2017 Annual Report

LPICM
Laboratoire de Physique des Interfaces et des Couches Minces

New Platforms
Support Teams
Collaborations
Prizes & Distinctions
Publications
IN A FEW WORDS

Pere ROCA i Cabarrocas, Director of LPICM

LPICM is a multidisciplinary laboratory where research and innovation are located at the crossroads of various disciplines: Thin Film deposition processes, Materials Science, Physics, Chemistry, Electronics and Optics. Our research, based on bottomup approaches, relies on the optimization of materials synthesis thanks to in-situ diagnostics, supported by modeling and numerical simulations.

LPICM researchers and engineers have continued to combine fundamental and applied studies to develop innovative plasma processes, optical characterization techniques such as Mueller polarimetry, as well as Enhanced Near Field Techniques (e.g. TERS) for the study of nanometric objects. Our specificity is the ability to cover the entire value chain of thin films, from atoms and molecules (NanoMax, ab initio modeling) to electronic devices (solar cells, OLEDs, batteries, sensors,...). The same applies in the biomedical field where research spans from fundamental studies (Mueller algebra, tissue polarimetry) to optical instruments for in vivo cancer detection (digital histology).

2017 has been another intense and productive year with two exceptional visitors: French President Emmanuel Macron to NanoMax and Total CEO Phillipe Pouyanné about our joint research team. Six new PhD students have joined LPICM, 20 interns have contributed with their research as well as three visiting professors (Meredith Kupinski, Sergej Baranovski, Ekaterina Borisova). Moreover during this year we have started the ERC starting grant project AquaRaman, renewed the joint research team with Total and signed the ANR industrial chair Pistol. But there is much more, please take a look to the report.

All the results contained here would have not been possible without the continuous commitment of our support teams: BEER, G2I and Administration. Many thanks to all of them, and to all the lab members, for making of LPICM a unique place to work.

Contact:
pere.roca@polytechnique.edu
NANOSIL

Plasma Processes & Nanostructured Materials for Photovoltaic & Optoelectrics
Introduction

The heart of the research activity of the NanoSil group continues to be plasma processes and nanostructured materials for large-area optoelectronics, particularly for photovoltaics. With this core expertise, we perform research going from fundamental plasma studies to processing, on to materials and devices, and through to characterization.

This year saw the end of two projects (ANR Projects APOCALYPSO), and the start of another (ANR HexaNW) while other projects continued to progress and produce good scientific results (ANR Projects, Platofil, Solarium, INDEED, IMPETUS, and PERSIL, as well as U. Paris Saclay Project MOMENTOM).

NanoSil’s relationship with our most important industrial partner in our work, Total, continues to flourish. We continue to work closely with them in the Ile-de-France Photovoltaics Institute (IPVF), as well as with our other industrial and academic collaborators.

In addition, 2017 saw the inauguration of the ANR Industrial Chair “PISTOL”, a new collaboration between the LPICM, Ecole Polytechnique, CNRS and Total on the topic of novel plasma processes. This chair marks a new direction in our research with Total, as it broadens the scope of our collaboration beyond PV, towards applications in microelectronics, display, sensors and more.

A key theme in the work of NanoSil is finding real-world applications for the discoveries we unveil. In this direction, we continue to work with our many other industrial partners (SOLAYL, SOLEMS, Riber,...) and a plethora of academic partners.

From all the great work that went on this year, here are a few highlights!

Erik Johnson, Group Director of NanoSil

Contact:
erik.johnson@polytechnique.edu
We have demonstrated the synthesis of tetragonal Si at 200 °C using plasma enhanced chemical vapor deposition. By combining X-ray diffraction and high resolution transmission electron microscopy measurements, we found that the epitaxial layer has smaller in-plane but larger out-of-plane lattice parameters as compared to the crystalline substrate. We attribute the formation of tetragonal Si to the unique cluster-assisted epitaxy process, although other possible reasons including host sites of hydrogen atoms and thermal expansion coefficients have also been analyzed.

Two dimensional high resolution XRD reciprocal space maps showing the peak of the c-Si epi-layer shifted with respect to that of the c-Si substrate. Numerical (Fourier filtered) darkfield images reveal the presence of dislocations at the interface.


Contact: pere.roca@polytechnique.edu
To circumvent the challenge of growing silicene on metallic substrates, we have directly deposited silicon on a chemically inert graphite substrate at room temperature.

Using on atomic force microscopy, scanning tunneling microscopy, and *ab initio* molecular dynamics simulations, we have revealed the growth of silicon nanosheets where the substrate–silicon interaction is minimized. Scanning tunneling microscopy measurements clearly display the atomically resolved unit cell and the slight buckling of the silicene honeycomb structure.

Observation of the metastable hexagonal phase of silicon in nanowires

The 2H polytype does not appear in the phase diagram of silicon. However, calculations show that 2H Si nanowires (NWs) would have a direct band gap, and correlatively higher optical absorption and luminescence yields than standard SiNWs.

Top: schematic of the growth. Bottom: stability of the structure upon annealing at 700°C.

We have demonstrated that Si NWs having the 2H phase can be produced by the vapour-liquid-solid method in a PECVD reactor: TEM characterizations using [1-210] zone axis show that the structure of several NWs is essentially 2H. This is the first unambiguous proof of the natural occurrence of this metastable phase to our knowledge. In situ annealing shows that the structure remains stable at 700°C.


Contact: jean-luc.maurice@polytechnique.edu
We have studied the performance of AlGaAs/SiGe tandem device performance using advanced optical and electrical modeling of the devices. It has been shown that the performance can reach 37% efficiency with an optimized III-V and SiGe subcells [1].

Below: Efficiency as a function of AlGaAs composition and SiGe thickness.

Above: Electro-magnetic field inside tandem device with grating at wavelength of 1000 nm.

Nanosized point contacts in c-Si solar cells

Simulations have recently shown that reducing the size of point contacts to the nanoscale can provide a new optimization point to trade-off surface passivation and series resistance. However, one must form these contacts in a cost-effective way. The thesis of Rasha Khoury focused on the use of sacrificial polystyrene spheres to form these point contacts.

In collaboration with our colleagues at GEEPS (SupElec) and UPC (Barcelona), Dr. Khoury demonstrated the formation of a dielectric mask with nanoholes using these spheres. By diffusing dopant through these holes, nano-sized point contacts were formed, and by using conductive AFM, these contacts were shown to present local photovoltaic behaviour.

Right: Current-voltage curves measured inside (black) or outside (colored) areas doped by diffusion through nanoholes in an oxide layer.

Left: Photocurrent map of array of doped nano-contacts formed by diffusion through holes in oxide layer, below.

