Grätzel solar cell

Physical principles

How can the cell be done?

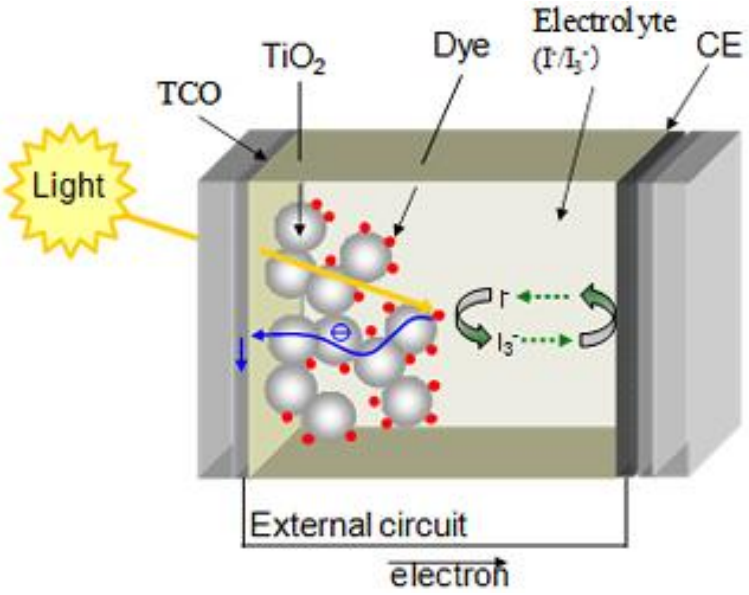
How does it work?

Outline

- Graetzel cell bibliography.
- The components of the Graetzel cell
- How does it work ?
- What we can chose for the dye?
- Natural dyes
- Does our cell work?
- How can we *see* our cells?
- Atomic Force Microscopy
- The best solar cells?
- After Graetzel.. →perovskite

Grätzel cells, components, bibliography

- Dye sensityzed solar cell
- **The physical process are very similar to chlorophyllian photosynthesis**



1. Grätzel, M., and O'Regan, B. "A Low-Cost, High-Effi ciency Solar Cell Based on Dye sensitized Colloidal TiO_2 Films" Nature, 353, 737-740, 1991.

2. Grätzel, M. et al., "Solid-state Dye-sensitized Mesoporous TiO_2 Solar Cells with High Photon-to-electron Conversion Effi ciencies." Nature, 395, 583-585, 1998.

3. Grätzel, M., "Photoelectrochemical Cells." Nature 414, 338-344, 2001.

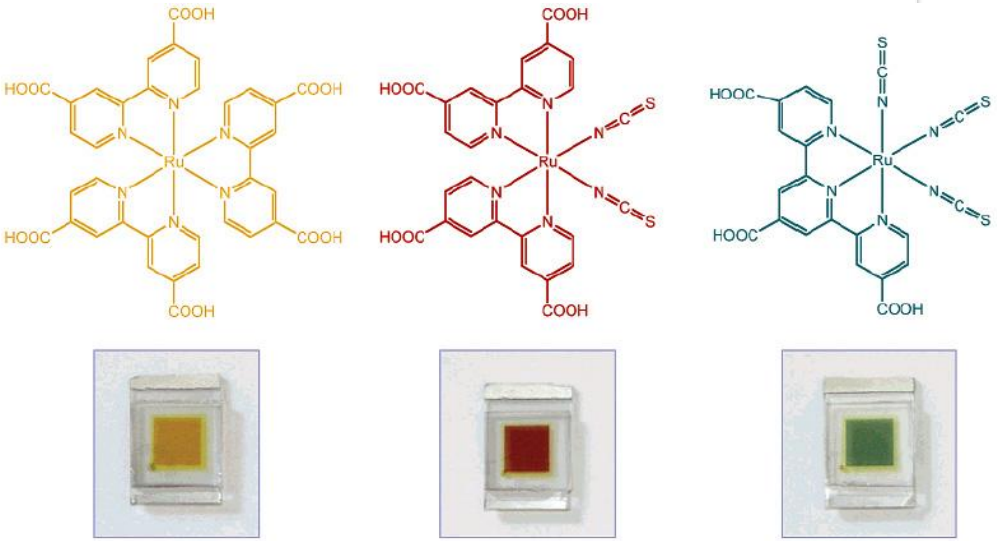
4. Grätzel, M., "Recent Advances in Mesoscopic Solar Cells." Acc. Chem. Res. 42, 1781-1798, 2009.

