ZnO/CdS CORE–SHELL NANOROD ARRAY THIN FILMS FOR SEMICONDUCTOR SENSITIZED SOLAR CELL (SSSC) APPLICATION

BY

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Outline

- ***Part-I***

  Introduction to solar cell

- ***Part-II***

  Chemical synthesis of ZnO/CdS core-shell nanorod array thin films

- ***Part-III***

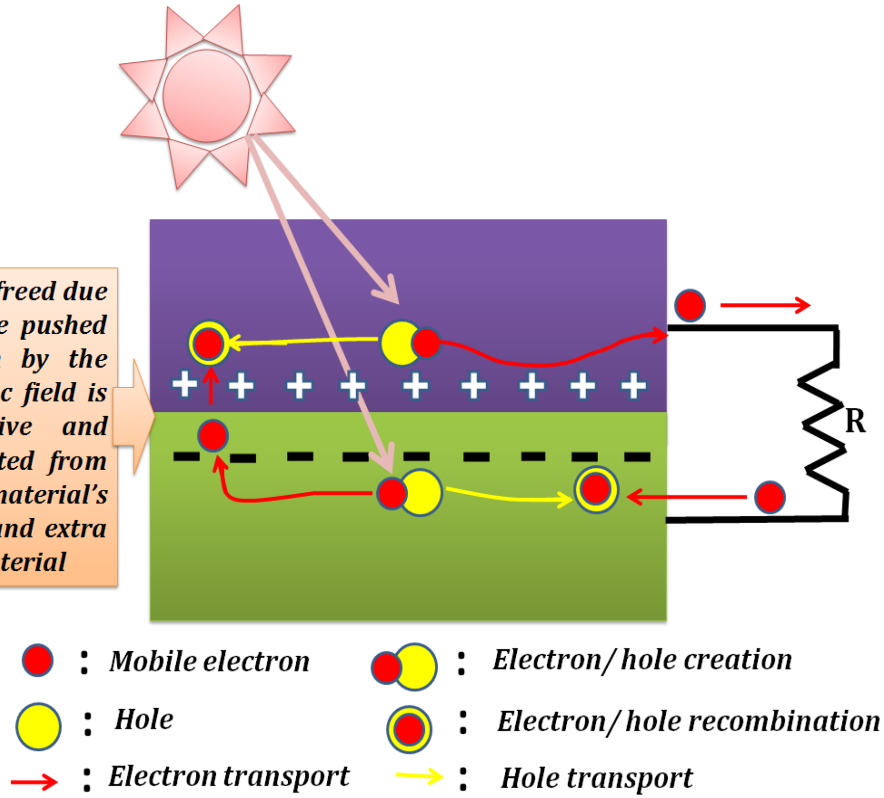
  Characterization of ZnO/CdS core-shell nanorod array thin films

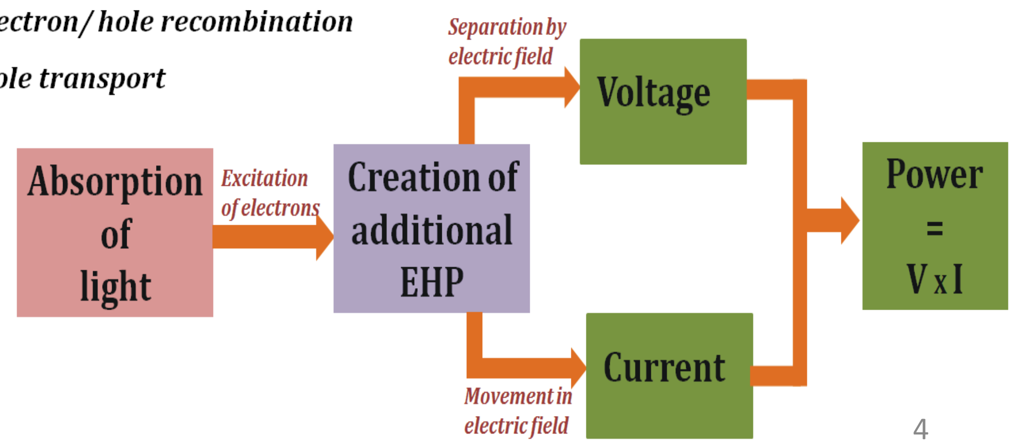
- *Summary and Conclusions*

Part-I
Introduction to solar cell

Photovoltaic effect

Essential step: Electrons freed due to photon absorption are pushed across the p-n junction by the electric field. This Electric field is created by the positive and negative charges, resulted from diffusion of extra n-material's electrons to p-material, and extra p-material's holes to n-material





Generations of solar cell

I st generation

- Single crystalline silicon solar cell
- Maximum theoretical efficiency limited by shockley -Quissor limit .
- Maximum achieved efficiency 20-27%
- High cost: expensive and tedious manufacturing process
- Much of the energy of higher energy photons, at the blue and violet end of the spectrum, is wasted as heat.

I Ind generation

- Amorphous silicon, CIGS, CdTe, CZTS thin film solar cells
- Maximum theoretical efficiency limited by shockley -Quissor limit .
- Maximum achieved efficiency = 10-20%
- Low cost as compared to Ist generation solar cells
- Though it possesses low efficiency the decreased cost makes up for this efficiency shortfall

III rd generation

- Dye sensitized solar cells (DSSC) and Semiconductor sensitized solar cells (SSSC), polymer solar cells etc.
- Theoretical maxima of efficiency is beyond the schockley -Quissor limit.
- Maximum achieved efficiency DSSC=12% & QDSSC=7% Still in research phase
- very Low cost compared to both 1st and 2nd generation solar cells

Third generation solar cell

ADVANTAGES

- Low energy high throughput processing technology
- Work even in low light conditions
- light weight, flexible so increases robustness of cell
- Bifacial cells capture light from all angles

DSSC

- Heavily investigated
- optimized configuration is TiO_2/N3dye/poly-iodide electrolyte/ Pt counter
- Maximum current conversion efficiency 11.1% but it reflects limits imposed by the low absorbance of dye monolayer and the low efficiency of dye multilayer.