Contact: erik.johnson@polytechnique.edu
Through the work of IPVF PhD student Fabien Lebreton, we have been able to show that the high fixed charge density (1·10^{12} \text{ cm}^{-2}) regularly reported in literature for Al_{2}O_{3} passivation layers is mainly trapped charges. We found that a low illumination of 1 mW.cm^{-2} is enough to inject electrons from the silicon substrate into Al_{2}O_{3} traps. Thanks to optical bandpass filters, we observed that 70% of the charge density at the Al_{2}O_{3}/c-Si interface are absent before illumination of the silicon substrate.

(a) PCD calibrated photoluminescence picture after 160h of illumination of a FZ c-Si wafer (3 \ \Omega.cm, 280\mu m thick) passivated by 20 nm of Al2O3 deposited at 250 °C. Numbers are places of different passband filters centered around different wavelength, 1: no filter; 2: 3.44 eV; 3: 2.88 eV; 4: 2.28 eV; 5: 1.28 eV

(b) Passivation results for the five different locations receiving different photon energy.

Contact: francois.silva@polytechnique.edu
Dry, plasma-based texturing to create low-reflectivity surfaces for PV is a promising option to achieve high optical performance from a broad range of silicon substrates. Many optical studies on such processes work on non-realistic, expensive, double-side polished substrates. Through the work of IPVF PhD candidate Guillaume Fischer, we studied the impact of the initial surface condition (SWS: slurry wire sawn, DWS: diamond wire sawn, DSP: double side polished, and LPD: lapped) on the process.

Using angularly and spectrally resolved optical reflectance techniques, we were able to observe the impact of the wafer type on the evolution in reflectance. This result could have consequences on the performance of devices throughout the day.

Guillaume Fischer, Etienne Drahi, Martin Foldyna, Thomas A. Germer, and Erik V. Johnson, *Optics Express* 25 (2017) 304532

Contact: erik.johnson@polytechnique.edu
In-situ characterization of nanowire growth

We have developed optical models for in-situ optical characterization of Si nanowires during their vapor-liquid-solid growth in plasma enhanced chemical vapor deposition reactor. Model allows to follow the growth for a better control of growth process.


Contact: martin.foldyna@polytechnique.edu
In addition to our important industrial contacts, NanoSil thrives on collaboration with the academic community within Europe and worldwide.

Sputtered NiO$_x$ layer for hole-contact. Result from Joint Research Lab with NAIST, Japan


Sunlight-thin nanophotonic monocrystalline silicon solar cell. EU Photonvoltaics Project

Contact: erik.johnson@polytechnique.edu
OLAE

Organic and Large Area Electronics
Introduction

Organic and hybrid large area devices have numerous advantages such as low cost of production, ease of design, light-weight deployment, and flexibility. The OLAЕ research team focuses on chemical synthesis, functionalization, integration and physical modelling of organic and hybrid materials, in connection with the design of high performance electronic large area devices. Based on a fundamental approach such as the synthesis of new molecules and polymers, functionalization of 1D and 2D materials and the modelling of charge transport, as well as on three dedicated technology facilities: CHIMORGА (organic material synthesis), ORGATECH (deposition, characterization of electronic devices) and PLATINE (Sensors elaboration and characterization), OLAЕ team aims to design reliable components for energy management (perovskite and tandem solar cells, OLED, LED) and sensors (biomedical, smart-farming and smart-cities applications). OLAЕ researchers collaborate with IPVФ but also with CEA and IFSTTAR in the framework of ORGASACLAY and NACRE joint research teams respectively.

Contact: yvan.bonnassieux@polytechnique.edu
In collaboration with Silvaco Europe, through Horizon 2020 Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE) Program (2015–2019) entitled DOMINO 645760 (Design Orientated Modeling for flexible electronics), we recently succeed in modeling transfer and output characteristics of OFETs based on a finite element method (FEM). The essence of the results is the use of the Gaussian density-of-states model for describing energetic states of disorder organic semiconductors as well as the expanded range of disorder that ensures the convergence of numerical calculation.

European Union’s Framework Programme
H2020-MSCA-RISE-2014

Contact:
yvan.bonnassieux@polytechnique.edu
Novel Fluorophores based on Regioselective Intramolecular Friedel-Crafts Acylation of the prene Ring Using Triflic Acid

Large polycyclic aromatic hydrocarbons are an important class of materials with useful optoelectronic properties. Acenes and p-conjugated materials composed of laterally fused benzenoid rings, have shown high charge mobility in organic fieldeffect transistors.

We have recently, shown that the extension of the pyrene ring from dimethyl 2,2’-(pyrene -1,6-diyl)di benzoate derivatives by an intramolecular Friedel–Crafts acylation can be realized in an efficient and regioselective manner using triflic acid as proton source.

Naphtho-tetracenone derivatives are obtained in high yields at room temperature while Bis-tetracene-diones are prepared upon heating. Both products display interesting fluorescence properties in the visible range with quantum yields varying from 50 to 60 %.


Contact: abderrahim.yassar@polytechnique.edu
Sensors for environment purposes are elaborated from the design of functional molecules to devices. Conjugated polymers are elements of choice for both their emissive and semi-conducting properties. They are used to elaborate solution and solid state optical sensors, and resistors where they are combined in synergy with carbon nanotubes.

Optical Sensor

Design and synthesis of conjugated polymers for the elaboration of optical sensors:

Conjugated Polymers/Carbon Nanotubes hybrids for the elaboration of electronic sensors:

Conjugated backbone

Sensitive and specific sensing

Wavelength [nm]

Intensity

380 400 420 440 460 480 500 520 540

0 100x10³ 200x10³ 300x10³ 400x10³ 500x10³ 600x10³ 700x10³

+ chlorine

Novel chemresistor prototypes for chemical water monitoring:
- 1st demonstration of CNT based sensors for hardness, nitrate and chloride monitoring
- 1st demonstration of 5 target multi-parameter CNT sensor array

Conjugated Polymers/Carbon Nanotubes hybrids for the elaboration of electronic sensors:

<table>
<thead>
<tr>
<th>pH</th>
<th>Chlorine</th>
<th>Nitrate</th>
<th>Calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer 1</td>
<td>5.7%</td>
<td>17%</td>
<td>16%</td>
</tr>
<tr>
<td>Polymer 2</td>
<td>5.2%</td>
<td>11%</td>
<td>16%</td>
</tr>
<tr>
<td>Polymer 3</td>
<td>3.8%</td>
<td>12%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Polymer 4</td>
<td>5.3%</td>
<td>12%</td>
<td>5.5%</td>
</tr>
<tr>
<td>el</td>
<td>6.6%</td>
<td>14%</td>
<td>7.5%</td>
</tr>
</tbody>
</table>

In-situ sensing, low power consumption, versatile and low-cost technology, IoT ready

Contact:
gael.zucchi@polytechnique.edu  
berengere.lebental@ifsttar.fr
First demonstration of real time detection of chloride or chlorine ingress and pH changes with CNT sensor array in Sense-city water network

Contact:
gael.zucchi@polytechnique.edu
berengere.lebental@ifsttar.fr
Creation of Startup Altaroad: generating traffic data for construction and transport

Development of two novel, massively multisensory prototypes, a mobile mat and a road-embedded mat tested in harsh construction site and on actual road structures.

