Optical studies of semiconductor quantum wires grown by vapor-liquid-solid method

Semiconductors are a group of materials which are characterized by a bandgap. A bandgap describes an energy range in which no electron states can exist. We can assume that in equilibrium the electrons of interest are on the bottom of the bandgap, while separated by energy ΔE are the closest allowed states. It means that if we shine a photon with lower than bandgap energy on the semiconductor, it will pass through, while for the higher than bandgap – it will get absorbed by the electron, which will now be in an excited state. Worth noting is that what defines a photon energy is its color (the more blue the more energetic, the more red, the less energetic).

After a photon had been absorbed, an empty place on the bottom of the bandgap was left. By a convention it is called a hole and is described as a positive charge carrier. The photon absorption act is followed by a recombination of electron and a hole, which, again, produces a photon. However in the short time in which the both carriers exist, they pull each other close and form a sort of „atom", called exciton.

This picture is correct for an infinitely large crystal. The situation changes, when its dimensions get restricted. It turns out that the electrons (and holes) can no longer have any energy. In a material in which confinement exist, so called bound states appear, characterized by well defined energies, higher than the bandgap energy.

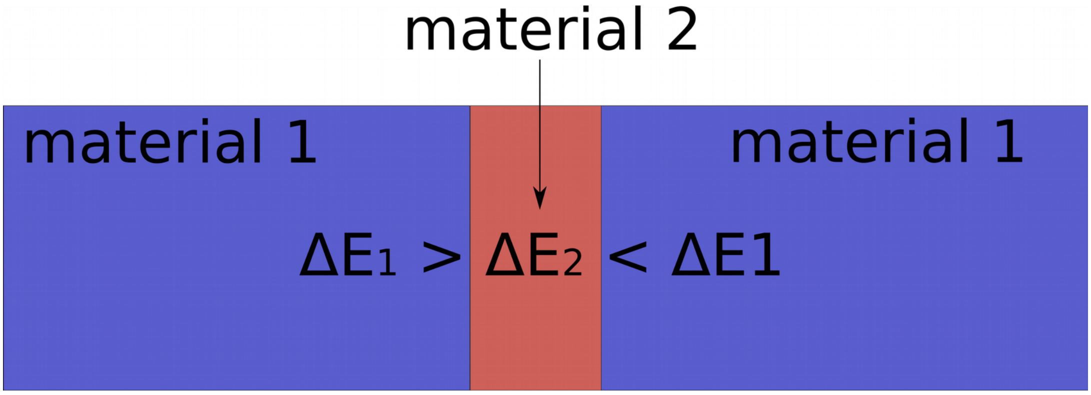

Illustration 1: Schematically shown cross section through a structure with one dimensional confinement, consisting of a material with wider bandgap (1) and narrower bandgap (2). So if a one dimensional confinement is reminescent of a layer, then two dimensional will look like a cylinder and a three dimensional – like a small ball. With thickness (or radius) of a material (2) getting smaller, bound states of higher and higher energy will appear.

A control of crystal thickness on the order of few nanometers (because only then the confinement effects are clearly visible) in two dimensionally confined structures is a tough task. A method for preparation of nanowires – structures about 30nm in diameter and about 1.5µm long is known, but only recently it was shown, that they can be further thinned down to a few nanometers in a very simple way. Namely, they have to be heated up – a material will start to sublimate and as an effect, a much thinner structure will be produced: a quantum wire. The structures for this project will be prepared exactly this way.

Yet another thing is connected with a quantum confinement – the aforementioned excitons get much closer together (they gather in narrower bandgap region). Thanks to that, they can pair up and form so called biexcitons, or bind an additional electron or hole and form a trion. Studying those complexes in quantum dots allowed for description of subtle phenomena concerning the charge carriers and their recombination. For quantum wires this topic is mostly unexplored.

Going back to the holes, it turns out that they are different than electrons in many ways. They can be divided into light and heavy holes (which is connected with the orbital an excited electron originates from). The states connected to the heavy holes are usually a little more energetically favorable, so in the process of excitation the heavy holes are created. It is however predicted, that for quantum wires the light holes will be energetically privileged, which is a rare and desired property.