Universität Basel

Research Project

Nanophononics: Phonon transport and interference in nanostructures

Third-party funded project

Project title Nanophononics: Phonon transport and interference in nanostructures
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Project start 01.04.2016
Probable end 31.03.2019
Status Completed
In the last decades, the power to control photons and electrons paved the way for extraordinary technological developments in electronic and optoelectronic applications. The understanding and ability to manipulate phonons as coherent waves in solids enables the control of heat conduction, which is of fundamental interest and could also be exploited in applications. Namely, phonon management and control over the interaction between phonons and charges, spins or photons is key to develop electronic, optoelectronic, quantum, sonic and thermal devices. In this respect, semiconductor nanostructures offer the possibility to modify to a large extent their phonon properties. In particular, nanowires (NWs) are a model system for 1D phonon transport and can exhibit modified phonon dispersion with eventually the appearance of surface phonon modes. Finally, NWs can be used as a template for more complex novel architectures, where phonon transport and phonon scattering can be engineered. Despite the several theoretical studies on phonon conduction in 1D nanostructures, there are still several open questions, which need to be addressed experimentally. This proposal aims at investigating and engineering phonon transport and phonon interference effects in NW-based heterostructures by means of a combination of spectroscopy techniques and transport experiments. The proposed research will be of great relevance for fundamental research as well as for technological applications. Phonon interference experiments (project A) Photons and electrons have been subject of studies exploiting their quantum-mechanical nature for a long time. Recently, researchers are trying to expose the quantum-mechanical nature of collective excitations like phonons, which is crucial for the understanding of the physics and the development of sonic and thermal materials and devices. In this proposal, single crystalline NW crosses are the platform for phonon interference experiments. Coherent phonon transport (project B) Coherent phonon heat transport can occur in periodic heterostructures. However, this regime was achieved only below150 K due to the quality of the interfaces. In this project, phonon transport regimes will be investigated in crystal-phase superlattice NWs exhibiting high structural quality. Phonon interference and phonon transport experiments will be realized with time-resolved Raman spectroscopy measurements and developing a thermal conductivity spectroscopic method by combining pump-probe Raman spectroscopy with electrical measurements synchronizing laser and electrical pulses. Thermoelectric properties of topological insulator nanowires (project C): Waste heat recovery through high-efficiency thermoelectric (TE) converters can have a major impact on energy production and enable new self-powered device applications. However, the adoption of TE devices is nowadays limited by their poor efficiency: good TE materials should exhibit high power factor and low thermal conductivity, but this elusive target has challenged researchers for decades. Topological insulators (TI) are a recently discovered class of materials, where edge or surface states electron transport is naturally protected from scattering. Therefore, this property can be used to decouple electron and phonon transport. Theoretical studies predict a sig-

nificantly enhanced efficiency of TIs, but such effects have not been experimentally demonstrated yet. Hereby, the TE properties of TI NWs will be extensively investigated with the use of suspended SiNx membranes with integrated microheaters.

Keywords Raman, thermoelectrics, phonons, nanowires, Phonon interference, Phonon transport, renewable energy, quantum computation

Financed by
Swiss National Science Foundation (SNSF)

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