Contact:
cecile.villette@altaroad.com
berengere.lebental@ifsttar.fr
The present work reports the first structure–property relationship study of a key class of organic semiconductors, that is, the four spirobifluorene positional isomers possessing a para-, meta- or ortho-linkage. The remarkable and surprising impact of the ring bridging and of the linkages on the electronic properties of the regioisomers has been particularly highlighted and rationalised. The impact of the ring bridging on the photophysical properties has been stressed with notably the different influence of the linkages and the bridge on the singlet and triplet excited states. The first member of a new family of spirobifluorenes substituted in the 1- position, which presents better performance in blue phosphorescent OLEDs than those of its regioisomers, is reported. These features highlight not only the great potential of 1-substituted spirobifluorenes, but also the remarkable impact of regioisomerism on electronic properties.

DOI: 10.1002/chem.201700570

Contact:  
bernard.geffroy@polytechnique.edu  
denis.Tondelier@Polytechnique.edu
First characterization of ionic migration in hybrid perovskite solar cells

In recent decades, the development of organic–inorganic hybrid perovskite solar cells (PSCs) has been increasing very quickly due to their high initial efficiency and low-cost process. However, key points such as crystal growth mechanisms, current–voltage hysteresis, and instability remain unexplained or misunderstood. Among several possibilities, ionic migration in PSCs has been suggested to explain the hysteresis effect. However, direct experimental evidence of ionic migration under operation or measurement conditions of PSCs is still missing. This work shows directly the ionic migration of halogen components (I− and Cl−) of a CH3NH3PbI3–xClx perovskite film under an applied bias using glow discharge optical emission spectrometry (GD-OES). Furthermore, no migration of lead and nitrogen ions is observed on a polarization time scale lower than 2 min. The ratio of fixed to mobile iodide ions is deduced from the evolution of the GD-OES profile lines as a function of the applied bias. The average length of iodide and chloride ion migration is deduced from the experimental results.

DOI: 10.1021/acsenergylett.7b00150

Contact:
bernard.geffroy@polytechnique.edu
Fabrication of perovskite solar cells using sputter-processed CH3NH3PbI3 films

Perovskite/crystalline silicon tandem structures have attracted much attention as promising high-efficiency solar cells. To achieve higher efficiencies, a method of depositing perovskite films on textured substrates is required. In this work, we established the process of fabricating perovskite films by sputtering. Sputterprocessed perovskite films showed characteristics similar to those of their solution-processed counterparts. In addition, a power conversion efficiency of 1.84% was attained from solar cells employing sputter-processed films. Moreover, it was confirmed that homogeneous films can be obtained even on substrates with significant roughness. Our results indicate that sputtering is a promising method of achieving high-efficiency tandem cells.

Applied Physics Express 10, 094101 (2017)
https://doi.org/10.7567/APEX.10.094101

Contact: yvan.bonnassieux@polytechnique.edu
NANOMADE

NANOCARB (THALES)
NACRE (IFSTTAR)
Overview

Controlling nanomaterials synthesis in-place (at the heart of future devices) and with tailored properties is one of the nanotechnology’s essential challenges. Through an established nanomaterials expertise and unique synthesis capacity (carbon nanotubes an nanofibers, inorganic nanowires, graphene and graphene related 2D carbon layer, transition metal dichalcogenides, nanoparticles and various types of core-shell hybrid nanostructures), NanoMaDe addresses these challenges by combining the fundamental studies of the growth mechanism of nanomaterials with the development of innovative synthesis tools and processing methods for fabricating devices of multifunctionality for electronics and nanoelectronics, energy and environmental applications.

Collaborations

Joint research team "NanoCarb":
a 14 year collaboration with TRT
- carbon nanotubes based Vacuum electronics (involving also Thales Electron Devices)
- Optoelectronic devices based on 2D nanomaterials Chaire "André Citroen" at Ecole Polytechnique (renewed 2016)
- automotive related nanosensors and nanoelectronics IMD – "Sustainable Mobility Institute" (founded in 2009 by Renault and ParisTech)
- "Battery technology" strand: nano-enabled electrochemical energy storage systems for future electrical vehicles Chaire "André Citroen" at Ecole Polytechnique (renewed 2016)
- automotive related nanosensors and nanoelectronics Joint research team "NACRE"
- implementing nanotechnologies for urban instrumentation

Contact:
costel-Sorin.Cojocaru@polytechnique.edu
The recent PHY-MECA 83 building hosts several new experimental facilities:

- An environmental (UHV and synthetic gas atmosphere) electrical characterization bench for future nano-sensors development. This facility developed with support from Chaire "André Citroen", DGA and "Sensecity" EquipEx has been recently finalized and allowed first nanosensors NOx detection in ppm ranges.

- Homemade UVH-MBE materials deposition system: multilayer deposition with atomic monolayer precision, to control the key step catalyst preparation for the synthesis of high-quality carbon nanotube carpets.

- Low-Pressure, Electric Field assisted CVD system: coupled to "FENIX" for in-situ characterizations and accepting up to 4 inch substrates, this new reactor will be dedicated to the exploration of the newly patented carbon nanomaterials synthesis technique in high vacuum and free radicals/under electric field conditions. ("3DRX-online" project and "Nanocarb" collaboration)

In situ & real time nanomaterials growth process characterization

"FENIX" facility has been successfully implemented in the new PHY-MECA 83 building. Fenix enables a particularly interesting approach, the in-situ real time monitoring by surface analysis (angle resolved XPS, UPS, high resolution Auger spectroscopy and reflection low energy EELS), as well as high resolution LEED and mass/ion energy spectroscopy. With the availability of more than 8 focused matter beams (vapors, free radicals, ions), this facility will allow future breakthroughs on understanding the growth mechanisms of graphene and other ultrathin 2D materials (e.g. MoS₂, WS₂, PtS₂ etc) and heterostructures, their doping, surface interactions or defects creation.
NanoMaDe

Nanostructured Li-ion batteries

Through their extremely large specific surface area, current collectors with tailored length/diameter aligned CNTs carpets, represent an ideal support matrix to accommodate a wide range of active materials (anode or cathode) for achieving improved electrochemical performance in Li-ion batteries. Our goal is to demonstrate that electrodes of hierarchic, core-shell nanostructures directly grown onto metal foils and consisting of vertically aligned carbon nanotubes decorated with silicon nanoparticles (VA-CNTs/Si) for anodes and lithiated metal oxides or sulfur nanoparticles for cathodes in Li-ion electrochemical storage systems, can meet simultaneously high energy and high power density, high rate capability and durability.

Towards deterministic synthesis of single-wall carbon nanotubes

Using prussian blue analog nanoparticles precursors we have developed a new generic, and versatile method to design specific bimetallic nano-catalysts for the deterministic single wall carbon nanotubes growth (semiconductor vs. metallic selectivity).

