Growth and optical properties of type II ZnTe/ZnSe core/shell nanowire quantum dots

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Introduction

A recent observation of excitonic Aharonov-Bohm effect in core/shell nanowires (NWs) has opened an exciting opportunity to study coherently rotating states in these structures [1], which could be, subsequently, applied in the field of quantum information storage. An important task for the observation of these states is the separation of electron-hole wavefunctions within a NW heterostructure. It can be achieved by buildig the heterostructure from two semiconductors characterized by a type II band alignment.

In this work, an approach for fabrication of NW quantum dots (NWQDs) with type II band alignment inside NW built of II-VI semiconductors is presented. In this step, our goal has been to observe an optical emission from a single ZnTe/ZnSe NWQD and to demostrate that electron-hole separation takes place in this structure. This result would open a path for investigating excitonic Aharonov Bohm effect in these structures. The nanowire heterostructures are grown by molecular beam epitaxy by applying the vapor-liquid-solid growth mechanism assisted with gold catalysts.

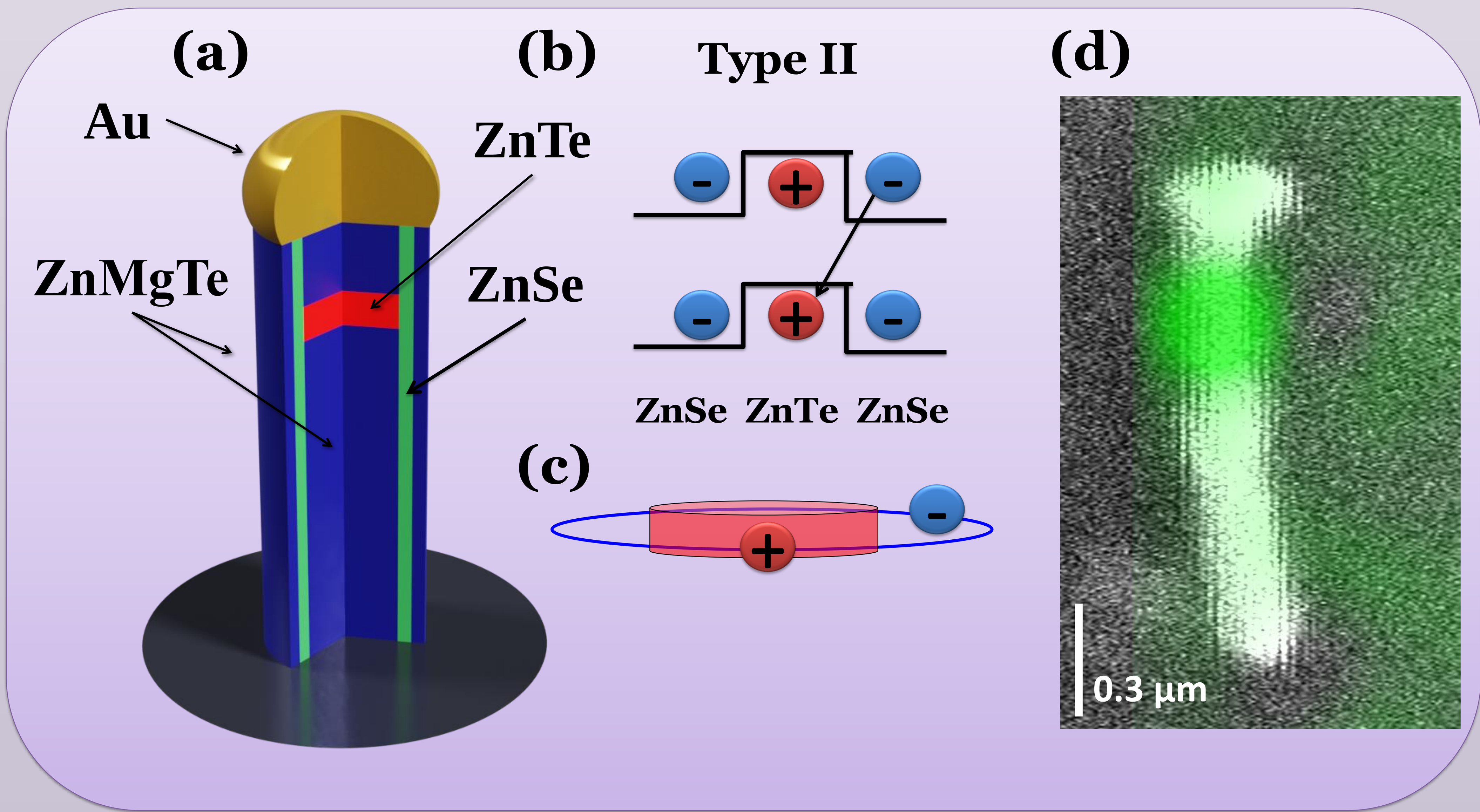


Fig. 1. a) Scheme of the investigated NW heterostructure. b) Band edge alignment in type II heterostructures; arrow – optical transition. c) Spatial separation of carriers occurring in studied NWs. d) Low temperature, Cathodoluminescence (CL) map of type II performed at 2.1eV from a single nanowire heterostructure

