PhD proposal

Si nanowire-based metamaterial for thermoelectric applications

Subject description

A PhD position is offered by the team « Microscopy and Electronic Transport in Nanostructures » (µTEN) at the Institut des Matériaux et de Microélectronique de Provence (IM2NP), Marseille (France). The candidate will also work in collaboration with different teams of the Lab and Prof. D. Narducci from the University of Milano-Bicocca. The PhD research project will focus on the growth (by Molecular Beam Epitaxy), the study (by Electron Microscopy) and thermoelectric measurements of Si nanowire (NW)-based material for energy harvesting.

Background

The growing demand for portable power required by miniaturized systems is driving the development of new technologies and materials to achieve efficient energy generation at the microscale.
Alternative power sources based on energy harvesting are promising candidates to substitute batteries due to their ability to extract unlimited power from the environment. In this direction, thermoelectric energy harvesters have received special attention in recent years.
The efficiency of a thermoelectric material is determined by its thermoelectric figure of merit ($ZT = S^2\sigma T / \kappa$), which is a function of three transport coefficients: the electrical conductivity (σ), the Seebeck coefficient (S), and the thermal conductivity (κ). The thermoelectric performance of a material can be improved through adjustment of these parameters. However, only materials with ZT ≥ 1 are usually considered as good thermoelectric materials.

Applications based upon silicon would be interesting for energy recovering because silicon is a low cost, widely available material but silicon has poor thermoelectric properties in bulk form (ZT ≈ 0.01). Low-dimensional structures provide a route to achieve significantly improved thermoelectric figures of merit in materials. Silicon nanowires were demonstrated to address the aim of increasing the material thermoelectric efficiency. Very recently [1], a theoretical and computational work has shown that a metamaterial based on a silicon thin film with an array of pillars erected on one or two of the free surfaces would lead to a low thermal conductivity much lower than the bulk silicon one by resonant coupling of the thin film itself with silicon nanopillars.

Research objectives

The candidate will be to establish the relationship between thermoelectric properties of the material with morphology, microstructure, chemistry and structure at the atomic scale. This is of crucial importance for a better understanding of phenomena and so, for the development of new materials.
In that particular case, the objective is to confirm, from an experimental point of view, that it is possible to improve thermoelectric figures of merit of silicon by coupling thin film to nanopillars and to find the conditions that optimize ZT (NW length, film thickness …).

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The growth of test structures will be done mainly by Molecular Beam Epitaxy [2] associated to chemical processes. The study, from the micron scale down to the atomic one, will be possible thanks to a combination of different equipments at the cutting edge of technology: a Variable Pressure High Resolution Scanning Electron Microscope equipped with different analysis techniques (EDS, WDS, EBSD …) and a Cs-corrected Transmission Electron Microscope (HREM, STEM-HAADF, EDS, …).
The electrical and thermal properties will be analyzed by resistivity and Seebeck coefficient measurements.

Bibliography

[1] Nanophononic Metamaterial: Thermal Conductivity Reduction by Local Resonance, Bruce L. Davis and Mahmoud I. Hussein, PHYSICAL REVIEW LETTERS, 112, 055505 (2014)
[2] Gold coverage and faceting of MBE grown silicon nanowires, Thomas David · Luc Roussel · Thomas Neisius · Martiane Cabie · Marc Gailhanou · Claude Alfonso, JOURNAL OF CRYSTAL GROWTH, 383,151 (2013)

Links

IM2NP: http://www.im2np.fr
CP2M: http://www.cp2m.u-3mrs.fr/home.htm
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HIT: http://amidex.univ-amu.fr/fr/hit

How to apply

Applicants are required to provide:
• academic CV;
• official full list of courses and marks from your university;
• cover letter outlining your suitability for the study and your research experience to date,
• contact details of two suitable referees.

Applications or any enquiries relating to the project should be emailed to: claude.alfonso@univ-amu.fr.
The successful candidate will be required to submit a full Aix-Marseille University application to fulfill the normal admissions process.

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