For different types of nano-alloy systems, by changing CVD growth temperature we succeeded to modulate the percentage of semi-conductor type in the assynthesised nanotubes. For the best nano-alloy system, a modulation from 45 % to more than 85 % could be obtained according to Raman spectroscopy. The nanotubes were furthermore integrated into high-quality SWNT-FET transistors with off/ratios outpassing eight decades.
AOP

Applied Optics & Polarimetry
Applied Optics and Polarimetry (AOP) group at LPICM has more than twenty years of experience working with polarized light. Our research activities cover fundamental Mueller polarimetry, advanced optical modeling and development of original polarimetric instruments (spectroscopic and imaging polarimeters as well as polarization sensitive nano-Raman microscopes) for the studies of optical and electronic properties of materials sensitive to the polarization of light for many applications including material science, chemistry, biomedical imaging, etc.

• The fundamentals of Mueller polarimetry and optical modeling activities constitute a research field of its own and are of paramount importance for the physical interpretation of the experimental polarimetric data.

• The instrumental development is one of our “core” competencies which allowed us to design and fabricate a variety of Mueller polarimeters, featuring either spectral or spatial resolution, and suitable for different applications:

  ✓ Spectroscopic ellipsometers and polarimeters cover a broad spectral range from ultraviolet to far infrared. These instruments have been used to study the optical properties of materials and nanostructures in photovoltaic solar cells and low-emissivity coatings. AOP group has collaborations and partnerships with the industrial companies (Horiba Scientific, Saint-Gobain) and the academic laboratories (CNRS, CEA, SOLEIL synchrotron).

  ✓ Polarimetric Microscopes take images in real and Fourier planes. They are aimed towards different applications: optical metrology of diffraction gratings, fundamental studies of light scattering by nanostructured surfaces in collaboration with laboratories in France, Spain, Finland, Norway, Sweden.

  ✓ Macroscopic polarimeters have been used in medical imaging to explore the potential of polarized light to detect and stage cervical and colorectal cancer. A long-term collaboration has been established with four hospitals in France and Belgium for pre-clinical studies on human tissues.

• Polarization-sensitive Raman spectrometer coupled to AFM microscope is a unique instrument developed in the AOP group. It is ideally suited for the studies of nanostructures (nanotubes, nanowires, etc.) as well as physical and chemical properties of single molecules deposited on SERS substrates with a subwavelength resolution of a few tens of nanometers. The system has also been used to study stressed semiconducting nanostructures in collaboration with CEA – LETI.

In 2017 the AOP group members have published 26 articles in peer-reviewed journals, have given 9 invited and plenary presentations at national and international conferences, participated in 13 national and international projects and multiple scientific committees.

Contact: tatiana.novikova@polytechnique.edu
Theory of polarimetry

The theoretical models for partially coherent polarimetry, both in the spatial, as well as in the spectral domain, have been successfully validated experimentally. An intimate link between depolarizing Mueller matrices and their associated Jones generators has been evidenced, resulting in a novel classification of Mueller matrices. The theory of the product decompositions of Mueller matrices with negative determinants has been extended to non-diagonal depolarizers and has been experimentally verified.

The widespread Yeh’s approach for calculating the polarized response of a multilayer stack has been generalized to handle optical activity. The equivalence between Young’s double slit and crystal double refraction interference experiments has been demonstrated both theoretically and experimentally.

Contact: razvigor.ossikovski@polytechnique.edu

Multimodal imaging Mueller polimetric microscope to analyse scattering media

We developed a compact and sensitive instrument for the characterization of scattering samples. The size, aperture, and direction of the illuminating beam can be controlled with an optomechanical configuration. The real plane imaging allows measuring the spatial distribution of the polarimetric response, whereas the Fourier plane imaging allows measuring the angular distribution of the intensity and polarization of light. The system has been applied to various types of samples such as nano and micro-patterned structures and histological cuts of tissues within the framework of international projects FLAG, FRAXOS, and POLHIS.

Contacts: sang.hyuk.lee@polytechnique.edu
enric.garcia-caurel@polytechnique.edu
Tip Enhanced Raman Spectroscopy

Tip Enhanced Raman Spectroscopy (TERS) exploits the enhancement of the local electromagnetic field induced by metal nano-tips to largely amplify the Raman scattering of molecules (up to $10^8 - 10^{10}$) located in the near-field of the tip apex. This creates a hot spot region spatially controllable with nanometric resolution, allowing for a chemical characterization of samples surface at the nanoscale.

The distance dependence (z-dependence) of the TERS response of self-assembled monolayers (SAMs) of two different molecules (C6 and C11 azobenzene thiol) has been extensively studied both experimentally and theoretically. The STM - TERS measurements have been supplemented with electrical conductivity and work function ones for getting better insight into the molecular tunnelling process. The theoretical model, based on the molecular bending picture [1], has been refined by including dielectric correction and response broadening due to parameter variability. The z-dependence of TERS experiments has been simultaneously modelled with the voltage-dependence to check the internal consistency of the molecular bending model. Partial results were presented at the International conference on enhanced spectroscopies (ICES) held in München (4-7/09/2017).


Contact:
antonino.foti@polytechnique.edu
Tip Enhanced Raman Spectroscopy in Liquids

The undeniable potential of TERS as a label-free tool for nanoscale chemical and structural characterization is, nowadays, limited to air and vacuum environments, with it failing to operate in a reliable and systematic manner in liquids mainly due to the low stability of the probes and their consistency.

We are creating a unique nano-spectroscopy platform that requires the coupling of a custom made scanning probe microscope with a micro-Raman spectrometer. Our new approach brings the opportunity to develop unprecedented TERS probes (beyond the classic and limited metallized solid probes), together with the implementation of ingenious and innovative measures to enhance tip stability, sensitivity and reliability, unattainable with the current techniques.

This project is sponsored by the European Research Council via a Starting Grant ERC-StG

Contact: aleix.guell@polytechnique.edu
Infrared Mueller Ellipsometer with Synchrotron Light–Technology Transfer

Collaborative project with SMIS beamline group at SOLEIL synchrotron

Objectives: To develop two innovative and exceptional instruments:

(i) spectroscopic Mueller ellipsometer, and, (ii) ellipsometric microscope to study the physical and optical properties of bulk materials and thin films (minerals, meteorites and flexible polymers).

Scientific Direction of SOLEIL synchrotron supported the project with a grant to develop an infrared microscope. In-plane components of the optical tensor show positive and negative values -> Hyperbolic material.

Contact: enric.garcia-caurel@polytechnique.edu
Simultaneous measurement of plasma-induced electric field and energy deposition using imaging polarimetry

Development of a robust and versatile optical diagnostic method to characterize atmospheric plasma jet properties. Plasma treatment of biological tissues, polymers, aqueous solutions, catalytic surfaces, etc.

Optical characterization method based on the use of an electro-optical crystal as a probe.

