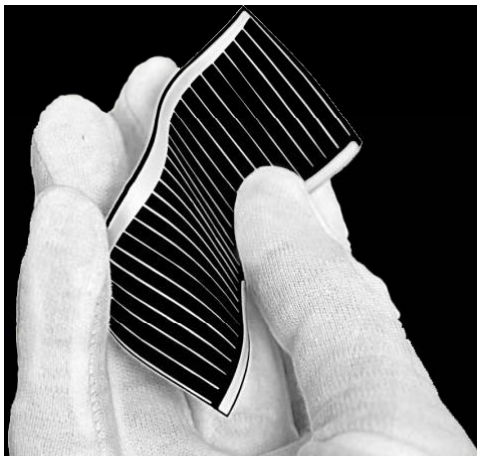
Flexible Solar cells
to expand solar energy applications

Helene FROUGE



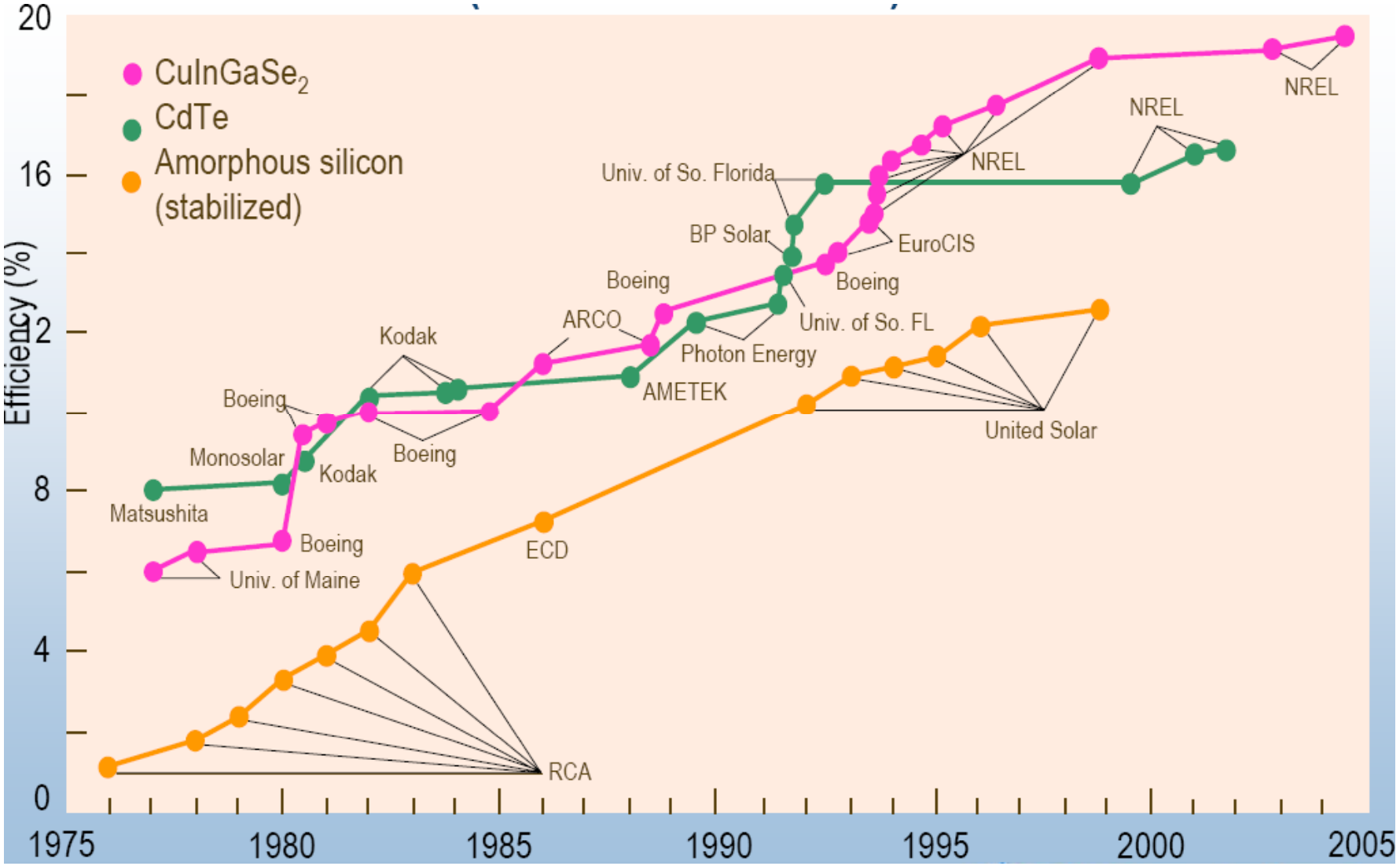
Outline

I. Thin films
II. Array of technologies
III. Roll-to-roll processing
IV. CIGS: from panel-type to flexible
V. Dye-sensitized solar cell