http://blogs.nature.com/news/2010/06/solar_cell_scientist_scoops_mi.html

The components of the cell:

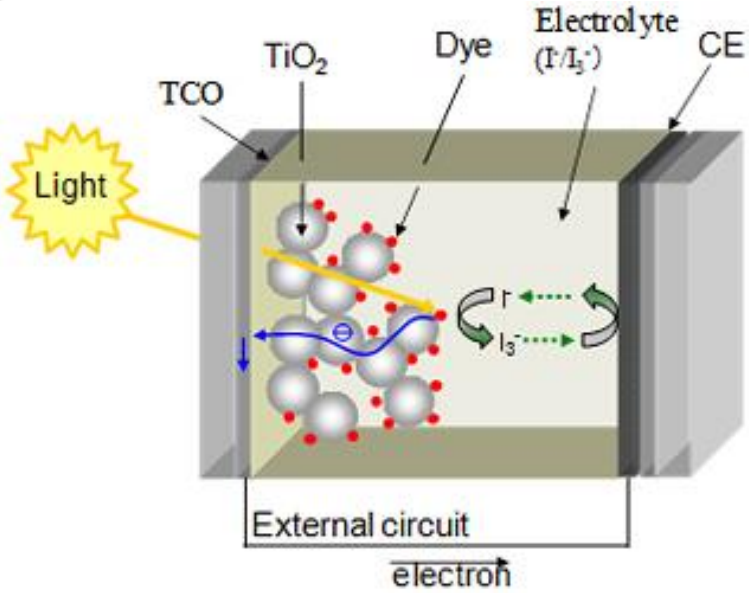
- The charge transport occurs at nanocrystalline titanium bioxide (nc-TiO_2)
  - Low cost, diffused material non toxic, it is used for many toothpastes bioc-compatible high energ gap insukator (e-h pairs d not recombine here)

- Dye: ruthenium compounds
- It must absorb sun radiation
- It must *attach* to nc-TiO_2 it is a ruthenium compound

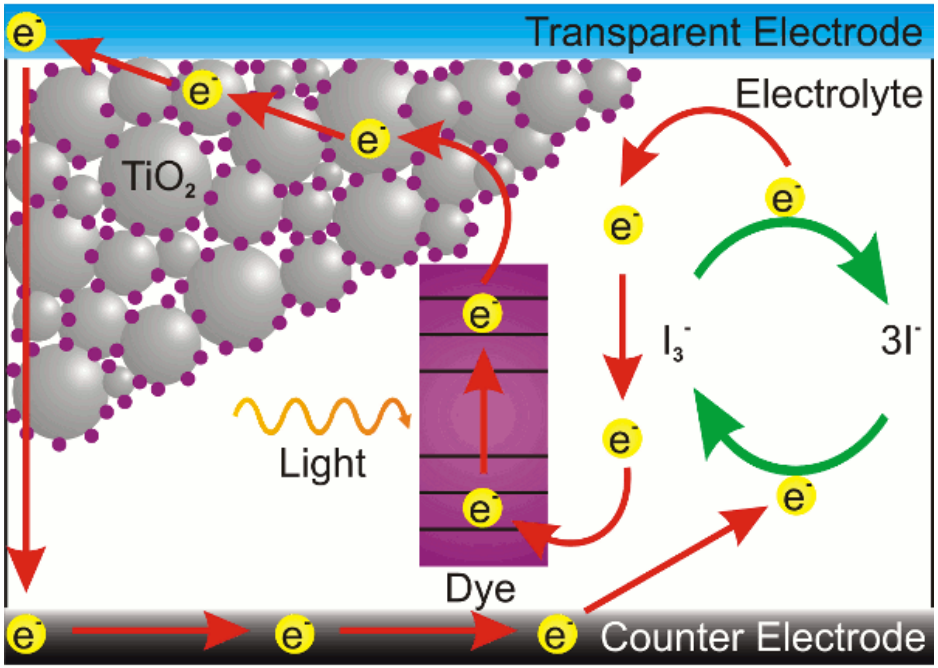


The components of the cell:

