Zinc oxide nanocrystals: ultra-long recombination times, mechanosynthesis, and mesoporous scaffolds for PSCs

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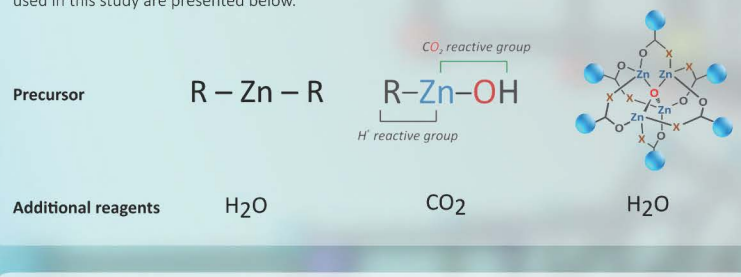
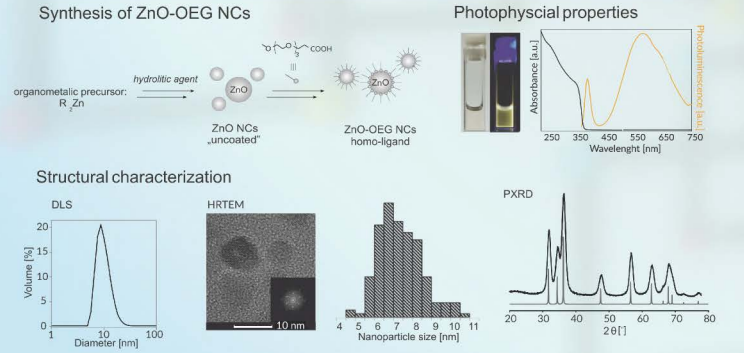
Principles

Zinc oxide was one of the first semiconductors used in dye-sensitized solar cells. In comparison to TiO_2, ZnO possesses a significantly higher electron mobility, which favours electron transport across its structures. However, at the same time, this property promotes charge separation and recombination, which a significant disadvantage regarding efficacy of devices. Another significant drawback, which has so far precluded large-scale application of ZnO, is its poor chemical stability in aqueous acidic and basic media. Overcoming these drawbacks cannot be possible without careful design and synthesis of ZnO-organic layer core-shell nanostructures.

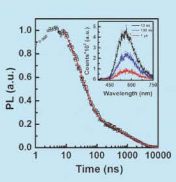
Our strategy of ZnO synthesis relies on molecular precursors chemistry principles. Careful design of precursors enable for direction of chemical reactions toward desirable product in an effective way under mild conditions or without using elaborated reagents. Types of Zn-based precursors used in this study are presented below.



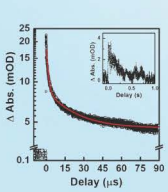
OEG-coated ZnO nanocrystals as electron-transporting materials for PSCs



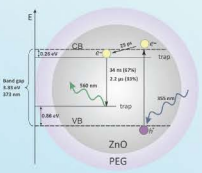
Size distribution of ZnO-OEG NCs in water estimated by DLS; HRTEM micrographs statistical analysis of the size of ZnO-OEG NCs (mean size: 7.1 ± 1.1 nm); the PXRD profile of ZnO-OEG NCs (*black line*) and simulated ZnO pattern (*gray line*). Based on the reflection broadening, according to the Scherrer equation, the crystallite size has been estimated to be 6.0 ± 0.2 nm.



Kinetic trace at 560 nm measured with nanosecond time-resolved fluorescence upon excitation at 355 nm of ZnO-OEG NCs in aqueous solution and selected spectra at different times in insert



Kinetic trace at 2050 cm^{-1} extracted from ns time-resolved mid infrared absorption spectra collected from 1850-2200 cm^{-1} of ZnO-OEG-B NCs excited at 532 nm in DMSO

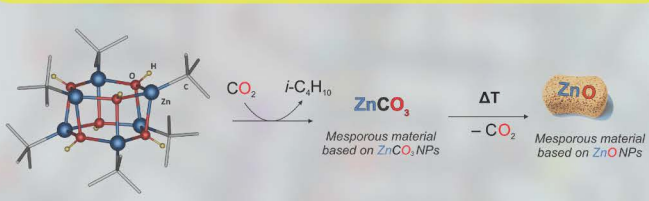


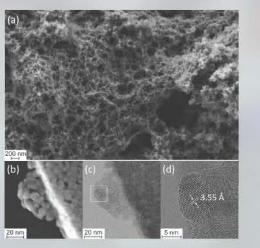
Schematic representation of charge transfers processes and associated time constants on the ZnO-OEG-B system

Fabrication of planar PSC devices based on porous ZnO scaffolds (initial results – more data to come)

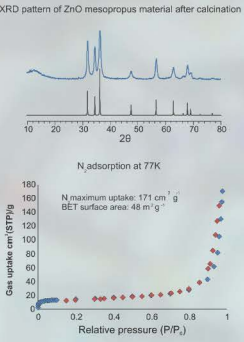
A. M. Cieślak et al. Nano Energy 2016, 30, 187–192.

Mesoporous ZnO nanostructures as potentails porous scaffolds tor PSCs



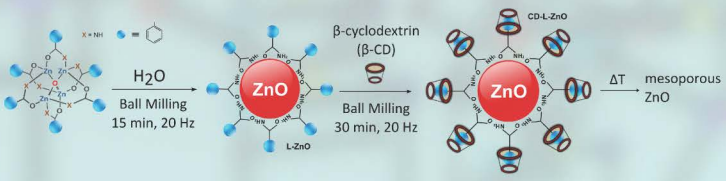


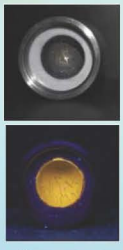
Morphology and structure of $ZnCO_3$ nanostructures: a) SEM image showing meso- and macropores; (b) STEM image showing nanosized pores; (c) the same fragment in TEM mode; (d) HRTEM image of a single particle showing the crystalline nature of the nanoparticle architecture (lattice fringes corresponding to the (102) reflections of trigonal $ZnCO_3$).



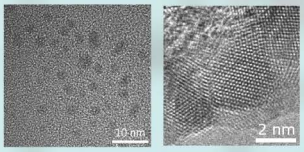
K. Sokołowski et al. Chem. Commun. 2014, 49, 5271–5274.

Mechanochemical approach to the synthesis of ZnO nanomaterials

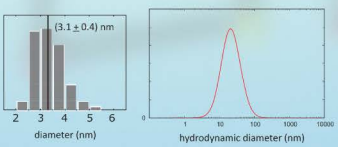




Milling jars in Vis (top) and UV (bottom) light just after reaction. Strong solid-state **L-ZnO** luminescence can be observed.



HRTEM micrographs of CD-L-ZnO. Addition of CD lead to better separation of semiconducting cores



Particle size distribution obtained from TEM measurements (left, core size), and DLS measurements in water (right, hydrodynamic diameter in solution)

CD-L-ZnO in Vis (left) and UV light (right). **CD-L-ZnO** is easily-dispersible in water with retention of luminescence

P. Krupiński et al. Chem. Eur. J. 2016, 22, 7817–7823.

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