Ensemble emission

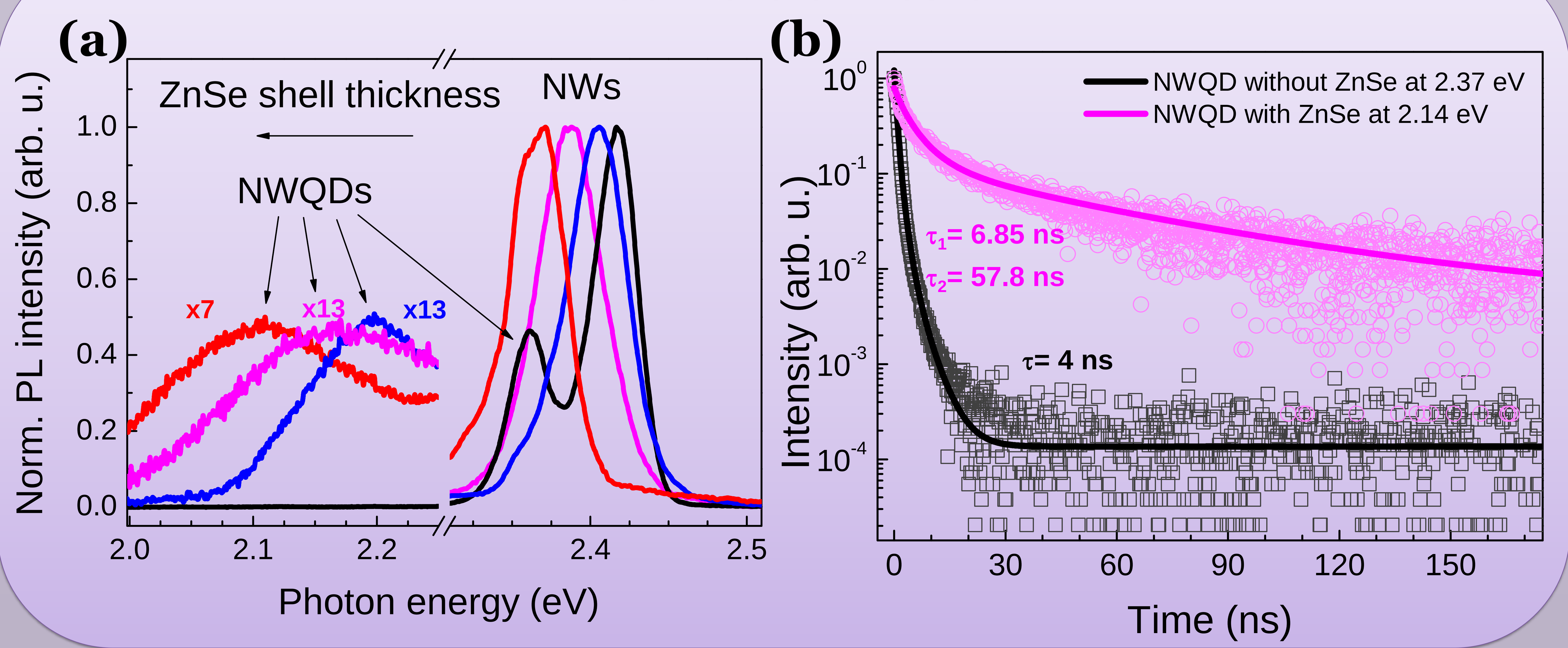
