Title : Growth and properties of type II ZnTe/CdSe radial nanowire heterostructures

Authors : J. Płachta[1], M. Szot[1], A. Kaleta[1], A. Petruchik[1] L.T. Baczewski[1], G Karczewski[1], T. Wojtowicz[1,2], J. Kossut[1] and P. Wojnar[1]

1) Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, Warsaw, Poland
2) International Research Centre MagTop, Warsaw, Poland.

Introduction :

Generally , there are two qualitatively different band layouts. The most common one, known as type I is used in standard quantum well designs. It allows for an effective recombination due to both charge carriers occupying the same region of the sample. Type II is reminescent of a diode design - it allows for a charge separation and can be used as a barrier for only one type of charges in photovoltaic devices. In type II junction, the recombination is still possible, however it is much less likely. It also exhibits a few different characteristics compared to type I.

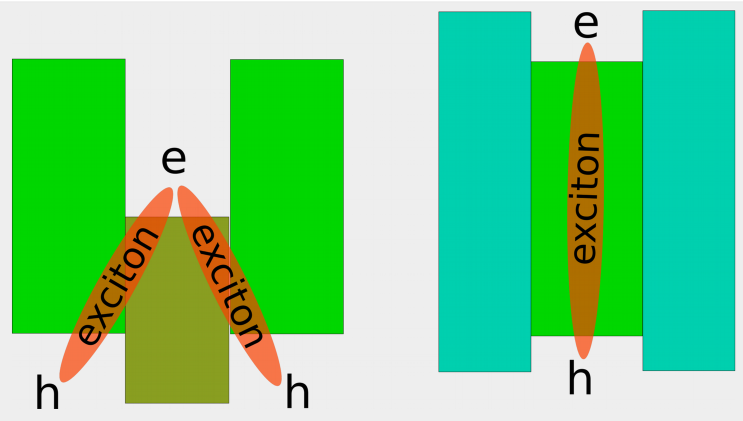


Fig.1 Two different types of junctions in respect to band layout, with localisation of charges and excitons indicated. a) presents type II, where the charges are spatially separated, b) type I, where charges occupy the same region.

Samples :

The nanowires were grown on (111) - oriented silicon substrate with a 0.6nm gold layer deposited in a separate process. Before loading, the substrates were deoxidized in 38% HF solution. The Au-Si eutectic droplets formed after annealing the substrate in 450°C in MBE chamber prior to growth.

The growth itself proceeded as follows:

- 35min. ZnTe core growth at 380°C
- 6 min. CdSe inner shell deposition at 350°C
- 10 - 15 min. outer shell deposition at 300°C - 330°C

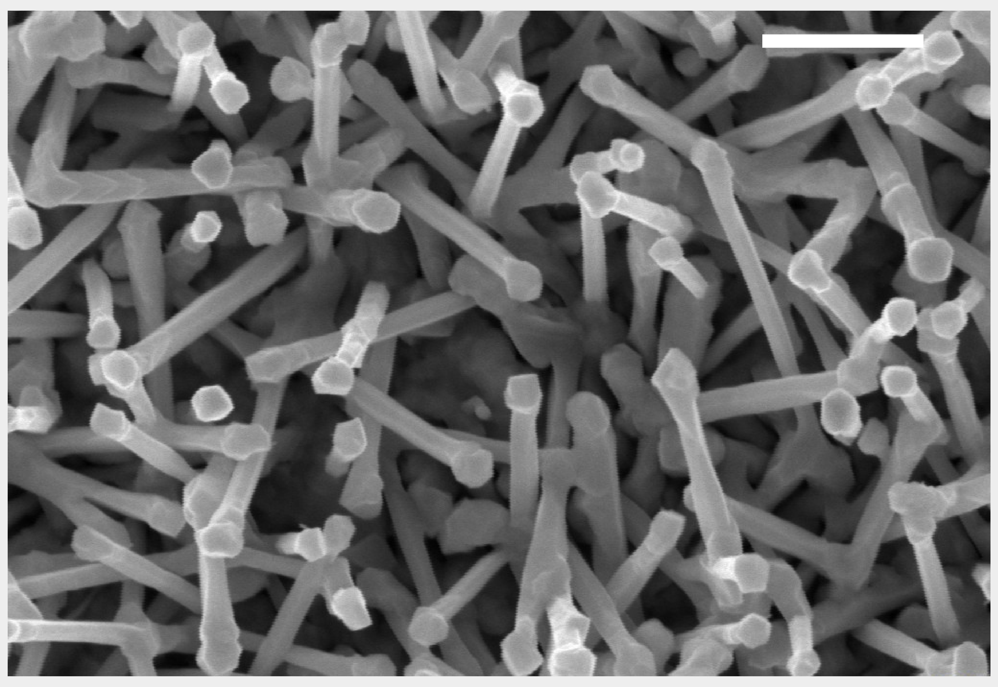


Fig. 2 SEM image of the as grown sample. The nanowires are about 1.5 μm long and 60 nm in diameter. The scale bar is 400nm

