Research internship at GREMAN lab
Level: Master 2 or 5th year of engineering school
Period: Feb 2023 to July 2023 (6 months)

Subject: synthesis of piezoelectric core-shell nanowires

Since the early 2000', advances in nanotechnologies have extended the range of piezoelectric materials for sensing and mechanical energy harvesting applications. Piezoelectric nanomaterials (nanoparticles or 1D nanomaterials like nanowires or nanorods) appeared as promising candidates, for various reasons, in particular due to their high flexibility, high elastic limit (high elongation or bending before fracture) and enhanced piezoelectric properties ESP2012.

By modifying the surface state of the NWs, their efficiency to do the electromechanical transduction, but also the properties of their electrical contacts are modulated. Then, the use of gold or platinum to functionalize the surface of ZnO NWs LU2016 has increased the energy harvested system performances. In the same manner, the functionalization of GaN NWs with a V_2O_5 shell has reduced the screening effects known to deteriorate piezoelectric responses, then leading to a strong increase of the generated output signal WAS2019.

Theoretical studies predicted the piezoelectric coefficients of wurtzite III–V (GaP, InP, GaAs and InAs) semiconductors. Based on these models, some combinations of III–V materials for the core and the shell of the nanowires seem to favor increased voltage levels, up to 3 orders of magnitude larger than the values generated by homogeneous nanowires ZAH2015.

In this context, nanogenerators based on ZnO nanowires, obtained by hydrothermal synthesis, have been developed at GREMAN, and studied in order to better understand the mechanisms at the origin of the polarization of nanowires under the effect of the applied force DAH2017. The simulation of ZnO nanowires decorated with metallic nanoclusters has also been carried out in order to explain the performances obtained on UV sensors realized at the University of Catania, partner of GREMAN BAH2020.

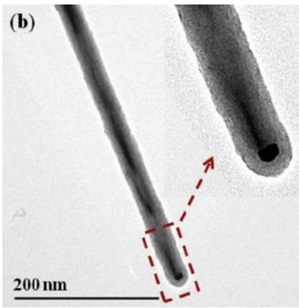

Figure : VLS growth of Au catalyzed c- and m-axis GaN NWs on c-plane GaN thin film using MOCVD WAS2019

References:

BAH2020 Bahariqushchi R. et al., (2020) Free carrier enhanced depletion in ZnO nanorods decorated with bimetallic AuPt nanoclusters, Nanoscale **12**, 19213, https://doi.org/10.1039/D0NR04134C

DAH2017 Dahiya A. S. et al., (2017) Organic/Inorganic hybrid stretchable piezoelectric nanogenerators for self-powered wearable electronics, Advanced Materials Technologies 1700249, 11 pp., https://doi.org/10.1002/admt.201700249

ESP2012 Espinosa H. D., Bernal R. A., Minary-Jolandan M., (2012) A review of mechanical and electromechanical properties of piezoelectric nanowires. Adv. Mater. **24**, 4656, https://doi.org/10.1002/adma.201104810

LU2016 Lu S. et al., (2016) The enhanced performance of piezoelectric nanogenerator via suppressing screening effect with Au particles/ZnO nanoarrays Schottky junction, Nano Res. 9, 372, https://doi.org/10.1007/s12274-015-0916-6

WAS2019 Waseem A., et al., (2019) Effect of crystal orientation of GaN/V2O5 core-shell nanowires on piezoelectric nanogenerators, Nano Energy **60**, 413, https://doi.org/10.1016/j.nanoen.2019.03.075

ZAH2015 Al-Zahrani H. Y. S. et al., (2015) Piezoelectric field enhancement in III-V core-shell nanowires. Nano Energy **14**, 382, https://doi.org/10.106/j.nanoen.2014.11.046

ZHA2010 J. Zhai et al., (2010) Core/shell structured ZnO/SiO2 nanoparticles: Preparation, characterization and photocatalytic property, Applied Surface Science, Volume 257, Issue 2, 393-397, https://doi.org/10.1016/j.apsusc.2010.06.091

Objectives of the internship:

The aim of this internship is to realize core-shell nanostructures in which the core is made of ZnO nanowire and the shell of a material allowing to modify the electrical behavior of the nanostructure and to make the nanogenerator more efficient for mechanical energy harvesting application.

Work program:

- To grow ZnO nanowires by Chemical Bath Deposition (CBD) within ECOSYM team. The substrates will be made of Silicon covered with a ZnO nucleation layer.
- To perform structural characterization of the ZnO nanowires: SEM, XRD, TEM
- To carry out various coatings within the OXYDES team : SiO_2 will be the first material deposited by Stober method ZHA2010, then other materials will be evaluated based on literature.
- To perform the structural characterization of core-shell nanostructures: SEM, XRD, TEM, zeta potential…
- To synthesize core-shell nanostructures for nanogenerators manufacturing by ECOSYM colleagues.

Supervisors:

OXYDES team : Cécile Autret, cecile.autret@univ-tours.fr
ECOSYM team : Guylaine Poulin-Vittrant, guylaine.poulin-vittrant@univ-tours.fr, Emmanuel Dumons, emmanuel.dumons@univ-tours.fr

Candidate profile:

Academic level: in progress of Master 2 or last year of engineering school

Required knowledge: The candidate should have basic knowledge of material chemistry, solid-state physics, and/or physical, electrical and electromechanical measurement techniques.
The candidate should have a strong interest for experimentation.