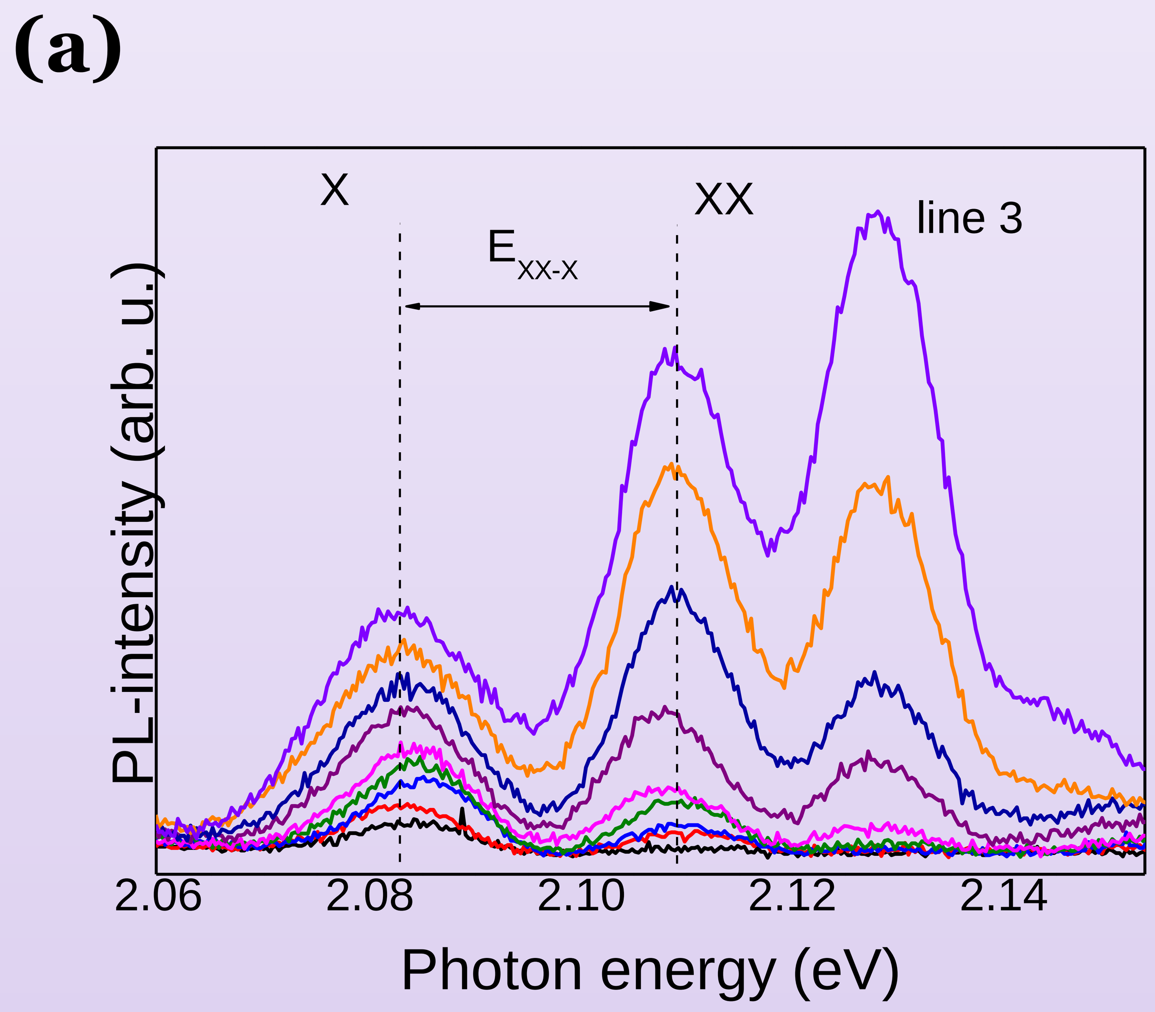


