Optical emission from highly strained CdTe/(Zn,Mg)Te nanowires

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Introduction

Semiconductor nanowires serve as versatile platforms, allowing structural configurations and effects not possible to achieve under planar conditions. In particular, it allows creation of highly mismatch and strained heterostructures without formation of misfit dislocations [1].

In this work, CdTe/(Zn,Mg)Te core/shell nanowires characterized by a large lattice mismatch (up to 4,9%) between core and shell semiconductor are investigated. In particular, the near band edge emission from highly strained semiconductor system can be observed. It is demonstrated that the presence of the compressive strain induces a significant blueshift of the emission energy.

In order to investigate these properties of studied system, combined methods of micro-photoluminescence (μ-PL), cathodoluminescence (CL) and scanning electron microscopy (SEM) were used.

Growth of the sample

CdTe/(Zn,Mg)Te nanowires are grown by employing vapor-liquid-solid growth mechanism in a system for molecular beam epitaxy. The growth takes place on a (111)-oriented silicon substrate, on which a 0,7 nm thick gold (4N) layer is deposited using Quorum Q150T plasma sputter coater prior to ensure proper growth of the nanowires.

Growth procedure is as follows: sample is first heated to temperature of 750°C to melt Au/Si eutectic, forming catalyst droplets and to ensure desorption of fluorine bound to Si surface after etching process. Temperature is then lowered to 500°C and 5 minutes ZnTe growth process start, followed by CdTe growth at temperature around 440°C for 50 minutes (with Te/Cd flux ratio around 1,2) and finally (Zn, Mg)Te shell deposition process for 2, 4, 6 and 8 minutes. The growth process used in this work is very similar to one previously described in [2]. The only difference relies on the fact that here, we have used (Zn,Mg)Te shell instead of (Cd,Mg)Te.

Conclusions:

1) Highly strained CdTe/(Zn,Mg)Te core/shell nanowires were successfully grown and investigated using combined optical and structural methods.

2) CdTe/(Zn,Mg)Te core/shell nanowires with shell thickness of around 40 nm show significantly higher emission insensity than nanowires with thinner or thicker shells. A significant blueshift of emission energy compared to unstrained CdTe bandgap is observed. This is caused by strain coming from lattice mismatch between the nanowire core and the shell.

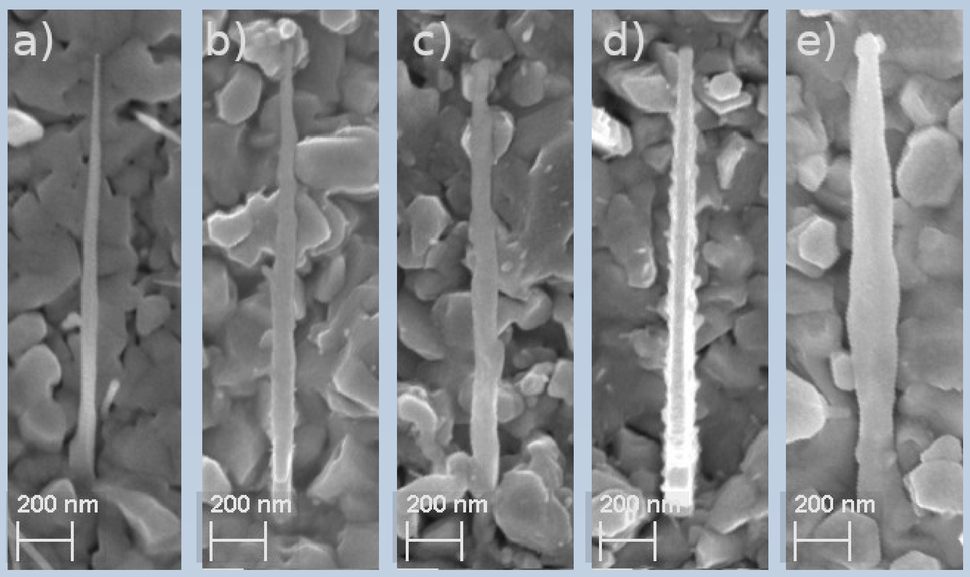
3) CL measurements demonstrate that the emission spectrum from a single nanowire may consist of several emission lines with the energy ranging from 1,63 eV to 1,76 eV. This distribution comes from different strain conditions along the nanowires, whereas larger strain leads to higher emission energies.