SSSC

- Investigations on SSSC explored in last few years only.
- The optimal SSSCs configuration has not been obtained yet.
- Up to now maximum efficiency obtained is 7% .

Advantages of SSSC

- SSSC has higher absorption compared with a single molecular layer of dye

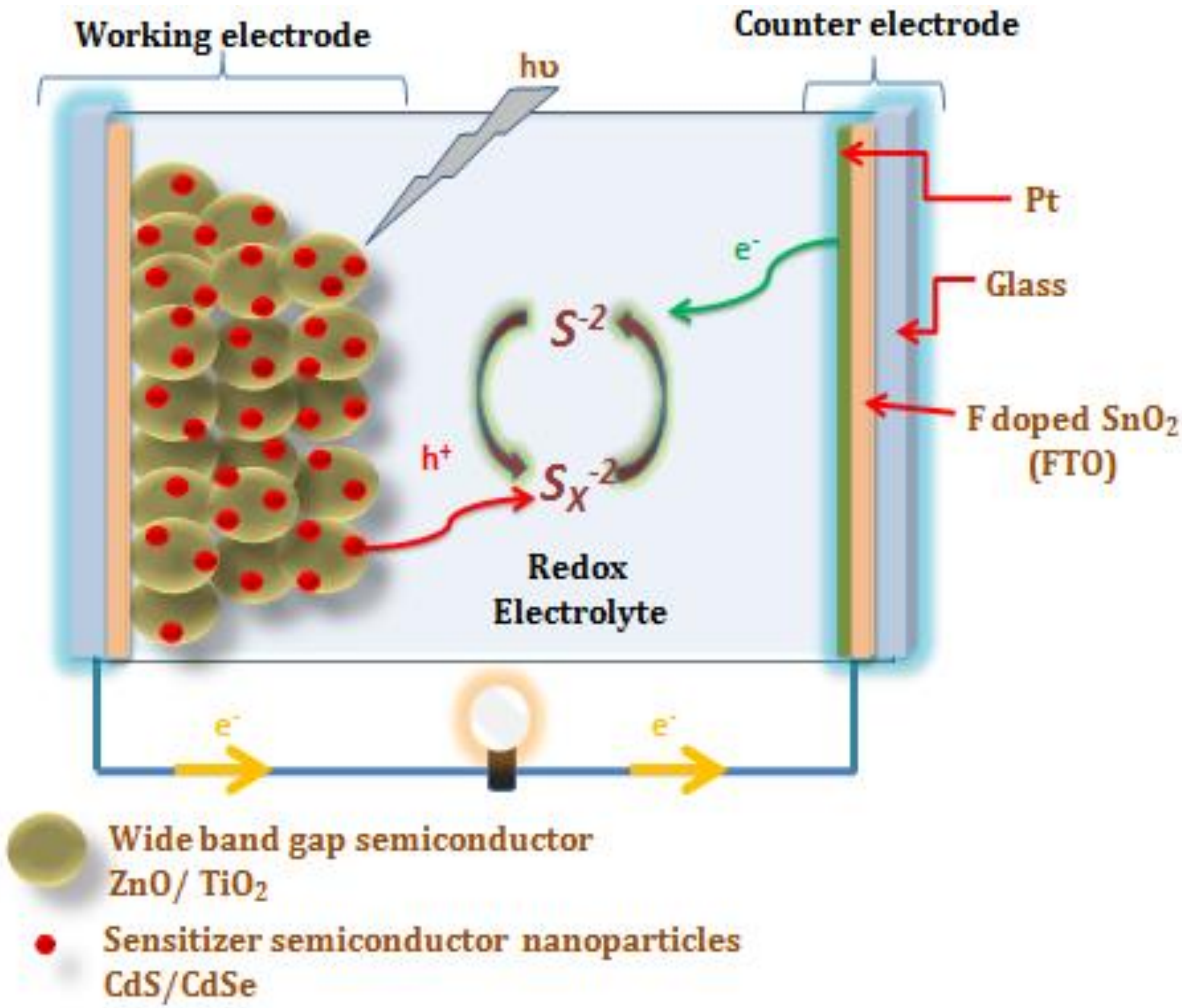
- Greater stability of the semiconductor compared to organometallic or pure organic dyes

- Tailoring of optical absorption over a wider wavelength range than possible with dyes due to size quantization effect

