NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Nm scale characterization of p-n junction electrical properties by Transmission Electron Microscopy

General scope:

Semiconductor p-n junctions are basic building blocks for devices like solar cells, avalanche photodetectors or light emitting diodes. To implement the junction, the electrical properties of semiconducting materials are engineered by adding dopant atoms that donate or accept an electron from conduction or band valence, respectively. In this way the density of mobile charges can be tuned over several orders of magnitude. It is very well known that a transition from one type of dopant to the other kind will generate a so-called p-n junction, giving rise to rectifying current voltage characteristics and potentially light emission, for example in light emitting diodes. However, challenges remain to control and measure the electrically active doping levels in semiconducting materials with nm precision, especially in wide bandgap materials with high dopant activation energies.

Research topic and available facilities:

The aim of this internship is to contribute to the study of p-n junction semiconducting materials regarding their electrical properties, in particular studied at nm length scales. The student will integrate a multi-institute, multi-disciplinary research group.

His/her role will be to fabricate electrical contacts to p-n junction nanowires or thin films of different materials, including GaN and AlN. The p-n junctions will be electrically contacted on membrane chips compatible with transmission electron microscopy (TEM) measurements, and the student will be in charge of their preliminary electrical characterization by current-voltage measurements. Combining in-situ biasing with the 4D Scanning TEM techniques sensitive to the electric field, we aim to obtain a quantitative description of the electrical properties of the object at the nm scale and improve our understanding of doping.

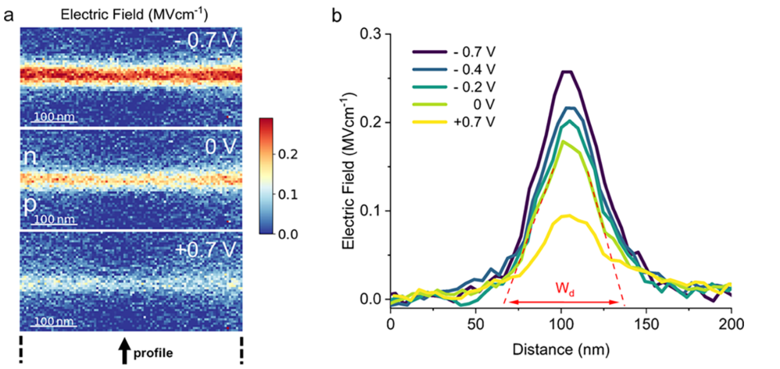

Figure 1. (a) In situ biased 4D-STEM electric field maps of a silicon p−n junction. (b) Profiles of the electric field obtained from the maps shown in (a) by integration along the entire map, as indicated in (a). The measured depletion length for zero bias is indicated. [https://doi.org/10.1021/acs.nanolett.2c03684]

The student's work will involve:

- Nanowire contacting in a cleanroom environment. It implies training in nanowire dispersion, mapping using scanning electron microscopy, making drawings of the contact lines, assisting electron beam lithography and finally preforming lift-off.
- Current-voltage measurements.
- The electron beam lithography step for nanowire contacting and TEM experiments will be performed by the supervisor, but the student will participate in the experiments.
- The student will be involved in the data analysis of 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 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 2023, earlier or later.
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