EPIPHY GROUP
Epitaxy and Physics of Heterostructures

iemn
Institut d'Electronique, de Microélectronique et de Nanotechnologie
UMR CNRS 8520

Permanent researchers : Djamila Hourlier (DR CNRS), Ludovic Desplanque (MCF), Dominique Vignaud (CR CNRS) and Xavier Wallart (DR CNRS)
Engineers: C.Coinon, J.-L.Codron
Post-doc: I.Colambo, G.Deokar
PhD Students: M.Fahed, V.K. Chinni , A.Bucamp, J. Hadid, S. Shishodia, S. Venkatachalam

Main thematics

Elaboration and characterization of (nano)materials for high frequency, low power applications and advanced devices:

- III- V semiconductors : 2D heterostructures and nanostructures
- 2D materials : graphene epitaxy on SiC and metals – hBN epitaxy - Transition Metal Dichalcogenides (TMDC)
- Organic-inorganic composite nanomaterials

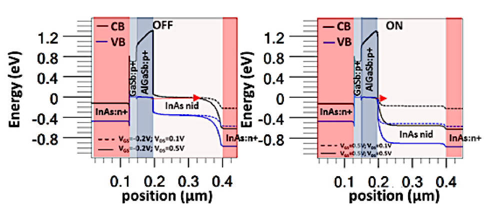
General objectives

- Growth of controlled structures for device purposes
- Understanding growth mechanisms
- Development of new processes or material heterostructures for advanced devices
- In-depth physical and chemical characterization of grown materials

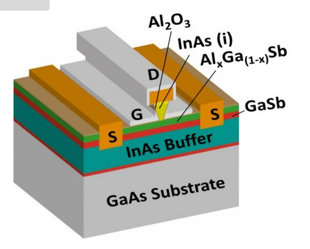
III-V semiconductor epitaxy for advanced electronic devices

Epitaxy of InAs/AlGaSb heterostructures for Tunnel FET
(Coll. Anode Group)

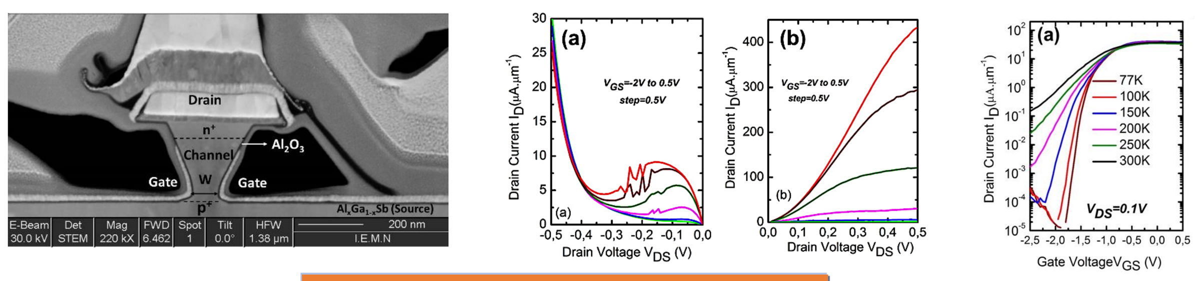
Context: Si CMOS power consumption 'crisis' and poor ON conductance of TFET
Goal: Use of low effective mass III-V SCs and near broken gap heterostructures



ANR Project JCJC *SAMBA*
PhD V.K.Chinni



Band offset + Strain relaxation engineering + vertical processing

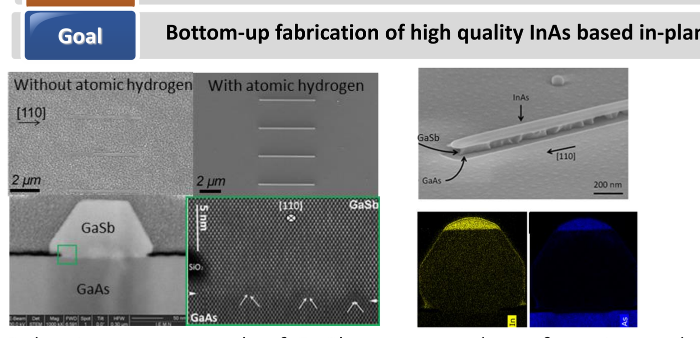


- First vertical AlGaSb/InAs TFET on GaAs
- Record I_{ON} > 430 µA.µm-1

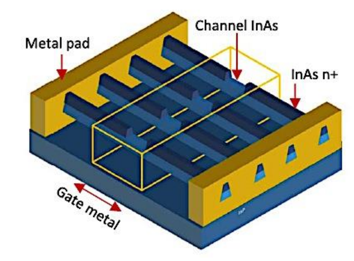
IEEE J. Electron Devices Soc. 5, 53 (2017)