Thin films

- Lightweight and flexible
- Modules are cheaper to manufacture:
  reduced material costs.
  energy
  handling
  capital
- Use of roll-to-roll processes

Cell efficiencies for thin films



Array of technologies

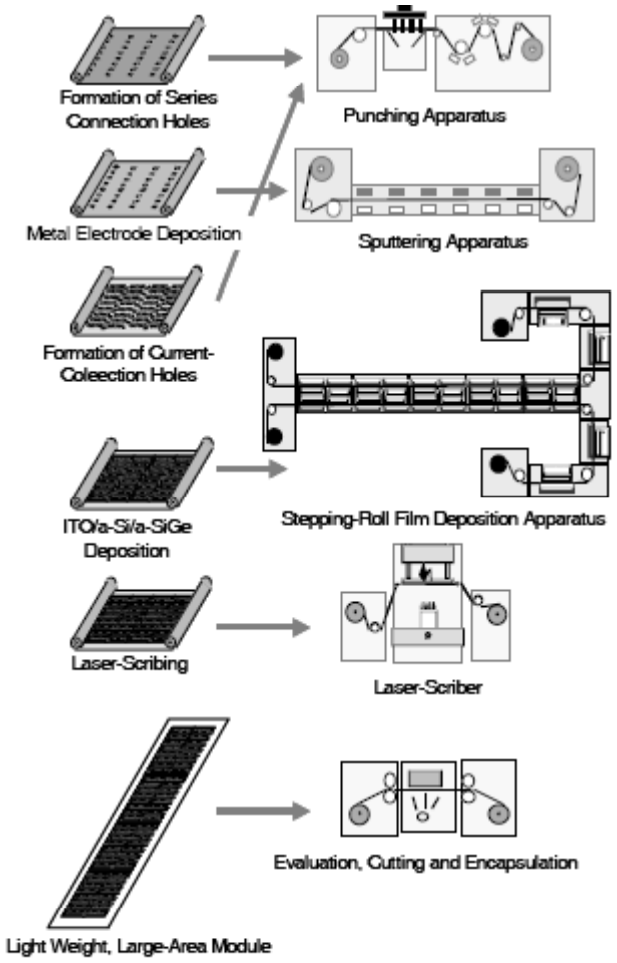
Tech.	η	Advantages	Major drawbacks	Application
a-Si	9%	Less expensive than c-Si	Low QE	Smaller-scale application: calculators, …
CIGS	15,9%	•Long-term reliability •Low cost manufacturing	Toxic cadmium	Can be integrated in all sorts of surface
CdTe	15%		Toxic cadmium	
Organic	5%	•Manufactured cheaply •Low environmental impact	•Low stability •Low strength	Supply power for small mobile devices
Dye-sensitized solar cell	11%	•Not elaborated manufacturing •Low production costs •Robust •Work in low-light conditions	•Chemical stability of electrolyte •Volatile organic solvents	•Roof-top solar collector •Not yet for large scale deployment

Roll-to-roll processing

Manufacture solar cells on a roll of flexible plastic or metal foil, much like newsprint speeding through a press → high production throughputs

NanoSolar thin-film production

Roll-to-roll method: example of production of a-Si flexible solar cell

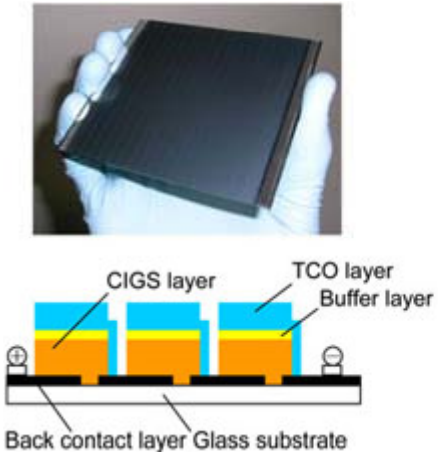


- Series connection through apertures formed on film substrate
- Metal electrodes deposited on both sides of the film substrate by a conventional roll-to-roll sputtering apparatus
- Current collection holes made on the plastic film substrate
- a-Si, a-SiGe and related layers, ITO and backside metal electrodes are deposited in succession in the stepping-roll apparatus
- Layers deposited on both sides of the substrate are divided by the laser-patterning technique to form unit cells

