Master Thesis Topic

Fabrication and characterization of transparent acoustic transducers for microwave-to-optical conversion and optomechanics applications

Background and Motivation

Transfer of information between GHz qubits and near-infrared photons can be done via piezoelectrically excited phonons, which can enable efficient microwave-to-optical conversion for scalable networks of quantum computers. We have shown that one novel approach is to use semiconductor microcavities (MCs) which provide efficient coupling between quantum well excitons and bulk acoustic waves (BAWs) injected by electrically driven bulk acoustic resonators (BARs) fabricated on top of MC. BARs are simple capacitor-like devices consisting of two conductive electrodes and a piezoelectric film sandwiched in between. A radio-frequency AC voltage applied to a BAR is resonantly excites BAWs.

So far, we have relied on the lateral injection of BAWs into the active region of MC, which becomes very sensitive to the sample roughness and temperature. Direct injection of BAWs is challenging, since BARs' metal electrodes are opaque in the visible and near-infrared spectral ranges. This challenge can be overcome by using transparent electrodes, e.g., doped indium tin oxide (ITO). This project aims to demonstrate the fabrication of ITO-BARs on patterned semiconductor microcavities. One benchmark will be the demonstration of efficient modulation of emission energy and intensity of quantum well excitons (and exciton-polaritons).

Objective

The main objective of the project is to develop the fabrication process for the transparent bulk acoustic resonators (BARs) with ITO contacts for the excitation of 5-20 GHz acoustic waves in semiconductor heterostructures. You will be working on the following tasks:

1. First steps. Develop a process to fabricate GHz BARs with patterned conductive ITO electrodes.
2. Push the BAR frequency to 20 GHz. Investigate effects of different piezoelectric film materials (e.g., AlN and ScAlN), film thickness and ITO-thickness on BAR frequency and efficiency.
3. BAR in action. Fabricate an ITO-BAR device on a semiconductor microcavity and demonstrate modulation of emission from a semiconductor microcavity with directly injected BAWs at different temperatures (10-300K).

Methodology

After you have received training, you will work in a clean room environment and supported by clean room technicians. You will use optical lithography, spattering and evaporation tools for the fabrication of BARs. You will carry out electrical characterization of BARs using state-of-the-art RF equipment (e.g., VNA). You will get experience in observing interactions between GHz acoustic waves and opto-electronic excitations using photoluminescence measurements down to liquid-He temperatures. You will also use finite element method simulations to refine your designs.

Expected Outcomes

- High frequency optically transparent BARs technology optimized for the coherent control of (quantum) devices and high-temperature optomechanics.
- Also, lots of fun doing fabrication and seeing things work.

Skills and Requirements

- Curiosity
- Base knowledge of semiconductor physics and materials

Opportunities and Benefits

- Modern labs with a wide range of experimental techniques.
- Supportive environment with experts for various scientific sub-fields.
- International and culturally diverse community.
- Location in the heart of Berlin with excellent public transport connections.
- Subsidized travel ticket.

Contact

Dr. Alexander Kuznetsov

+49 30 20377-430

kuznetsov@pdi-berlin.de

For further details or clarification, please feel free to contact us. Lab tours are also available for interested applicants.