Functional thin films and surface nano-engineering (FUNSURF)

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Wet Chemistry and Surface Functionalization

M. Langlet, D. Riassetto, C. Ternon

Context

Need in functional surfaces for various application fields of topical interest:

- Optical surfaces
- Surfaces for water management
- Biofunctional surfaces

Objectives

Dual objectives of this research:

i/ To explore different soft chemistry synthesis methods in liquid solution and to study/optimize reaction mechanisms.

ii/ To attach species formed in solution on various supports (silicon, glasses, stainless steels, metals, polymers, textiles…) and to prospect/exploit derived surface functionalities.

Skills and Competences

Developed know-hows rely on:

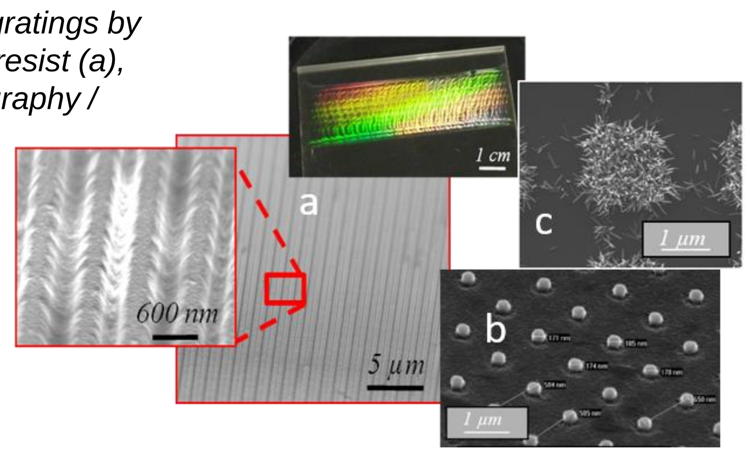
i/ The nature of species formed in solution in relation to the development of synthesis methods: inorganic or hybrid organic/inorganic (O/I) polymeric species by sol-gel process, oxide nanoparticles (NPs) and nanowires (NWs) by hydrothermal synthesis, metal NPs by photochemistry, semiconducting 2D/3D nanoscale networks (nanonets) by liquid processing of NWs…

ii/ The structuration of functionalized surfaces by lithographic methods based on the development of specific procedures: sol-gel inorganic or hybrid O/I resists for photolithography, (photo-)nanoimprint, colloidal (photo-)lithography…

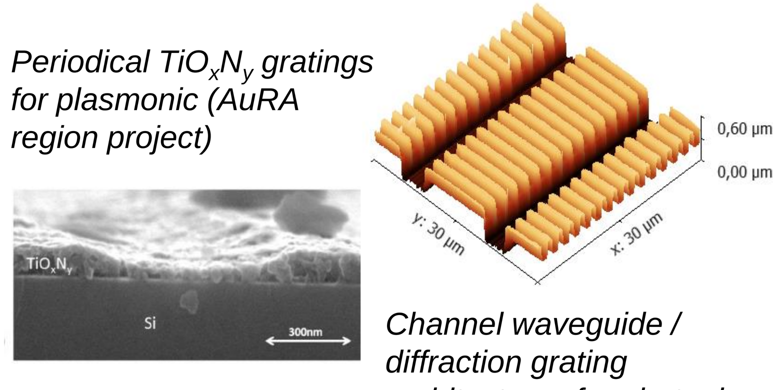
Optical surfaces

Development of all inorganic sol-gel resists imprintable by photolithography and/or nanoimprint to form submicronic or nanoscale patterns (left) and extrapolation to functional architectures (right)

Submicronic diffraction gratings by photo-patterning a TiO_2 resist (a), nanoplots by photolithography / nanoimprint coupling on a TiO_2 resist (b), selective hydrothermal growth of ZnO NWs on a photo-patterned ZnO resist

