Changes of the light hole / heavy hole character of the excitonic emission from (Cd,Mn)Te/(Cd,Mg)Te core/shell nanowires induced by the strain and quantum confinement

P. Wojnar[1], **J. Plachta**[1], **T. Kazimierczuk**[2], **P. Kossacki**[2], **T. Wojtowicz**[3]

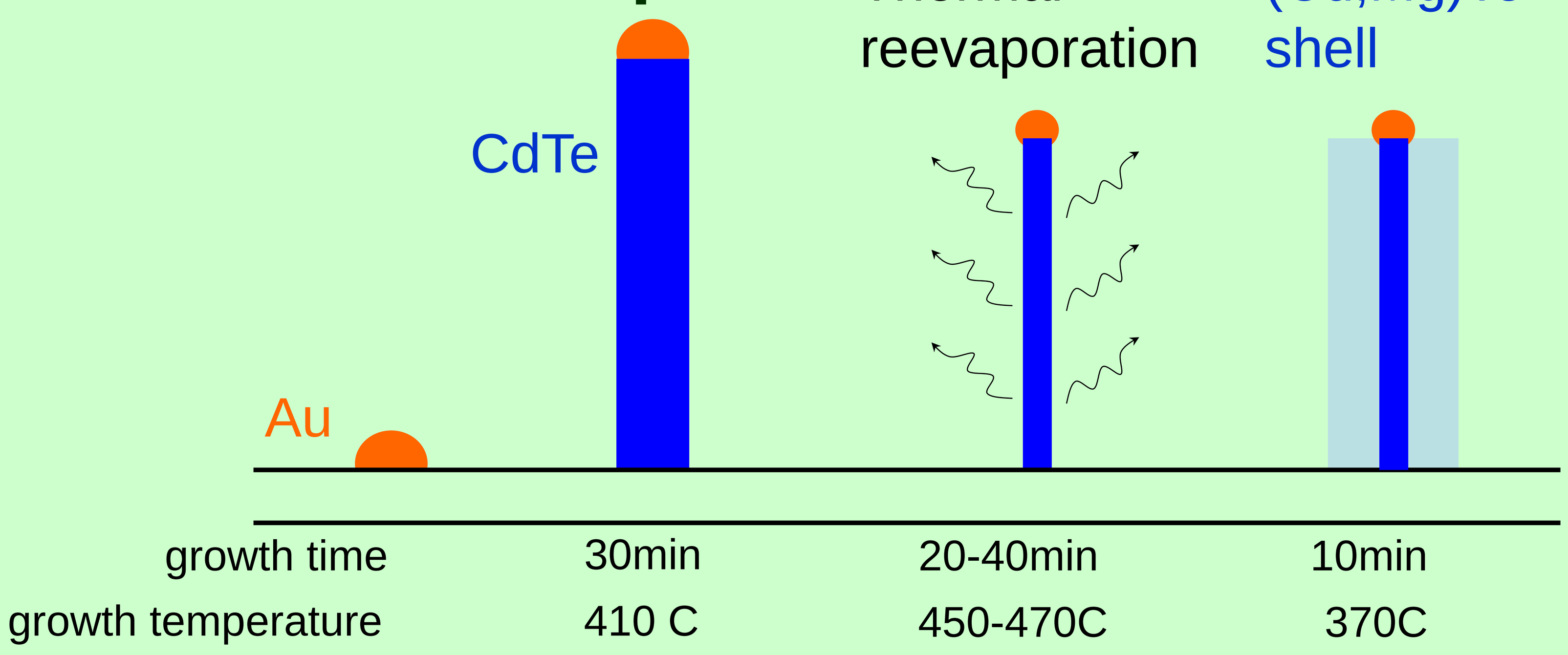
[1] Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, PL-02-668 Warsaw, Poland
[2] Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
[3] International Research Centre MagTop, Aleja Lotników 32/46, PL-02-668 Warsaw, Poland

Motivation:

Nanowires (NWs) built of large and intermediate band gap semiconductors, such as CdTe, GaAs, GaN or Si, are usually described by three-dimensional (3D) bulk-like properties. Despite of the large aspect ratio (length to diameter) typical for these structures their diameters are still too large to exhibit typical features of one-dimensional (1D) quantum confinement. In order to observe the quantum size effect one needs to reduce the NW diameters typically below 20 nm.

