contact
- LFM/EFM/MFM

**- Mesure Electrique AFM/Résiscope en mode contact**

# **PLATEFORME Microscopies Raman et Photoluminescence**

# Plateforme de microscopie confocale:



## Moyens:

*Mesures co-localisées à l'échelle sub micronique*

- **Raman:**

Longueur d'onde: 532 nm

Résolution spatiale: XY: 250nm; Z: 1  $\mu$ m

- **PL:**

Longueurs d'onde: 532, 785 nm

Plage de détection: 535-1700 nm

- **TRPL:**

Longueur d'onde: 640 nm

Résolution temporelle: 100 ps – 10  $\mu$ s

- **Cartographies en Température**

[80-550K]

Résolution spatiale: XY: 1  $\mu$ m; Z: 3  $\mu$ m



- **AFM**

➤ AC

➤ Non Contact

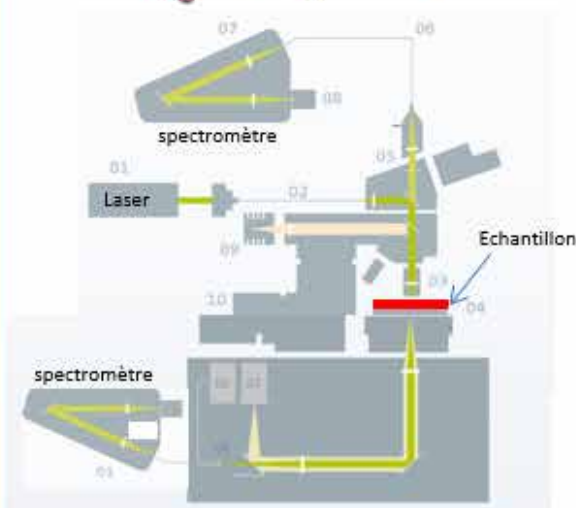
➤ Contact

- **Extensions électriques:**

➤ CP-AFM

➤ Light Beam Induced Current (LBIC)

➤ Electroluminescence (EL)



## Prochains développements:

➤ Luminescence à deux photons

➤ Raman à 405 nm

➤ Evolution CP-AFM



# PLATEFORME

# Spectroscopies Electroniques

# Plateforme Spectroscopies Electroniques

## PHI 5000 VersaProbe

Etude physico-chimique des matériaux (micro-analyse : 10 $\mu$ m/100nm)

### Analyse des premiers nanomètres

- Spectroscopies XPS et AES :

- Détection de tous les éléments (sauf H et He)
- Concentrations
- Etats chimiques

Neutralisation de charge (ions/électrons)

- Spectroscopie UPS :

- Etude des bandes de valence
- Mesure du travail de sortie

### Analyse plus en profondeur

- Profil non destructif (AR-XPS) / destructif (Ar/C60)



Etude des surfaces, volumes et interfaces de matériaux organiques et inorganiques