CIGS, from panel-type to flexible

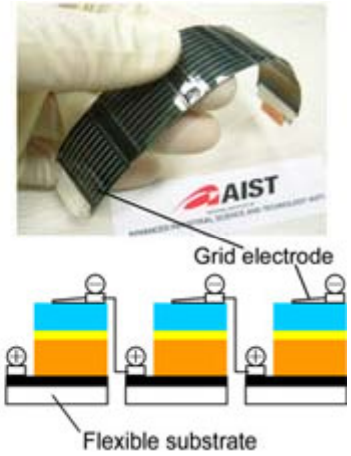
Since the highest conversion efficiency among thin-film solar cells is realized by the CIGS solar cell, the realization of a high-performance flexible CIGS solar cell module was strongly desired.

Panel-type: integrated structure



Solar cells connected in series on a glass substrate

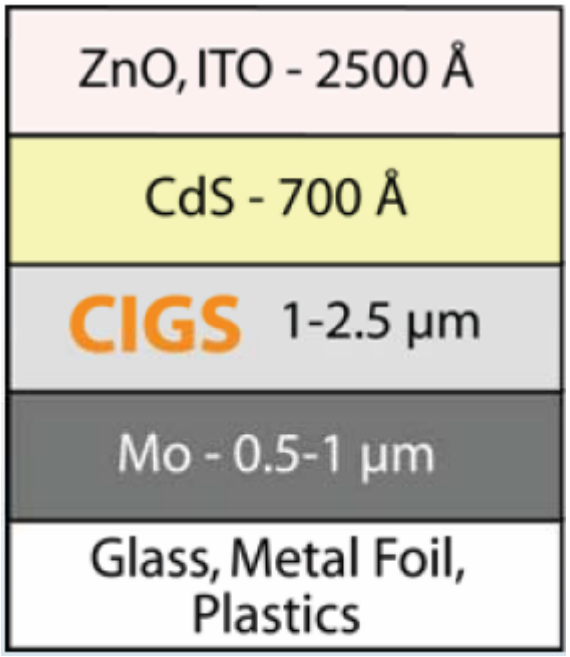
Flexible type: grid-electrode type



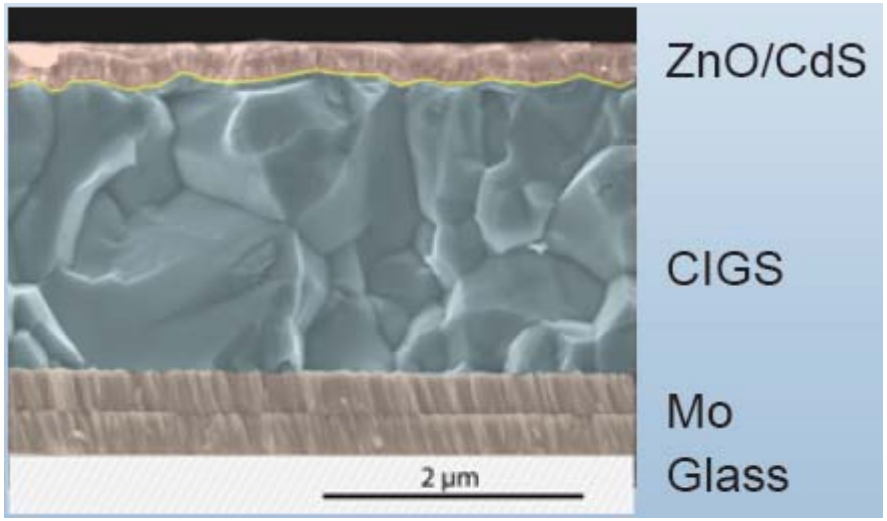
- A cell is prepared on each substrate (metal foil). Cells are connected using metal electrodes.
- Alkali addition control: add alkali metal → increase η
- Integrated structure on flexible substrate

