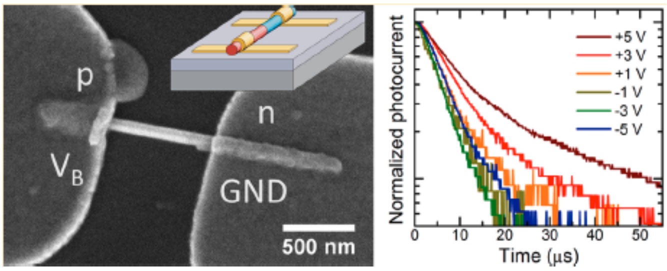
# NÉEL INSTITUTE Grenoble

## Topic for Master 2 internship – Academic year 2021-2022

### p-n junction nanowires for solar cells

**General scope:**

Semiconductor nanowires (NWs) with controlled composition and dimensions can be fabricated using optimized growth conditions (bottom-up method) or by lithography and etching of a suitably designed substrate (top-down method). Moreover, it is possible to tune the electrical properties by doping, and p-n junctions can be implemented in NWs. These structures are interesting, for example for application as NW solar cells or high-speed photodetectors. Among others, NWs present one major advantage for such applications: they act as antennae and therefore can absorb the light more efficiently using less material. However, challenges remain to control and measure the doping levels in such nano-objects with nm precision. Furthermore, the role of the NW surface on their electrical properties requires further investigation.




*Left: SEM image of a contacted NW with schematic in the inset. Right: photocurrent time response of the NW.*

**Research topic and available facilities:**

The aim of this internship is to contribute to the study of p-n junction semiconducting NWs regarding their opto-electrical properties. The student will integrate a multi-institute, multi-disciplinary research group. His/her role will be to optimize the etching process of GaN NWs from a bulk substrate containing a planar p-n junction defined during molecular beam epitaxial growth. She/He will use nanosphere lithography followed by a two-step etching process (reactive ion etching + wet chemical etching) to define the NW length and diameter, potentially followed by a high temperature annealing step to further reduce the NW diameter. Then the obtained NWs will be electrically contacted on membrane chips compatible with transmission electron microscopy (TEM) measurements, and the student will be in charge of their electro-optical characterization. This includes current-voltage and complete characterization as a photodetector (responsivity, linearity, spectral selectivity, time response). These results will be correlated to detailed characterization by transmission electron microscopy, performed on exactly the same single NW. Combining in-situ biasing with the 4D Scanning TEM techniques sensitive to the electric field, we may obtain a quantitative description of the electrical properties of this object at the nm scale. Using this combination of techniques, we will improve our understanding of NW solar cells.

The student's work will involve:

- Top-down NW fabrication in cleanroom environment. It implies training in nanosphere lithography, electron beam metalization, reactive ion etching and scanning electron microscopy.
- Current-voltage measurements and electro-optical characterization as a photodetector.
- Nanowire contacting and TEM experiments will be performed by a postdoctoral researcher, but the student will participate in the experiments.
- The student will be involved in the correlation of electro-optical and 4D STEM results.

**Possible collaboration and networking:** The internship will be in collaboration with Eva Monroy (CEA-IRIG, PHELIQS).
**Possible extension as a PhD:** Not granted in advance, but we are open to support applications for a PhD grant.
**Required skills:** Interest in solid-state physics, electrical and optical properties of semiconductors and advanced characterization techniques like transmission electron microscopy.
**Starting date**: Jan/Feb 2022 or earlier.
**Contact**: den Hertog Martien & Eva Monroy
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