The aim of this study is to investigate the quantum size effect in ultra thin CdTe nanowires. In order to reduce the NW diameters thermal reevaporation process is applied. A similar technique has already been used to investigate 1D confinement in GaAs nanowires [Loitch B, Advanced Materials **2015**, *27*, 2195].

Growth of the samples



Cadmium telluride nanowires (NWs) are grown in a system for molecular beam epitaxy by employing the vapor-liquid-solid growth mechanism assisted with gold catalysts. Subsequently, in a process of thermal reevaporation, NWs are thinned down to diameters *even below 10 nm*. In the final step, a (Cd,Mg)Te passivation shell is deposited in order to obtain an efficient optical emission.

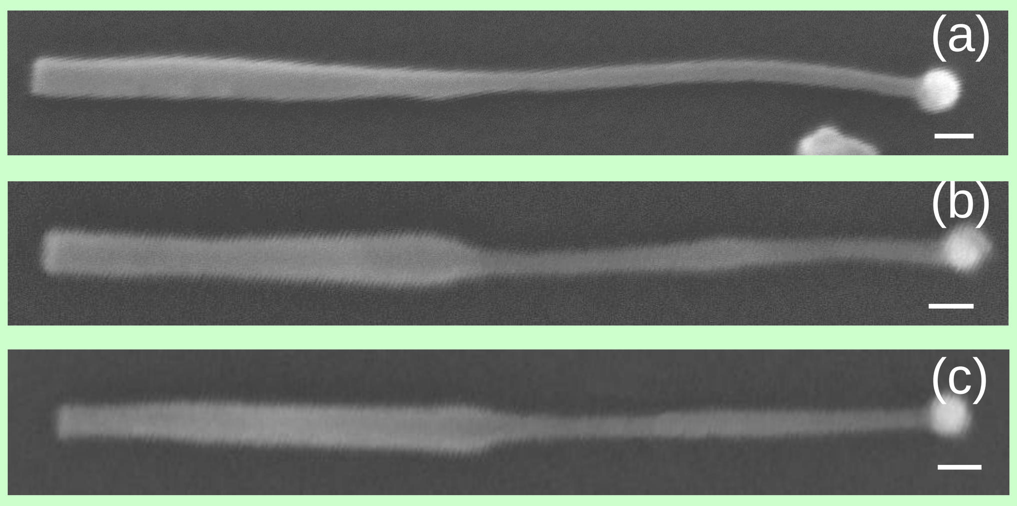


Fig.1 Scanning electron microscope images of three CdTe NWs thinned in the thermal evaporation process at 470C. The diameters at the thinnest position amount to (a) 12.3 nm (b) 9.4 nm (c) 9.7 nm. The scale bars are always 20nm. The electron acceleration voltage amounts to 5 kV and the probe current 50 pA