References:

[1] F. Glas; Physical Review B vol. 74 121302

[2] J. Płachta, A. Kaleta, S. Kret, T. Kazimierczuk, K. Połczyńska, P. Kossacki, G. Karczewski, T. Wojtowicz, J. Kossut, P. Wojnar, Nanotechnology 31 215710

Results and discussion



	Average diameter [nm]	Standard deviation [nm]
CdTe	54,32	9,10
CdTe/(Zn,Mg)Te 2 min	95,95	18,05
CdTe/(Zn,Mg)Te 4 min	107,49	16,67
CdTe/(Zn,Mg)Te 6 min	138,31	19,96
CdTe/(Zn,Mg)Te 8 min	207,93	48,02

Tab. 1 Average diameter of grown nanowires (in nm).

Fig. 1 Scanning electron microscope images of “as grown” CdTe (a) and CdTe/(Zn,Mg)Te core/shell nanowires with 2, 4, 6 and 8 minutes shell growth time ((b), (c), (d) and (e), respectively). The average shell thickness was estimated to range from around 20 nm for 2 minutes (Zn,Mg)Te growth time to 75 nm for 8 minutes (Zn,Mg)Te deposition time. Scale bars are 200 nm in all images.

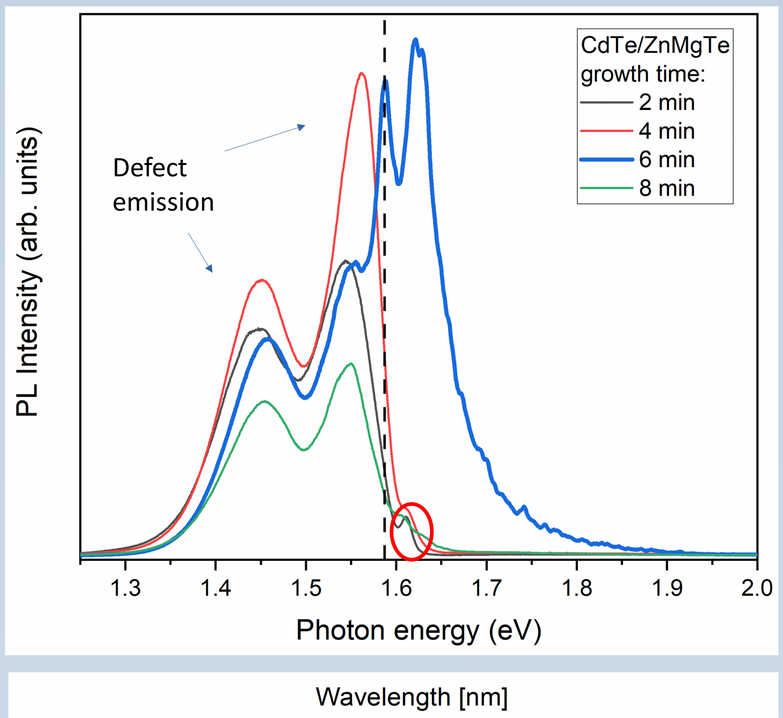


Fig. 2 Photoluminescence (PL) spectra of CdTe/(Zn,Mg)Te core/shell nanowires with different shell thicknesses (7-8 K, 405 nm excitation laser). Upon reaching sufficient shell thickness (around 42 nm, achieved in the case of 6 minutes growth time), compressive strain within structure causes a blueshift of the emission energy above 1,59eV (which corresponds to the unstrained CdTe bang gap, dotted line on the figure). Thinner shell does not provide a good enough passivation of surface states, which leads to a significantly lower emission intensity, while further increase of the shell thickness causes, most likely, the formation of misfits dislocations, which also act detrimentally on the emission intensity (marked by red circle on the figure).

