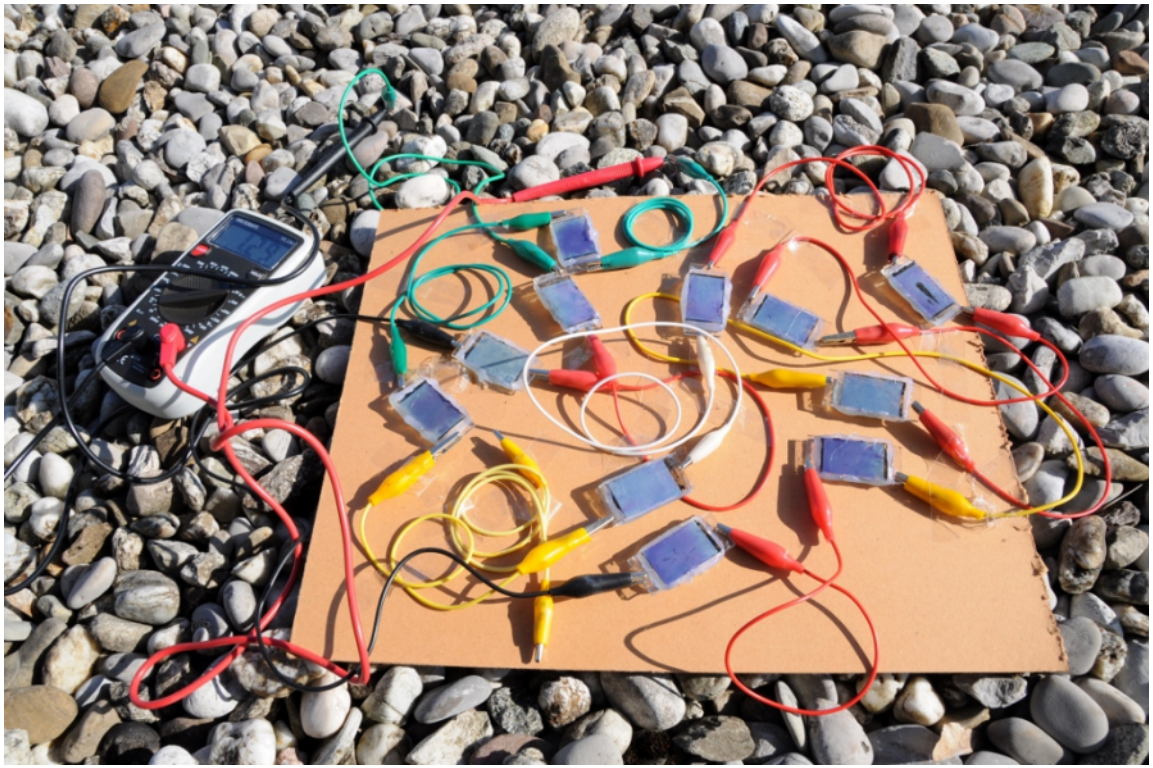
Make Your Own Solar Cells

DYE SENSITIZED CELLS



a workshop by Selena Savić

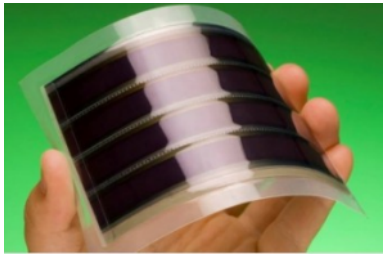
after a method patented by prof. Michael Grätzel at the EPFL

About

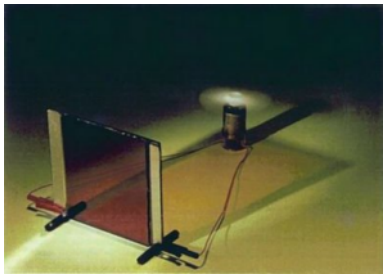
A dye-sensitized solar cell works as a photoelectrochemical system. It is a thin film solar cell, based on a semiconductor formed between a photo-sensitized anode and an electrolyte, Dye solar cell, is also known as the Grätzel cell, after its inventor, profesor Michael Grätzel who patented it at the École Polytechnique Fédérale de Lausanne in 1991.

