ZnS Quantum Dots Doped with Transition Metals for Photovoltaic Applications

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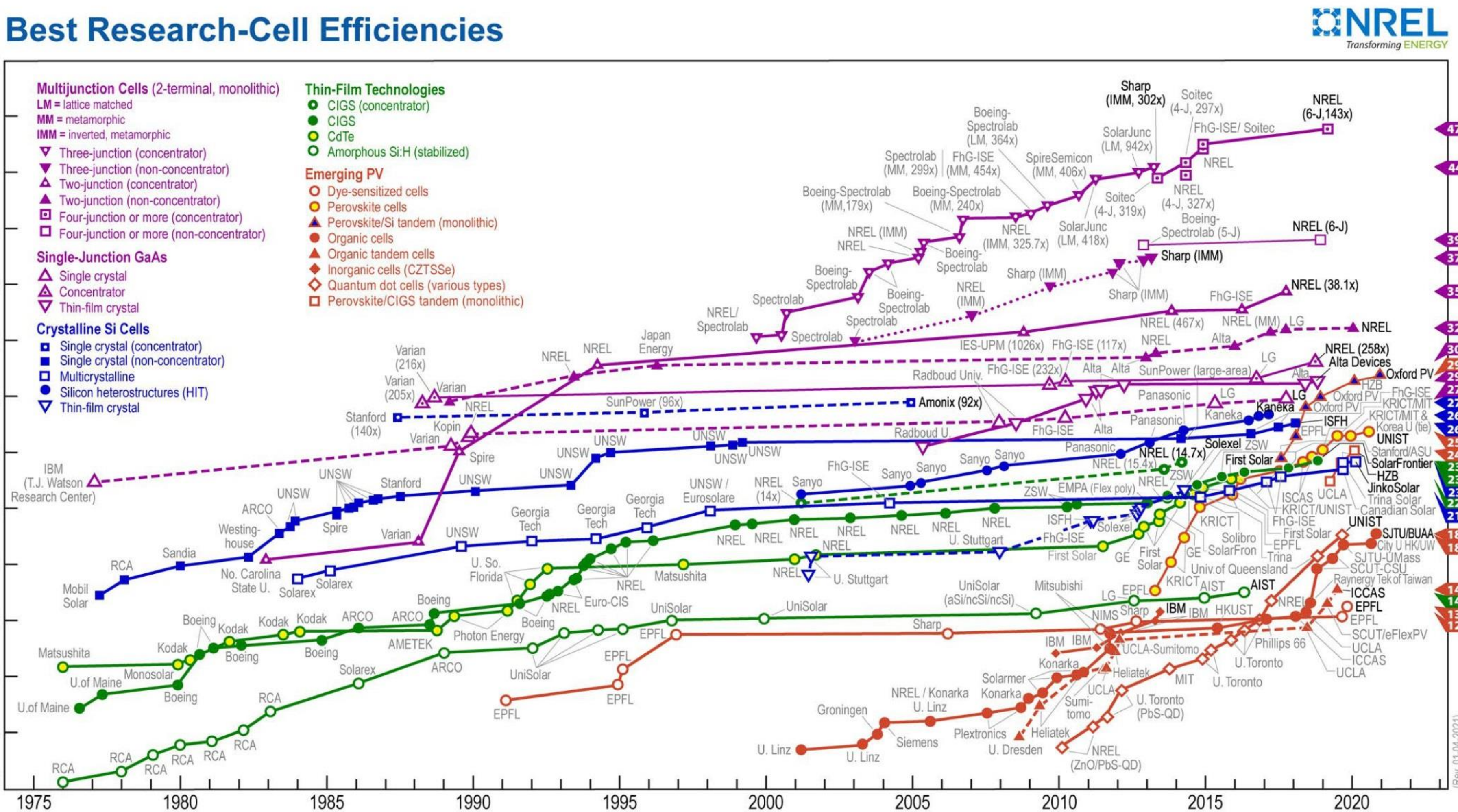
Solar Cells