Atmospheric plasma jet impinges the crystal, deposes electrical charge and raises crystal temperature.

The optical response of the crystal (linear and circular retardance) is measured with an imaging polarimeter in transmission.

The electro optic and the photo-elastic tensor of the probe relates respectively birefringence changes with electric field distribution, and temperature gradient induced by plasma exposition.

Collaborative project between TU/e Eindhoven (plasma modeling and characterization, Dr Ana Sobota), LPP-Ecole polytechnique (plasma source, Dr Olivier Guaitella) and AOP LPICM (optical instrumentation and polarimetry).

Contacts:
enric.garcia-caurel@polytechnique.edu
elmar.slikboer@lpp.polytechnique.fr
A New instrument - Mueller polarimetric colposcope – was developed for the optical biopsy of cervical intraepithelial neoplasia (CIN). It enables a fast acquisition (≈ 1s) of 16 Mueller matrix images of a human uterine cervix.

It has been successfully tested on several tens of patients in clinical settings, and proved to be a very promising tool for early detection of cervix pre-cancer (CIN).

The pioneering results on using Mueller polarimetry for the imaging of human inner organs were published in Nature Scientific Reports [1].


(a,b) Unpolarized RGB pictures of Cervix 1 and Cervix 2 respectively. (c,d) Standard deviation of the Azimuth computed for each pack of 3 × 3 pixels.

Contacts:
jeremy.vizet@polytechnique.edu
angelo.pierangelo@polytechnique.edu
Binary Classification of the Polarimetric Images for Cervical Cancer Detection

Project BiCPIC, Chaire d’Alembert (collaboration with Prof. M. Kupinski, the University of Arizona, Tucson, USA).

Intensity images of 16 cervical specimens with diagnosis of pathologist: red zones - CIN 2-3, light gray zones - healthy.

To quantify the ability of multi-spectral Mueller imaging polarimetry to differentiate between healthy and pre-cancerous tissue, polarimetric Mueller images of seventeen cervical specimens were compared to results from histopathology.

Improvement of the detection performance by using a novel classification algorithm (J-optimal channelized quadratic observer J-CQO) designed to compute quadratic classifiers from high-dimensional image data.

The mean AUC (Area Under the ROC Curve) value increases with increasing wavelength. The detection performance using only the measurements at 600 nm wavelength is very similar to the detection performance using combined measurements at all three wavelengths for the detection task.

Receiver operating characteristic (ROC) curves for (a) 450, 550, and 600 nm measurements, (b-d) is using only 450, 550, and 600; respectively. The different colored lines represent different selections of testing and training sets amongst patient population.

Contacts: 
tatiana.novikova@polytechnique.edu
angelo.pierangelo@polytechnique.edu
Fluorine doped tin oxide nanocomposites for good light trapping

Nanostructured fluorine doped tin oxide (FTO) material was developed for a strong light diffusion inside thin film solar cells. A novel approach is based on coating clusters of conductive oxide nanoparticles by FTO layer. It leads to a decreased sheet resistance and strongly diffusing surface structure. The angular dependence of scattered light intensity was measured using angle-resolved Mueller matrix polarimeter [1].

Left panel: scanning electron microscopy image of the nanostructured FTO film. Right panel: diffused light intensity as a function of the incident angle and azimuth measured by angle resolved Mueller matrix ellipsometry.


Contact: martin.foldyna@polytechnique.edu
New Platforms
PLATINE is an experimental platform dedicated to nanodevice production and assessment of their nanoreliability by way of serial production tools, ex-situ nanoscale characterization equipment and facilities for in-situ microscale characterization under Multiphysics loading.

The core of PLATINE is an experimental platform enabling the application of multiphysics loadings, i.e. electrical, mechanical, thermal, environmental, on nanodevices, while their electro-thermo-mechanical response is monitored at various scales. This platform is essential to pinpoint where and why failure occurs in the devices, as well as to assess systematically device lifetime.

Jointly, the platform provides capabilities for ex-situ analyses of the micro and nanoscale mechanisms responsible for failure initiation. Additionally, the PLATINE platform is crucial to provide relevant data for the development and the assessment of fatigue models and lifetime predictions tailored to the physics of nanodevices.

A significant part of the investigated devices are produced directly in PLATINE. The platform offers a chain of equipment for fabrication of nanoparticle-based inks, characterization of the properties and then deposition on various substrates. The activities focus on ensuring device reproducibility and quality over serial production. The project brings together interdisciplinary and complementary expertise from different research teams: one team from the field of mechanical reliability (LMS), one team specialized in nanoelectronics (LPICM) and one team specialized in civilian applications of nanosensors (LISIS at IFSTTAR Université Paris-Est).

https://portail.polytechnique.edu/platine

Contacts:
berengere.lebental@polytechnique.edu
laurence.bodelot@polytechnique.edu
The NanoMAX microscope is a prototype developed on the basis of a FEI Titan ETEM (Environmental Transmission Electron Microscope) equipped with a spherical aberration-corrector of the objective lens. Thanks to a differential pumping system, it allows up to 3 mbar of gas in the sample chamber. The main originality of the project lies in the ability of NanoMAX to bring the atoms on the sample in the form of beams, while maintaining a high vacuum (a guarantee for a better controlled growth). These beams can be either gaseous molecules (for example methane as precursor for the carbon nanotube synthesis), atoms, gaseous radicals (cracked molecules).

With these, NanoMAX can partly mimic the environment existing in LPICM macroscopic reactors which use plasmas.

Above all, these beams can be made up of individual atoms: the first experiments of molecular beam epitaxy (MBE) ever carried out in-situ in a transmission electron microscope were successfully designed and conducted in Nov. 2016 by researchers and engineers of C2N-CNRS, partners of NanoMAX. This in situ growth capacity under matter beams is unique worldwide.

The gas system installation has been almost completed at the end of 2017. First experiments with gas/radicals have been carried out in 2018. In 2017, NanoMAX experiments were dedicated to in situ MBE growth of III-V nanowires and produced real-time images unveiling unsuspected growth mechanisms (partners C2N and LPICM).
Very strong involvement in teaching

6 teachers in the Department of Physics (2 full time)
1 teacher in the Department of Chemistry
PSC, Modal, PHY 589, ...