Photoluminescence - PL

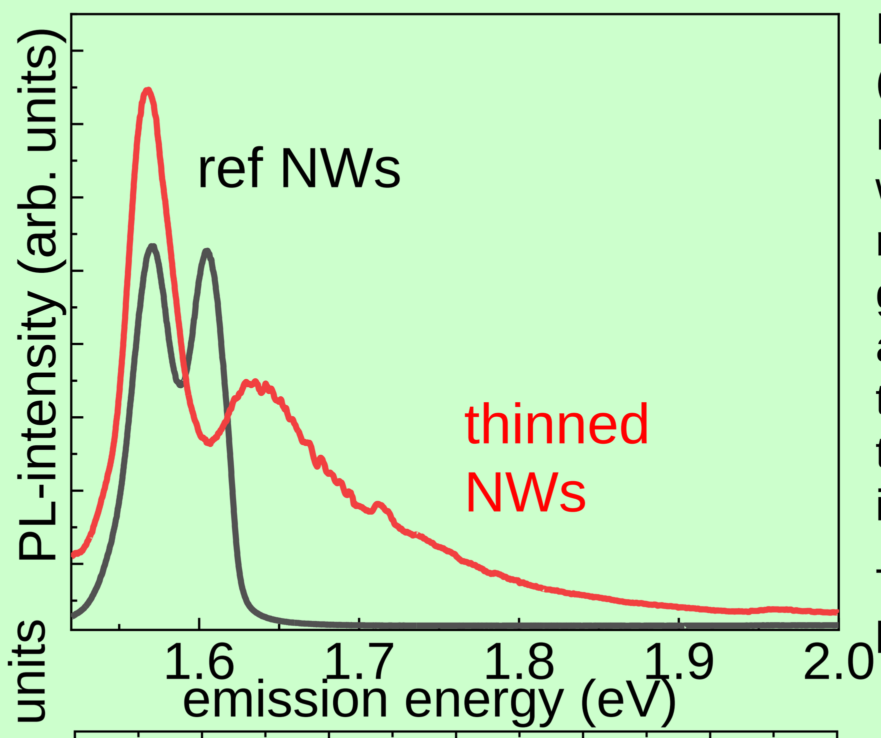


Fig.2 Normalized PL spectra from (Cd,Mn)Te/(Cd,Mg)Te core/shell NWs. Red line corresponds to the sample with thinned NWs and black line to a reference sample. Both samples are grown in the same conditions, one just after the other. The only difference is the use of the reevaporation process in the case of the sample which spectrum is given by the red line.

T = 10 K, excitation with the 473 nm laser.

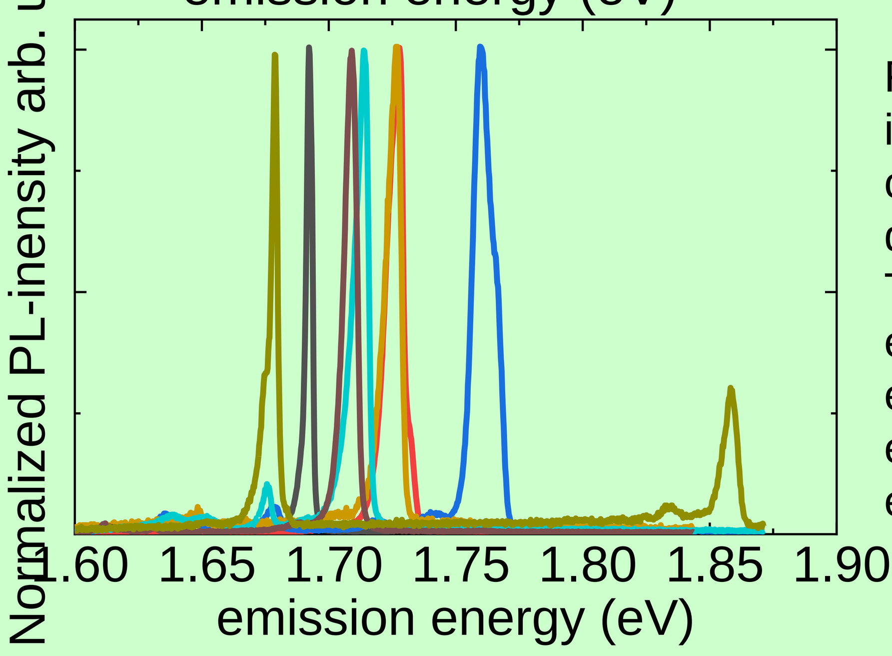


Fig.3 Micro-PL from the several individual thinned (Cd,Mn)Te/(Cd,Mg)Te core/shell nanowires. The nanowires are dispersed on a non-emitting substrate. The emission lines appear at various energies corresponding to the high energy tail present in the NW ensemble emission (red line in Fig 2). T=10K, excitation 405nm, exc. spot size 3μm

