Indian Institute of Technology Bombay

National Center for Photovoltaic Research and Education

Thin film devices Group

IAP Meeting, Jan 13th 2017

NCPRE

National Centre for Photovoltaic Research & Education
IIT Bombay

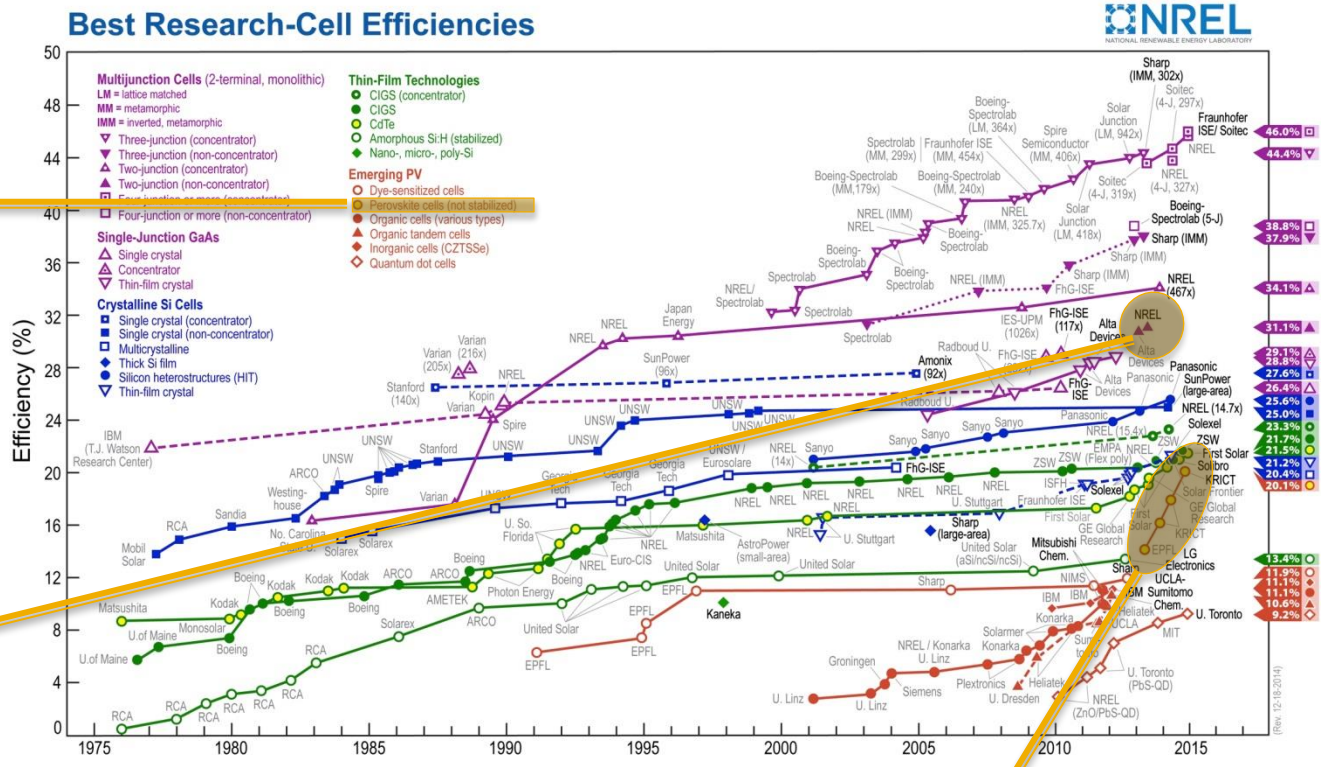
Major Activities

- 1 cm^2 tandem cell based on perovskite top cell with Si and/or CZTSSe, with > 15% PCE
- Inorganic, organic, and C-based HTMs to replace Spiro-OMeTAD
- Chemical modifications to obtain better inherent stability and make Pb-free perovskite light absorbers
- New materials – Oxides, phosphides, sulphides etc..

Perovskite thin film solar cells

- Plagued by stability issues
- Develop stable perovskites
- Encapsulation / protective TCs

- Tandem Devices with higher efficiencies
- Develop two-junction devices
- Perovskite-kesterite



- Perovskite based solar cells
- Recent prominence
- High efficiencies in a short time