Experimental manipulations in the laboratory

Ingénieurs Polytechniciens

2nd year: MODAL Electronics, PSC, and materials chemistry classes
3rd Year: PA Electrical Engineering, Energy of the 20th Century, Technological Innovation

Masters

REST (M2): Renewable Energy Science & Technology
SMNO (M2): Materials Science and Nano-Objects
MOCHI (M2): Molecular Chemistry and Interfaces
IES (M1 & M2): Enterprise and Society Innovation

Graduate Program

STEEM : Energy Environnement: Science Technology

Executive education

Entrepreneurship training in renewable energies

Contact:
pere.roca@polytechnique.edu
<table>
<thead>
<tr>
<th>Who</th>
<th>Title</th>
<th>From</th>
<th>When &amp; Where</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ange Maurice</td>
<td>Defective graphene: Fabrication, characterization and applications</td>
<td>LPICM/NTU</td>
<td>04/01/2017, 9:30. LPICM 408</td>
</tr>
<tr>
<td>Zuzana Mrazkova</td>
<td>Optical modelling and characterization of materials and nanostructures for photovoltaic applications</td>
<td>LPICM</td>
<td>01/03/2017, 9:30. LPICM 408</td>
</tr>
<tr>
<td>Chiara Toccafondi</td>
<td>Characterization of Self-Assembled Monolayers and nano-materials using Tip-Enhanced Raman Spectroscopy</td>
<td>LPICM</td>
<td>08/03/2017, 9:30. LPICM 408</td>
</tr>
<tr>
<td>Lukas Halagacka</td>
<td>Demonstration of optical nonreciprocity on magnetoplasmonic nanogratings. These: Study of the use of Zno as n-type contact in hybrid perovskite photovoltaic devices</td>
<td>IPV/LPICM</td>
<td>15/03/2017, 9:30. LPICM 408</td>
</tr>
<tr>
<td>Warda Hadouchi</td>
<td>Scalarable 3D integration of organic printed transistor and circuits</td>
<td>LPICM</td>
<td>20/03/2017, 14:00. Amphi Becquerel</td>
</tr>
<tr>
<td>Prof. Sungjune Jung</td>
<td>Current development of flexible organic solar cells in Japan</td>
<td>Pohang University of Science and Technology, South Korea</td>
<td>27/03/2017, 9:30. LPICM 408</td>
</tr>
<tr>
<td>Prof. Susumu Yoshikawa</td>
<td>Development of Highly Sensitive Photoresponsitive Materials and Air-Stable n-Type Thermoelectric Carbon Nanotubes</td>
<td>Kyoto University</td>
<td>28/03/2017, 11:00. LPICM 408</td>
</tr>
<tr>
<td>Prof. Kawai</td>
<td>Characterizing materials with scattering ellipsometry</td>
<td>NAIIST, Japan</td>
<td>29/03/2017, 10:00. LPICM 408</td>
</tr>
<tr>
<td>Thomas A. Gemer</td>
<td>Developing carbon related material for thermal management applications</td>
<td>NIST, USA</td>
<td>05/04/2017, 9:30. *LPICM 408</td>
</tr>
<tr>
<td>Jian Tang</td>
<td>These: From Silicon to Germanium Nanowires: growth processes and solar cell structures</td>
<td>LPICM</td>
<td>07/04/2017, 14:00. Amphi Becquerel</td>
</tr>
<tr>
<td>Kong Yin Fu</td>
<td>Surface- and Tip-Enhanced Raman Spectroscopy of Biomolecules</td>
<td>Saratov National Research State University, Russia</td>
<td>12/04/2017, 9:30. *LPICM 408</td>
</tr>
<tr>
<td>Antonino Foti</td>
<td>These: Développement d’un colposcope polarimétrique de Müller pour le dépistage du cancer du col utérin: premières mesures in-vivo</td>
<td>Saratov National Research State University, Russia</td>
<td>19/04/2017, 9:30. *LPICM 408</td>
</tr>
<tr>
<td>Stanislav Drishy</td>
<td>These: Modélisation d’un plasma de silane-hydrogène avec dynamique de nanoparticules pour applications photovoltaïques</td>
<td>Saratov National Research State University, Russia</td>
<td>26/04/2017, 9:30. *LPICM 408</td>
</tr>
<tr>
<td>Jean Maximine Oriach</td>
<td>Fundamentals and advances of tissue optical clearing</td>
<td>Saratov National Research State University, Russia</td>
<td>02/05/2017, 14:00. Amphi Becquerel</td>
</tr>
<tr>
<td>Prof. Valery Tuchin</td>
<td>Chemical Modeling in the Materials, Life and Environmental Sciences These: Nouveaux Matériaux exotiques Nanostructurés : Prévisions théoriques et verifications expérimentales</td>
<td>Saratov National Research State University, Russia</td>
<td>03/05/2017, 9:30. *LPICM 408</td>
</tr>
<tr>
<td>Prof. Gilles Pesilherbe</td>
<td>Crystalline silicon photovoltaics: towards the limit and beyond</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 9:30. *LPICM 408</td>
</tr>
<tr>
<td>Faïme JARDALI</td>
<td>Introducing BALM (Backside Absorbing Layer Microscopy)</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
</tr>
<tr>
<td>Prof. Jan Schmidt</td>
<td>Spotlight on microspherical nanoscopcy: Experimental and theoretical</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
</tr>
<tr>
<td>D. Ausserré</td>
<td>Tuning the dielectric properties of the 2D-3D halide perovskites by</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
</tr>
<tr>
<td>V.N. Astratov</td>
<td>These: Nano Engineering with Electrons</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
</tr>
<tr>
<td>Laurent Pedesseau</td>
<td>Atmospheric-pressure/High-pressure plasma deposition and etching</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
</tr>
<tr>
<td>Daniel Chua</td>
<td>Multifunction metal oxides utilizing carbon nanotubes</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
</tr>
<tr>
<td>Mark H. Rummeli</td>
<td>NUS, Singapore</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
</tr>
<tr>
<td>Prof. Hiromasa OHMI and Prof. Hiroaki KAKIUUCHI</td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saratov National Research State University, Russia</td>
<td>10/05/2017, 14:30. Amphi Caudry</td>
<td></td>
</tr>
<tr>
<td>Who</td>
<td>Seminar or These</td>
<td>From</td>
<td>When &amp; Where</td>
</tr>
<tr>
<td>----------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Arthur Onno</td>
<td>Monolithic epitaxial growth of 1.70eV Al 0.22 Ga 0.78 As solar cells on Si using dislocations filters: an alternative pathway toward III-V/Si tandem junction solar cells</td>
<td>University College London</td>
<td>07/07/2017, 11:00, LPICM 408</td>
</tr>
<tr>
<td>Pavel Bulkin</td>
<td><strong>HDR Defense:</strong> HDP CVD FOR THE SILANE-BASED DEPOSITION OF DIELECTRICS</td>
<td>LPICM</td>
<td>07/07/2017, 14:00, Amphi Monge</td>
</tr>
<tr>
<td>Prof. Chao Sung LAI</td>
<td>Workshop on: Crystalline Silicon for Low Cost Photovoltaics</td>
<td>CGU, Taiwan</td>
<td>10/07/2017, 10:30, LPICM 408</td>
</tr>
<tr>
<td>Ronan Leal</td>
<td>Nitrided and Fluorinated Graphene for the Applications on High Mobility</td>
<td>CGU, Taiwan</td>
<td>11/07/2017, 14:00, Amphi Gay-Lussac</td>
</tr>
<tr>
<td></td>
<td>Graphene Transistor, Memory and Chemical Sensor</td>
<td>LPICM</td>
<td>12/07/2017, 9:00, Amphi Gay-Lussac</td>
</tr>
<tr>
<td>Young Hee Lee</td>
<td><strong>These:</strong> Low-temperature formation of epitaxial emitter in crystalline silicon solar cells by plasma-enhanced chemical vapor deposition using SiF4/H2/Ar gas mixtures</td>
<td>Sungkyunkwan University</td>
<td>30/08/2017, 9:30, *LPICM 408</td>
</tr>
<tr>
<td>Anna Shirinskaya</td>
<td><strong>These:</strong> Physical modeling of Biosensors based on Organic Electrochemical Transistors</td>
<td>07/09/2017, 14:30, Amphi Becquerel</td>
<td></td>
</tr>
<tr>
<td>Vadim Markel</td>
<td>Some Exactly Solvable Nonlinear Inverse Models: From Toy to Real-Life Problems</td>
<td>University of Pennsylvania, USA / Fresnel Institute, France</td>
<td>08/09/2017, 10:30, LPICM 408</td>
</tr>
<tr>
<td>Maria Guadalupe Mendez-Medrano</td>
<td>Modification of Semiconductors by Metal Nanoparticles: Photocatalysts</td>
<td>LPICM</td>
<td>20/09/2017, 9:30, *LPICM 408</td>
</tr>
<tr>
<td>Takaaki FUYUKI</td>
<td>With High Activity Under Solar Light</td>
<td>NAIST</td>
<td>09/10/2017, 11:30, LPICM 408</td>
</tr>
<tr>
<td>Junkang Wang</td>
<td>Quality Diagnosis of PV Modules by Integrated Measurement of Current-voltage Characteristics with Electrochromism</td>
<td>McGill University, Canada</td>
<td>10/10/2017, 14:00</td>
</tr>
<tr>
<td>Prof. Audrey Moore</td>
<td><strong>These:</strong> Novel concepts in the PECVD of silicon thin films: from plasma chemistry to photovoltaic device applications</td>
<td>University of Arizona</td>
<td>11/10/2017, 9:30, *LPICM 408</td>
</tr>
<tr>
<td>Meredith Kupinski</td>
<td>Nanoparticles and Catalysis for Green Chemistry</td>
<td>Russian Academy of Science</td>
<td>12/10/2017, 13:15, Auditorium de l'Institut d'Optique</td>
</tr>
<tr>
<td>Prof. Victor Loschenov</td>
<td>The fluorescence diagnosis and photodynamic therapy methods and equipment for the treatment of cancer and some inflammatory diseases</td>
<td>Russian Academy of Science</td>
<td>18/10/2017, 9:30, *LPICM 408</td>
</tr>
<tr>
<td>Rasha Knouy</td>
<td><strong>These:</strong> Nanometer-scale point contacting techniques for silicon photovoltaic devices</td>
<td>University Marburg, Germany</td>
<td>29/10/2017, 9:30, *LPICM 408</td>
</tr>
<tr>
<td>Prof. Sergei Barnovski</td>
<td>Challenges related to the effects of disorder in solid state</td>
<td>Fraunhofer Institute for Solar Energy Systems ISE</td>
<td>09/11/2017, 11:00, LPICM 408</td>
</tr>
<tr>
<td>Romain Cariou</td>
<td>Monolithic Two-Terminal III-V/Si Triple-Junction Solar Cells beyond 30% Efficiency under 1-Sun AM1.5g</td>
<td>University of Arizona</td>
<td>15/11/2017, 9:30, *LPICM 408</td>
</tr>
<tr>
<td>Meredith Kupinski</td>
<td>Binary Classification of Polarimetric Images for Cancer Detection</td>
<td>IRDEP</td>
<td>22/11/2017, 9:30, *LPICM 408</td>
</tr>
<tr>
<td>Alaric Desmarcelier</td>
<td>Chiral small organic molecules for tunable catalysts and optoelectronic devices</td>
<td>IRDEP</td>
<td>06/12/2017, 14:30, Amphi Faure</td>
</tr>
<tr>
<td>Forel Solomè</td>
<td><strong>These:</strong> SWCNT growth from bimetallic nanoparticles: a parametric study of the synthesis up to potential applications in nano-electronics</td>
<td>IRDEP</td>
<td>20/12/2017, 14:00, Amphi Poisson</td>
</tr>
<tr>
<td>Mariam Ezzedine</td>
<td><strong>These:</strong> Silicon surface passivation properties of aluminium oxide grown by atomic layer deposition for low temperature solar cells processes</td>
<td>University College London</td>
<td>20/12/2017, 14:30, Amphi Becquerel</td>
</tr>
</tbody>
</table>
Research Support Teams
Research Equipment & Design Department (BEER) is one of the 3 support teams of the laboratory. This team is composed of five members and is at the service of the 4 PICM research groups.