$Cu(InGa)Se_2$, thin film

- Eg=1.1 – 1.2 eV



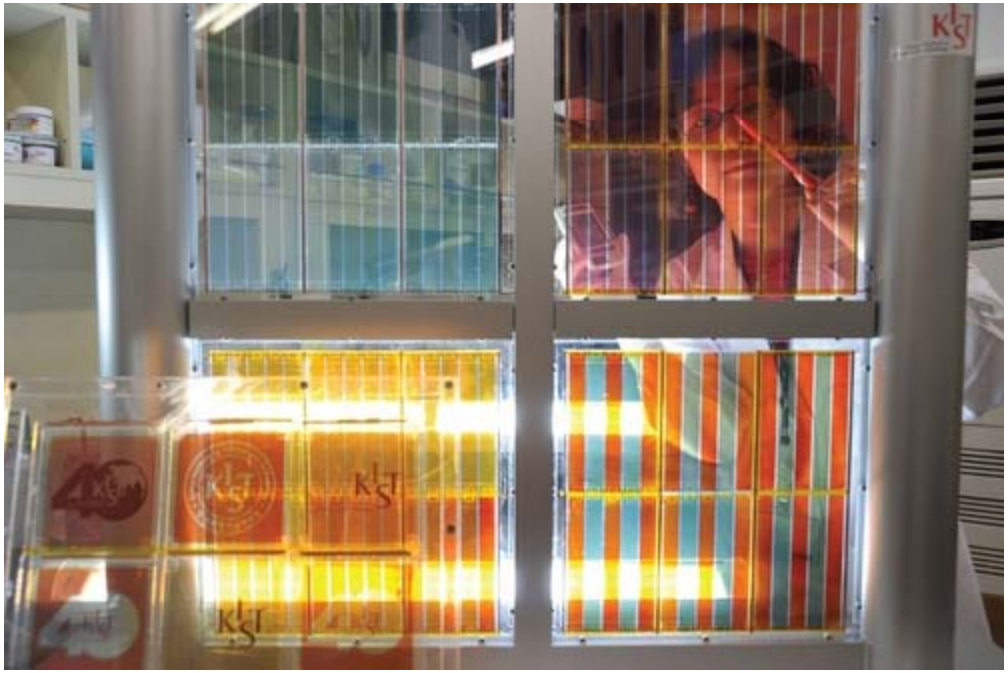
Voc= 0.676 V
Jsc= 32 mA/cm2
FF= 79.5%; Eff= 17.2%



- A deposition method: nano-particles (ink)

Photo-electro-Chemical solar cell: dye-sensitized

- Imitates the way that plants/algae convert sunlight into energy
- Light is not absorbed in a SC layer. Absorption occurs in dye molecules, adsorbed at a highly porous structure of nano-particules of transparent $Ti0_2$