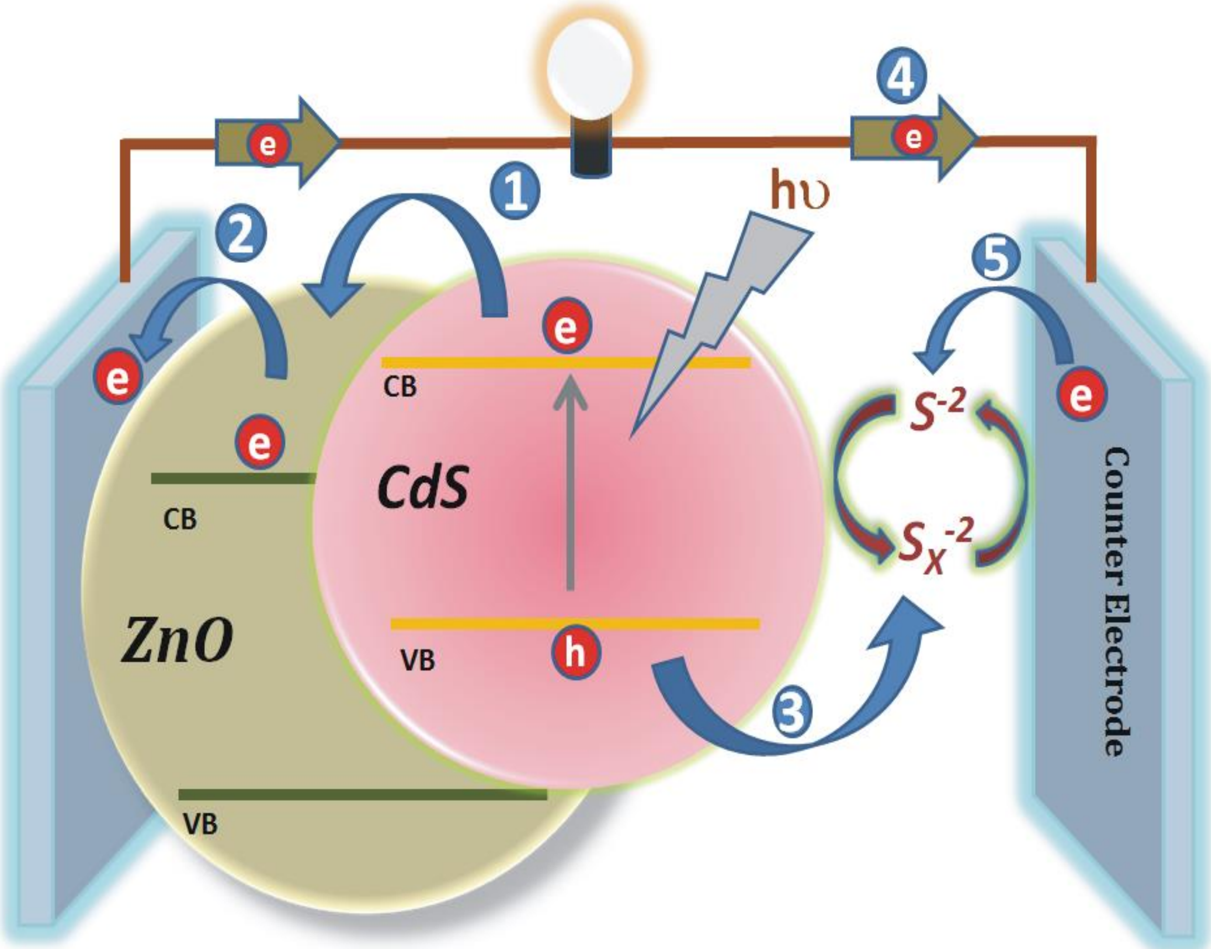
- One can use solid electrolyte to overcome the difficulties arising due to liquid electrolyte

- Possibility of exploiting multiple exciton generation to obtain high efficiencies adds another potential advantage.

STRUCTURE OF SSSC



WORKING OF SSSC



Why ZnO and CdS based photoelectrode

ZnO

- ZnO has direct band gap (3.37 eV)
- High electron mobility (100 $cm^2V^{-1}s^{-1}$)
- Low cost material
- Compared to TiO_2 the nano-structures of ZnO can be easily grown with various deposition techniques

CdS

- CdS has direct band gap (2.4 eV)
- good chemical stability
- positions of conduction band and valence band edges with respect to ZnO which favors the easy charge transport in accordance to type-II band alignment in semiconductor sensitized solar cell (SSSC)
- Easy preparation

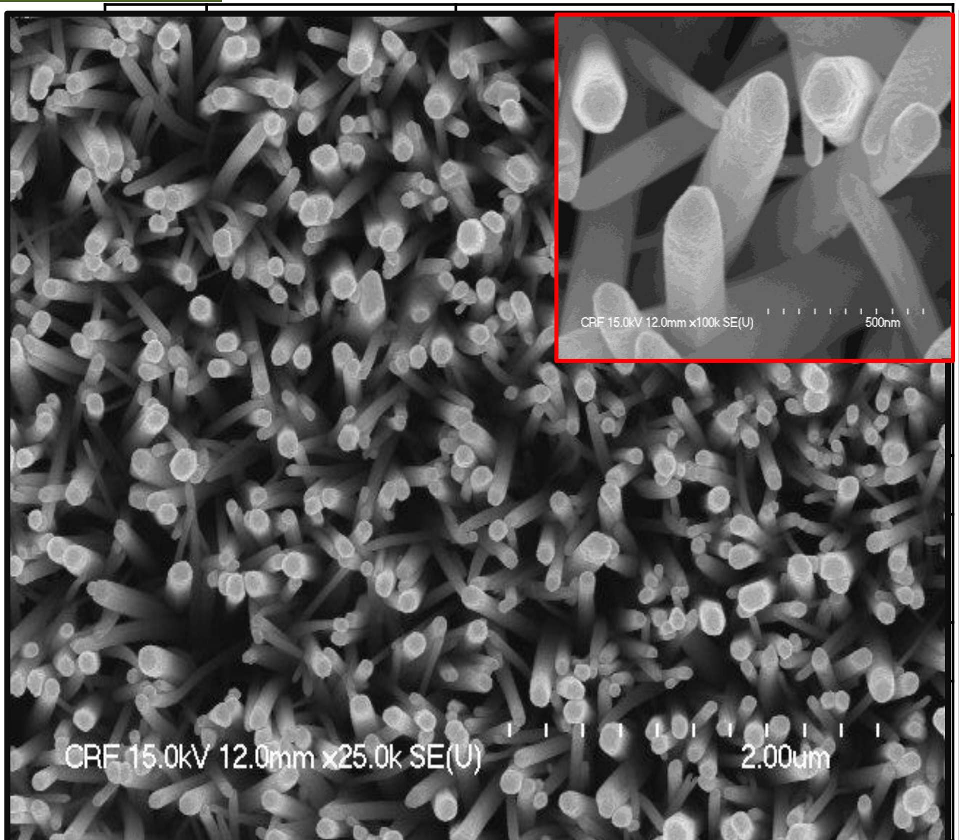
Part-I I
Synthesis of ZnO/CdS core-shell nanorod array thin films