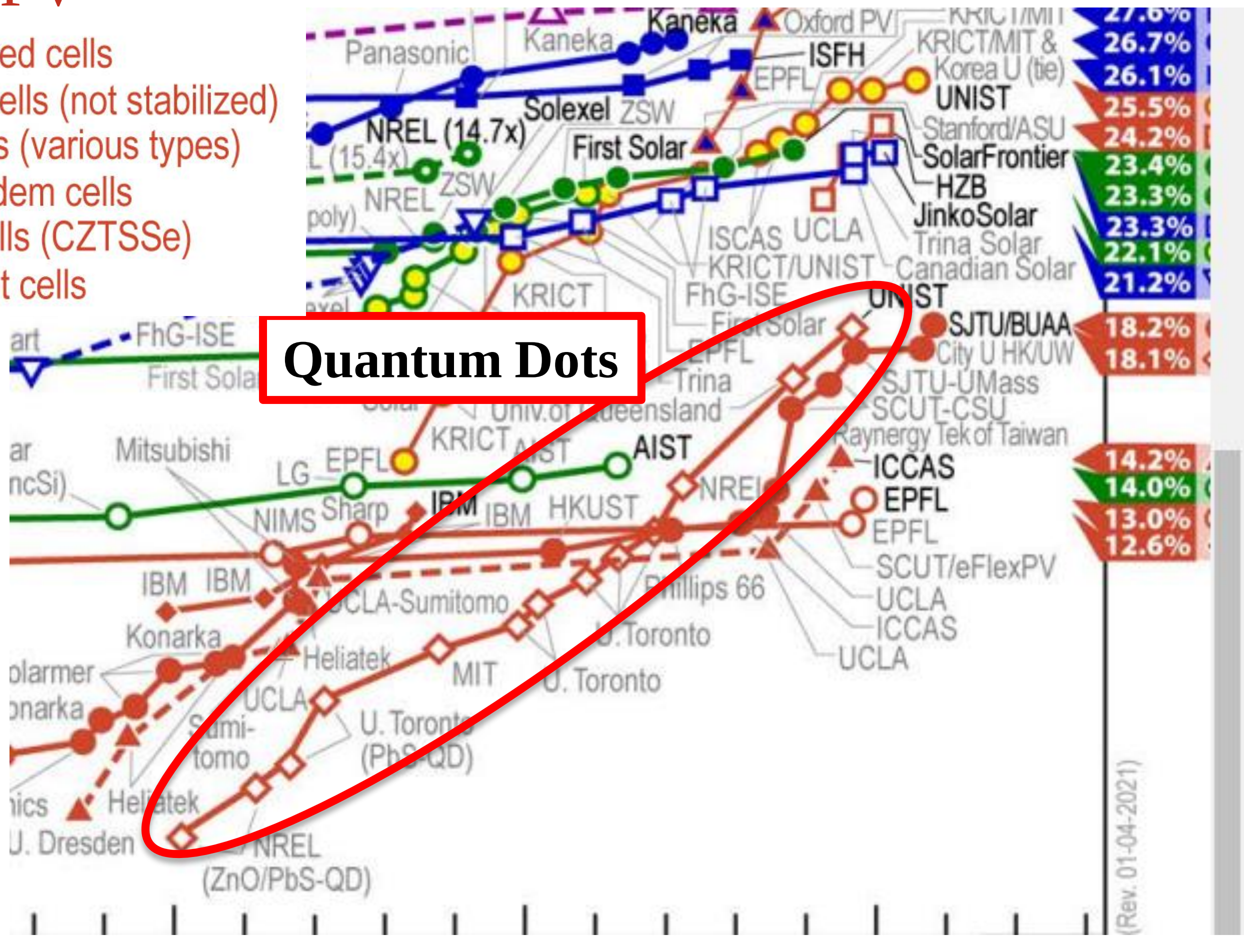
Best Research-Cell Efficiencies
NREL
Transforming ENERGY
Cell Efficiency (%)
Multijunction Cells (2-terminal, monolithic)
LM = lattice matched
MM = metamorphic
IMM = inverted, metamorphic
Three-junction (concentrator)
Three-junction (non-concentrator)
Two-junction (concentrator)
Two-junction (non-concentrator)
Four-junction or more (concentrator)
Four-junction or more (non-concentrator)
Single-Junction GaAs
Single crystal
Concentrator
Thin-film crystal
Crystalline Si Cells
Single crystal (concentrator)
Single crystal (non-concentrator)
Multicrystalline
Silicon heterostructures (HIT)
Thin-film crystal
Thin-Film Technologies
CIGS (concentrator)
CIGS
CdTe
Amorphous Si:H (stabilized)
Emerging PV
Dye-sensitized cells
Perovskite cells
Perovskite/Si tandem (monolithic)
Organic cells
Organic tandem cells
Inorganic cells (CZTSSe)
Quantum dot cells (various types)
Perovskite/CIGS tandem (monolithic)
47.1%
44.4%
39.2%
37.9%
35.5%
32.9%
30.5%
29.5%
29.1%
27.8%
27.6%
26.7%
26.1%
25.5%
24.2%
23.4%
23.3%
23.3%
22.1%
21.2%
18.2%
18.1%
14.2%
14.0%
13.0%
12.6%
(Rev. 01-04-2021)