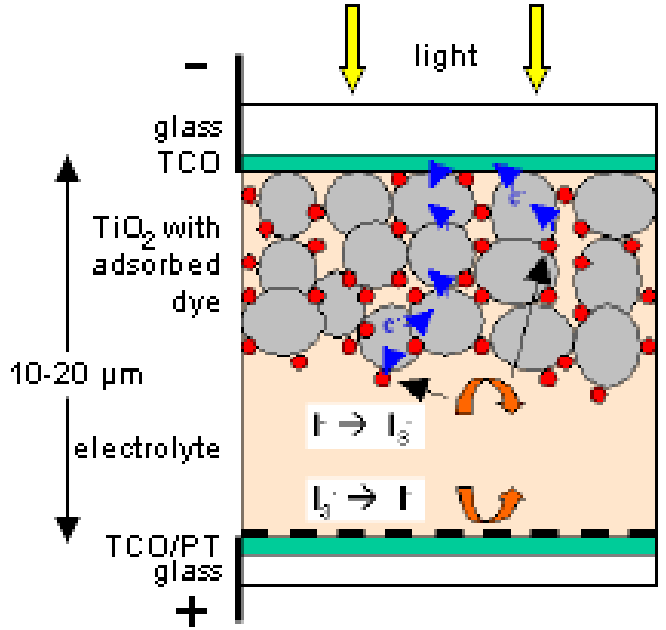
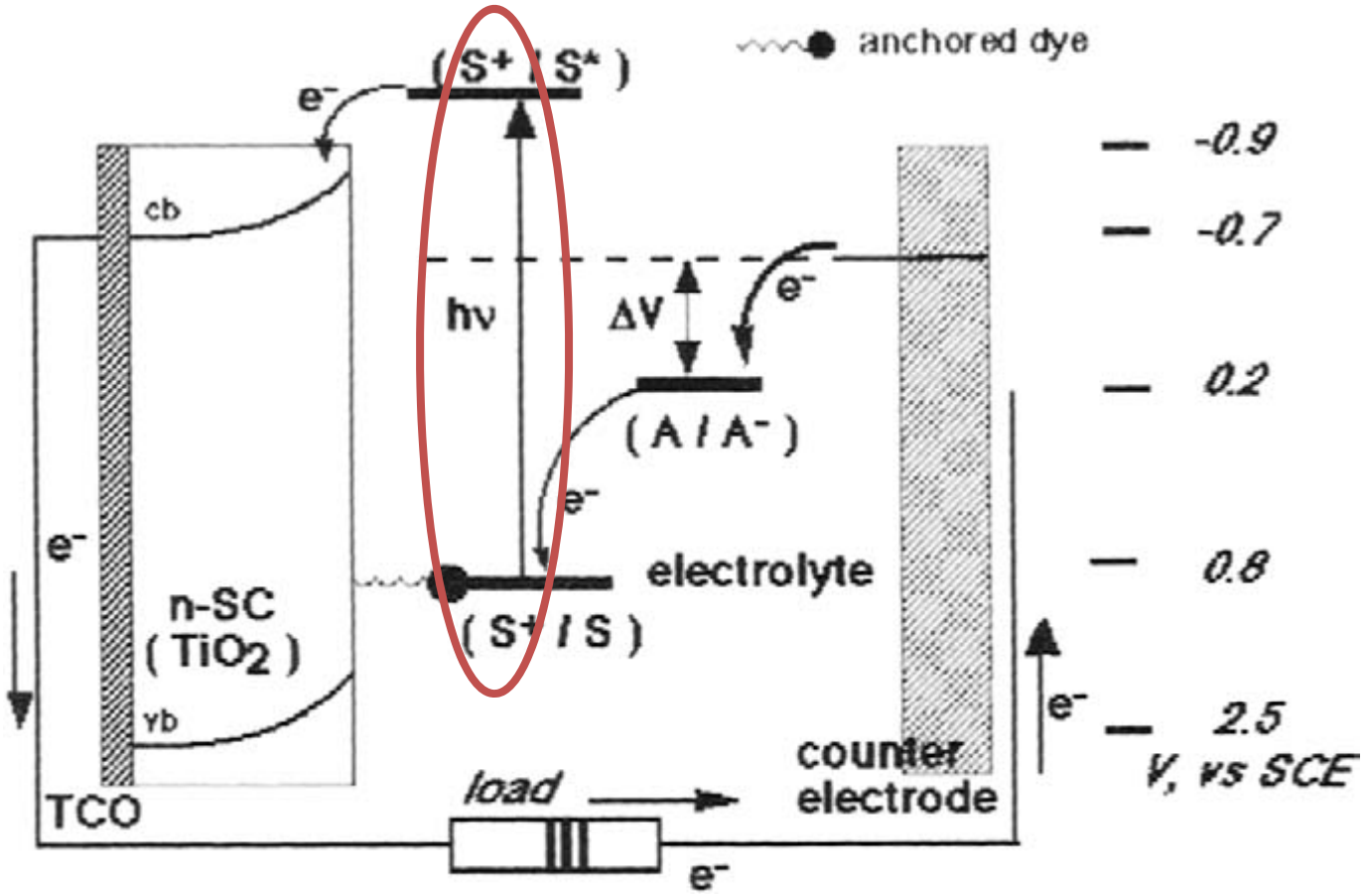