Need to do it now

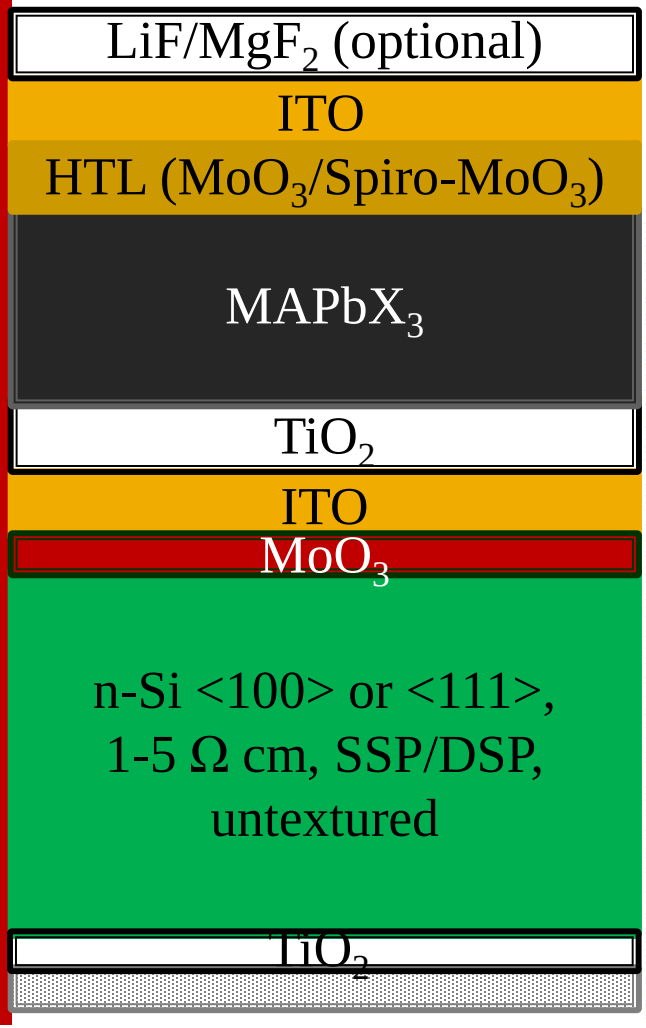
Image Source: http://www.nrel.gov/ncpv/images/efficiency_chart.jpg

Tandem Solar Cells (PCE)

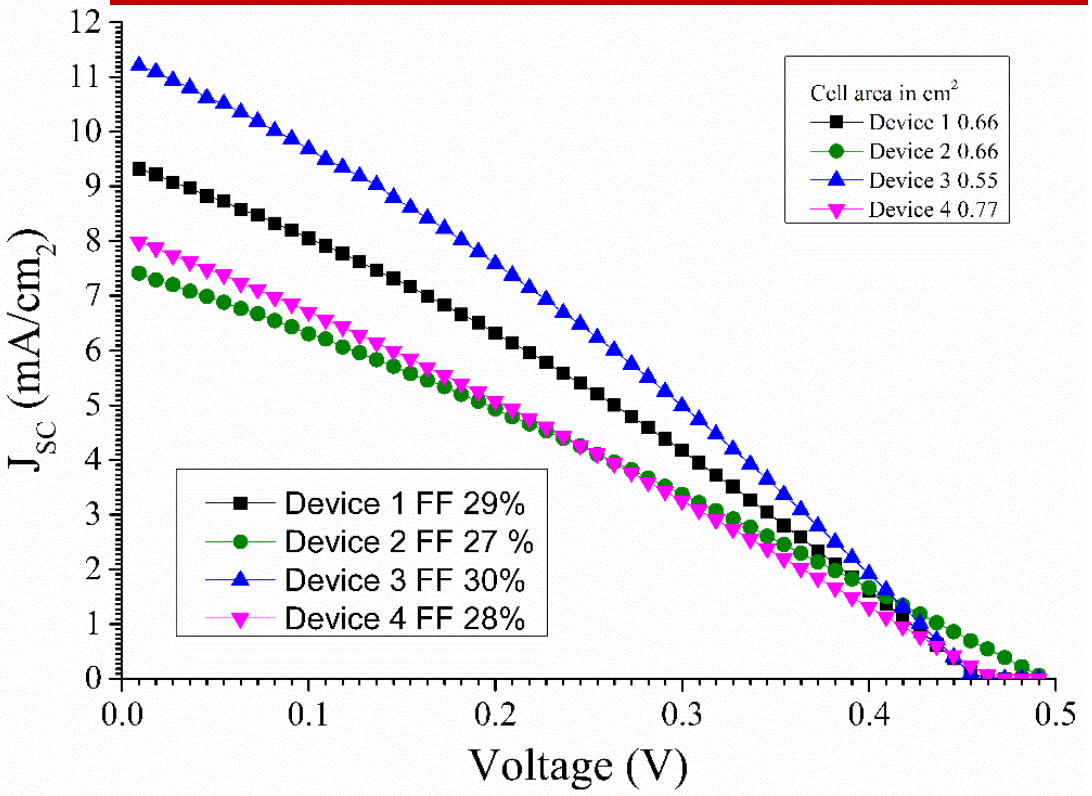
Back Metal Electrode	Back surface field	Si sub cell	Tunnel Junction	Electron Transport Layer	Perovskites	Hole Transport layer	Front Metal Electrodes	Tandem cell Efficiency reported
ITO Al	n+ a-Si	c-Si	p+ a-Si	(PEDOT:PSS)	$CH_3NH_3PbI_3$	PCBM	ITO	PCE 25%
AZO Ag	i a-Si n a-si	n c-Si	i a-Si p a-Si	SnO_2	$CH_3NH_3PbI_3$	spiro-OMeTAD MoO_3	ITO LiF_3	PCE 19.9%
Ag	n a-si	n c-Si	n a-Si:H P a-Si:H	TiO_2 Mesoporous TiO_2	$CH_3NH_3PbI_3$	spiro-OMeTAD	Ag nanowire LiF_3	PCE 13.7%
Sputtering Thermal Evaporation	PECVD		PECVD	Spin Coating Atomic layer Deposition	Spin Coating	Spin Coating	Thermal Evaporation	