Solar Cells

NATIONAL RENEWABLE ENERGY LABORATORY

Emerging PV

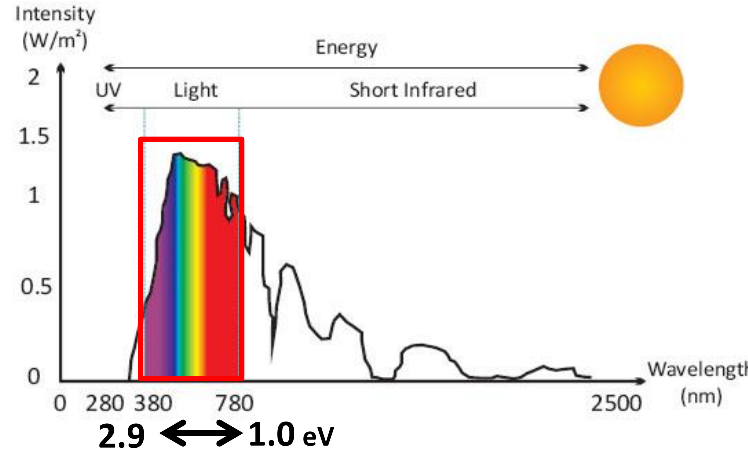
- Dye-sensitized cells
- Perovskite cells (not stabilized)
- Organic cells (various types)
- Organic tandem cells
- Inorganic cells (CZTSSe)
- Quantum dot cells



Quantum Dots

II-VI semiconductor quantum dots (QDs)

- ❖ Cadmium Sulfide (CdS) $E_g = 2.42$ eV
- ❖ Zinc Sulfide (ZnS) $E_g = 3.54$ eV

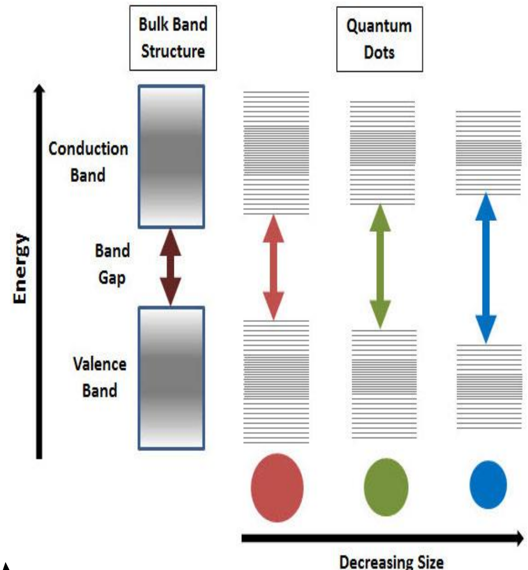


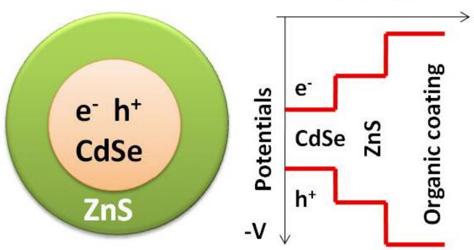
For photovoltaic it requires,

- ✓ reduction of the band gap
- ✓ absorb more light in visible region

How to tailor the band gap?