- Electrolyte (iodine):
  - Iodine must replace the electrons lost by the die molecule, it contains I- which will receive electrons from the counter electrode that will replace the electrons lost by the dye molecules.
- Counter electrode
  - It will give electrons to the I-



How does it work? (1)

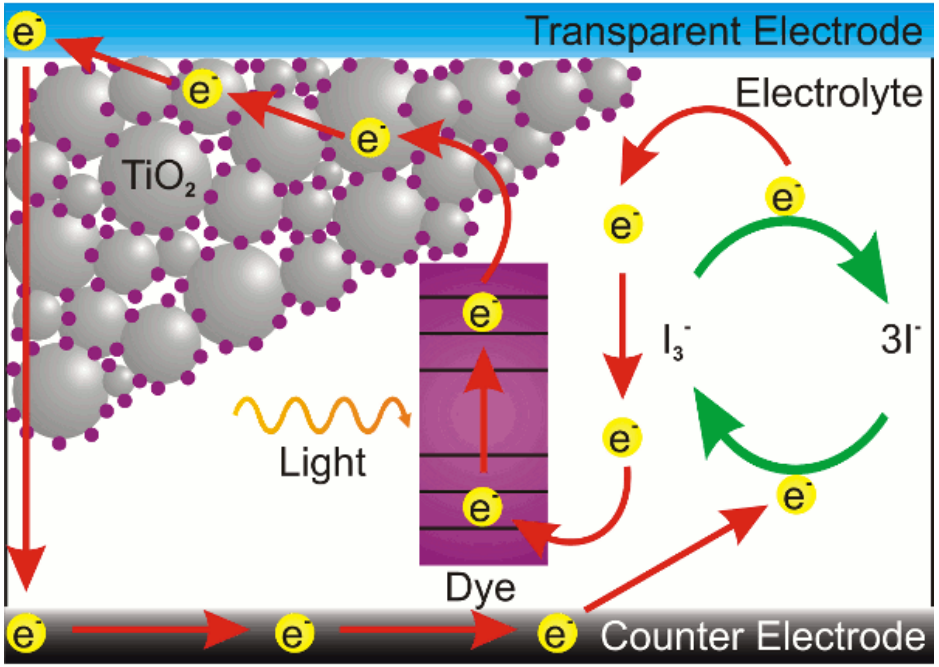


- The dye is adsorbed in the nanocrystalline, nanoporous TiO_2
- TiO_2 : the dye molecule absorb a photon forming an excited state (dye*)
- The dye* can be seen as an electron hole pair

- The dye transfer a hole to the TiO_2 (semiconductor) leaving the hole in the dye [dye^{*+}]
- The hole recombines with one electron from the iodine ion (electrolyte) [$2dye^{*+} + 3I^- \rightarrow 2dye + I_3^-$]

How does it work?(2)

- The electrons from TiO_2 go towards the cathode
- The anode is covered by a catalyzer (carbon) which injects electrons in the cell (in the iodine)
- The REDOX mediator is (I^-/I_3^-)



*Why **«nano»** is important in this case?*

Discussion with the students, surface / volume ratio, role of the interfaces…

How does it work? (3)

- dye + photon ⇒ excited dye
- Excited dye + TiO_2 ⇒ $e^-(TiO_2)$ + oxidised dye (hole)
- oxidised dye (hole) + (3/2) I^- ⇒ dye + ½ I_3^-
- (½) I_3^- + e^-(counter-electrode) ⇒ (3/2) I^-

The TiO_2 nanoparticles behave as electron acceptors, iodine behaves as electron donor, the dye works as a photochemical pump
In the photosynthesis these roles are done by carbon dioxide, water and chlorophyll

$H_2O + CO_2 +$ energy $\leftrightarrow$ carbohydrides $+ O_2$

What can we choose for the dye?