Perovskite-Si tandem cells

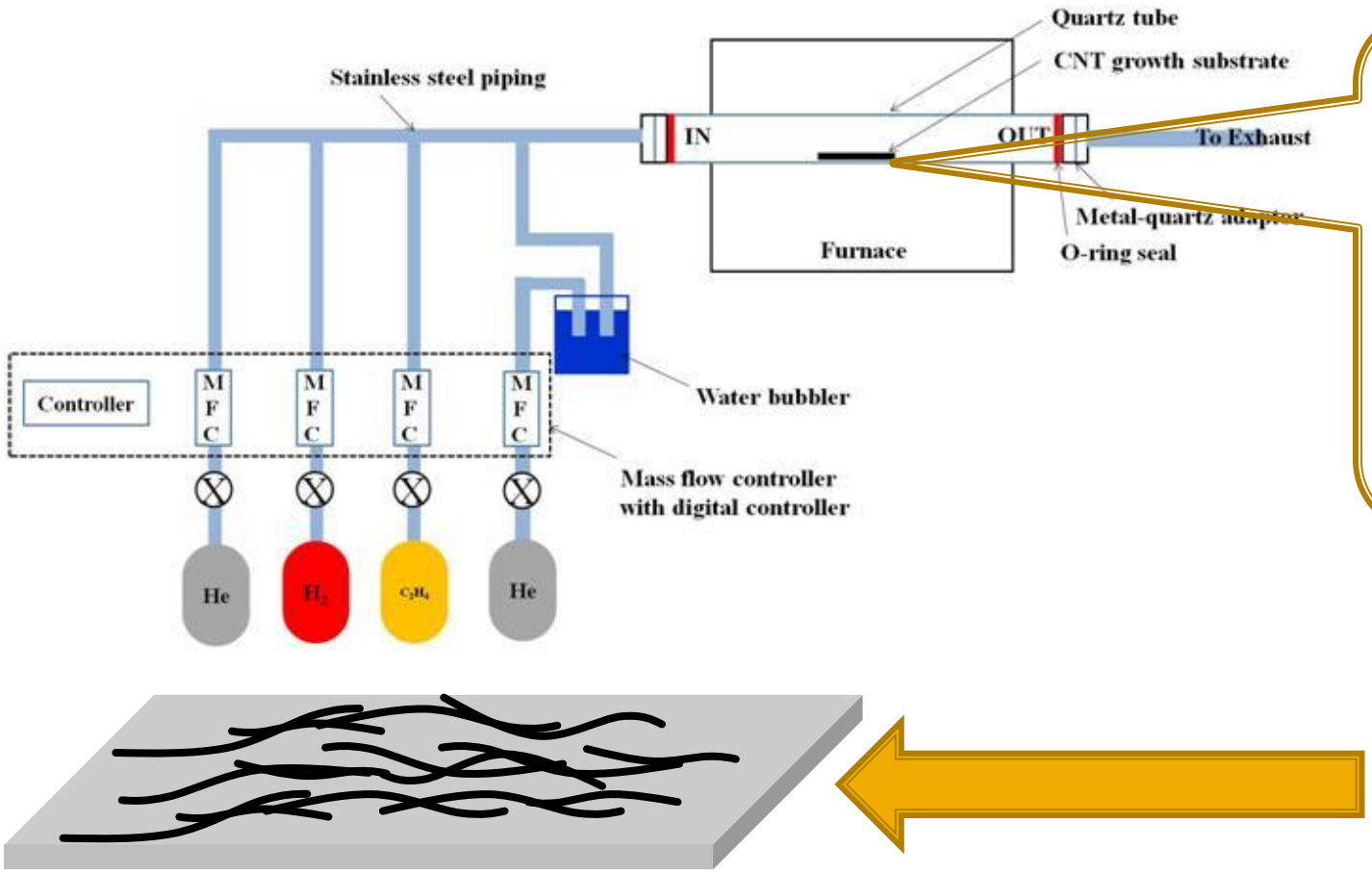
CSC-Si/perovskite tandem stack



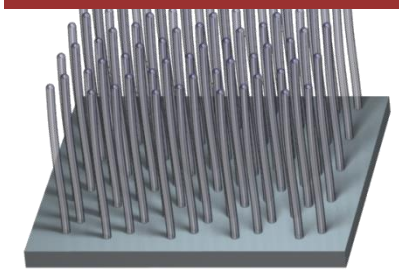
Bottom Cell: carrier selective contact (CSC) Si cell