Our missions:

✓ Conceptualization, design, fabrication and validation of vacuum deposition reactors.
✓ Numerical simulation of deposition processes.
✓ On-demand fabrication of custom mechanical parts.
✓ Maintenance and management of the research platforms.
✓ Safety: Training of users and maintenance of installation systems.
✓ numerical simulations:

Examples of gas flow structure in a gas injection "Shower head PECVD reactor"

Highlights for 2017:

✓ Retrofit of a reactor for depositing silicon nanowires (PLASFIL).
✓ Implementation of equipment at the 406 and for the future experimental rooms of the wing 4.
✓ Retrofit of an evaporator for depositing materials.
✓ Computational Fluid Dynamics modeling.

Contact: cyril.jadaud@polytechnique.edu
“Le groupe Instrumentation & informatique” (G2I) has service missions (IT asset management) and maintenance missions (maintenance of optical characterization tools and measurement tools). G2I is also engaged in R&D operations for all of the laboratory’s scientific teams. The team is composed of 5 peoples; two are mainly involved in IT management, one is involved in the management of the optical characterization instrument park and two are more dedicated to the realization of characterization test bench.

In general terms, the group’s missions are as follows:

- IT asset management.
- Installation & maintenance of optical characterization tools and measurements tools.
- Development and monitoring of security and processes Programmable Logic Controller (PLC) devices.
- Realization of characterization test benches.
- Instrumentation, data acquisition.
The main achievements of the year 2017 are:

➤ The end of the “retrofit” of the Plasfil deposition reactor: with the help of the BEER group, we have redefined all aspects of control of the reactor and thus developed the software to control the entire reactor (vacuum, gas and safety management) by the use of LabVIEW® System Design Software. We chose to use a Beckhoff® PLC as an interface system with the reactor.

➤ Since mid 2016 we are also involved in the retrofitting of 2 other PECVD reactors: PHILIX and ATOS. In this case we decide to use Beckhoff® industrial programmable controller as interface with reactors. The software will also develop with LabVIEW®.

➤ The development of Kelvin probe test bench to characterize SAM (Self Assembled Monolayer) for the OLAE team.

➤ Commissioning of a data server for the research and modeling work of the NanoMax team.