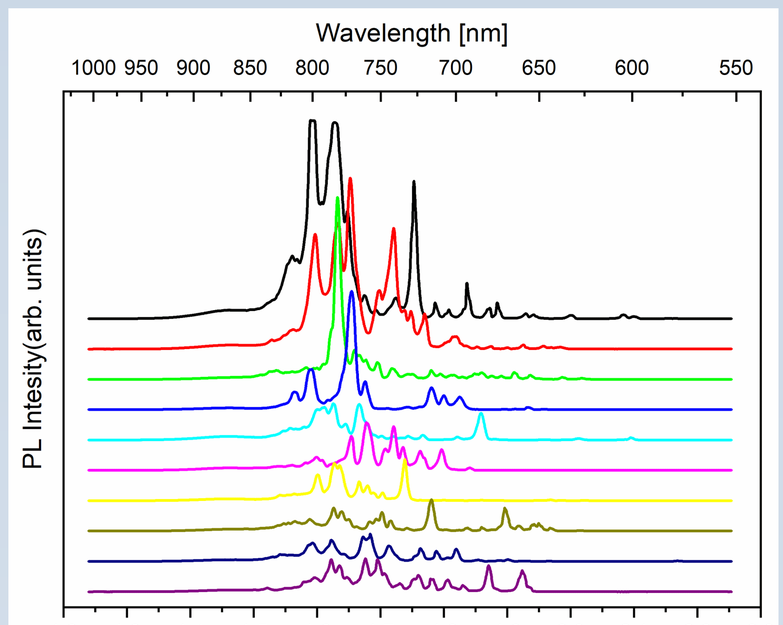


Fig. 3 Micro-photoluminescence spectra of CdTe/(Zn,Mg)Te core/shell nanowire with shell thickness of around 42 nm measured at different spatial positions on the sample (7-8 K, 405 nm excitation laser). Several relatively sharp lines originating from different nanowires are observed. Different emission energies reflect different strain conditions in these nanowires.

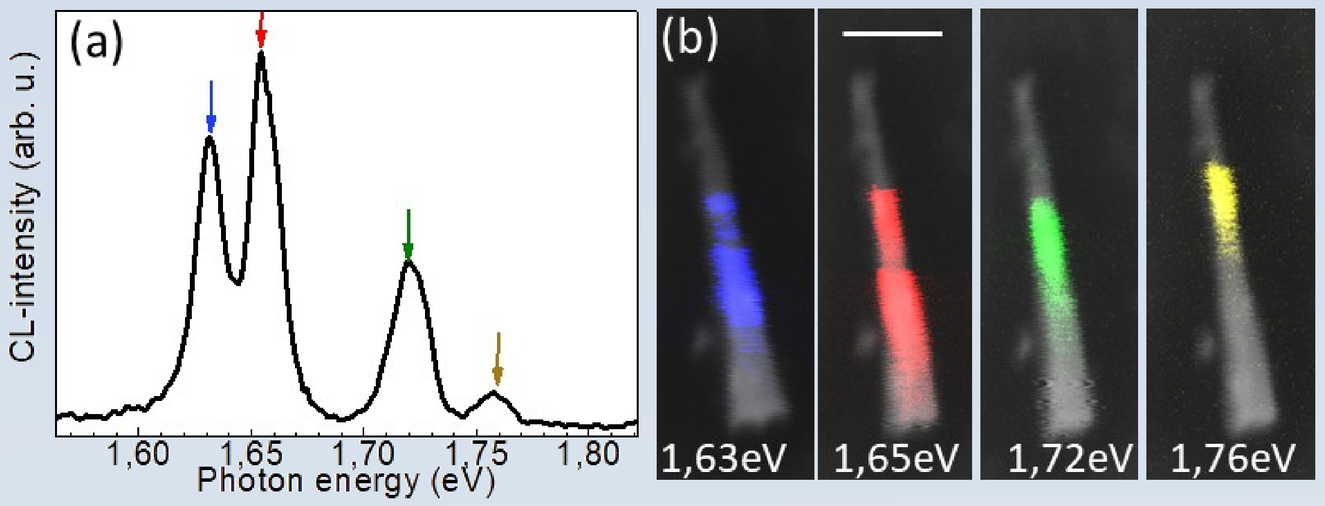


Fig. 4 Cathodolumiscence (CL) from a single nanowire: emission spectrum (a) (U=5keV, I=500pA, T=10K) and CL-maps (b) performed at various energies; scale bar is 400nm. Different emission lines are, most likely, the result of different strain conditions along the nanowire axis. They suggest the existence of exciton localization areas at various positions along the nanowire.

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