Cathodoluminescence - CL

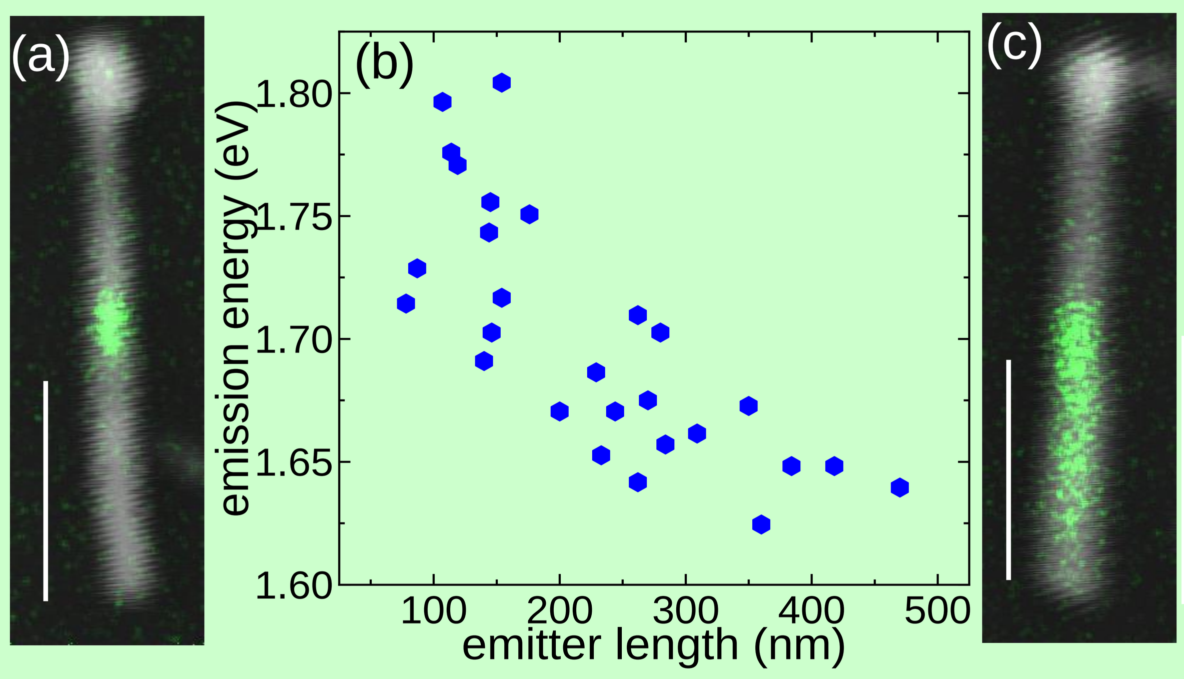
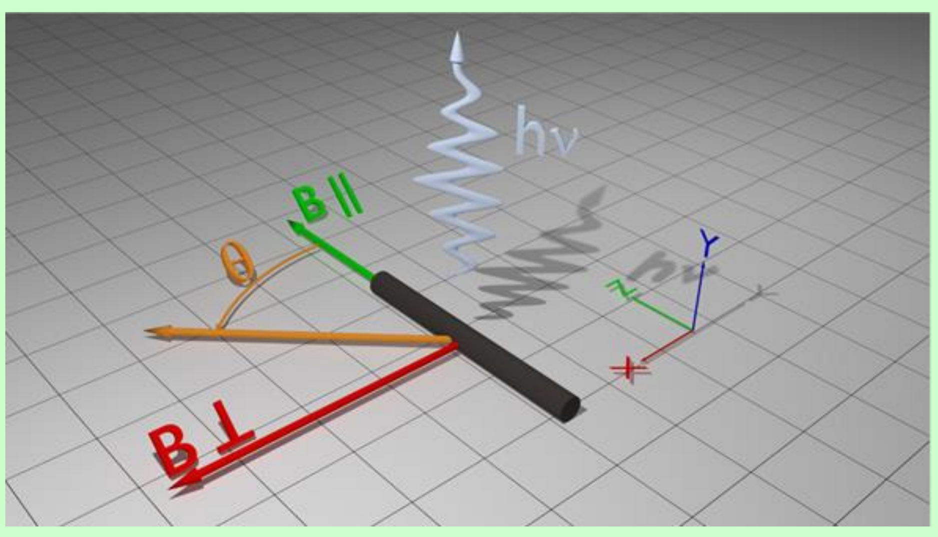


Fig.4 Cathodoluminescence (CL) from individual nanowires. The emission energy correlates with the length of the emitting area. (a) and (c) show CL maps performed on a nanowire emitting at high and at low energy, respectively. The CL maps (in green) are superimposed on SEM images of the NWs. (b) Emission energy vs the emitter length determined from CL maps from 20 individual nanowires. Scale bars are 500nm. T=10K, U=15kV and probe current 500pA.

Magneto-photoluminescence



Geometry of the experiment.

NW lies in the XZ plane. Z axis corresponds to the NW axis, X-axis is perpendicular to it, excitation and emission take place along Y axis. Magnetic field is applied in the XZ plane

The measurements of the Zeeman shift as a function of magnetic field applied parallel and perpendicular to NW axis are used to determine whether the emission has a light- (LH) or heavy hole (HH) character.