➤ Establishment of a new server (Adonis) system for the laboratory.

Contact:
jean-charles.vanel@polytechnique.edu
* 54 contracts for a total amount of 2982 K€
* 641 purchase orders for equipment and running costs
* 170 travel files for missions

+ 70 files for access to LPICM
+ 25 recruitment files with fixed term contracts
+ 20 files for master’s trainees or engineering students
+ 20 files for « titres de séjour »

Keys figures for 2017

Contact:
laurence.gerot@polytechnique.edu

Base funding 2017
École polytechnique 138 K€
CNRS 90 K€
In order to inform permanently, LPICM strengthens its communication on its strategic direction policy addressing the scientific world as well as the general public. Web site: https://portail.polytechnique.edu/lpicm/en

In terms of communication, 2017 has been particularly rich on the national and international level. Among the many visits, exchanges and media events, we can note:

7th congress of the LPICM

Organization of the 7th congress of the LPICM in Piriac sur mer 2-4 October 2017, 80 participants and industrial partners invited (TOTAL - THALES ...)

National

Visit of Patrick Pouyanné, TOTAL’s CEO, to meet the members of TOTAL – LPICM research team.

February; Inauguration of the PISTOL Chair: The ANR, the CNRS, the Ecole polytechnique and Total are joining forces to create a chair in the field of semiconductors. This project is leaded by Mr. Erik Johnson, CNRS researcher at LPICM.

On the occasion of his visit to the site of the Ecole Polytechnique, on October 25, the President of the Republic, Emmanuel Macron, visited NanoMax ( Equipex TEMPOS) a unique TEM with in-situ growth capabilities.
International

January 2017:
A researcher from the LPICM, Erik Johnson, was part of the Ecole polytechnique delegation to Japan, and accompanied President Jacques Biot in visiting our partner universities (Kyoto University, NAIST, and University of Osaka).

December 2017:
Vice President of Harbin Institute of Technology Xu Dianguo met with Vice President for Marketing and International Relations Rachel Maguer and visited the LPICM with Martin Foldyna, CNRS researcher.

Young people & newcomers

In order to encourage vocations in research, LPICM has also organized many student visits:
- Delegation of polytechnique students-X in the framework of the technological seminar «Green Energies and Entrepreneurship”.
- Visit of the students of senior high school Participation in the “Fête de la Science”

Welcoming newcomers to the Ecole polytechnique visiting the LPICM

Contact:
jean-luc.moncel@polytechnique.edu
Collaborations
Arthur Marronnier won the Oral Communication Award at the 3rd Perovskite Hybrid Days in Angers on May 10, 2017. "Structural Instabilities related to Highly Anharmonic Phonons in Halide Perovskites"
Publications
Publications by NANOSIL members in 2017


Publications by NANOSIL members in 2017


- Guillaume Fischer, Etienne Drahi, Martin Foldyna, Thomas A. Germer, and Erik V. Johnson, *Plasma nanotexturing of silicon surfaces for photovoltaics applications: influence of initial surface finish on the evolution of topographical and optical properties*, *Optics Express* 25 (2017) 304532. https://doi.org/10.1364/OE. 25.0A1057


PUBLICATIONS

Publications by NANOSIL members in 2017


➤ Ka-Hyun Kim, Erik V. Johnson, Andrei Kazanskii, Mark V. Khenkin, and Pere Roca i Cabarrocas, Synthesis of silicon nanocrystals in silane plasma and their contribution to growth of polymorphous silicon thin films, *Scientific Reports* 7 (2017) 40553. DOI: 10.1038/srep40553


Poster R. Peyronnet, G. Fischer, T. Blévin, E. V. Johnson, E. Drahi, and M. Lemiti Texturing optimization for bifacial n-PERT: are pyramids and/or black Silicon the way to go for thinner devices?, 7th International Conference on Silicon Photovoltaics (SiliconPV, Freiburg, Germany, April 2017). Published in Energy Procedia 124 (2017) 250-259

Poster Fabien Lebreton, Raphaël Lachaume, Pavel Bulkin, François Silva, Sergej A. Filonovich, Erik V. Johnson, Pere Roca i Cabarrocas, Deleterious electrostatic interaction in silicon passivation stack between thin ALD Al₂O₃ and its α-SiNₓ:H capping layer: numerical and experimental evidences, 7th International Conference on Silicon Photovoltaics (SiliconPV, Freiburg, Germany, April 2017). Published in Energy Procedia 124 (2017) 91-98


Poster Mutaz Al-Ghzaiwat, Martin Foldyna, Takashi Fuyuki, Wanghua Chen, Erik V. Johnson,


NANOSIL - Oral Conference Presentations and Invited Talks - 2017


➤ Invited Pere Roca i Cabarrocas: “Low Temperature Plasma Deposition Processes: From Amorphous Silicon to Nanowires and Epitaxial Growth”. 11th Asian-European International Conference on Plasma Surface Engineering (AEPSE 2017), September 11 to 15, 2017, Jeju, South Korea


**Oral**: Christoph Lechner, Philippe Baranek, and Holger Vach, "Multiscale Modeling of the Insertion and Diffusion of H3 and Cl36 in UNGG Graphite", EMRS Fall Meeting 2017, Warsaw, Poland, September 18 to 21 (2017)


Publications by NANOMADE members in 2017

**Book Chapters (invited):**


**Patents**


**Conference (oral) communications**


M. Ezzedine, M.-R. Zamfir, I. Florea, C. S. Cojocaru. “Fabrication of hierarchical hybrid nanostructured electrodes based on nanoparticles decorated carbon nanotubes for Li-ion batteries” 8e Journée thématique « Batterie Lithium Ile de France » 12 décembre 2017, l’ICMPE, Thiais

L. Sacco, S. Forel, C. S. Cojocaru. “NO2 detection from the ppb level up to ppm concentrations using single-walled carbon nanotube (SWCNT)-based field effect transistors” Hetero Nano-Carb 2017, Benasque, Spain, 11-15 December, 2017.
Conference Posters


S. Forel, A. Castan, L. Catala, I. Florea, F. Fossard, F. Bouanis, A. Andrieux-Ledier, S. Mazerat, T. Mallah, V. Huc, A. Loiseau, C.S. Cojocaru “SWNT growth from various bi-metallic catalyst nanoparticles”, NT17, June 2017, Bello Horizonte, Brazil
Publications by AOP members in 2017

Articles in Peer-Reviewed Journals


PUBLICATIONS

Publications by AOP members in 2017


Publications by AOP members in 2017

Plenary Talks


Invited Talks


➤ Visit of Professor Igor Meglinski, (University of Oulu, Finland)- March 2017
Publications by AOP members in 2017


National and International Conferences with Proceedings


Publications by AOP members in 2017


Accueil LPICM Bâtiment 406, 1er étage

Home LPICM building 406, 1st floor

Plan des Laboratoires

Building 408
Seminar room