Dye sensitized solar cells can be made of low-cost, (mostly) readily available materials. It's main parts like glass, white pigment (TiO2), natural dye, carbon and betadine can be purchased regular stores - like glass stores, pharmacies and ordinary chemestry shops. They can be engineered into transparent, flexible sheets, opening up possibilities for interesting applications in architecture (windows, furniture).

flexible solar cell

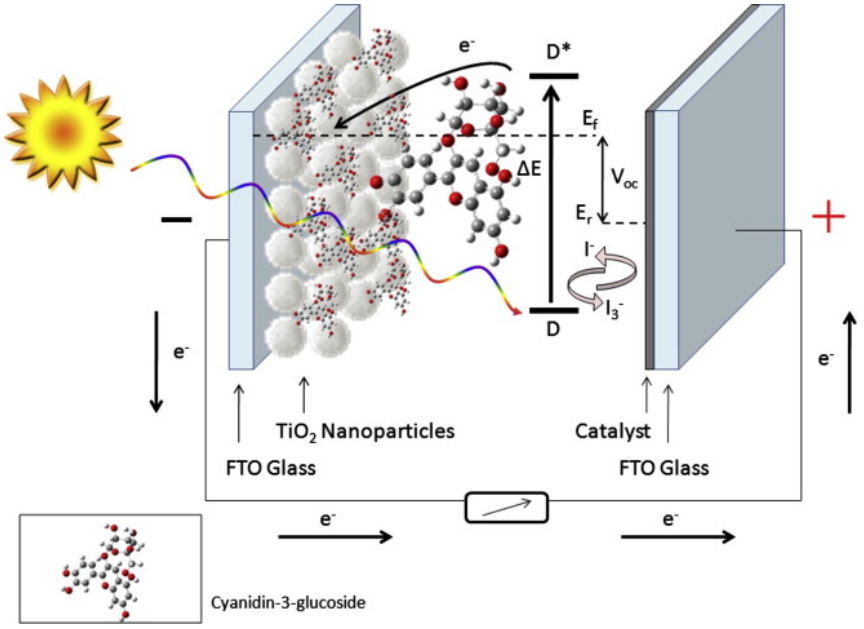


graetzel cell powering a small fan



How Does It Work?

Photoexcitation is a process in which electrons in the semiconductor (TiO2 layer with dye) get 'excited' when exposed to the photons of the sunlight. It is a process similar to photosinthesys. The cell is composed of a thin semiconductor film - the porous layer of titanium dioxide nanoparticles, sensitized by dye molecules that absorb sunlight. As in a conventional alkaline battery, an anode (the titanium dioxide) and a cathode (the platinum) are placed on either side of a liquid conductor (the electrolyte).



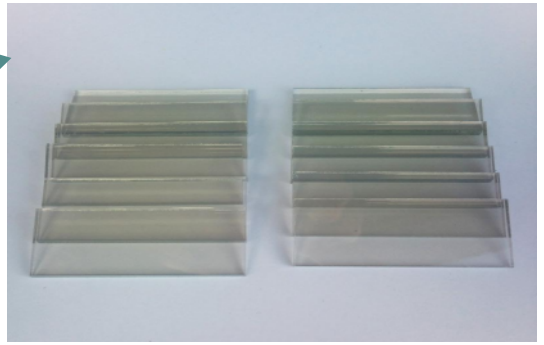
Efficiency

Their conversion efficiency is less than the best thin-film cells, but in theory it can compete with fossil fuel electrical generation, when used in grids. Dye-sensitized solar panels currently convert about 11 to 12 percent of the sunlight that hits them into electricity. Their silicon counterparts, which currently convert about twice as much radiation as the dye-sensitized panels.

Read more at:
http://phys.org/news/2012-08-sun-partnership-efficient-dye-sensitized-solar.html

Dye Sensitized Solar Cell: Parts

2 sheets of conductive glass - coated with FTO (fluorine doped tin oxide) / ITO (indium tin oxide):



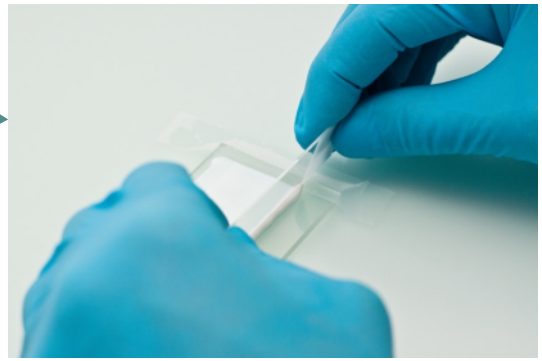
conductive glass, industrially produced

Anode

(Glass sheet coated with TiO2 paste)

Titanium dioxide paste

TiO2 powder + solution (acetone, Triton X-100, dest. water) applied on the conductive surface of one glass sheet



coating with TiO2 paste

Cathode

(Glass sheet coated with carbon (candle fumes) or graphite (pencil, spray))