Selective area Molecular Beam Epitaxy for InAs Nanowire MOSFET
(coll. Anode Group, C2N)

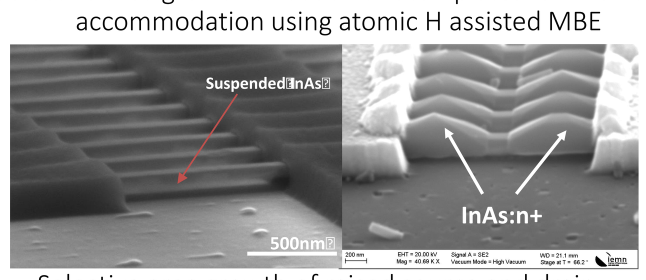
Context: III-V CMOS and advanced quantum devices
Goal: Bottom-up fabrication of high quality InAs based in-plane nanostructures



Selective area growth of GaSb nanotemplates for mismatch accommodation using atomic H assisted MBE



ANR Project *MOSINAS*
PhD M.Fahed, M.Pastorek (Anode)



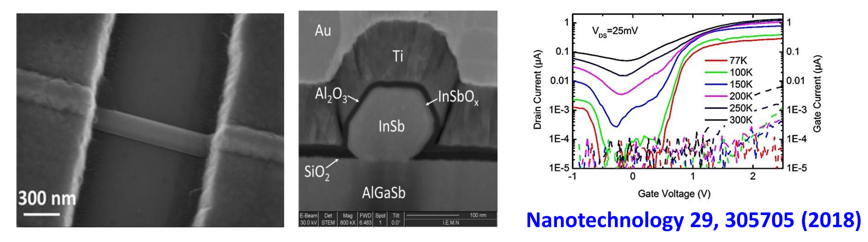
Selective area growth of raised source and drain contacts using HSQ dummy gate

- Selective area growth of InAs/GaSb
- In-plane InAs NW MOSFET without dry etching nor transfer
- Bottom-up sub-30 nm gate length MOSFET

Nanotechnology 27, 505301 (2016)
J. Cryst. Growth 477, 45 (2017)
Nanotechnology 30, 035301 (2019)

On-going studies and outlook...

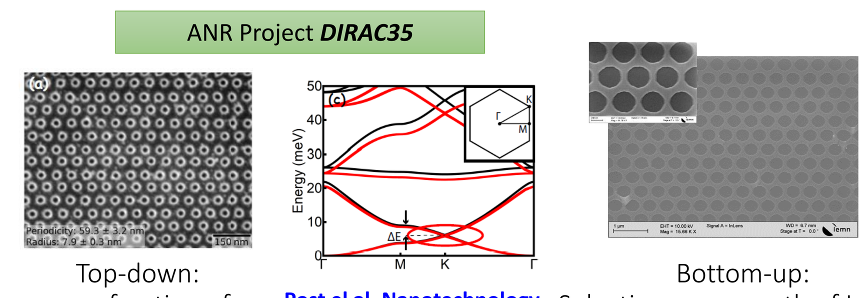
Selective Growth and characterization of in-plane InSb NW for spin devices



Nanotechnology 29, 305705 (2018)

III-V based artificial graphene using top-down and bottom-up honeycomb lattice nanostructuration
(Coll. Physics Group, Debye Institute of Nanomaterials Science, LPCO)

ANR Project *DIRAC3S*



Top-down: nanoperforation of an InGaAs QW

Post el al, Nanotechnology (2019), to be published

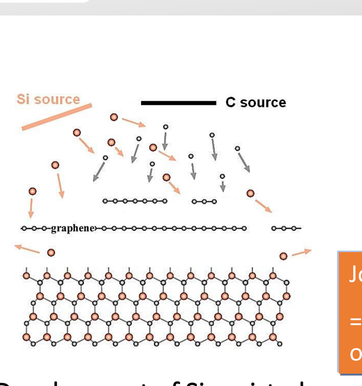
Bottom-up: Selective area growth of InGaAs using a dielectric mask