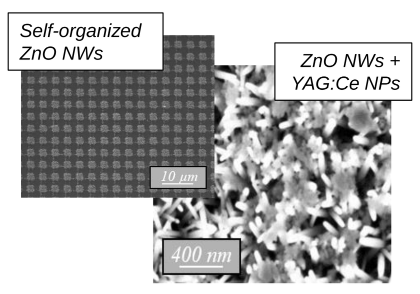


Periodical TiO_xN_y gratings for plasmonic (AuRA region project)



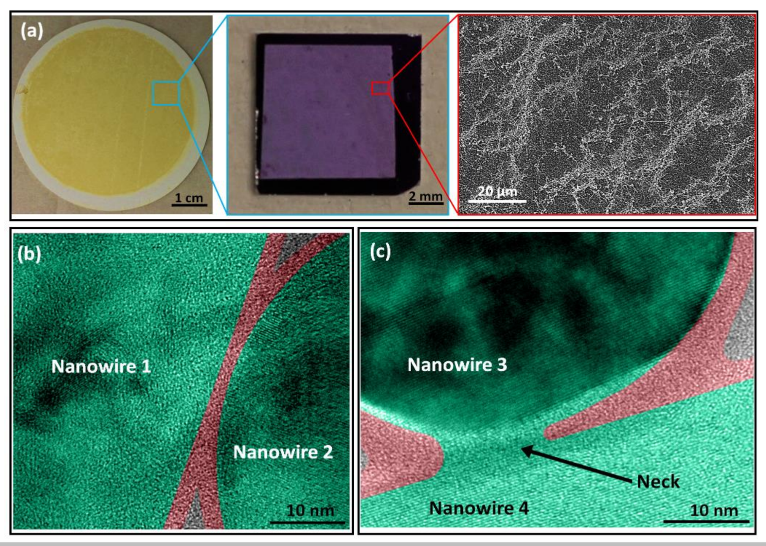
Channel waveguide / diffraction grating architectures for photonics (CEMAM Labex project)

Self-organized NWs / NPs luminescent composite coatings for LED lighting (ANR project)



Biofunctional surfaces

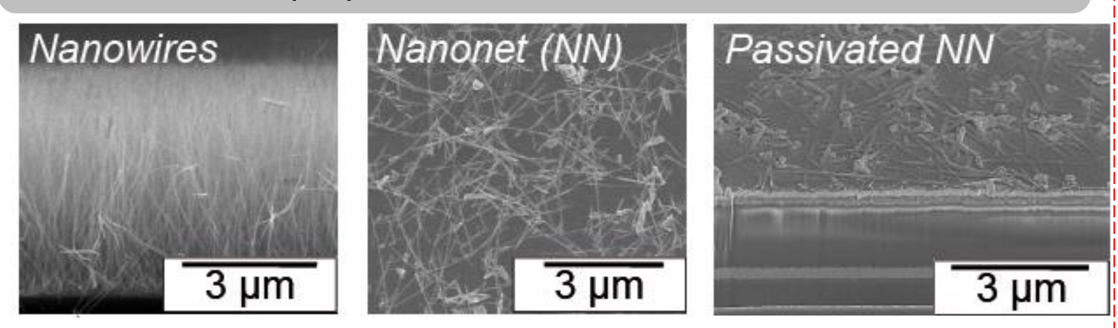
Silicon Nanonets



Silicon nanonet morphology from macro- to nano-scale. (European project)

Mastering the material to control the morphological and electrical properties in view of biofunctionalization

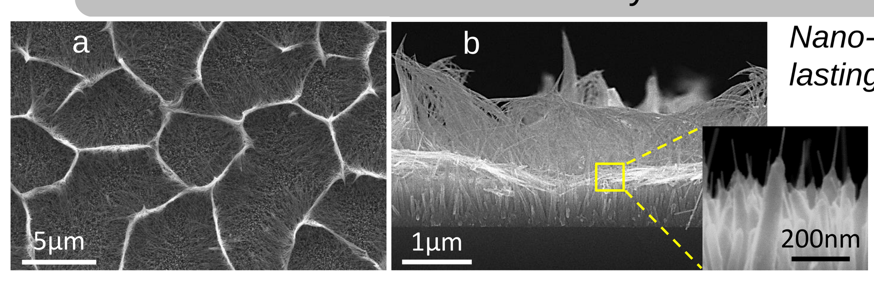
ZnO Nanonets



From ZnO NWs to passivated nanonets to improve morphological and electrical stability (European project)

