**PhD offer at Ecole Polytechnique - IPP, France**

“Towards Ultra-wide bandgap semiconductors synthesis using low-temperature plasmas: deposition, fundamental aspects and process optimization through artificial intelligence approach”

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| **Topic** | Plasma, semiconductors, artificial intelligence |
| **Doctoral school** | Ecole Polytechnique - Institut Polytechnique de Paris |
| **Laboratory** | Laboratoire de Physique des Interface et des Couches Minces – LPICM, Ecole Polytechnique, Palaiseau, France |
| **Supervisors** | Karim OUARAS, Pere Roca i Cabarrocas |
| **Starting date** | No later than December 2025 |
| **Funding** | Funding of 3 years fully secured |

Many efforts have been made in recent years to switch from Silicon to other semiconductors of superior/complementary optoelectronic properties such as wide and ultrawide bandgap (UWBG) materials (GaN, AlN, h-BN, $Ga_2O_3$) but also to combine them with silicon, so marrying the best of both worlds. However, even though those materials do provide extraordinary optoelectronic performances, the difficulties in processing them offsets many of their advantages. In particular, the most conventionnal growth methods such as MOCVD and MBE are expensive because of the equipment’s cost and/or inefficient utilization of gases that can be toxic. In addition, they operate at high temperature (>600 °C), compromising the combination of materials having different thermal expansion coefficients (TEC).
In order to go beyond the predominance of silicon, it is required to widen the use of III-Vs in the industry and not only to serve niche applications. This relies on our ability to develop low-cost and eco-friendly deposition methods for growing high quality UWBG thin films. Moreover, it is of great importance to have access to deposition processes that run at lower temperature to avoid as much as possible the drawback of TEC mismatch. This could pave the way towards the direct growth of stacked monocrystalline films of different nature (hetero-epitaxial growth).This project is driven by the motivation of taking up this challenge, being a project that aims at developing a versatile, eco-friendly and low-cost approach to achieve the growth of next-generation semiconductors including GaN, $Ga_2O_3$ and AlN at low temperature (less than 200 °C) by using non-equilibrium plasma processes trough sputtering approach. Recent promising results on the growth of GaN thin films of polycrystalline nature using the plasma reactor developed at LPICM set the first step toward this goal (Fig.1).

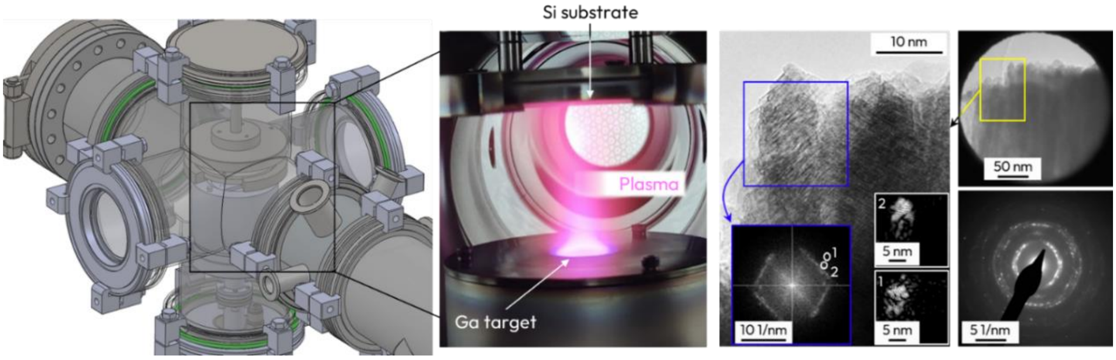


*Figure 1. Overall view of the plasma reactor for the deposition of GaN films at room temperature. On the right: TEM images of the film.*

The PhD student will aim at pursuing the recent work by **optimizing the growth of GaN films in terms of structural, electrical and optical properties along with exploring AlN and $Ga_2O_3$ deposition**. A particular attention will be paid to address the **fundamental aspects of the growth by probing the plasma and relating gas phase information to that of the growing films using an innovative diagnostics based on Terahertz spectroscopy**.The work will involve a rich variety of topics encompassing plasma/material interactions studies, material/plasma reactor optimization, as well as the design and fabrication of devices based on the grown films. In addition, **the PhD student will participate in the development of a novel plasma reactor (cluster) enabling the doping of the materials.** This will be a great opportunity for the applicant to enrich his skills in plasma reactor design. All the deposition and plasma/gas-phase characterizations will be performed at LPICM, the student will also have access to complementary facilities provided by close partners when it comes to ex-situ characterizations. She/he will have access to state-of-the-art in-situ high resolution transmission electron microscopy at the Electron microscopy centre of École polytechnique (CIMEX). **As this project aims at optimizing the process for achievieng challenging high-quality UWBG films; it will lead to the generation of a large number of experimental data (from ex-situ and in-situ measurement). Therefore, she/he will develop a way to optimize/guide the experiments trough artificial intelligence approach (machine/deep learning) that he will develop internally.**
At the end of the thesis, we expect to reach these objectives: (i) further understand and optimize the plasma processes to have a better control of the growth of UWBG semiconductors having high crystalline quality layers and (ii) perform diagnostics (probing both plasma and material) for addressing thin film growth route scenario from the atoms (Ga, As, N, Ar, H, O) to the thin films.

**The applicant should have a background on materials and/or plasma science and be willing to develop AI solutions for process optimization.**

## Application

Please address the following documents to : karim.ouaras@polytechnique.edu and pere.roca@polytechnique.edu
- CV (containing a complete overview of education, supervised professional training and professional work).
- Diploma and marks of master's degree.