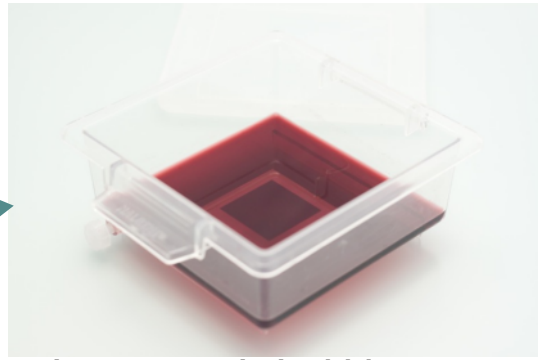
Carbon / graphite layer

Candle fumes; soft graphite pen or graphite spray applied on the conductive surface of the other glass sheet

cathode: carbon coating with candle fumes

Natural dye solution

Hibiscus leaves, purple or red berries



anode: TiO2 coating dyed with hibiscus

Electrolyte

betadine or lemon juice

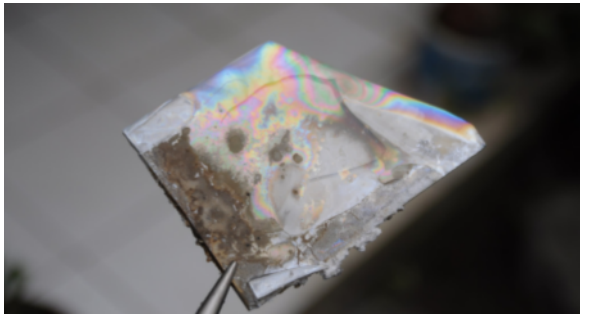
electrolyte: betadine drops

Preparation

0. Conductive glass

- buy, or
- make it, using ordinary window glass + glass cutter + stannous chloride powder

(under "useful links" you will find one where this process is explained)



conductive glass: coating with SnCl oxyde (at home)

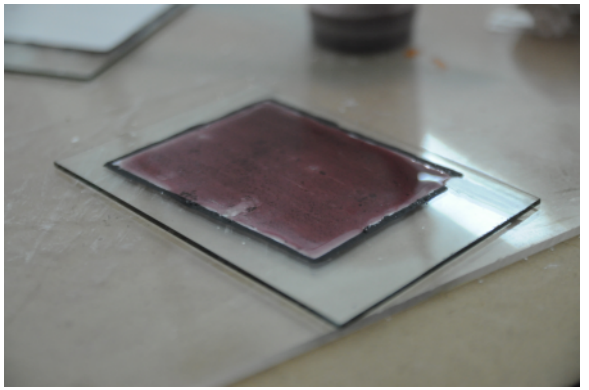
1. TiO2 coating

1.1. Add 10 mL vinegar gradually to 6 g Titanium Dioxide, stirring and grinding with a mortar and pestle until smooth and lump-free (about 5 minutes). Add one drop of clear dishwashing detergent (Ivory) or a few drops of the Triton X-100 surfactant, mix lightly, and let sit for 15 minutes. The mix you obtain should have a smooth consistency, somewhat like latex paint.
http://teachers.usd497.org/agleue/Gratzel_solar_cell%20assets/instructions%20for%20making%20the%20gratzel%20cell.htm

TiO2 coating after baking with a heat gun

1.2. HTL Braunau: Mix 3g TiO2 with 10ml solution. The solution is made from 1,25ml acetyl acetone + 2,5ml Triton X-100 (1/5 vol.) in H2O dest. + 5ml polyethylene glycol 20000 (100g/l) in H2O dest. + 50ml H2O dest.
http://www.youtube.com/watch?v=qaGrHrLdRhs

Apply a thin layer on the conductive side of the glass sheet. Leave it to dry. Bake the sheets for 10 to 20 minutes on a temperature around 450°C to 550°C. This can be done in a ceramic oven, or using a heat-gun and 'baking nests' from aluminum to protect the glass from sudden changes in temperature.



anode: TiO2 coating dyed with raspberry juce

2. Dyeing the Anode

When the glass has colled down, put it in the dish with dye (hibiscus, berries, beetroot...) and leave for about 5 minutes.

3. Cathode

Use the other sheet of glass to make the positively charged electrode.

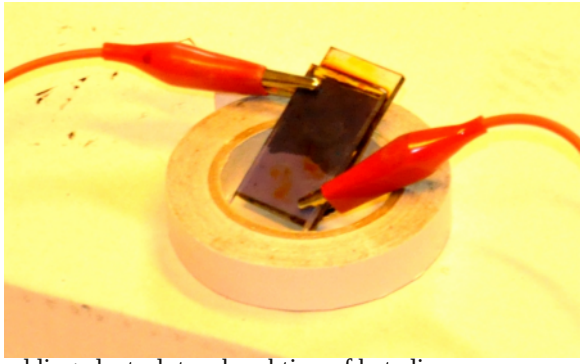
One way to do this is using a candle. Light up a candle and hold the conductive side od the glass above the flame. Be careful not to break the glass by overheating it (move away often).