- The dye can be also obtained from **blueberries, blackberries, red oranges, pomegranates, or eggplant!**






DSSC with natural dyes

Solar Energy Materials & Solar Cells 92 (2008) 1341–1346

Contents lists available at ScienceDirect

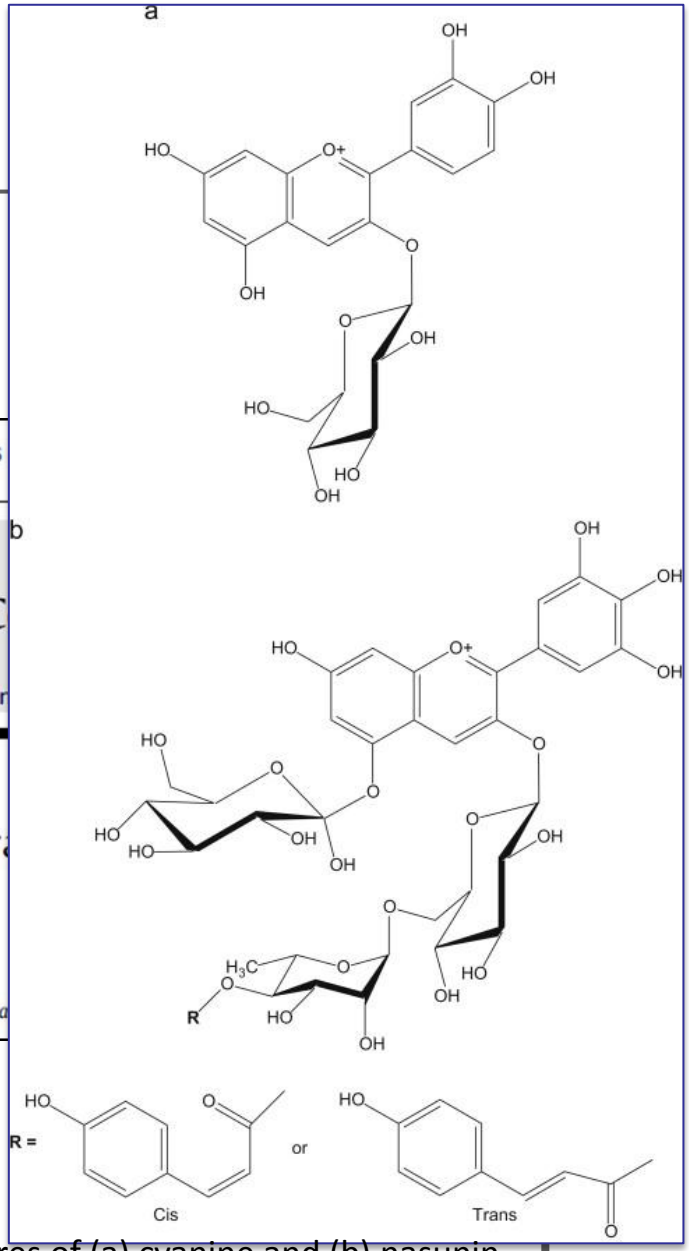
Solar Energy Materials & Solar C

journal homepage: www.elsevier.com/locate/solr

Red Sicilian orange and purple eggplant fruits as natura
dye-sensitized solar cells

Giuseppe Calogero *, Gaetano Di Marco

CNR, Istituto per i Processi Chimico-Fisici (Sede di Messina) Salita Sperone, C. da Papardo, 1-98158 Faro Superiore Messina