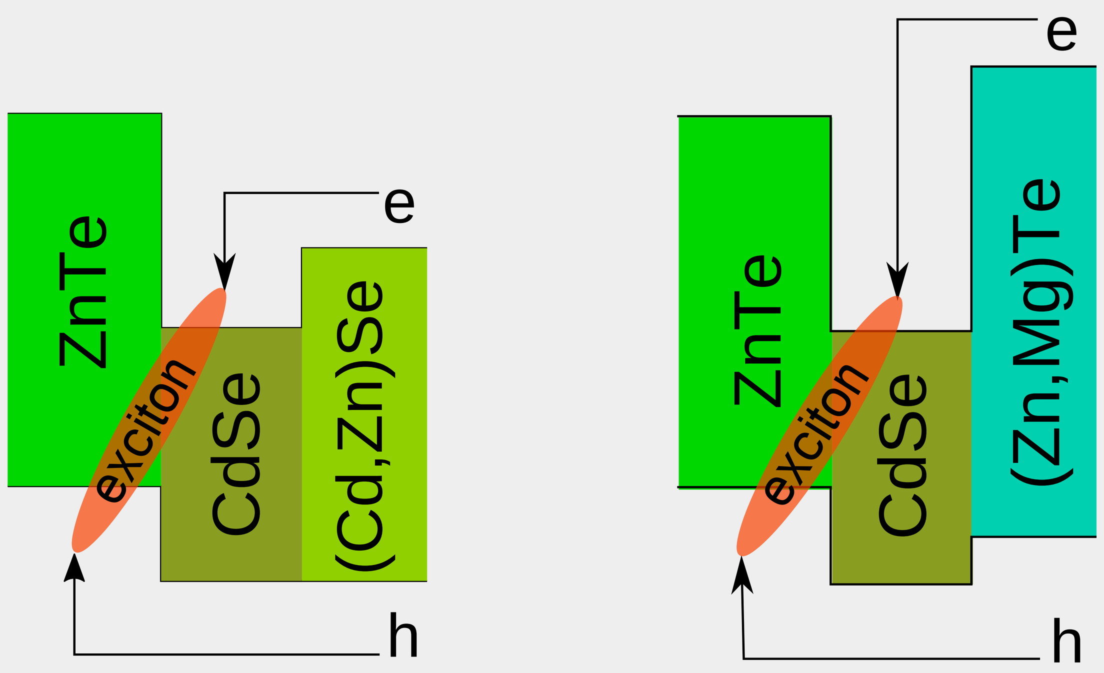


Fig. 3 Compounds used to create heterostructures exhibiting a type II band alignment. The use (Zn, Mg)Te shell resulted in much better optical properties of the samples.

The majority of the work was dedicated to grow high quality samples, i.e. those with most efficient type II transition. A wide variety of parameters and approaches was checked, including different outer shells, shell thicknesses and growth temperatures, inner shell Zn content (to move the transition to higher energies), inclusion of quantum dot in the core and so on.