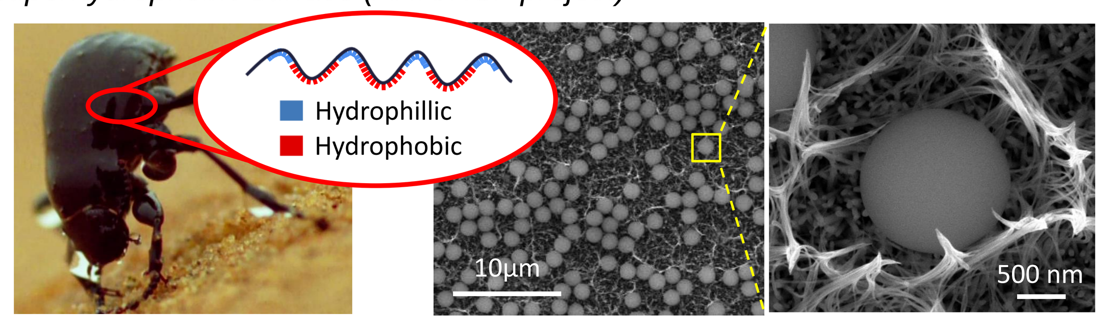
Surfaces for water management

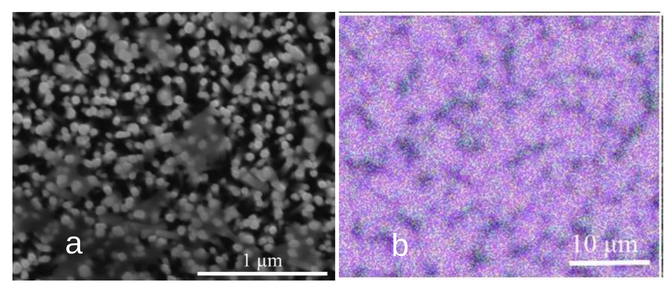
Controlling water's adhesion, condensation and drinkability



Nano-architectured long lasting superhydrophobic surface: top view (a) and cross section (b) (CEMAM Labex project)

Desert beetle mimicry for water harvesting: hydrophilic spheres on superhydrophobic surface (ANR/NSF project)





ZnO Nanowires impregnated with PDMS for water filtration applications: SEM (a) and EDX image (b). Green and violet dots represent the presence of Si and Zn, respectively (Nanoscience Foundation project)

Nanostructures for chemical and biological sensors

V. Stambouli, C. Ternon, M. Langlet

Context

The field of portable, low cost chemical and biological sensors is expanding driven by numerous applications such as :

- Health: biomarker continuous monitoring for point of care, personalized medicine, *in vivo* devices…
- Environment: quality of air monitoring with volatile organic compound detection, water and biological media control…
- Agrifood, defense, etc…

Objectives

Development of arrays of micro and nanotransducers for "label-free" optical and electrical detection of molecules.

Challenge : engineering from the sensitive material to the final device

→ mastering the fabrication, integration and surface functionalization while optimizing the characteristics: architecture, sensitivity, specificity, stability and robustness of final devices.