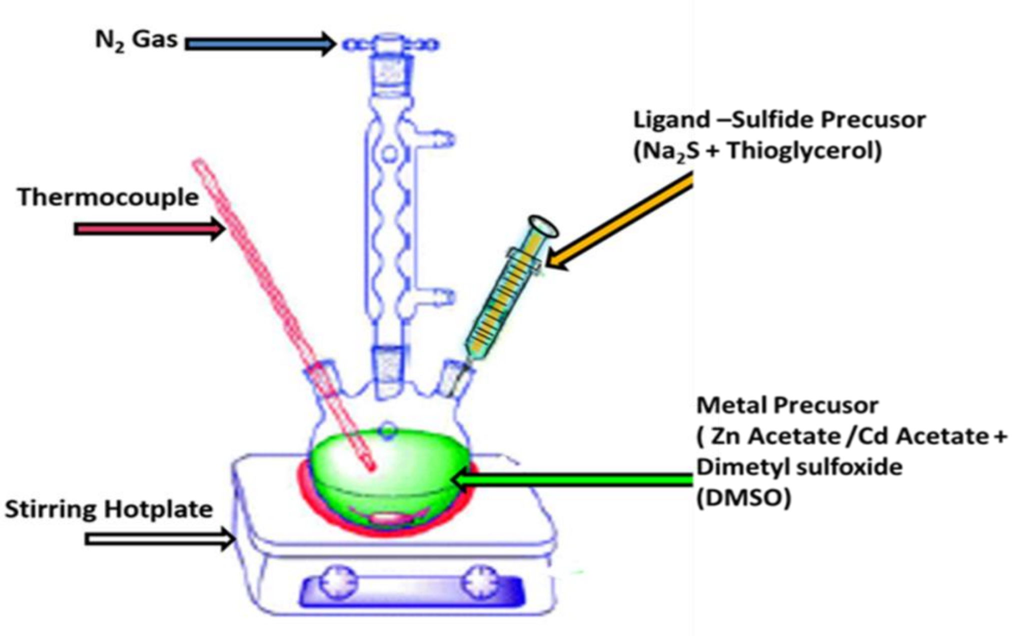
- ✓ By Changing the size of the QDs
- ✓ By adding an additional layer called shell to the core Ex: CdSe/ZnS
- ✓ By doping with Transition Metals





sigma-Aldrich: "Quantum Dots,"
Sanehira et al. *Science Advances*, ***3***, *10* (2017).
https://bohatala.com/preparation-of-quantum-dot-solar-cell-qds/

Synthesis Method

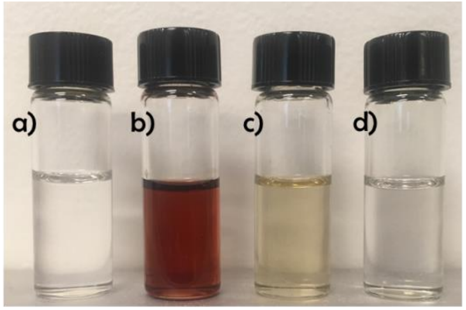


The dilute magnetic semiconductors were synthesized by the following procedure:

- The zinc acetate dihydrate was dissolved in dimethyl sulfoxide and then 1-thioglycerol was added dropwise.
- The mixture was heated at 60°- 70°C, with constant stirring; aqueous Na_2S solution was injected.
- The solution is heated on the hot plate for 9-12 hours .
- To doped quantum dots, the desired transition metals (Cobalt, Nickel, and Manganese Acetate) were added to the mixture of ZnS Acetate solution.