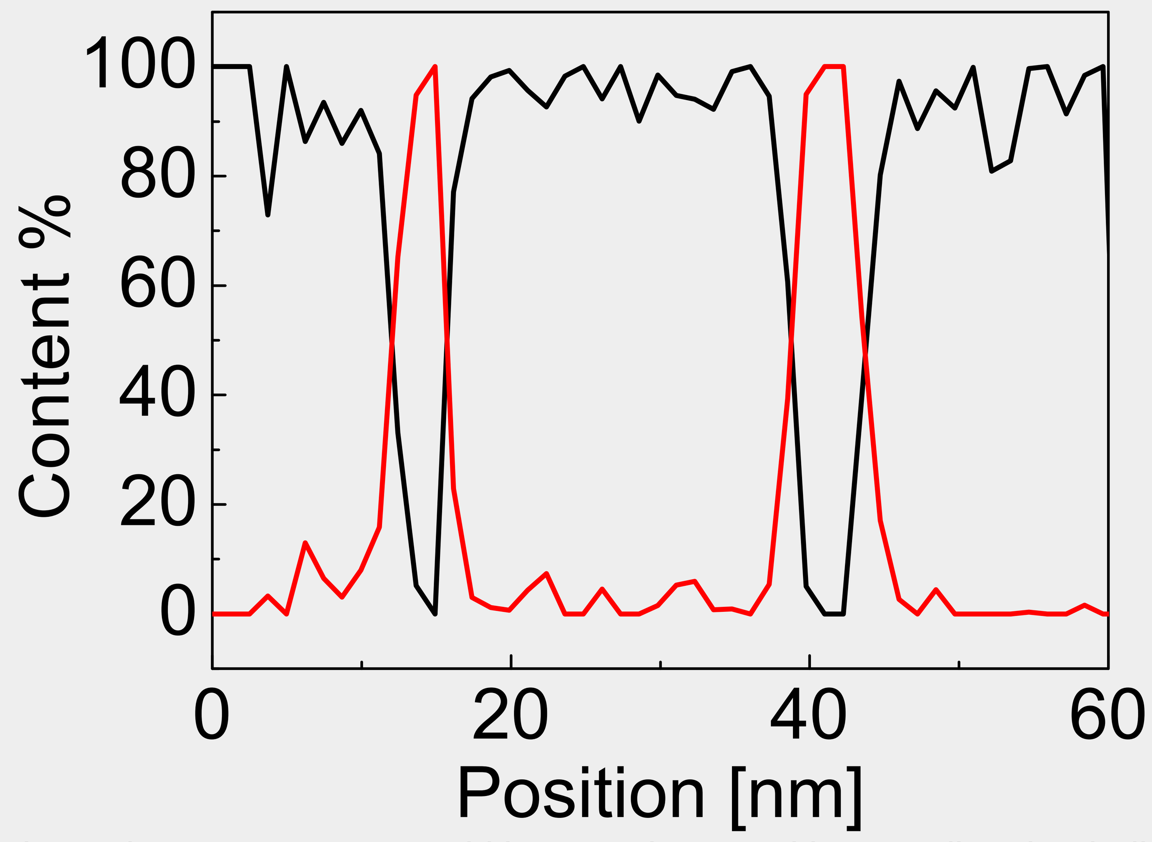
A curious result is that (Cd, Zn)Se shell performed much worse than (Zn,Mg)Te, even though the band alignment indicated otherwise.

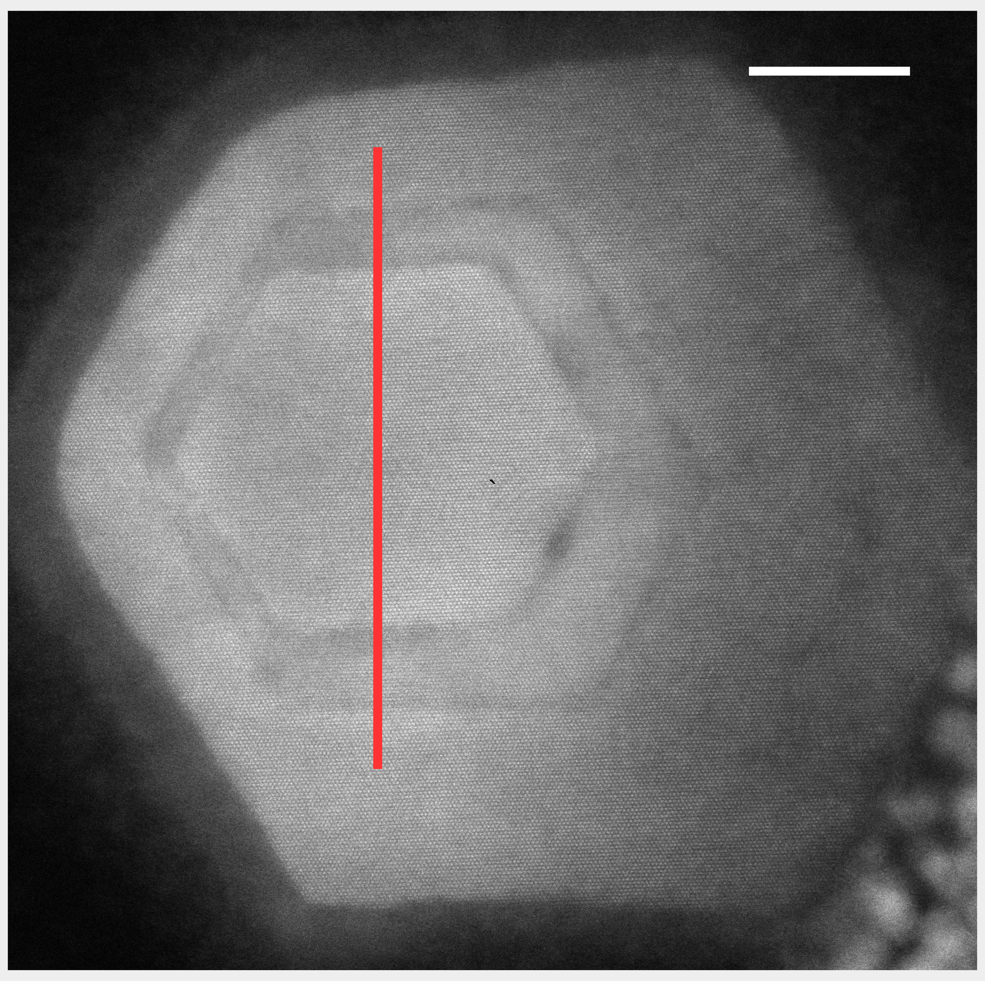
The localization of the indirect exciton was also investigated by changing Mg content in the outer shell. The emission energy didn't change.