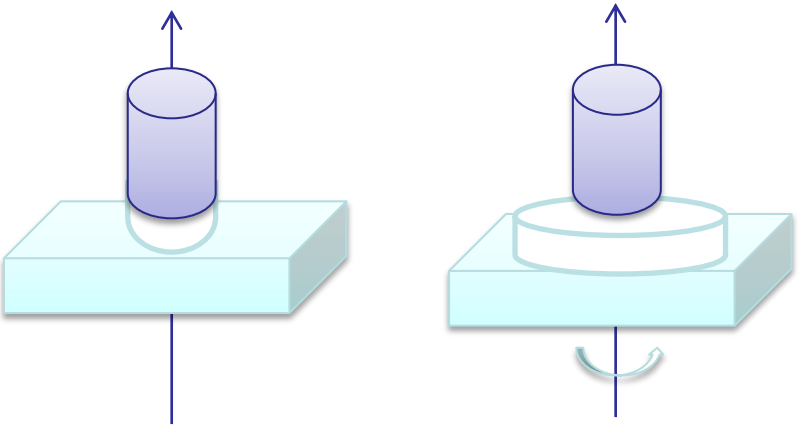


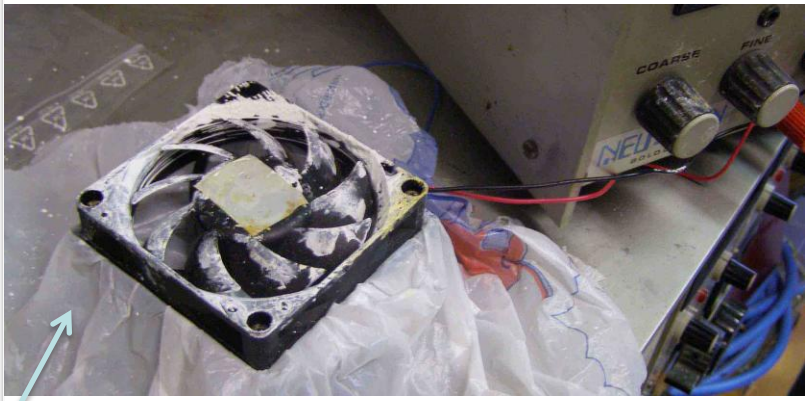
Chemical structures of (a) cyanine and (b) nasunin

Problem: stability!!

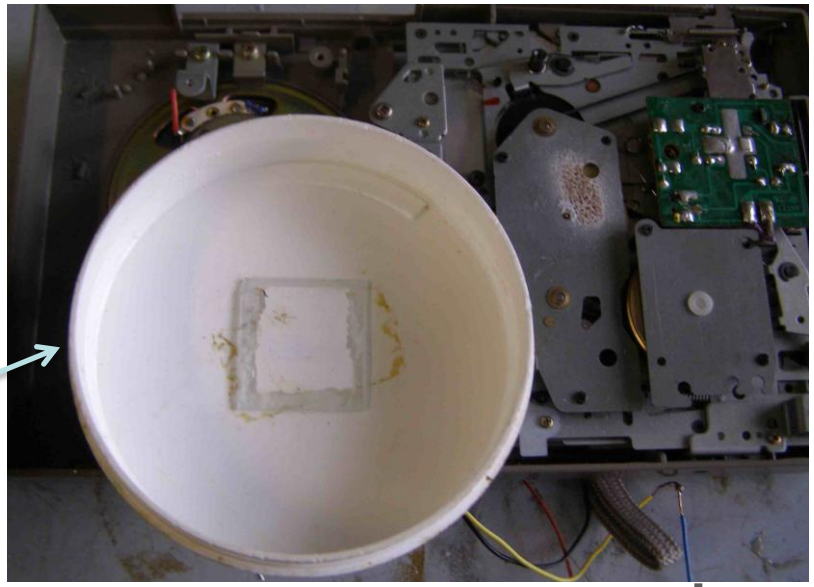
Very simple deposition methods

- By ***spin-coating or stretching the TiO_2 layer***





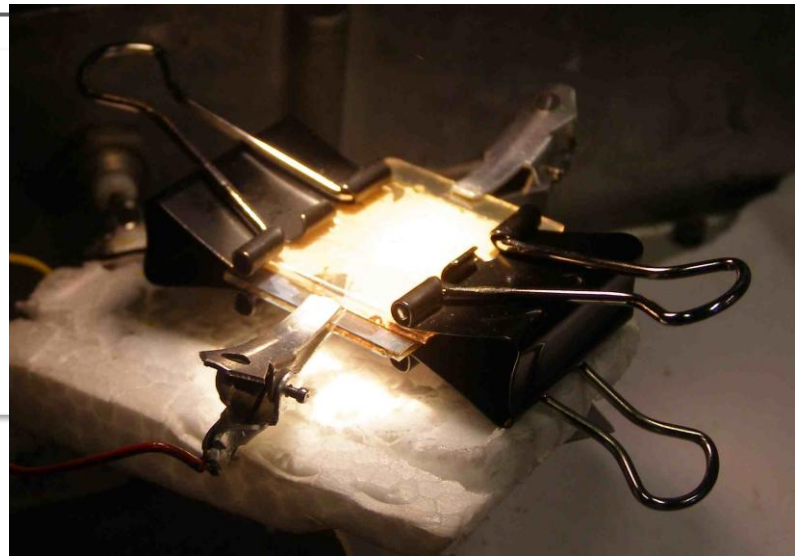
- Example the ***spin coater has been done recycling a computer fan***