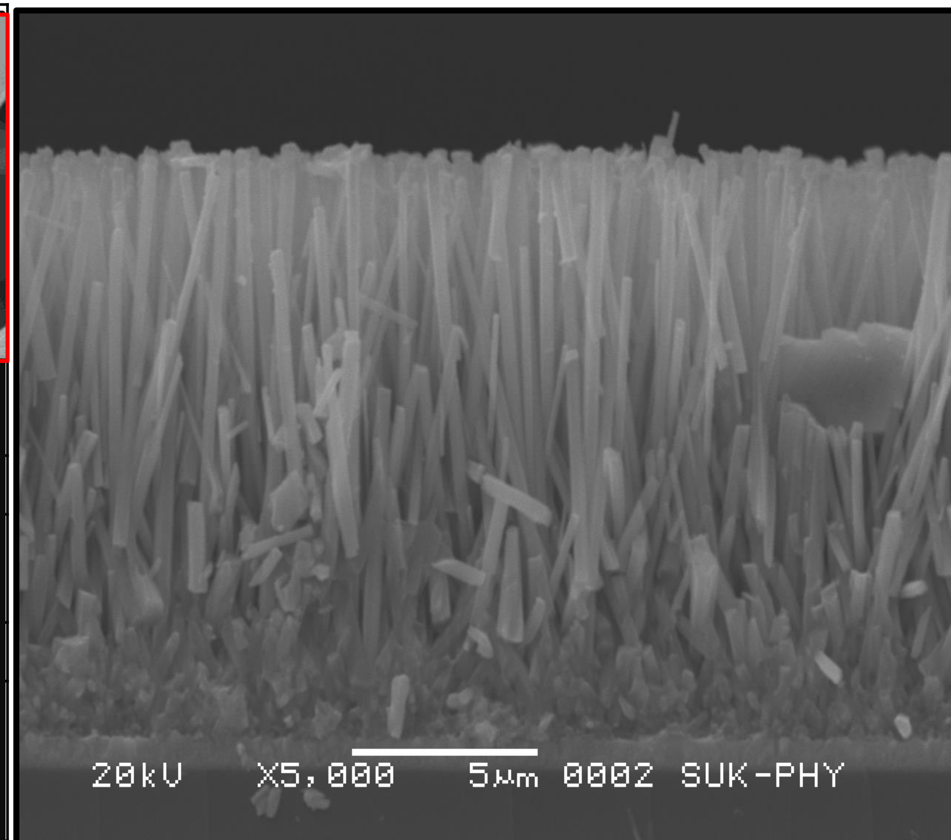
Synthesis parameters of ZnO/CdS core-shell nanorod array thin films

STEP-I ***Deposition of seed layer on FTO***

The seed layer was deposited by dipping substrate in 0.025 M ethanolic solution of zinc acetate for 20 s and then film was allowed for heat treatment in air at $400^{o}C$ for 10 min.