Epitaxy of 2D materials

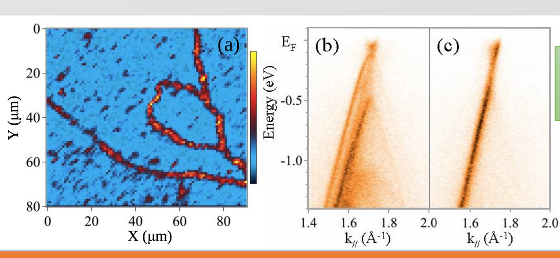
MBE growth of Graphene
(Coll. Synchrotron Soleil)

Context:
- Graphene on SiC generally obtained by graphitization
- Mastered process on Si face SiC face but not on the most promising C face

Goal:
- Molecular beam epitaxy of graphene on SiC C face using a C source
- Angle-Resolved PhotoEmission Spectroscopy (ARPES) studies of the electronic structure of epitaxial graphene

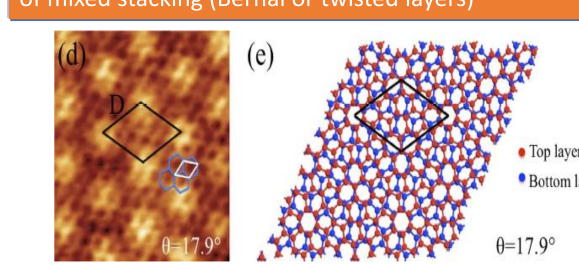


Development of Si-assisted MBE of graphene to increase the growth temperature



European Project *GRADE*
Post Doc I.Colambo

- Joint nano-ARPES / Scanning Tunneling Microscopy study
- => complex structure of graphene on C face of SiC, because of mixed stacking (Bernal or twisted layers)



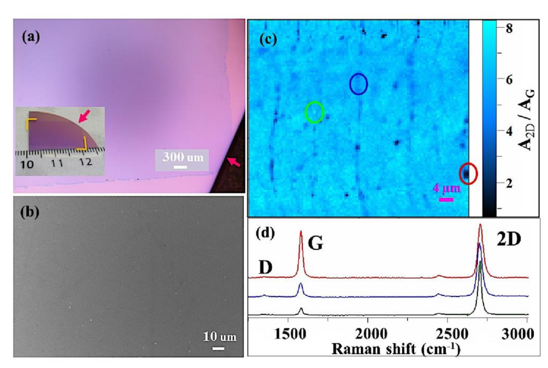
Phys. Rev. B 92, 035105 (2015)
Sci. Rep. 6, 27261 (2016)

Graphene growth by CVD on metal
(Coll. Carbon Team)

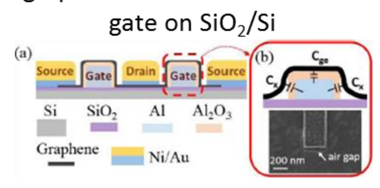
Context:
- Growth of graphene by chemical vapor deposition on metals is a rather robust process, but requires transfer on other (insulating) substrates

Goal:
- Optimisation of the CVD growth, towards monolayer graphene
- Development of the wet transfer process

ANR Project *GRACY*
Post Doc G.Deokar

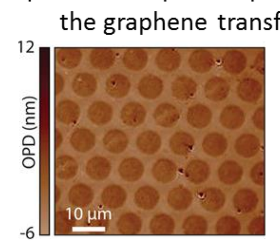


graphene FETs with Al bottom gate on SiO_2/Si



Wei et al. IEEE Tr. Electr. Dev. 62, 2769 (2015)

quantitative phase optical imaging of the graphene transfer process



Graphene monolayer array on glass

Khadir et al. ACS Phot. 4, 3130 (2017)

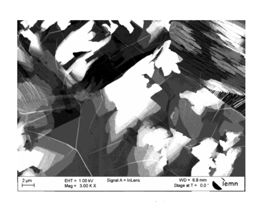
=> High-quality monolayer graphene transferred on many substrates (Si, Au, glass, SiC, kapton, Si nanorod array...)

Deokar et al. Carbon 89, 82 (2015)

On-going studies and outlook...