Fig. 1: Schema of dye-sensitezed solar cell

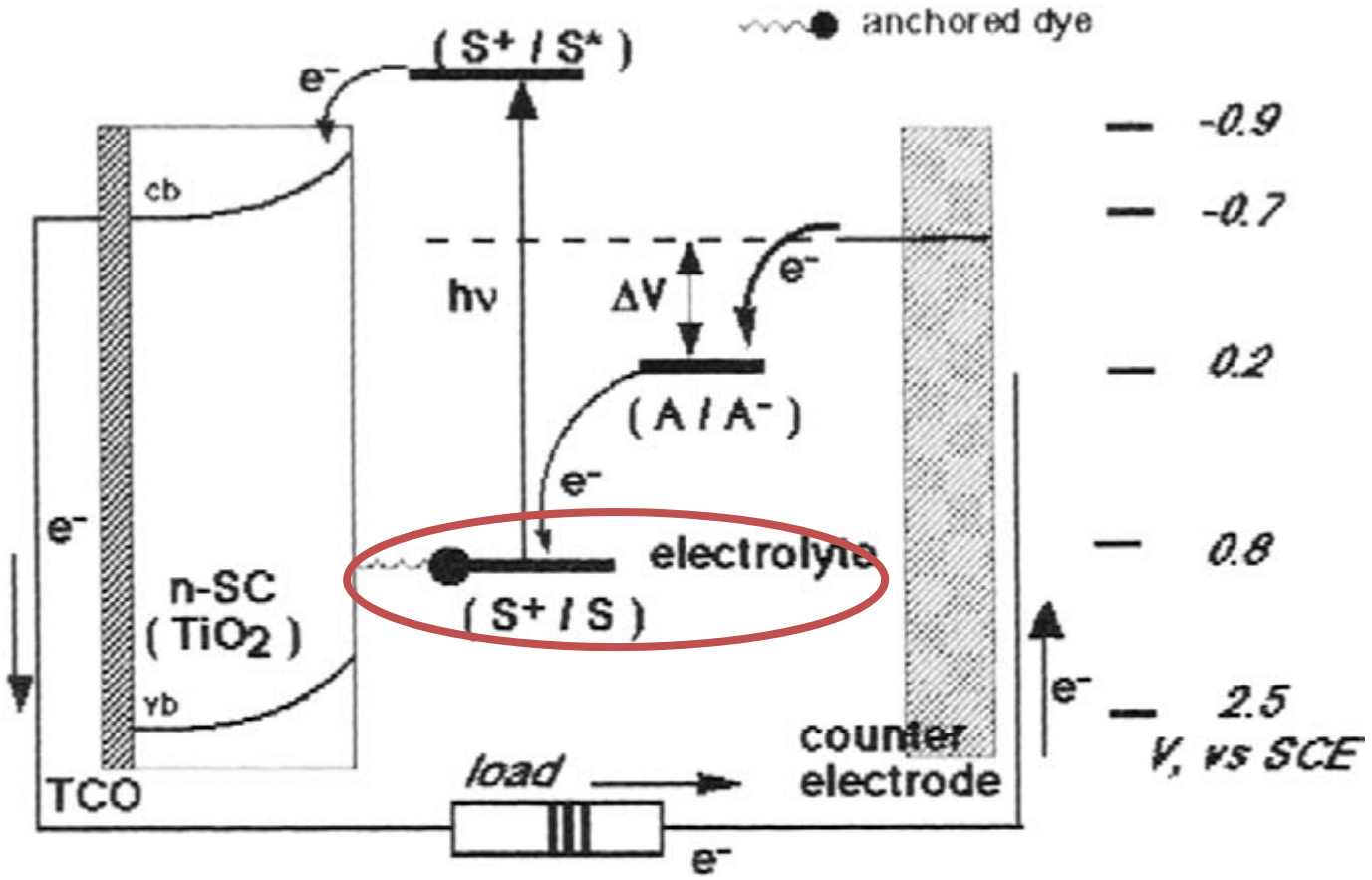
Regeneration cycle in a dye-sensitized solar cell



