PHYSICS GROUP
Experimental activities

Permanent researchers : A. DEVOS, H. DIESINGER, B. GRANDIDIER, R. LETURCQ, T. MÉLIN, D. STIÉVENARD

In the Physics group, we study thin layers, hetero- and periodic structures, individual or assemblies of biomolecules and of low-diensional materials of high interest for electronics, optics, acoustics, opto-electronics and nanotechnology. We combine theoretical and experimental research in several directions: transport, optoelectronic properties and theoretical studies of semiconductor nanostructures ; phononics/phoXonics, plasmonics, and nano-acoustics in micro and nanostuctured materials ; structure and dynamical properties of materials.

ULTRAFAST ACOUSTICS

acoustics at nanoscale using ultrashort laser pulses

Probing elastic properties using optics from micro to nanoscale on various, as deposited, materials.

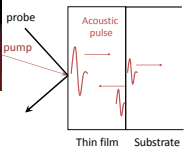
CNRS Patented technology: APiC Spectroscopy in Ultrafast Acoustics

Topics: fundamental/applied
- Hypersonic phononic crystals
- Phonons in Membranes and Quantum dots
- (Hyper)sound attenuation in glasses
- Thin-film characterization

MENAPiC

Spin-off launched in 2010

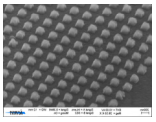
Pump-probe setup

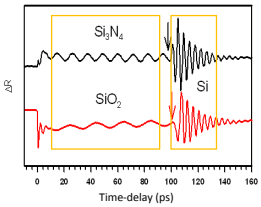


Tunable Ultrashort laser

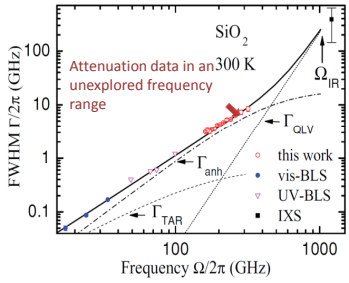
Idea

SONAR at nanoscale :
30 Å < thickness < 10 µm





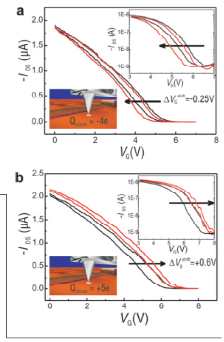
Thickness and sound velocity measurement

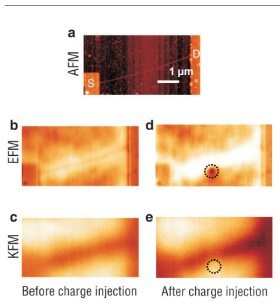


ELECTROSTATICS AND PHYSICS OF NANOSTRUCTURES

Probing the local electrostatic and electronic properties of nanostructures and nanodevices by atomic force microscopy

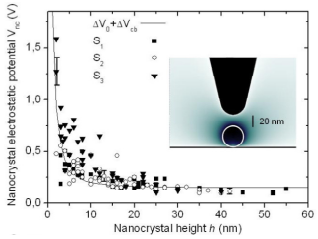
Carbon nanotube field effect transistor subjected to a local charge

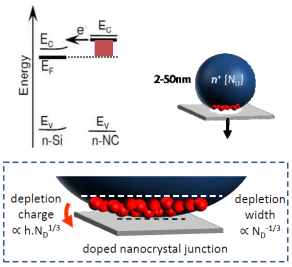




Local electrostatic mapping (EFM, KPFM) of the CNTFET charge sensor

Doped silicon nanocrystals studied by Kelvin probe force microscopy : quantum confinement and doped nanocrystal junctions

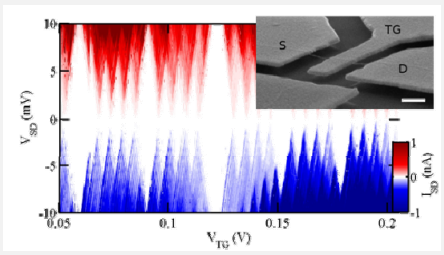




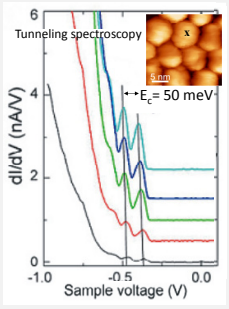
PHYSICS OF NANOSTRUCTURES AND QUANTUM DEVICES

Quantum effects & electron transport

Coulomb diamonds of a suspended carbon nanotube



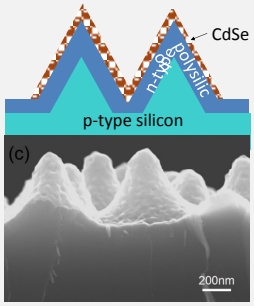
Coulomb energy in core-shell nanocrystals