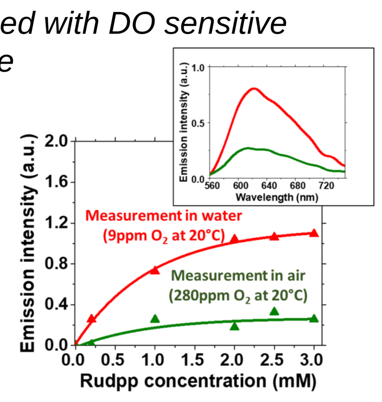
Skills and Competences

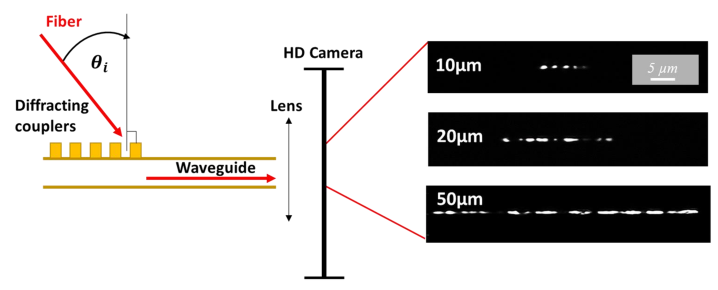
- Technology of guiding layers, nanonets, nanowires while controlling their characteristics
- Integration, contact deposition, fluidic cell
- Functionalization with organosilane in vapor phase
- Molecule detection : optical, electrical

Optical chemical sensors in guided mode

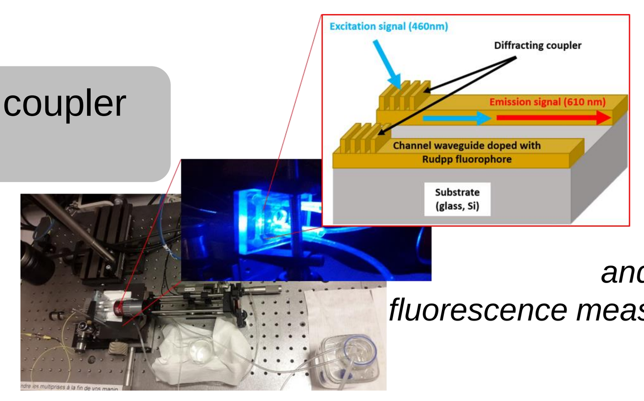
Development and exploitation of sol-gel derived fluorescent channel waveguide / diffracting coupler architecture for dissolved oxygen (DO) detection in liquid medium

Guiding layer doped with DO sensitive Rudpp fluorophore => DO detection by fluorescence quenching





Demonstration of light coupling between diffraction gratings and channel waveguides of various width

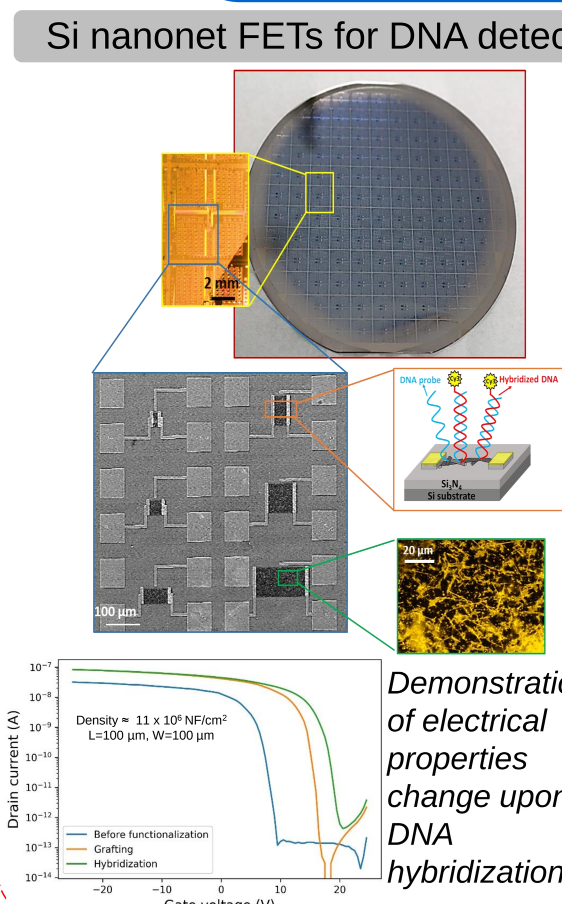


Encapsulation of the guiding architecture in a microfluidic cell and integration in a fluorescence measurement device

Ongoing and future work: optimization of measurement device and protocol; extrapolation to DO detection studies (CEMAM Labex project)