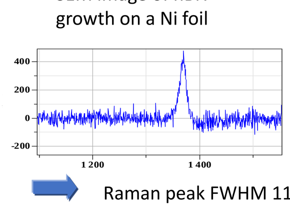
Graphene/hBN heterostructures

- Goal : High quality large area hBN layer
- Molecular Beam Epitaxy
- 2 approaches
  - Atomic B effusion cell + N2 RF plasma cell
  - $B_3N_3H_6$ gas injector + thermal cracking



SEM image of hBN growth on a Ni foil

PhD thesis J. Hadid



Raman peak FWHM 11 cm-1

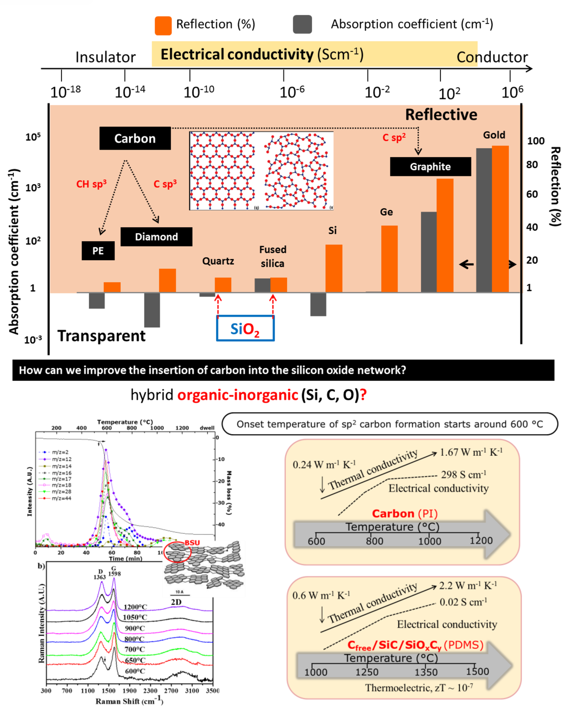
MBE growth of Transition Metal DiChalcogenides (TMDCs)

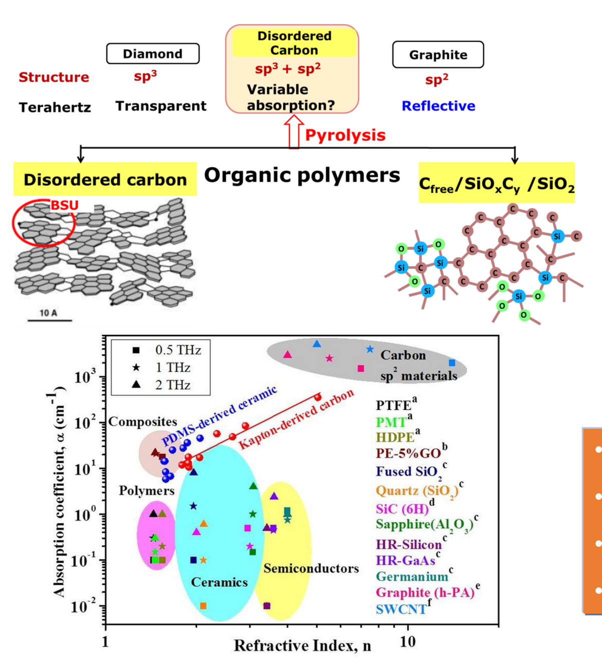
- Context :
  - Unique properties of TMDCs
  - Studies and applications mainly restricted to exfoliated materials
- Goal : large scale growth of
  - TMDC heterostructures
  - Hybrid SC/TMDC heterostructures
- New MBE reactor (scheduled installation in Fall 2019)
- UHV coupling with a III-V MBE reactor and an ESCA system

Polymer-derived carbon materials

Polymer-derived carbon materials for THz wave absorption
(Coll. THz Photonics Group)