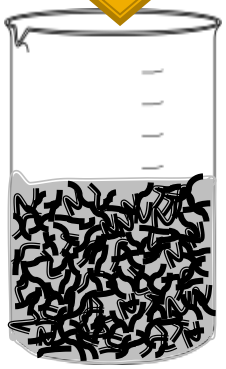


Alternate hole transport materials



Single wall carbon nanotube forest



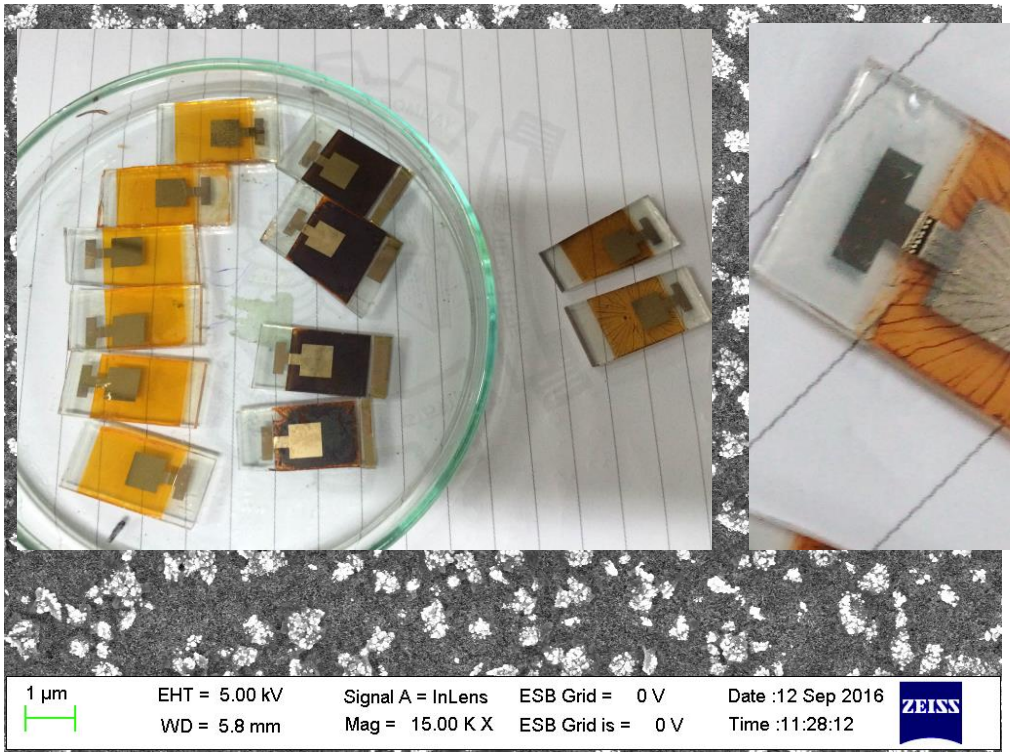


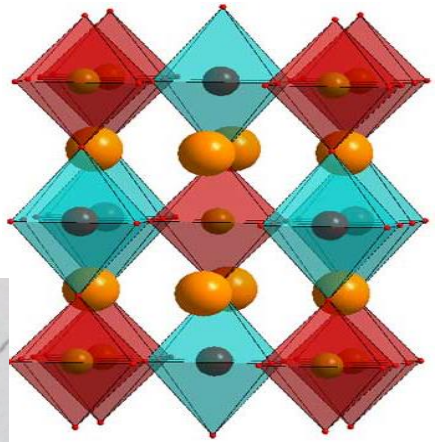
CNT conductive ink

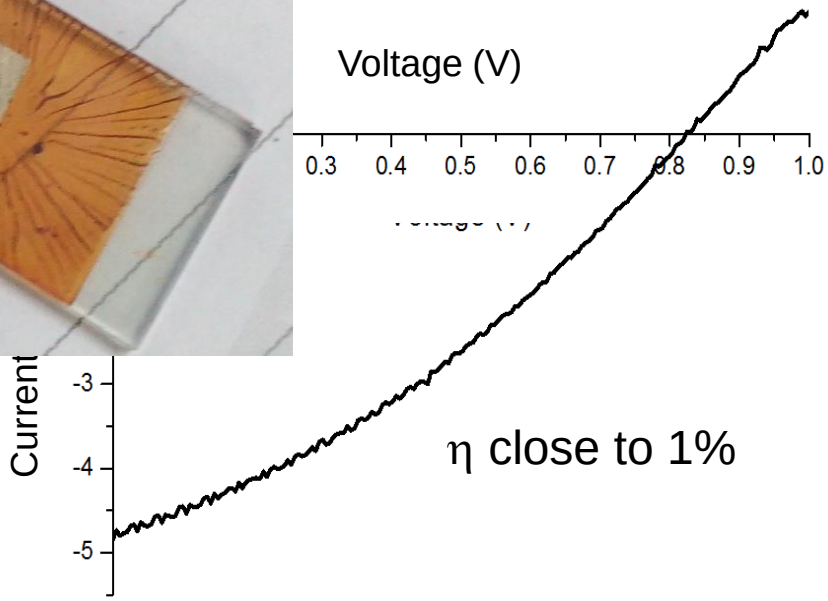
Transparent coating of nanocarbon CNT on arbitrary substrate