STEP-II ***Deposition of ZnO nanorod arrays***

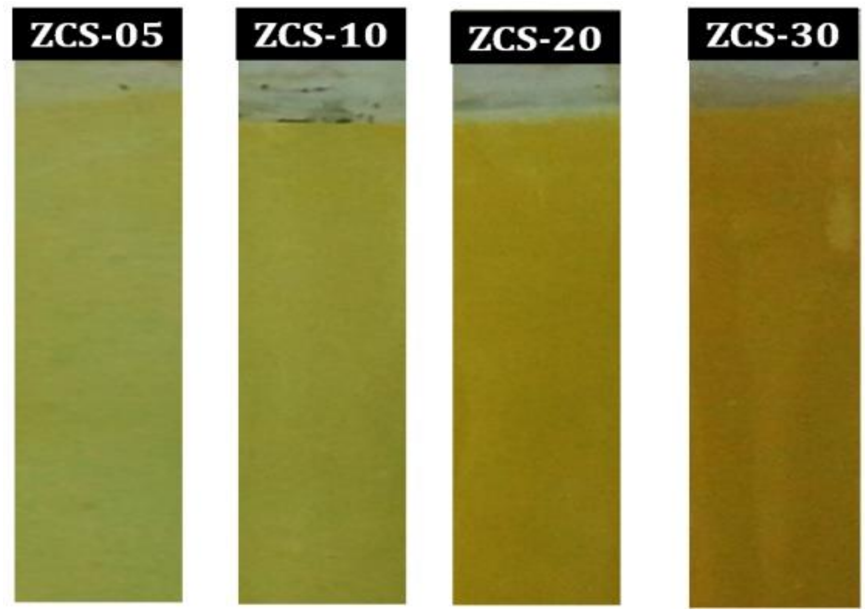




Synthesis parameters of ZnO/CdS core-shell nanorod array thin films

STEP-III ***Sensitization of ZnO nanorods with CdS***

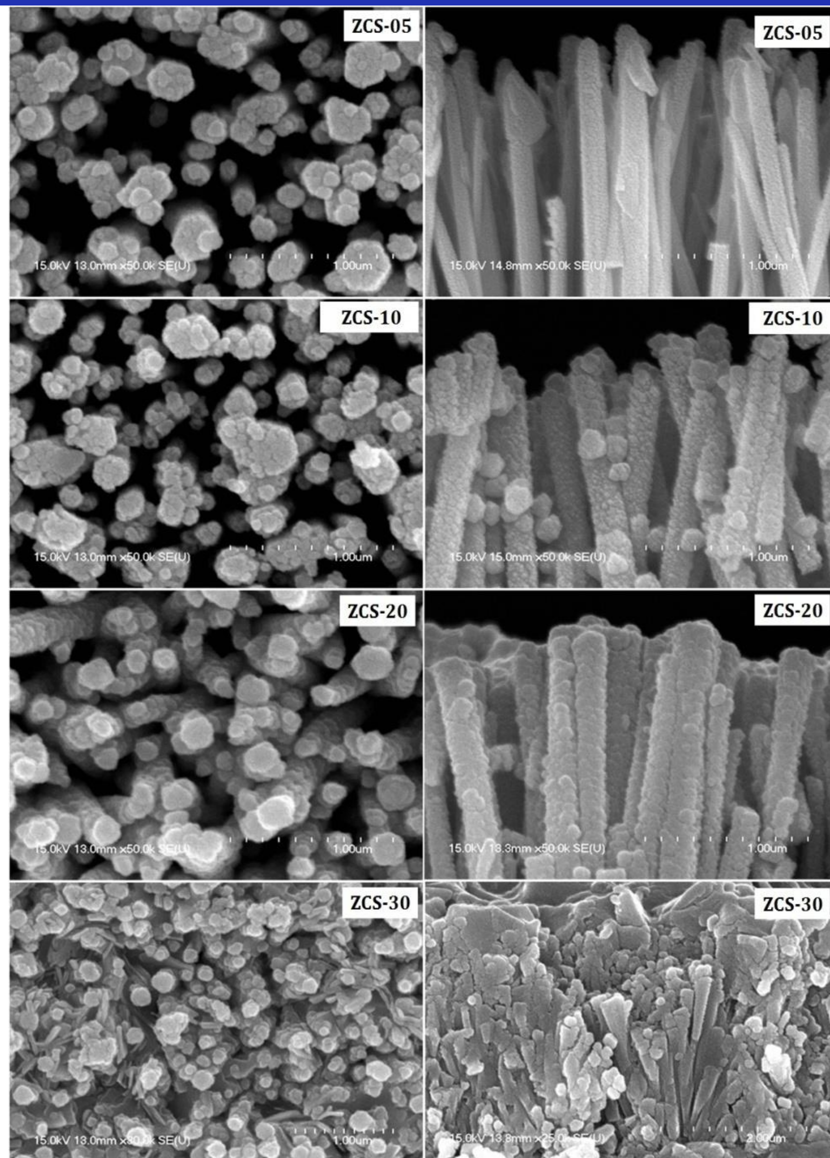
Sr. No	Film	ZnO/CdS core-shell
1	technique	Reflux
2	Medium	Aqueous
3	Bath composition	0.0025 M $3CdSO_4 \cdot 8H_2O$ $+CS(NH_2)_2$+ ammonia-water
4	pH	~11
5	Deposition time	ZCS-5= 5 min deposition ZCS-10=10 min deposition ZCS-15=15 min deposition ZCS-20=20 min deposition ZCS-25=25 min deposition
6	Temperature	90±5°C
7	Substrate	ZnO nanorod array thin films



Digital photograph of CdS sensitized ZnO thin film samples

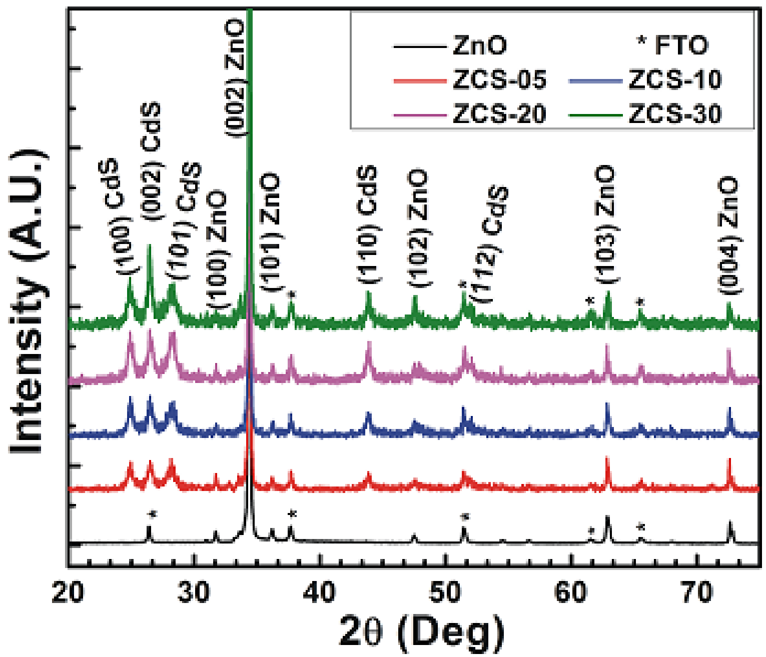
Part-III
Characterization of ZnO/CdS core-shell nanorod array thin films