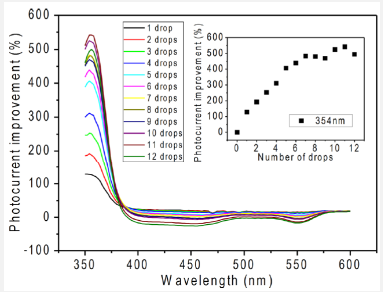


Nature Physics 5, 322 (2009); Phys. Rev. Lett. 105, 226404 (2010); Phys. Rev. B 81, 201303 (2010); Phys. Rev. B 84, 195133 (2011)

Photovoltaics with nanomaterials

Enhanced performance of solar cells via luminescent downshifting



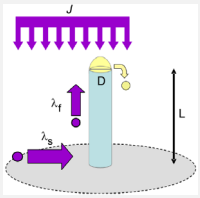


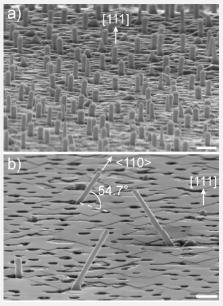
Nanotechnol. 22, 315710 (2011); J. Appl. Phys. 112, 033506 (2012); Appl. Phys. Lett. 103, 051102 (2013)

Nanowires : grown, structure & transport

MBE-growth

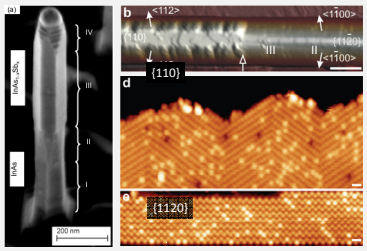
a) Si and b) Ge NWs





Nanoscale Res. Lett. 6, 113 (2011)
Phys. Rev. Lett. 108, 105501 (2012)

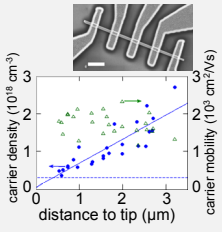
Surface structure of semiconductor NWs



Phys. Rev. B (2010), Nanotechnol. (2012) ; Appl. Phys. Lett. (2013)

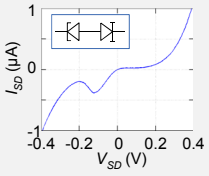
Transport

Inhomogeneous doping of Si-doped InAs NWs (n-type)



Appl. Phys. Lett. (2013)

Sharp tunnel junction obtained by chemical S-passivation on Be-doped InAs NWs (*p*-type)



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

cnrs · Université Lille1 Sciences et Technologies · Université de Valenciennes et du Hainaut-Cambrésis · ISEN école d'ingénieurs · RENATECH

PHYSICS GROUP
Theory and simulation

Permanent researchers : G. ALLAN, A. AKJOUJ, F. CLERI, C. DELERUE, B. DJAFARI-ROUHANI, L. DOBRZYNSKI, C. KRZEMINSKI, I. LEFEBVRE, E. LAMPIN, G.LÉVÊQUE, P-L. PALLA, Y. PENNEC

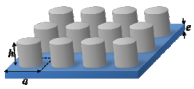
EPHONI PHONONIC, NANOPHOTONIC AND INTERFACES

We currently study 1D/2D periodic structures of high interest for technological breakthroughs in optics, acoustics, opto-mechanics and nanotechnology. We combine theoretical research (FE, FDTD, PWE, Green's fuctions methods) and experimental issues in collaborations with national and international groups.

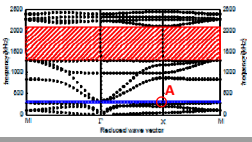
Phononic Crystals and Acoustic Metamaterials

- Engineering of band gaps in Phononic crystal slabs: Bragg gaps and resonance gaps.
- Tunable phononic crystals: Effect of external stimuli on dispersion curves.
- Extraordinary Acoustic Transmission, refractive properties and negative refraction.

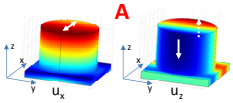
Stubbed phononic membrane.



Large Bragg gap (red) and Low Frequency Gap (blue).



Origin of the Low Frequency Gap: localization of the elastic field

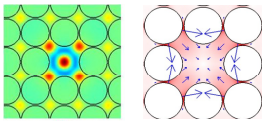


Phoxonic crystals

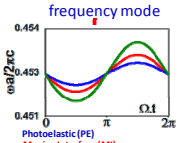
- Simultaneous confinement of phonons and photons.
- Enhanced opto-mechanical couplings.

Cavity in 2D infinite crystal of air in silicon (a ~ 500nm)

Simultaneous confinement of the photonic (λ ~ 1550nm) (left) and the phononic (f ~ few GHz) (right) waves



Acoustic modulation of the photonic cavity frequency mode

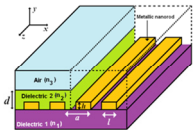


Photoelastic (PE)
Moving Interface (MI)
(PE + MI)

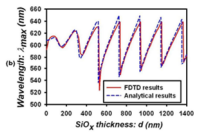
Photonics and plasmonics nanostructures

- Cavity coupled plasmonic waveguides. Application to filtering and sensing
- Plasmon resonance of nanoparticles embedded in dielectrics.
- Light absorption in Si and semiconductor nanowires. Application to photovoltaics

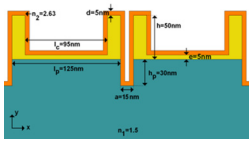
The localized-plasmon-resonance wavelength of metal nanowires oscillates with the thickness of an overcoating dielectric layer, even at long distances.