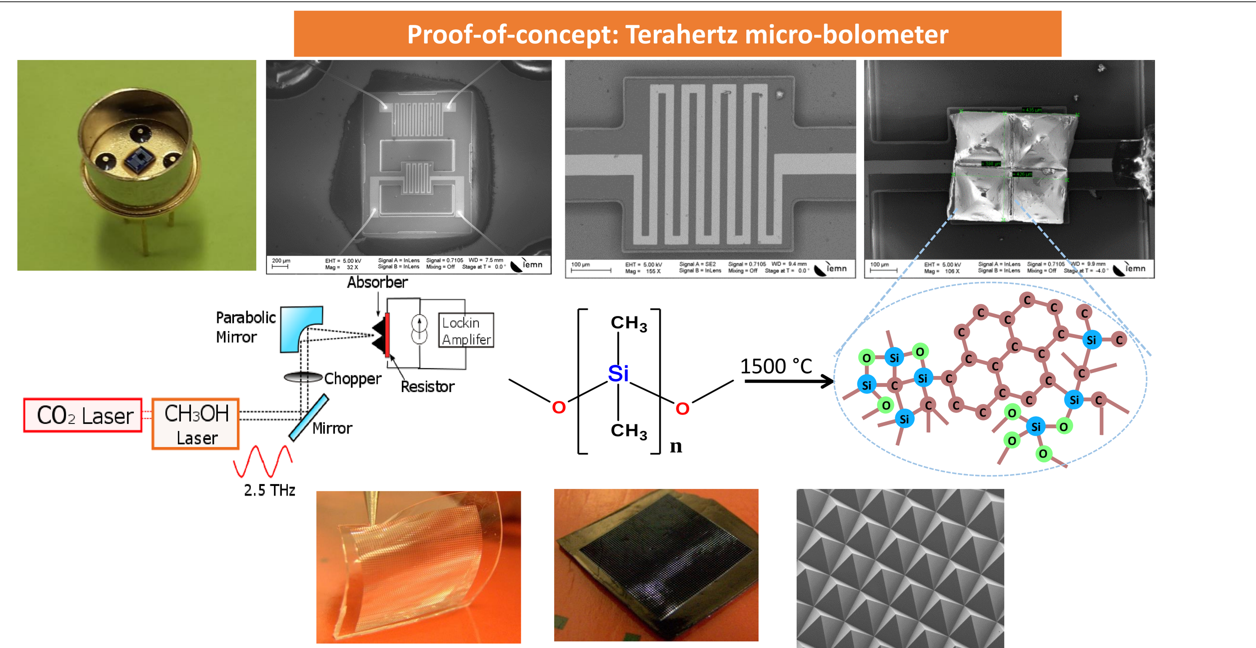
Context: Limited number of efficient and tunable THz absorbers
Goal: Efficient and broadband terahertz absorber via pyrolysis of polymers (organic or hybrid organic-inorganic)





Comparison of polymer-derived material properties with the state-of-the art

Proof-of-concept: Terahertz micro-bolometer



- Higher absorption coefficient
- Variable absorption coefficient
- Harsh atmosphere resistant
- Proof-of-concept of a THz micro-bolometer

PhD S. Venkatachalam

Carbon 100, 158 (2016)
Carbon 114, 134 (2017)
J. Anal. Appl. Pyrolysis 123, 296 (2017)
Materials & Design 120, 1 (2017)

On-going studies and outlook...

High temperature thermoelectric materials
(Coll. UDSMM)

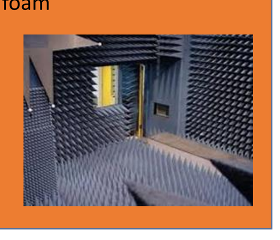
PhD S. Shisodia

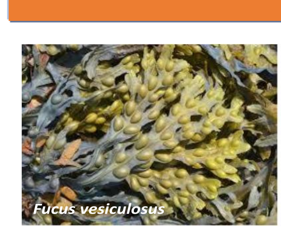
Incorporation of metal particles to increase the electrical conductivity and Seebeck coefficient of polymer derived carbon materials

Eco-friendly electromagnetic absorber: Carbon-based composites as microwave absorbers for an application in anechoic chamber
(Coll. IETR)

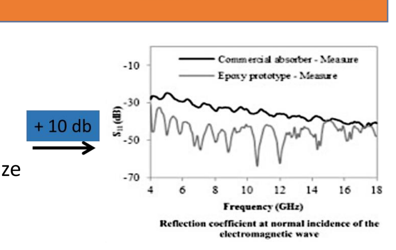
PEPS-CNRS *ARCHIVERT*

- Context :
- Commercial absorbers : carbon particles loaded polyurethane foam
- Expensive, subject to damage, < 200 MHz ??
- Better absorption performance with Carbon-Epoxy prototype
- Goal:
- Carbon embedded into EPOXY matrix
- Use of seaweeds as eco-friendly carbon source





Lightweight
High performance
Cost effective
Desirable shape and size



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