Type II heterostructures in II-VI semiconductor nanowires: fabrication and investigation of spatially indirect optical emission

Semiconductor nanowires belong to the mostly studied structures with nanometer sizes. They consist of single crystals with typical diameters being in the range of a few or a few tens of nanometers and lengths of several micrometers. In a single nanowire, several semiconductors can be merged forming so called nanowire heterostructures. Two examples of these structures are presented in Figure 1a. The first one is a coaxial nanowire, in which the semiconductors alternate in the radial direction forming a core/shell structure. In the second structure, an additional axial insertion made of a third semiconductor is built in the nanowire core. If the length of this insertion would be of the order of a few nanometers, it could act as zero-dimensional nanowire quantum dot. In the frame of this project, we plan to fabricate both kinds of structures shown in Figure 1a. Moreover, these structures will have some peculiar optical properties directly related to the electronic structure of semiconductors that they will be composed of.

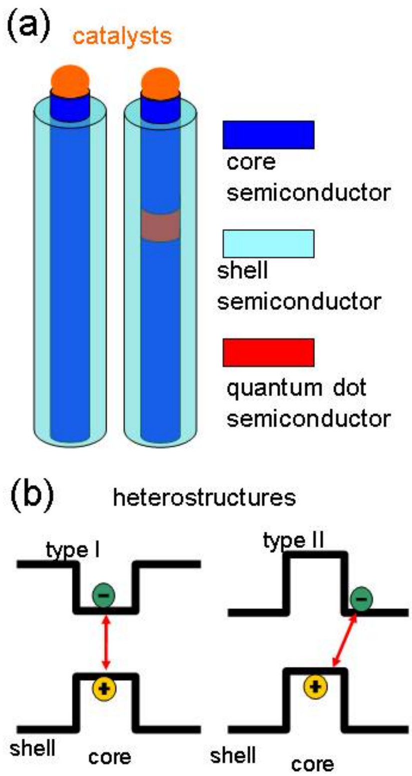

Fig. 1 (a) schematics of a coaxial nanowire and coaxial nanowire containing an axial quantum dot. (b) band edge alignment in coaxial nanowire with type I and type II heterojunctions. Red arrow indicate optical transitions

The properties of electrons inside a semiconductor are determined by the compounds that the semiconductor is built of as well as their crystalline structure. Electrons inside a semiconductors may have energies from several ranges of energies called electronic bands. What will happen after merging two semiconductors, i.e., after creation of a semiconductor heterostructure? The heterostructures can be generally divided into type I and type II heterostructures. The difference between them relies on the relative electronic band edge alignment of the two semiconductors at the junction, Figure 1b. In type I heterostructures, the band carriers: electron from the topmost electronic band – conduction band and holes from the next band – valence band tend to enter into the same semiconductor. In type II semiconductors, band carrier separation takes place. It is more favorable for electron to find itself in another semiconductor then for the holes. This situation is schematically shown in Figure 1b.

Let us consider a coaxial nanowire, Figure 1a, with type II junction between the core and shell semiconductor, as an example. In this structure, we expect that one kind of band carriers (electrons or holes) will tend to localize in the nanowire core and the other will tend to find itself in the shell. Electrons and holes will be, therefore, spatially separated.

In the frame of this project, we plan to fabricate nanowire heterostructures characterized by the type II band alignment and to perform investigations of optical effects induced by the separation of electron and holes at the junction. Our study will involve the impact of several parameters of nanowires, such as core diameter, shell thickness, their chemical compositions, as well as the axial length of nanowire quantum dots. The novelty issue of these investigation is related to the fact that spatially indirect optical transitions have not been studied systematically in nanowire heterostructures so far, to the best of our knowledge.

One of the most interesting effect that we would like to observe in type II nanowire heterostructures is the optical Aharomov-Bohm effect, which is a direct consequence of the quantum nature of electrons and holes. This effect describes the phase shift of the wave function of a *charge* particle moving on a closed trajectory as it orbits a magnetic flux. In optical measurements, however, excitons, i.e., *neutral* electron-hole pairs, are studied. The observation of the optical Aharomov-Bohm effect could be possible only due to carrier separation at the type II interface which would induce different trajectories for electrons and holes.