Nanowires without an outer shell did not exihbit any luminescence.

Structural study :

Despite having different electronic properties, ZnTe and CdSe have nearly identical lattice constant, which makes them perfect for this type of structure. Thanks to this the nanowires have nearly perfect, hexagonal shape. The inner shell's shape and composition is very well defined, as proven by STEM and EDX study. It is found to be about 8 nm thick. The visible non-uniformity of the thickness is caused by random direction of growth brelative to substrate, which causes partial „shading" of the structure.





Fi.g 4 a) EDX spectrum and b) STEM image with scan direction indicated. In a) sum of Zn and Te signal is marked as black and sum of Cd and Se signal as red. The different materials are also obviously visible in b) thanks to Z contrast of STEM mode. The scale bar in b) is 20nm

Photoluminescence :

The chosen band alignment resulted in a near infrared emission at about 1.05eV, which agrees very well with a theoretical prediction. It also exhibits a strong bluseshift, which confirms the type II character of the transition. To confirm that the emission comes from core-inner shell interface, a series of samples with variation of Mg in the outer shell was prepared. It did not have an impact on emission energy, which confirmed the emission origin. An attempt to move the emission to visible wavelengths was also performed, but unfortunately the emission intensity rapidly decreased with Zn content in the inner shell.

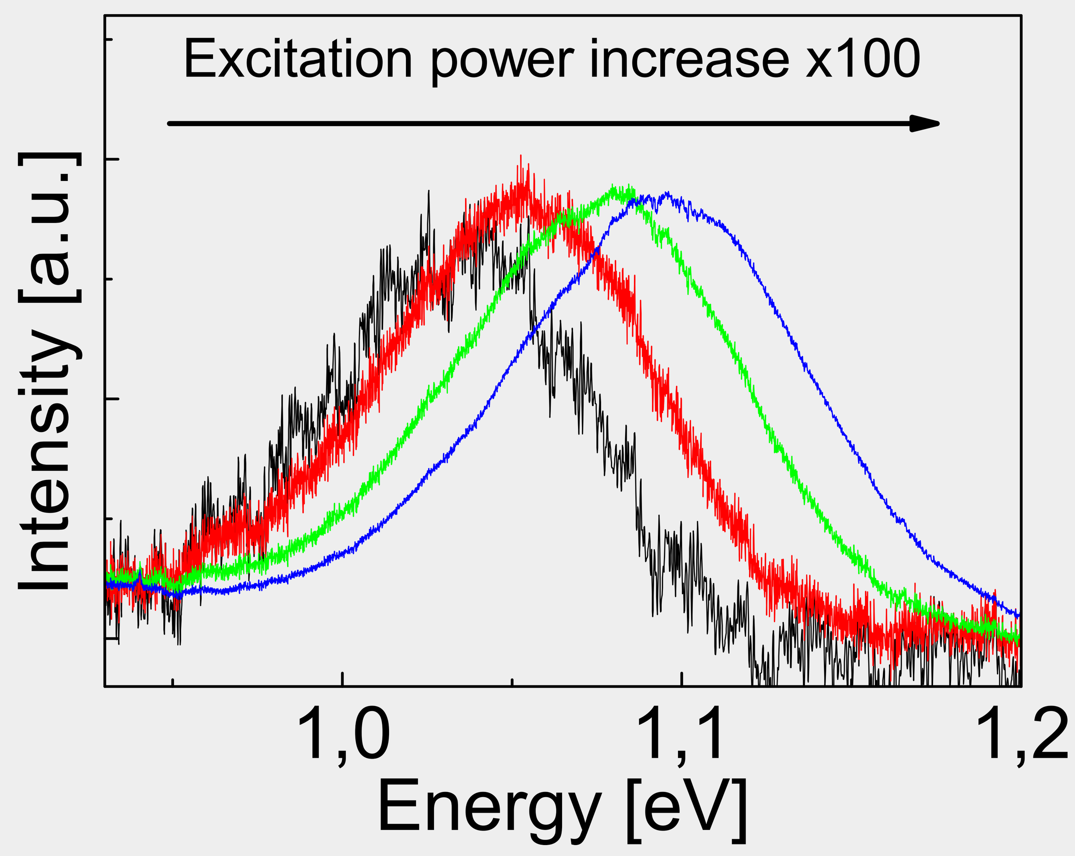


Fig. 5 More than 60meV blueshift observed for 100x excitation power increase. It is most probably originating from nanowires – proven by removing nanowires from the substrate and checking luminescence from the resultant sample.