This long-range oscillation results from the interaction between the layer Fabry-Pérot modes with the wire plasmon mode.

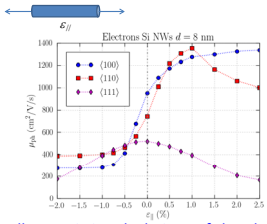


More elaborated geometries allow to achieve very high sensitivities, of about 900 nm/RIU at a resonnace wavelength of 1500 nm, even with 2D structures.



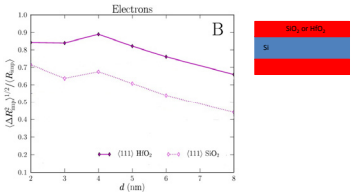
THEORETICAL SPECTROSCOPY OF SEMICONDUCTOR NANOSTRUCTURES

- Optical spectroscopy of semiconductor nanocrystals :
  - nanocrystals of chalcogenides (HgTe, PbSe, PbTe, PbS)
  - carrier multiplication for photovoltaics
  - 2D arrays of nanocrystals
- Transport properties of ultimate Si (Ge) nanowires (NWs)
  - variability in NW transistors
  - phonon-limited mobility
  - strain engineering



Fully atomistic calculations of the phonon-limited mobility in Si NWs under strain.

Mean variation of the electron resistance induced by a single B impurity in a Si nanowire.

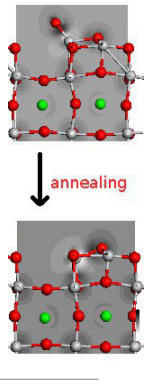


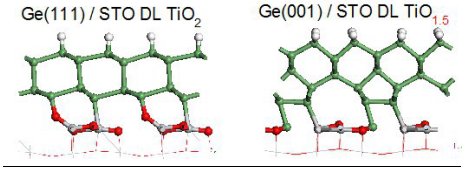
TETRAHEDRAL SEMICONDUCTOR ON PEROVSKITE OXIDES

Perovskite oxide surfaces
- $SrTiO_3$ reconstructions (double layer 2X1 TiO_2)
- $SrTiO_3$ oxygen-depleted reconstruction

Interfaces structure and growth routes
- Ge(001) ou Ge(111) on $SrTiO_3$(001)

Annealing effect on the SrTiO3 DL 2X1 TIO2 surface

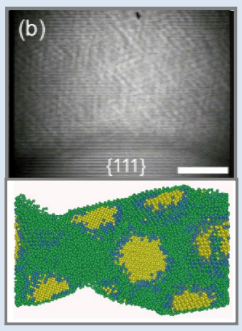




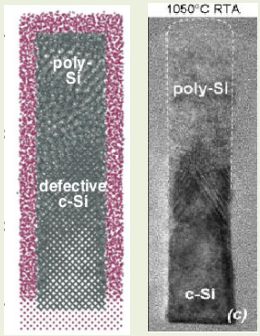
Interface and growth direction of Ge on $SrTiO_3$ surface

STRUCTURE AND DYNAMICS OF NANOMATERIALS

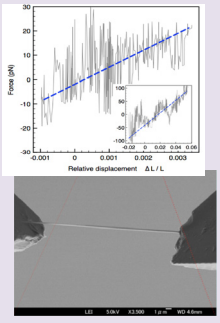
We focus on the theory and computer simulation (by Molecular Dynamics, Monte Carlo, statistical modelling) of the thermodynamics and the physical chemistry of nanostructured systems, of macromolecular aggregates and biomolecules for nanotechnology, under various external constraints (thermal, mechanical, chemical, etc.).



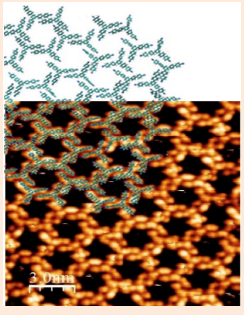
All-atom molecular dynamics simulation of a superplastically deformed poly-Si nanostructure, at 20-fold elongation. Above, experimental TEM image of a MEMS nanocontact which inspired the computer simulation (Cnrs-LIMMS Tokyo).



Molecular dynamics simulations of a FinFET device (Philips) to study the dynamical growth of the Si/oxyde interface. On the right, experimental TEM image after thermal annealing.



Molecular dynamics simulations of a stretched DNA artificial structure, and its stress-strain plot for estimating Young's modulus. Bottom: SEM micrograph (Cnrs-LIMMS Tokyo) of a DNA bundle stretched between the tips of MEMS nano tweezers.



A combined molecular dynamics, Monte-Carlo and metadynamics simulation of a self-assembled monolayer of tricyano-biphenil-benzene molecules on the Si:B(111) surface. The simulation result is superimposed on the STM image (IEMN)

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