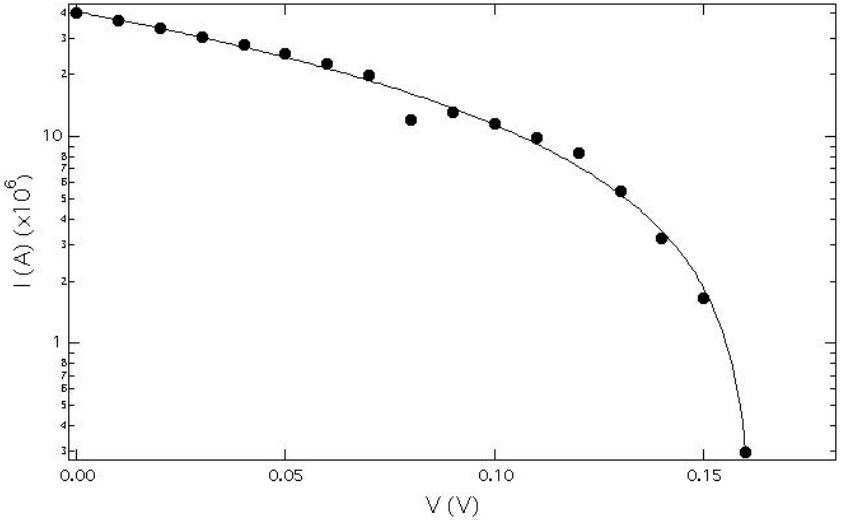


Does our cell work?
Does it generate an electrical power?

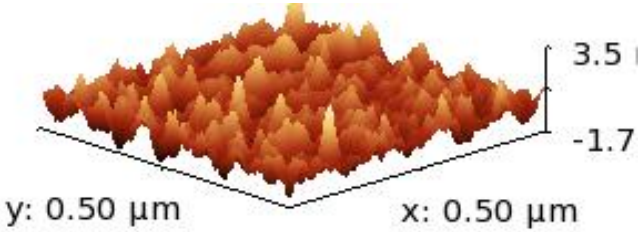
- IV (current voltage) characteristics under illumination and in darkness

$$efficiency = \frac{P_{out}}{P_{in}}$$



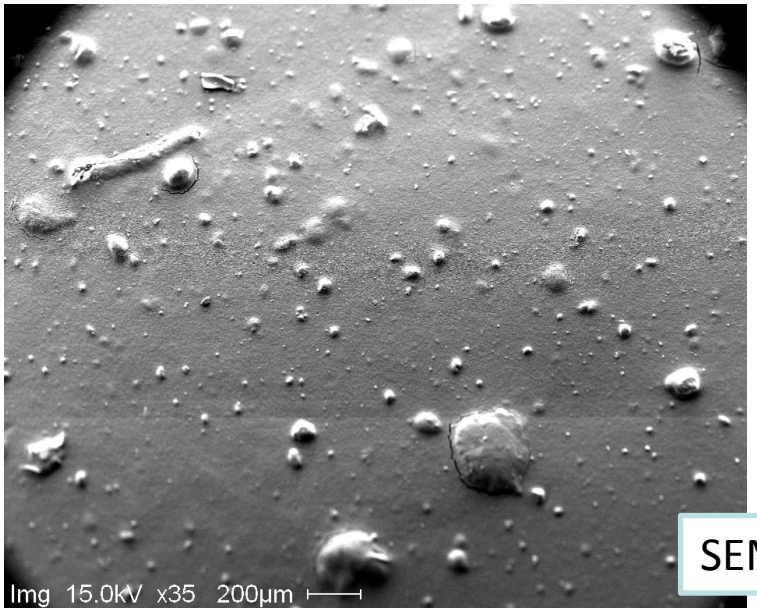


What about the surface of the cell?