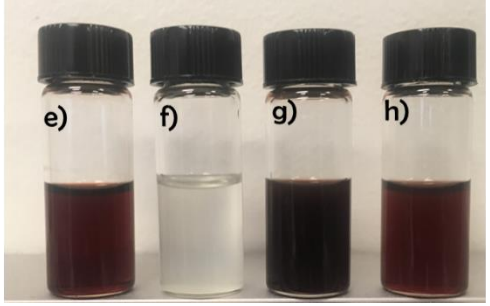
Doped QDs

Single doped QDs



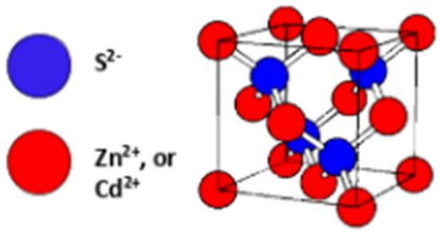
a) ZnS.
b) Co:ZnS.
c) Ni:ZnS.
d) Mn:ZnS

double and tri- doped QDs

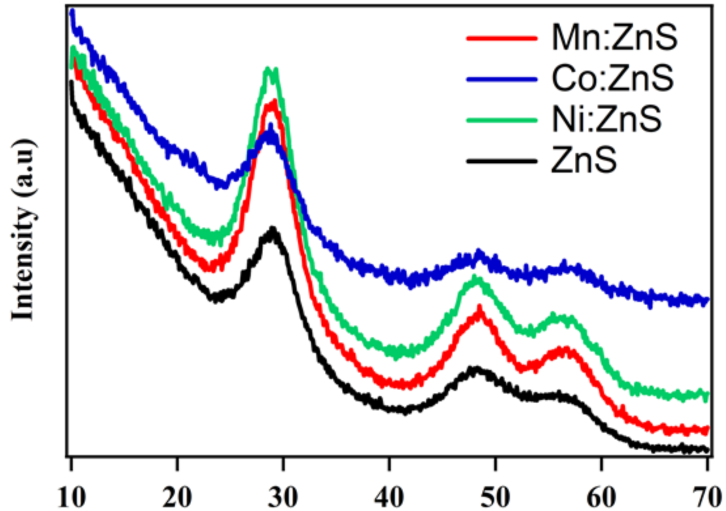


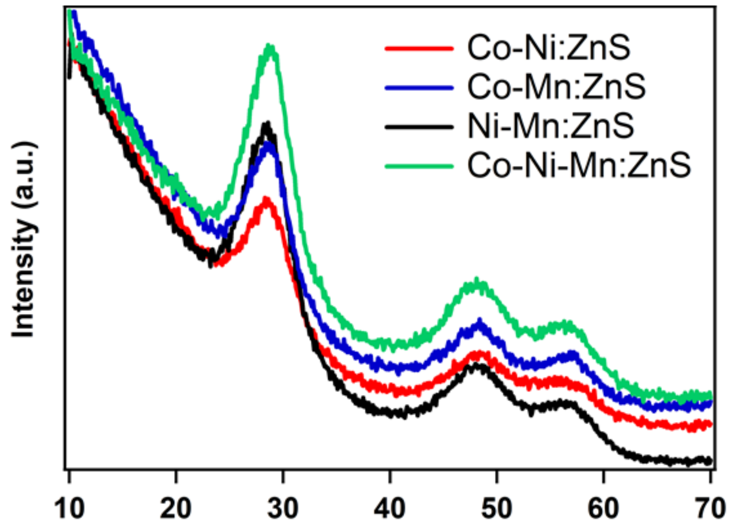
e) Co-Ni:ZnS.
b) Ni-Mn:ZnS.
c) Co-Mn:ZnS.
d) Co-Ni-Mn:ZnS