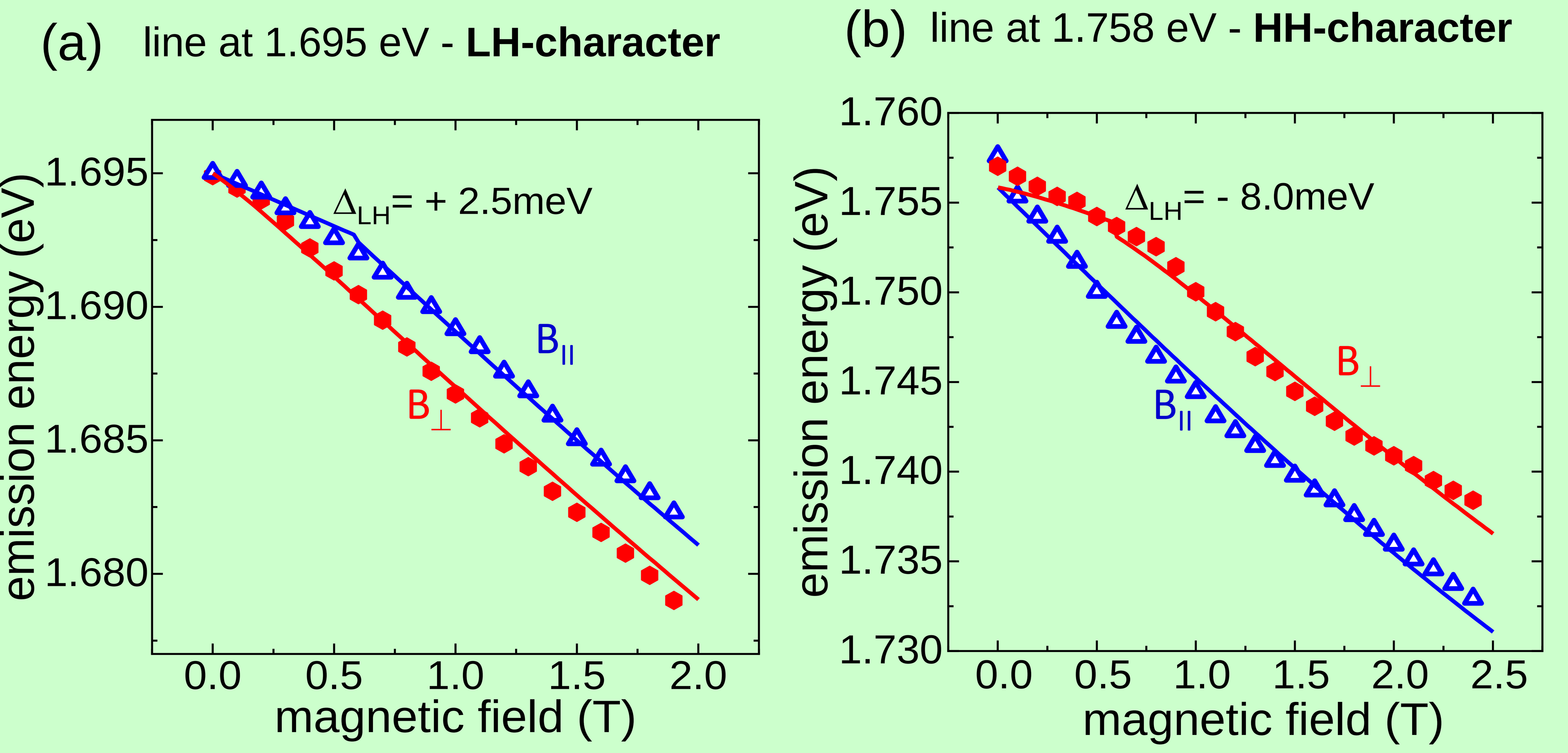


Fig. 5 Zeeman shift measured for two individual (Cd,Mn)Te/(Cd,Mg)Te nanowires emitting at (a) 1.695 eV – light hole (LH) character of the excitonic emission and (b) 1.757eV – heavy hole (HH) character of the excitonic emission, T = 1.8K excitation with 515nm line, P=1μW