Surface morphological study



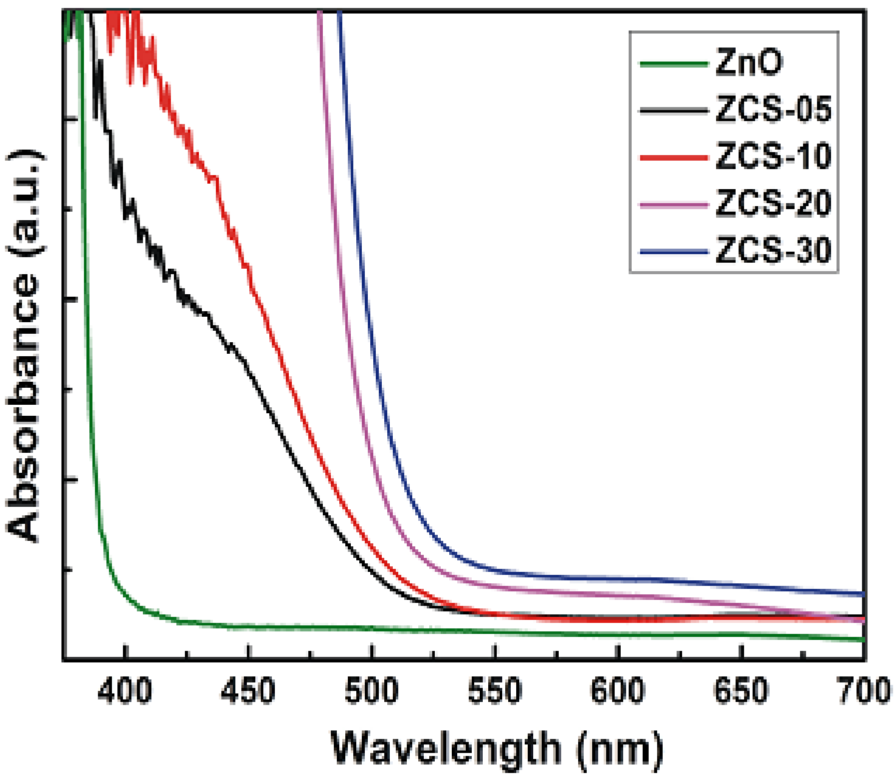
Surface and cross-section SEM images of CdS sensitized ZnO nanorod thin films

X-ray diffraction study and optical absorption spectroscopy



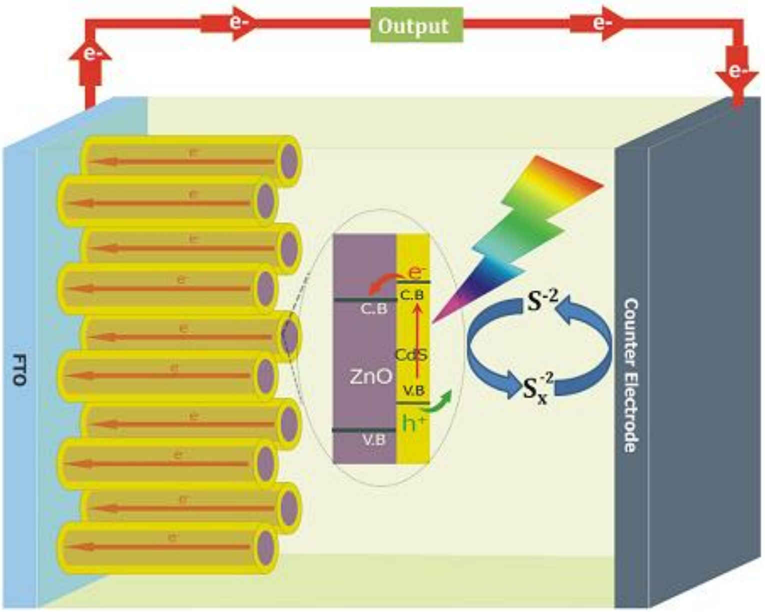
X-ray diffraction pattern of bare ZnO, and CdS sensitized ZnO films