Zinc Blende Structure



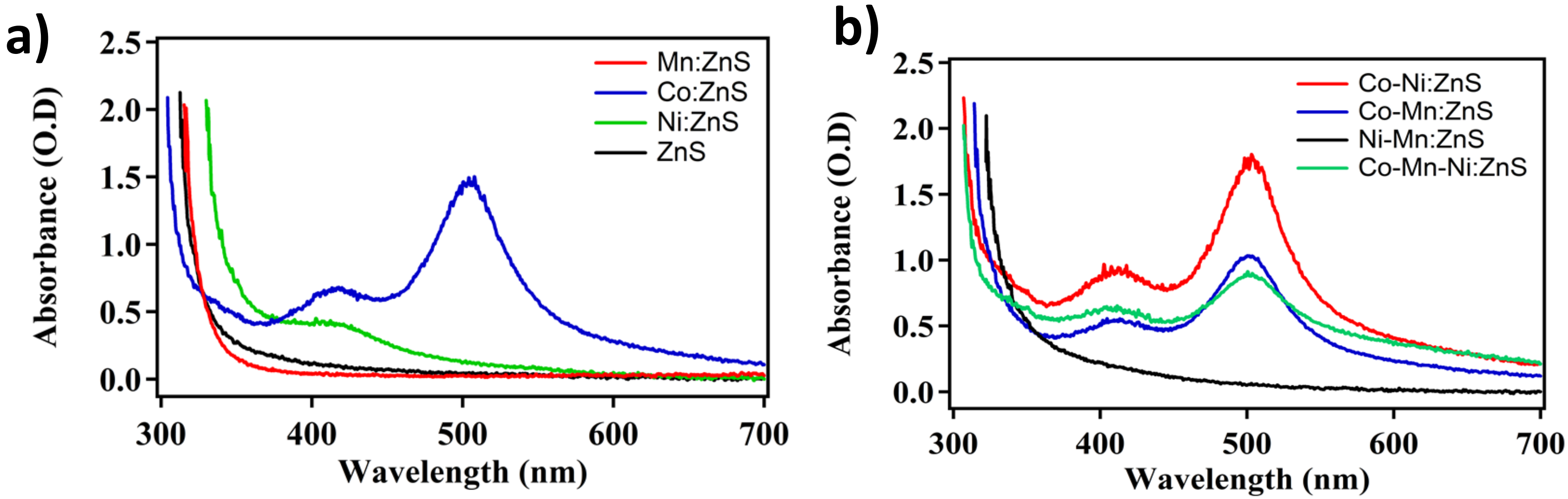
X-Ray Diffraction



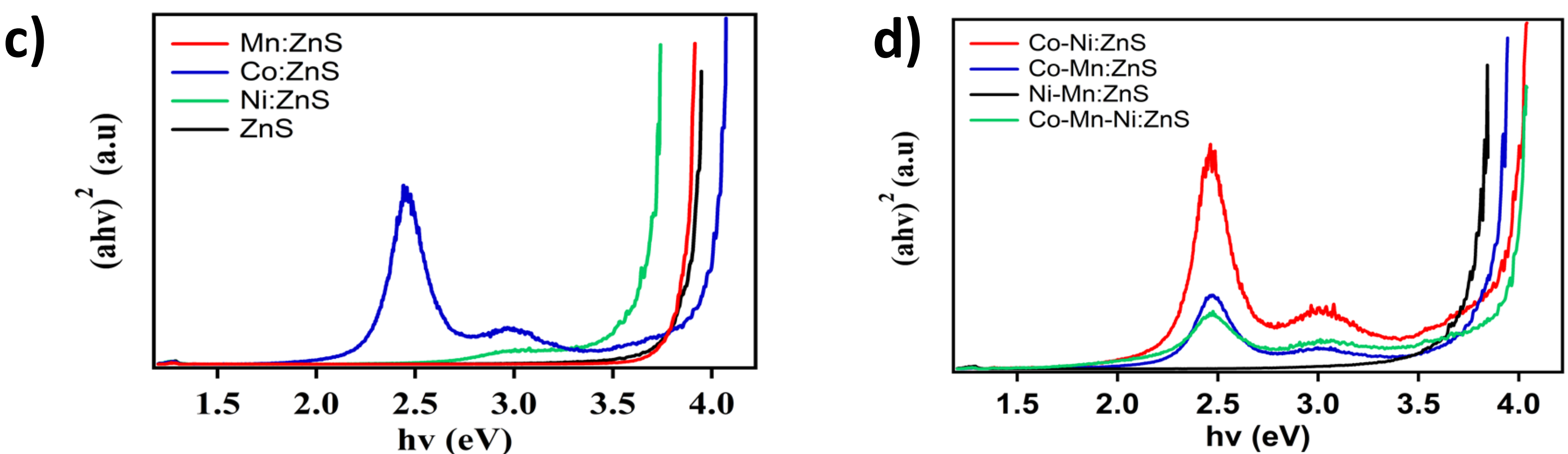


Optical Characterization

Absorption spectrums of single and double and tri-doping



Tauc plot of single and double and tri-doping.



Optical Characterization

Transition Metals Doped Quantum Dot	Band Gap (eV)
ZnS	3.90
Mn:ZnS	3.86
Ni:ZnS	3.71
Co:ZnS	4.05
Co-Mn:ZnS	3.68
Ni-Mn:ZnS	3.91
Co-Ni:ZnS	3.97
Co-Ni-Mn:ZnS	4.02

Conclusion

- Properties of the doped quantum dots were studied through optical characterization and X-ray diffraction.
- Through the band gaps extracted from the tauc plot, co-doped quantum dots seems to have a wider band gap in comparison to undoped and single doped ZnS.
- The absorption data shows that Cobalt-Nickel doped ZnS has the highest absorbance the visible range out of all the single and co-doped and tri-doped quantum dots which made it the best candidate for optoelectronic device fabrication.
- Future work: X-ray Photoelectron Spectroscopy and Scanning Tunneling Microscope.

Acknowledgement

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Thank you