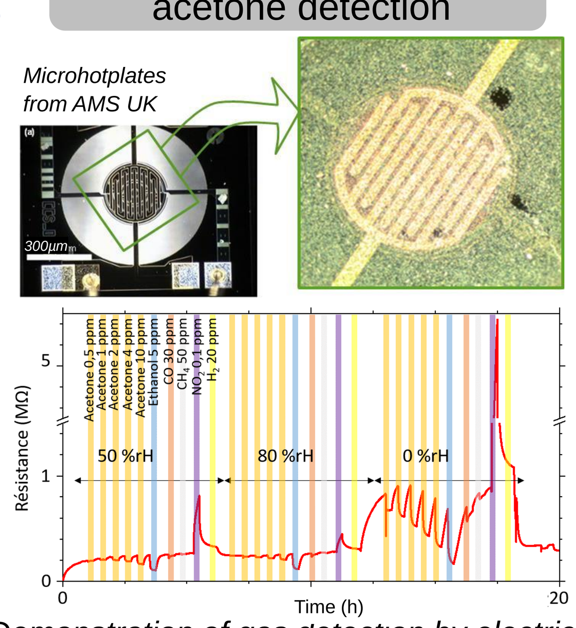
Nanonets for electrical detection

Si nanonet FETs for DNA detection



Demonstration of electrical properties change upon DNA hybridization

ZnO nanonet resistors for acetone detection

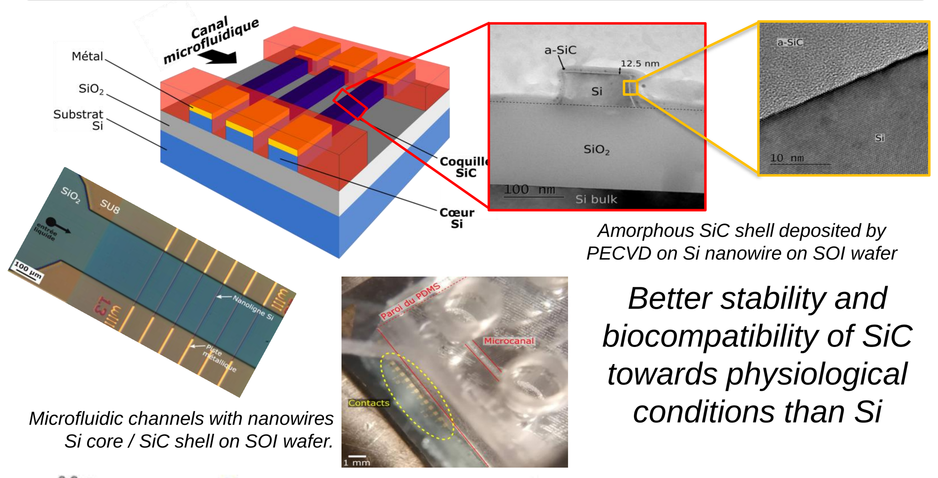


Demonstration of gas detection by electrical detection even in humid atmosphere (%rH)

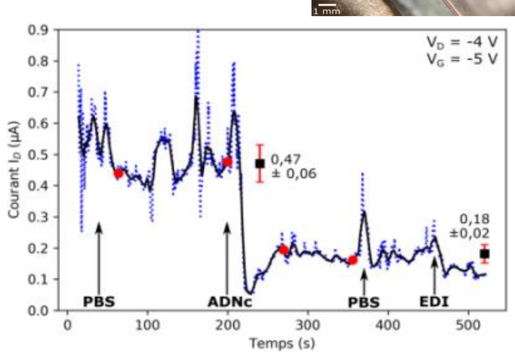
Future work:
Improve selectivity, sensitivity.
Integrate on low power CMOS readout chip

SiC/Si Nanowire FETs for electrical detection

Si core/SiC shell nanowire FETs for DNA detection



Better stability and biocompatibility of SiC towards physiological conditions than Si



Demonstration of electrical properties change upon DNA hybridization in liquid

Future work:
Improve selectivity, sensitivity and stability *in vivo* applications

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