Optical absorption study

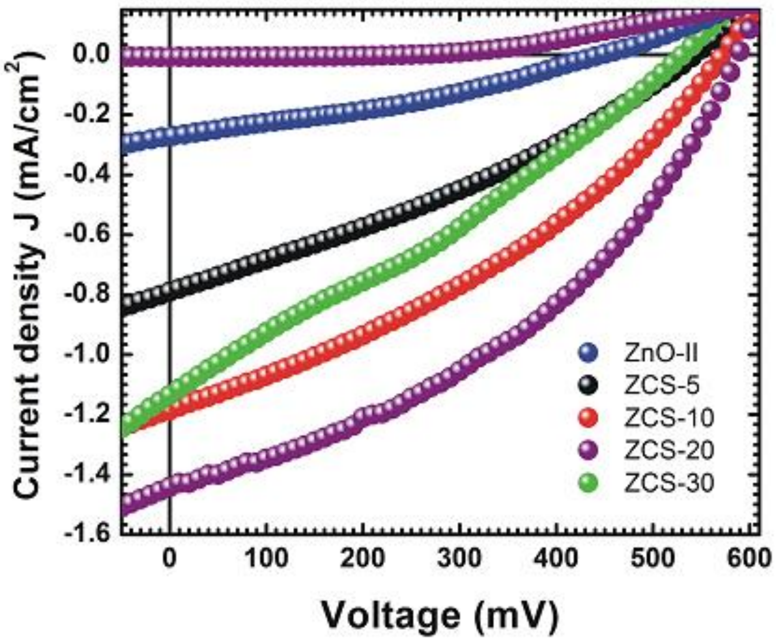


UV-VIS absorption spectra of bare ZnO, and CdS sensitized ZnO films

Photo-electrochemical solar cell study



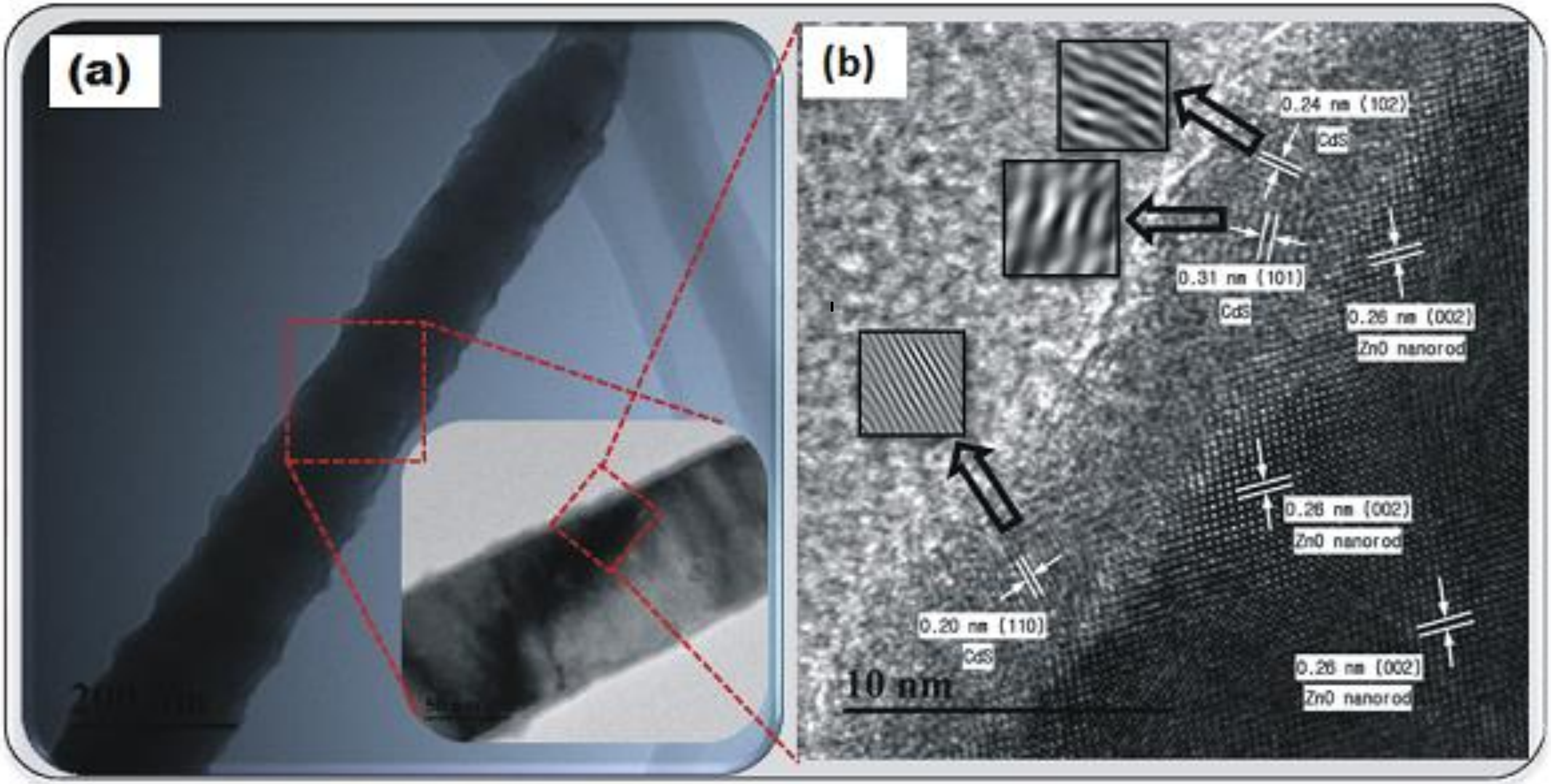
Schematic diagram of ZnO/CdS core-shell based SSSC, inset fig. shows formation of type-II band alignment at ZnO/CdS interface



PEC performance of bare ZnO, and all CdS sensitized ZnO thin films

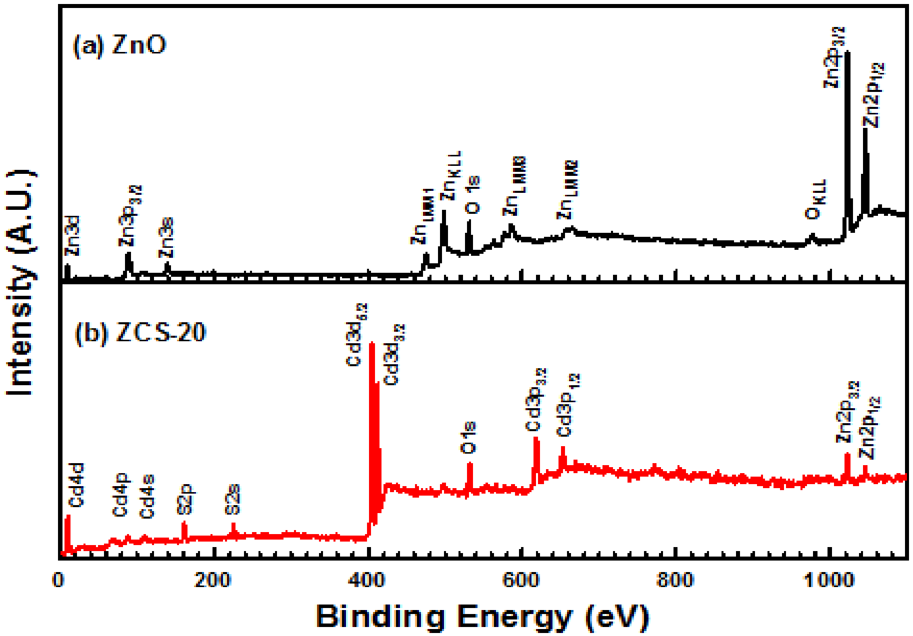
Sample code	Short circuit current density J (mA/cm^2)	Open circuit Voltage V (mV)	Series resistance R_S (Ω)	Shunt resistance R_{Sh} (Ω)	Fill factor FF	Efficiency (η)%
ZnO	0.27	446	994	2291	0.32	0.54
ZCS-5	0.79	544	355	1113	0.37	0.59
ZCS-10	1.19	574	207	1252	0.34	0.86
ZCS-20	1.44	589	139	1242	0.39	1.23
ZCS-30	1.13	530	141	1024	0.29	0.64

