NÉEL INSTITUTE Grenoble

Topic for PhD – Academic year 2024-2025

Low temperature transport and Transmission Electron Microscopy of silicon aluminum interfaces

General scope:

The combination of superconducting and semiconducting materials at nm length scales is an intensely studied topic as new device functionalities can be realized by combining these material combinations at such small length scales. In particular, these structures are regarded as promising building blocks for quantum computing. More specifically, the Al-Ge and Al-Si material combination has been studied in depth in our groups during the last 10 years, both for its structural aspect by using transmission electron microscopy (TEM) as well as by low temperature transport, in collaboration with researchers at the Technical University of Vienna, Austria. The most intriguing aspect of this material combination is that upon heating an Al contacted semiconductor section, an exchange phenomenon takes place where Al enters the semiconducting material from the contact pads, while the semiconductor material flows through a surface diffusion channel into surfaces and grain boundaries in the Al contact pad. In this way and atomically abrupt interface propagates into the semiconducting region during the annealing, see fig.1. After heating is stopped, a semiconducting region of well-defined length is then created between two crystalline aluminum contacts. Both the interface properties (Josephson effect) as well as quantum size effects due to the size of the semiconducting region (for example Coulomb blockade) can be studied at low temperature.

Research topic and available facilities:

This project aims to fabricate silicon membranes starting from silicon on insulator (SOI) substrates. Our collaborator at TU Vienna (Alois Lugstein and his group) is currently working on the exchange reaction of aluminum with silicon strips defined in SOI. The same fabrication process will be applied to the silicon membranes, to create the same structure compatible with TEM characterization. These Al-Si interfaces will then be studied by low temperature transport. All results will then be correlated by TEM characterization of the identical interface, regarding interface abruptness and shape, as well as crystalline quality. It is then possible to go a step further and combine low temperature transport and TEM directly in the TEM using an in-situ biasing cryogenic TEM sample holder. The aim here is to establish the possibilities, and potentially observe charge related phenomena in the TEM. The student's work will involve:

- Fabrication of silicon membranes (support from supervisor and nanofab cleanroom staff).
- Contributing to the device conception, fabrication will be carried out at TU Vienna.
- Carrying out low temperature transport measurements.
- Carrying out TEM characterization (support from supervisor)
- Data analysis and interpretation

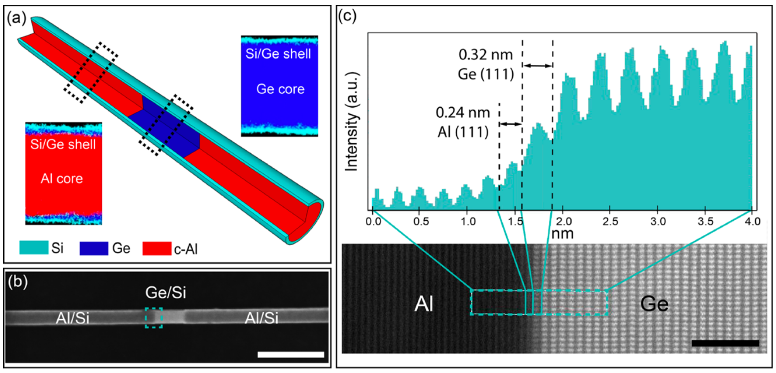

Figure 1. (a) Schematic illustration of an axial Al−Ge−Al NW heterostructure with an ultrathin semiconducting shell wrapped around it. The insets show EDX chemical maps at the respective positions along the heterostructure showing the Al−Ge−Al heterostructure. (b) SEM image of the heterostructure arrangement. Scale bar is 200 nm. (c) High-resolution HAADF STEM obtained at the Al−Ge interface and corresponding intensity profile obtained at the cyan dashed square shown in (b). Scale bar is 2 nm. [ACS Nano 104, 102102 (2019)].

Possible collaboration and networking:.TU Vienna, Neel, CEA Grenoble.

Required skills: Interest in solid-state physics, low temperature transport, electrical properties of semiconductors and advanced characterization techniques like transmission electron microscopy.

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