Lead-free perovskites

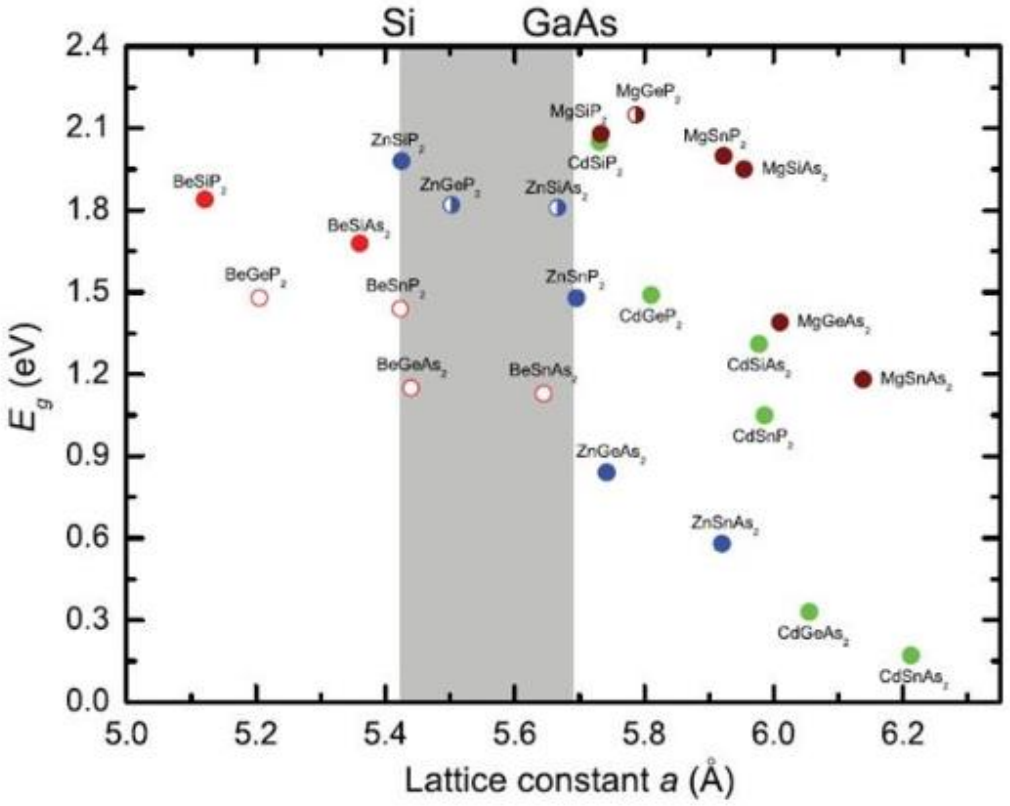
Double perovskite, $A_2B'B''X_6$
B’ as Ag, Cu and B’’ as Bi





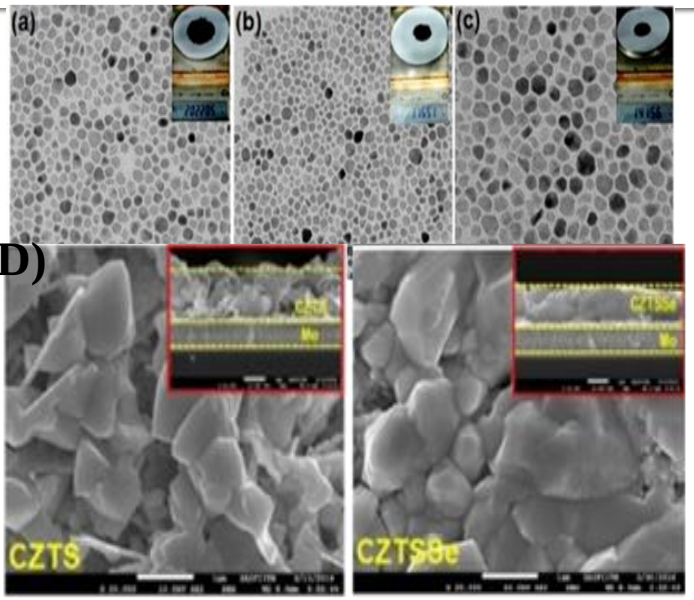


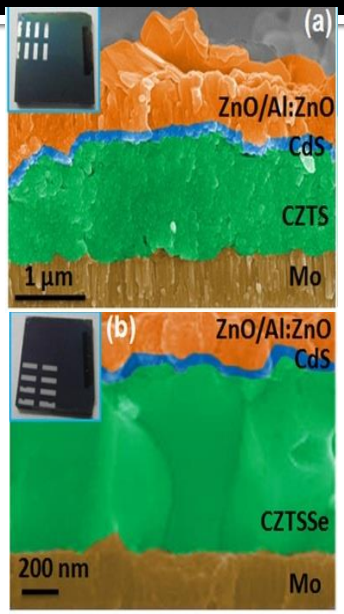
Oxides, Phosphides, Sulphides …



- Chalcopyrite p-type $ZnSnP_2$
  - Optical bandgap of 1.63 eV
  - Carrier concentration ~ 10^{16} cm^{-3}
  - Absorption coefficient of ~ 10^4 cm^{-1}
- Excellent candidate for tandem cells with Si and GaAs
- SQ limit ~28%

CZTS: nanoparticle Ink to Films



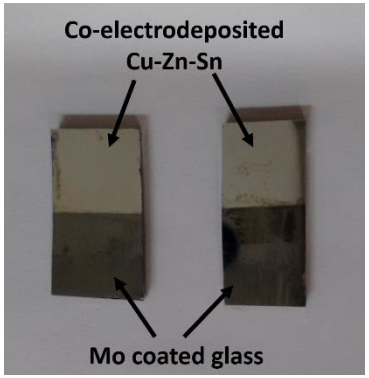


INK → FILM → STRUCTURAL PROPERTIES → DEVICING

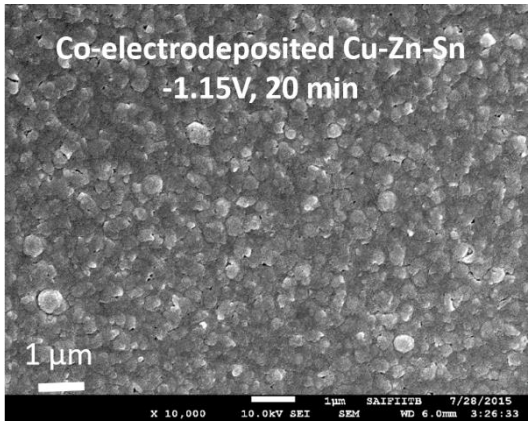
- A simple and economical approach to synthesize size-controlled Cu_2ZnSnS_4 (CZTS) nanoparticles : an absorber
- Engineering the matter with Anions/Cations: Control the formations of the secondary phases, the band gap, and the micro structure of Cu_2ZnSnS_4.
- Stoichiometric control over Cu, Zn and Sn concentrations.