Transmission Electron Microscopy

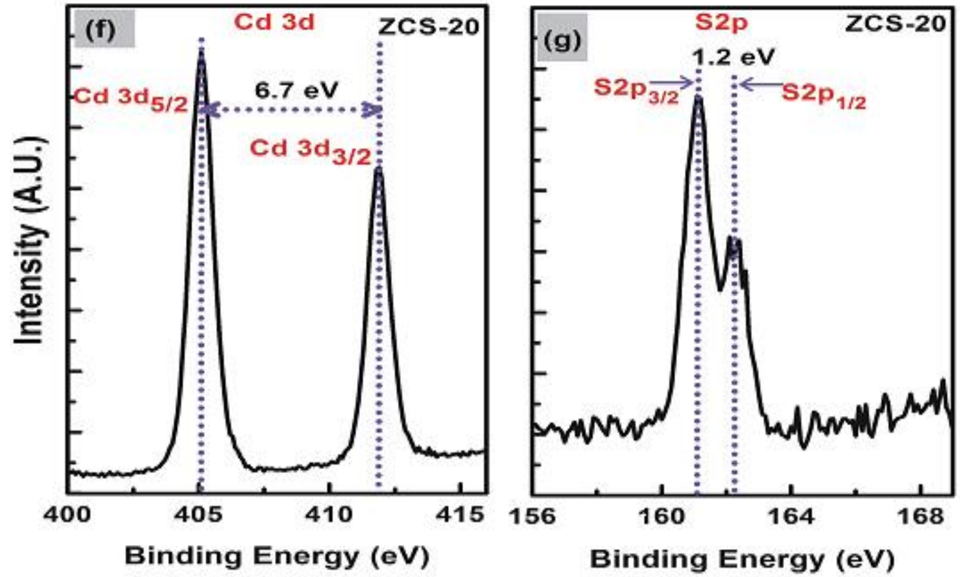


(a)TEM image of ZnO/CdS nanorod and (b) HRTEM showing lattice arrangement of ZnO nanorods and CdS coating.

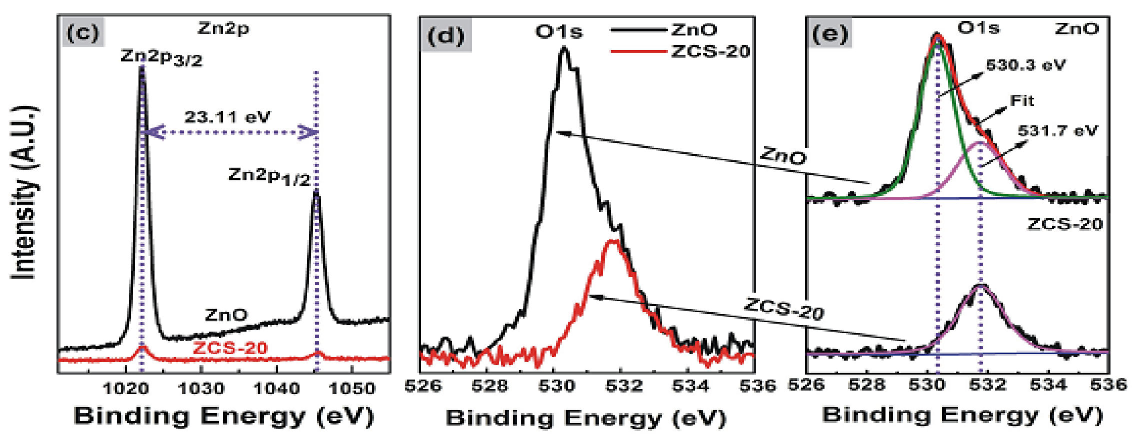
X-ray Photoelectron spectroscopy (XPS)



Survey spectrum of pure ZnO (a) and CdS sensitized ZnO (b)



Core level XP spectrum of Cd 3d (f) and S 2p oxidation states from CdS/ZnO thin film



Core level XP spectrum of Zn 2p states (c) and O1s states (d) along with a systematic deconvolution of O1s state (e) before and after CdS sensitization

Summary and conclusions

- ZnO/CdS core-shell nanorod array thin films were successfully synthesized by simple chemical route.

- Formation of Core-shell structure was confirmed by FESEM and HR-TEM characterizations.

- Optical absorption and photo electrochemical study reveals that the ZnO/CdS core-shell nanorod extends the absorption edge of ZnO in visible region of solar spectrum and thereby enhances the PEC solar cell performance of films.

- The maximum photo-conversion efficiency 1.23% is obtained for ZnO/CdS core-shell photoelectrode.

Thank you