AFM

- *Atomic force microscopy*

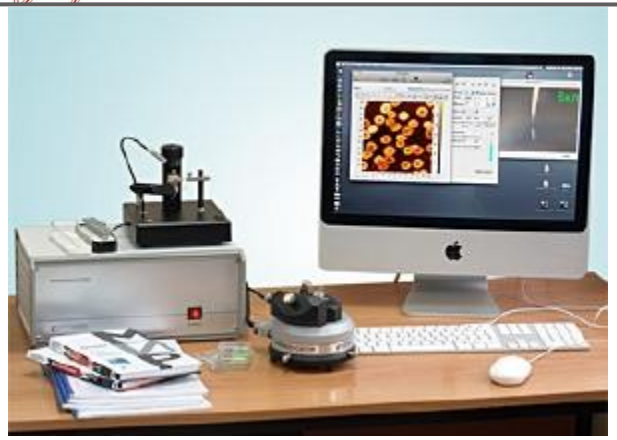


SEM

- *Scanning electron microscopy*

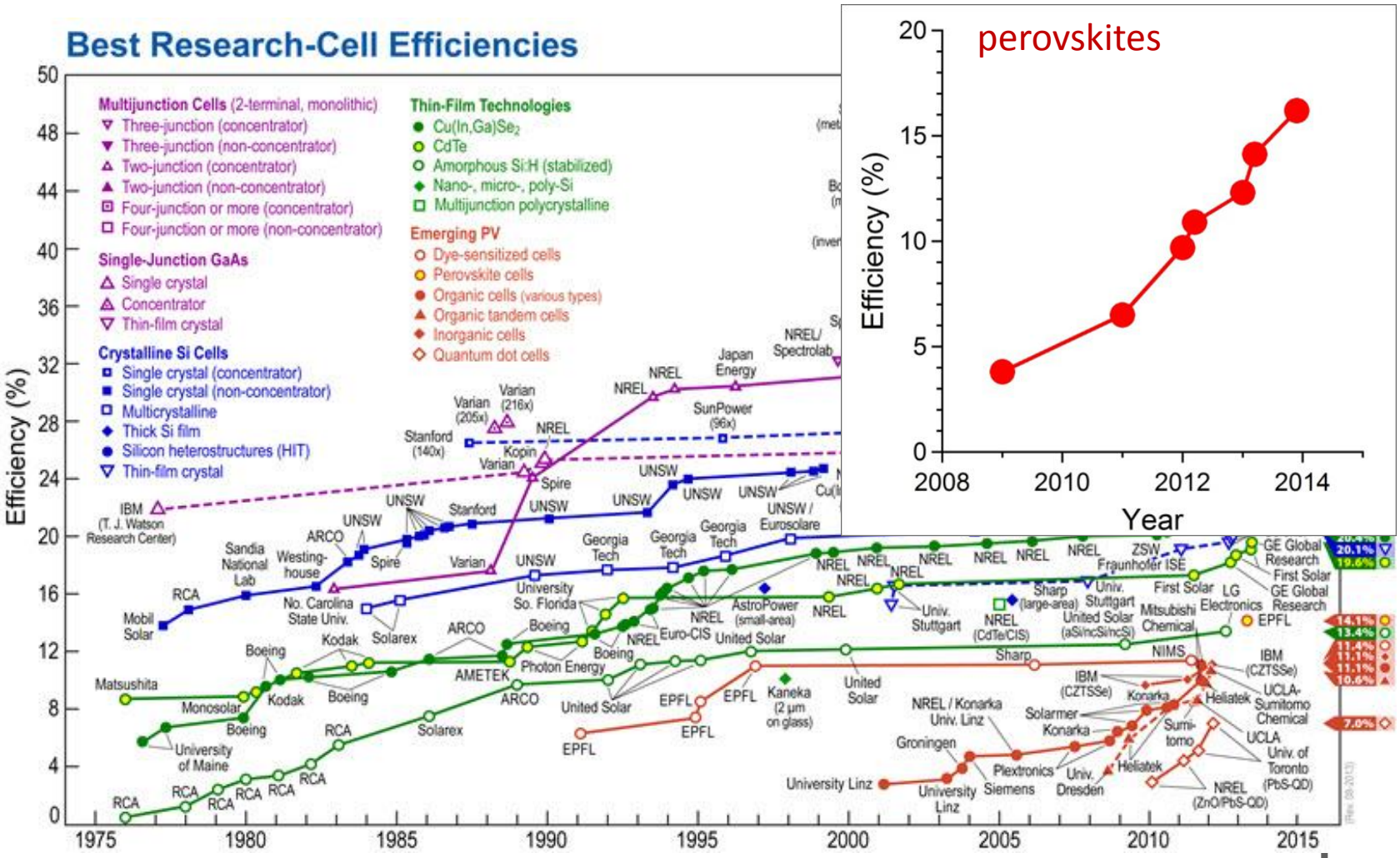
Keywords: renwable energy, use of natural substance