CZTS co-electrodeposition

Co-electrodeposition, ref (Ag/AgCl), CE– Pt
Electrolyte (salts of Cu, Zn, Sn and tri-sodium citrate in water)

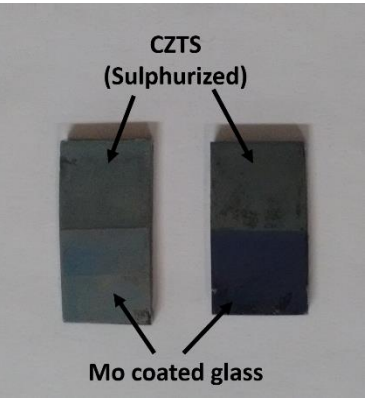


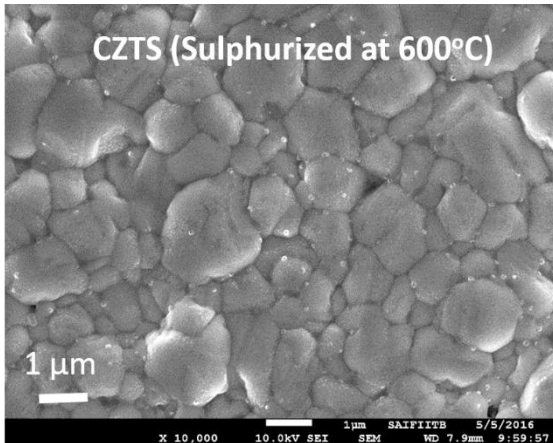
Electrodeposition at -1.15V for 20 min.



Thin film (Cu-Zn-Sn) containing intermetallics of (Cu, Sn) and (Cu,Zn) – (around 700 nm)

Annealing at 600°C, 15min in the presence of S in Ar atmosphere

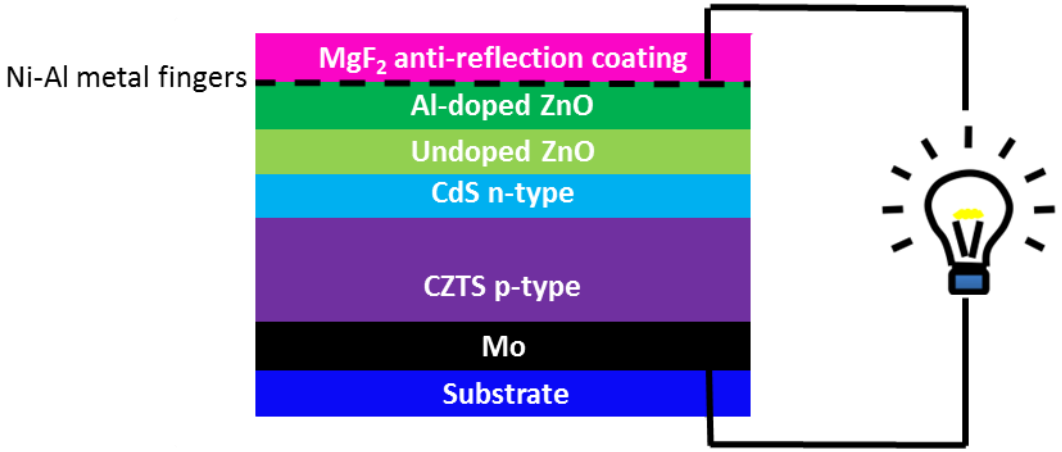




Dense, continuous CZTS film with more than micron size grains and optical band gap of around 1.5eV

CZTS based thin film solar cell

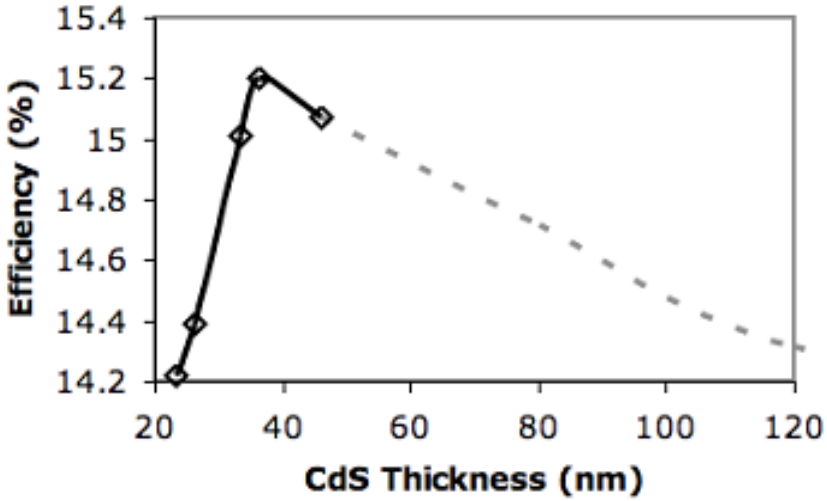
- Back contact (Mo)
- Absorbing layer (CZTS)
- **Buffer layer (CdS)**
- Intrinsic ZnO layer/AZO layer
- Top contact (Ni/Al grid)