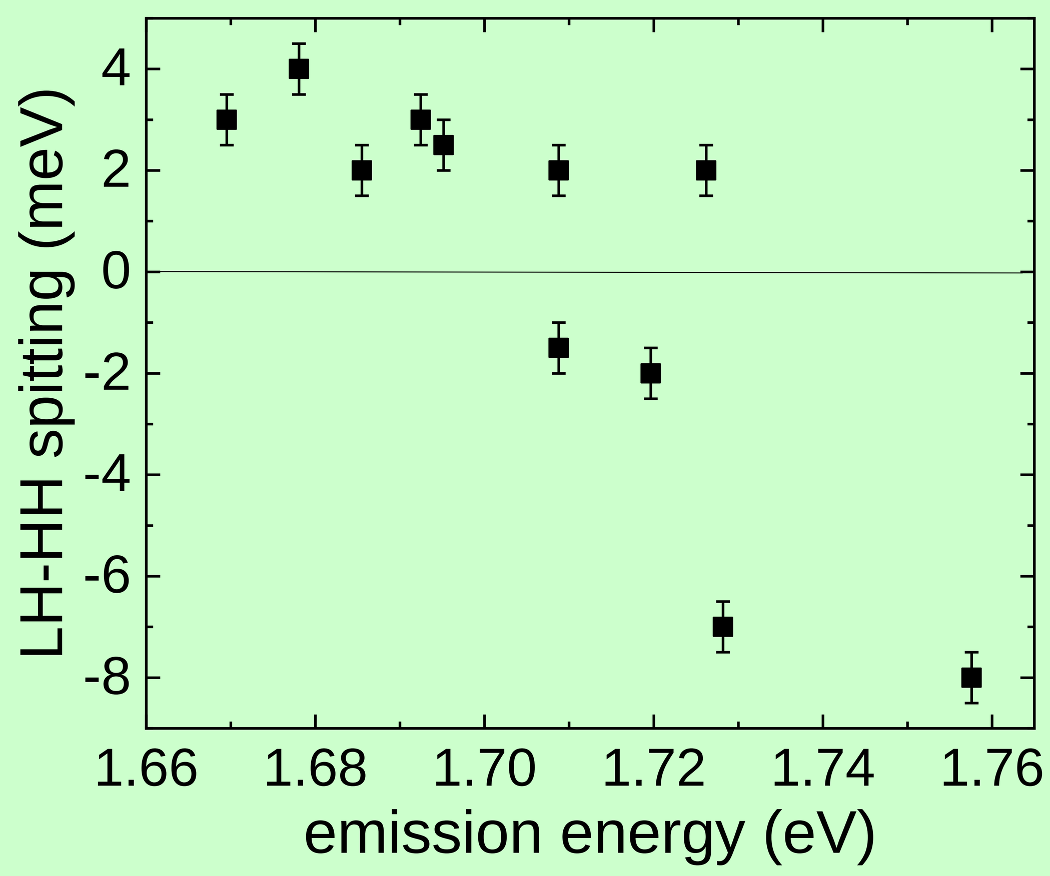


Fig. 6 LH-HH splitting as a function of the emission energy at zero field for 10 NWs. T=1.8K, λ_{ex} = 515 nm. Values larger than 0meV - light hole (LH) character of the emission. Values smaller than 0meV – heavy hole (HH) character.

The lines emitting at lower energies show LH character and those emitting at higher energies – HH character

Summary

✓ CdTe and (Cd,Mn)Te nanowire are thinned down to diameters below 10nm by applying the thermal reevaporation technique in a system for molecular beam epitaxy.

✓The optical emission from the ultra-thin nanowires takes place at higher energies (1.6eV – 1.9eV) as compared to the emission from reference nanowires (1.6eV – 1.65eV) with diameters of the order of 30nm - 40nm.

✓ Emission lines from individual nanowires can be resolved by using either micro-PL or CL techniques.

✓CL measurements reveal that the length of the emitting area in the axial direction is quite well correlated with the emission energy. Smaller objects emit at higher energies.

✓ Magneto-PL study performed on several individual nanowires reveals whether the optical emission is due o light- or heavy hole recombination. Light hole related emission is typical for nanowires emitting at relatively low energies (< 1.70 eV). Heavy hole recombination is typical for the lines emitting at relatively high energies (> 1.70 eV) i.e., from small objects.

This work has been partially supported by the National Centre of Science (Poland) through grant 2017/26/E/ST3/00253, and by the Foundation for Polish Science through the IRA Programme co-financed by the EU within SG OP (grant No. MAB/2017/1).