Fig. 2. a) Photoluminescence (PL) spectra of investigated nanowires with different thickness of ZnSe shell. Black line is the spectrum from a reference sample without ZnSe. A significant redshift is observed with increasing ZnSe shell thickness. The temperature of the measurement is 7 K and the excitation wavelength 405 nm. b) TRPL decay from NWQDs. Black line is decay from the reference sample. Magenta line is signal from nanowires with a ZnSe internal shell. In type II NWQDs significant increase of PL lifetime is observed.

Single NWQD emission



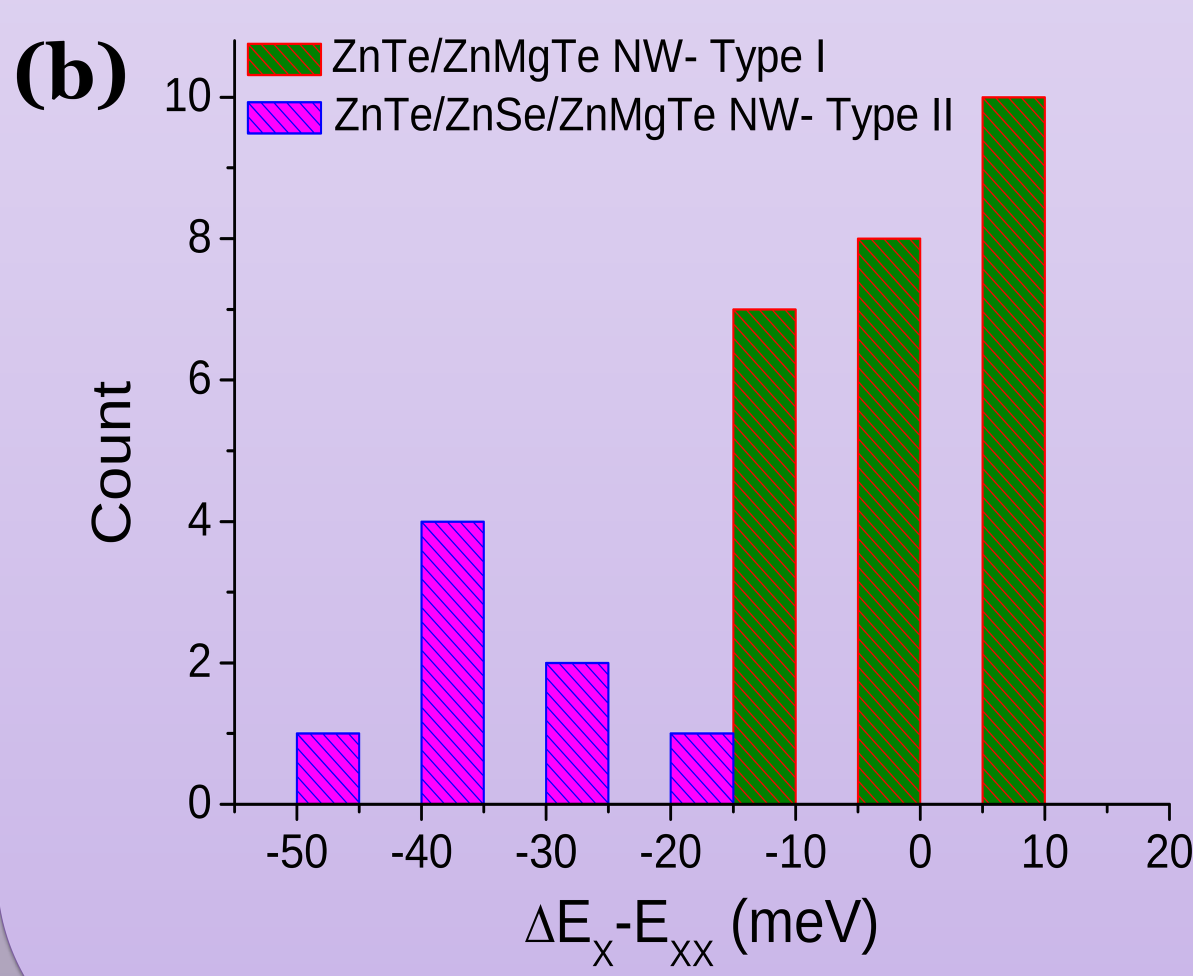


Fig. 3. a) µ-PL spectra of individual NWQD with ZnSe shell with increasing excitation power. Excitonic and biexcitonic emission can be identified. The temperature of the measurement is 7 K and the excitation wavelength 405 nm. b) Histogram of the biexciton binding energy (E_X-E_{XX}) for type I and type II NWQDs.

Conclusions

- In the case of the studied ZnTe/ZnSe/ZnMgTe structure, PL consist of two optical emission lines coming either from the nanowire (Zn,Mg)Te cores or from the ZnTe /ZnSe NWQDs.
- Cathodoluminescence (CL) study has shown that optical emission lines with lower energy originates from NWQDs.
- The addition of only one monolayer thick ZnSe shell significantly changes the optical emission spectrum. The emission energy of the quantum dot emission shifts significantly from 2.37 eV to 2.1 eV.
- PL intensity drops by about one order of magnitude and the decays times increase by the factor of about 10. These observations are consistent with the type I to type II band alignment transition resulting from the presence of ZnSe shell.
- In µ-photoluminescence the broad emission at 2.1 eV splits into several relatively lines coming from individual nanowire quantum dots. This association is confirmed by the appearance of multiexcitonic emission lines when increasing the excitation power.
- In nanowires with ZnSe internal shell biexciton appears in higher energies than exciton. In reference sample this effect is also visible, but biexcitonic binding energy (E_X-E_{XX}) values are significant smaller. In the case of nanowires with ZnSe shell the impact of the spatial electron-hole separation at the type II dot/shell interface contributes to the biexciton binding energy.

[1] Corfdir P, *et al.* *Adv. Mater.* **31** 1805645 (2019)

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