CZTS solar cell structure

CdS buffer layer thickness :

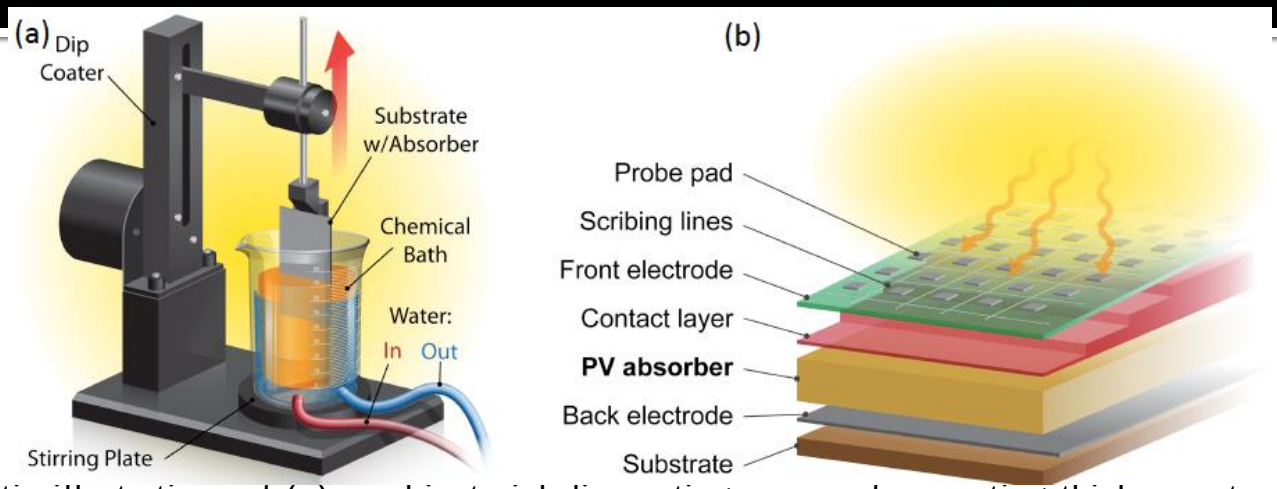
- Shunting between the absorber and the electrode (too thin contact with buffer layer)
- high series resistance of the PV devices and the photon absorption (too thick contact)



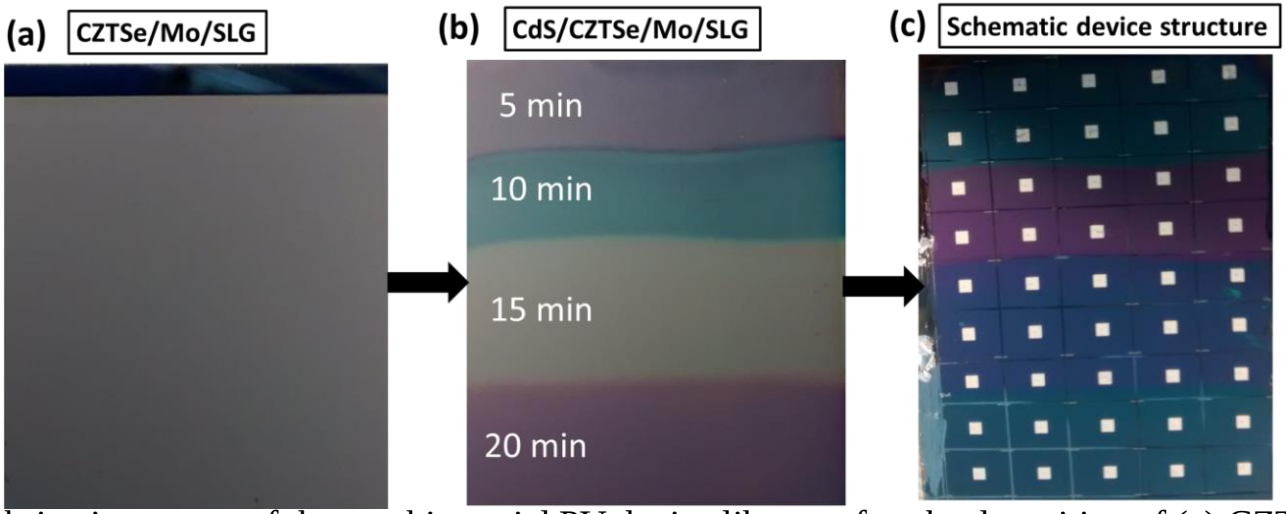
CIGS efficiency as a function of CdS thickness

Ref: I. Repins,," NREL/CP-520-46235 July 2009
M. Ali, Sol. Energy, **120** (2015) 131–146