We have used an atomic force microscopy AFM «educational»



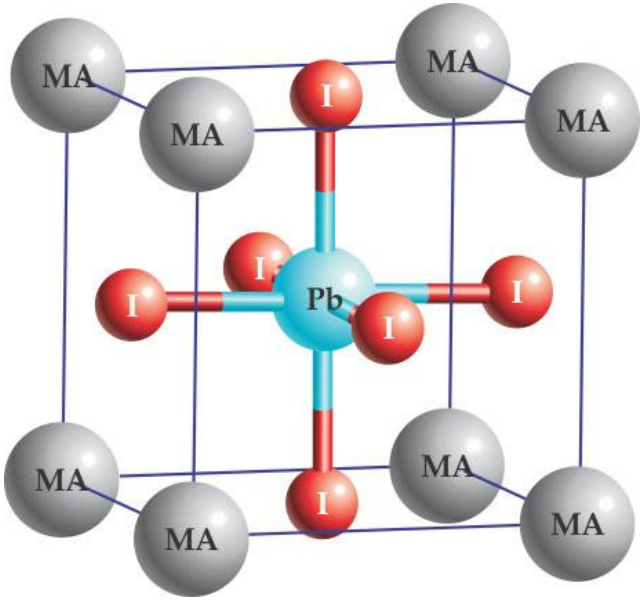
Where we can fabricate the tips

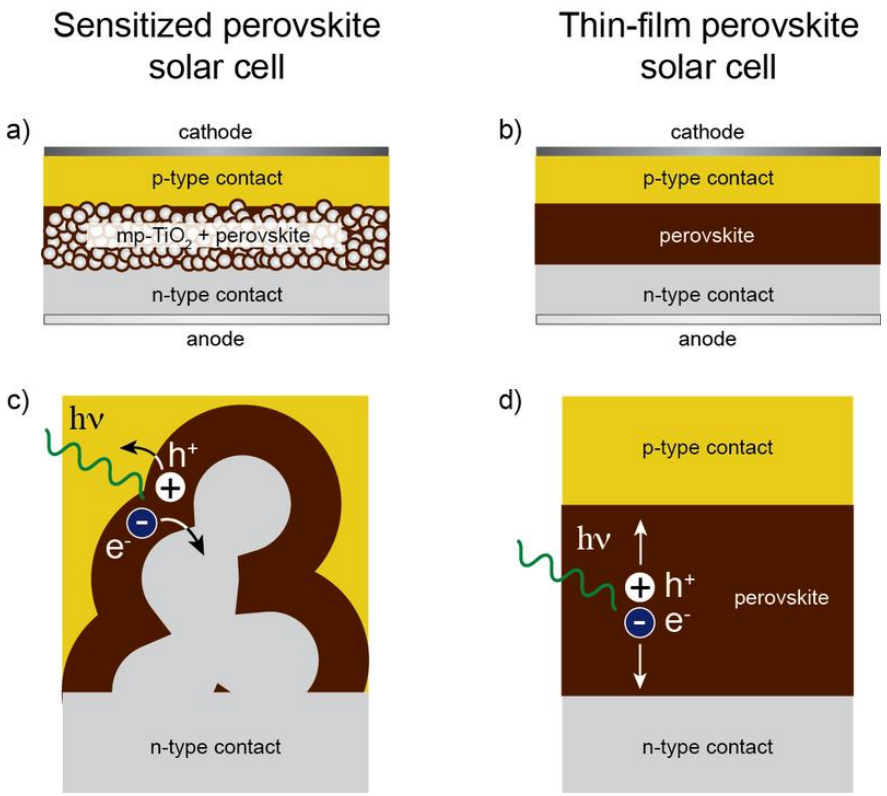
Solar cells, what is the efficiency of the best ones?



Perovskite solar cells

ABX_3 Ex: methylammonium lead trihalide ($CH_3NH_3PbX_3$, con X ione alogeno I−, Br−, Cl−), high bandgap 2.3 eV e 1.57 eV.





three ion types: positively charged methylammonium (MA, a polyatomic organic ion) and lead and negatively charged iodide.

In conclusion…

- Grätzel cells have shown enormous potentialities low cost applications e BIPV (building integrated PV)
- They can be done with natural dyes
- They have a very new exciting applications now (perovskites)!