The dye is photoexcited → relaxation by electron loss to SC substrate

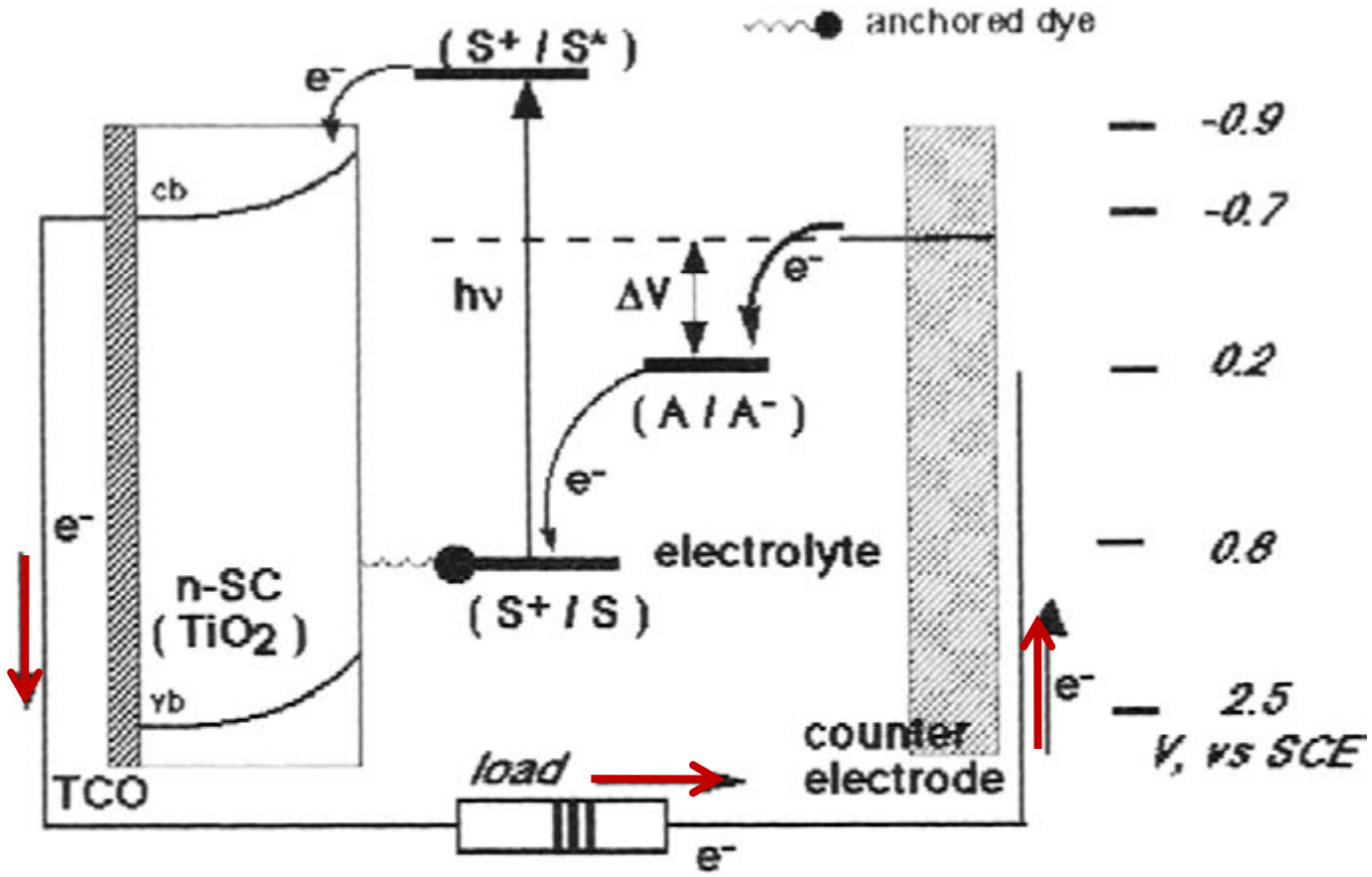
S= sensitising dye

Regeneration cycle in a dye-sensitized solar cell



The positive charge remaining is neutralised by the electrolyte,

Regeneration cycle in a dye-sensitized solar cell



which in turn recovers the electron through the external circuit and metallic cathode. A- = redox anion

Photo-electro-Chemical solar cell: dye-sensitized

- Molecular engineering of suitable dye
- Adsorption as a monomolecular film on a wide bandgap SC → adequate optical absorption
- Ohmic contact → deliver the resulting current
- Establishment of a regenerative system through a catodic counter electrode and redox electrolyte

Main sources

- *Solar Cells: Materials, Manufacture and Operation,* Markvart (2004)
- *High Efficiency CdTeand CIGS Thin Film Solar Cells: Highlights of the TechnologiesChallengesNational,* NREL,Rommel Noufi (2006)
- *Production Technology of Large-Area, Light-Weight, Flexible Solar Cell and Module*, Japan (2008)
- *New Efficiency Benchmarkd For Dye-Sensitized Solar Cells*, Science Daily (2008)

Thanks for listening!