Combinatorial dip coating of CdS buffer layer



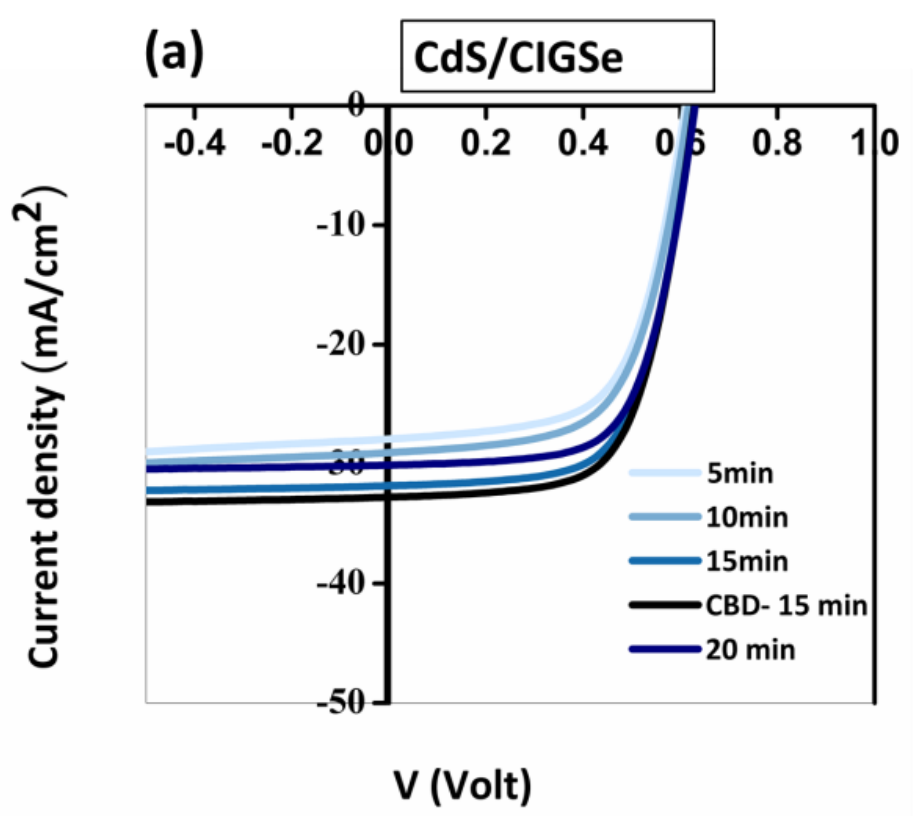
Schematic illustrations of (a) combinatorial dip-coating process for creating thickness steps in the CdS contact layer, and (b) PV device structure with integrated combinatorially deposited CdS contact layer/buffer layer

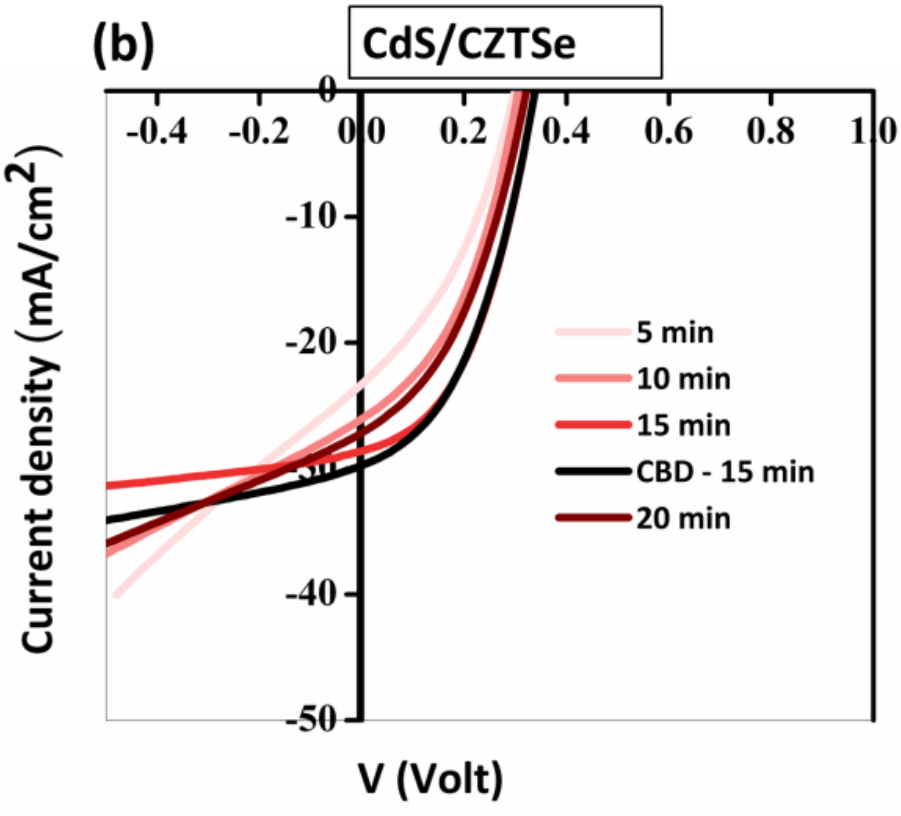


Fabrication stages of the combinatorial PV device library, after the deposition of (a) CZTSe absorber, (b) CdS contact with thickness steps, and (c) TCO and metal electrode pads

Ref: **Krishnaiah Mokurala** etal . **ACS. Comb. Sci. 2016, 18 (9) 583–589**

J-V measurements of thin film solar cells





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Screen printed DSSCs