You can also use graphite, either in spray or a shoft pencil. Apply a thin graphite layer on the conductive side of the second glass sheet you are making your cell from.

catode: carbon coating with candle fumes

4. Electrolyte

Put the two glass sheets together, so that the dyed and carbonised side are touching (that is, condctive sides of the glass sheets). Turn them so that on each side you have som space left to connect an aligator clip or wire. Press the glasses together with clips. Hold the cell upright and put a line of betadine on the top side. Leave the cell in this position until betadine is evenly 'sucked in' through all the surface. If needed, add a little bit more of it.

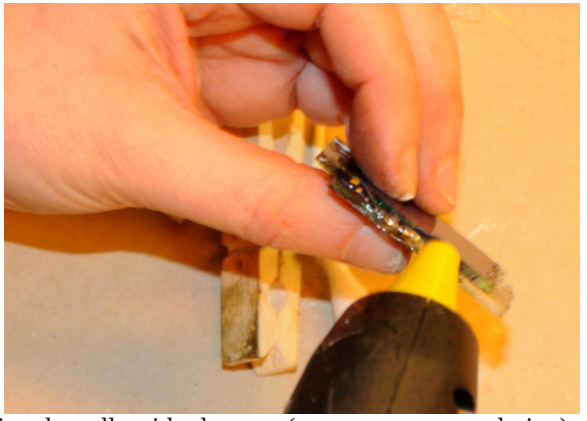


adding electrolyte: absorbtion of betadine

5. Sealing

Once betadine is evenly distriuted inside the cell, it is very important to seal it well. You can do so by using a strong glue or melted tar. The cell has to be cleaned well before this.

If it is not sealed well, betadine from the middle will evaporate quickly and the cell will loose all its power. You can try refilling it later.



sealing the cells with glue gun (not a permanent solution)

Shopping List

chemical store:

- TiO2 powder
- Destilled water
- Ethanol
- Stannous Chloride *

pharmacy:

- Betadine
- Laxative
- Aceton

supermarket:

- Hibiscus tea / Berries / Red Beats
- Washing-up liquid, transparent!
- Spirit vinegar
- Candles
- Aluminum foil
- Toothpaste *

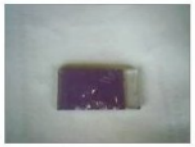
Tools, Containers

- Digital scale
- Mortar and pestle
- Heat gun / Spirit burner / Ceramic oven
- Water cooker
- Bowls
- Glue gun **
- Electric meter

* Stannous Chloride and toothpase are needed only in case you are making your own conductive glass

** Glue gun is not going ot perfectly seal the cells; I am searching for a more durable solution. In the meantime, it is the easiest tool to work with.

Results

- 1T gives 0.16V at 17:25; sun: YES |  |  | * dyed with hibiscus 10mins, then blueberries 10mins;
- **@ 17:00 it gives 0.33V;**
- 2T gives 0.54V at 16:15; sun: NO |  |  | * dyed with hibiscus 10mins, then blueberries ~15mins
- @ 17:00 it gives 0.54V;
- 3T gives 0.56V at 14:55; sun: NO |  |  | * dyed with hibiscus 10mins and then blueberries 20mins
- @ 17:00 it gives 0.57V;
- 4T gives 0.04V at 16:10; sun: NO |  |  | * dyed with blueberries ~20mins
- @ 17:00 it gives 0V;
- 2B gives 0.57V at 14:10; sun: NO |  |  | * dyed with hibiscus 10mins
- @ 17:00 it gives 0.13V;
- 3B gives 0.54V at 14:17; sun: NO|  |  | * dyed with hibiscus 10mins
- @ 17:00 it gives 0.25V;
- mansolar gives 0.22V at 18:16; sun: YES |  |  | * dyed with hibiscus 20mins
- **@ 17:00 it gives 0.43V;**

Results

Solar workshop at Make Me, Belgrade
June 2011

Using regular, non-conductive glass, with a pattern drawn with liquid sliver paste;
TiO2 paste applied but not baked;
Dye: Raspberries and Hibiscus tea;
Sealing with two-component glue (lets the inside of the cell evaporate, while keeping the glass sheets inseparable)

measurements:

Cells work like bateries, where the reaction between betadine, raspbery juice, silver and carbon can give up to 0.6V per cell; This gradually decreases and the cell empties out in one to two days;

Results

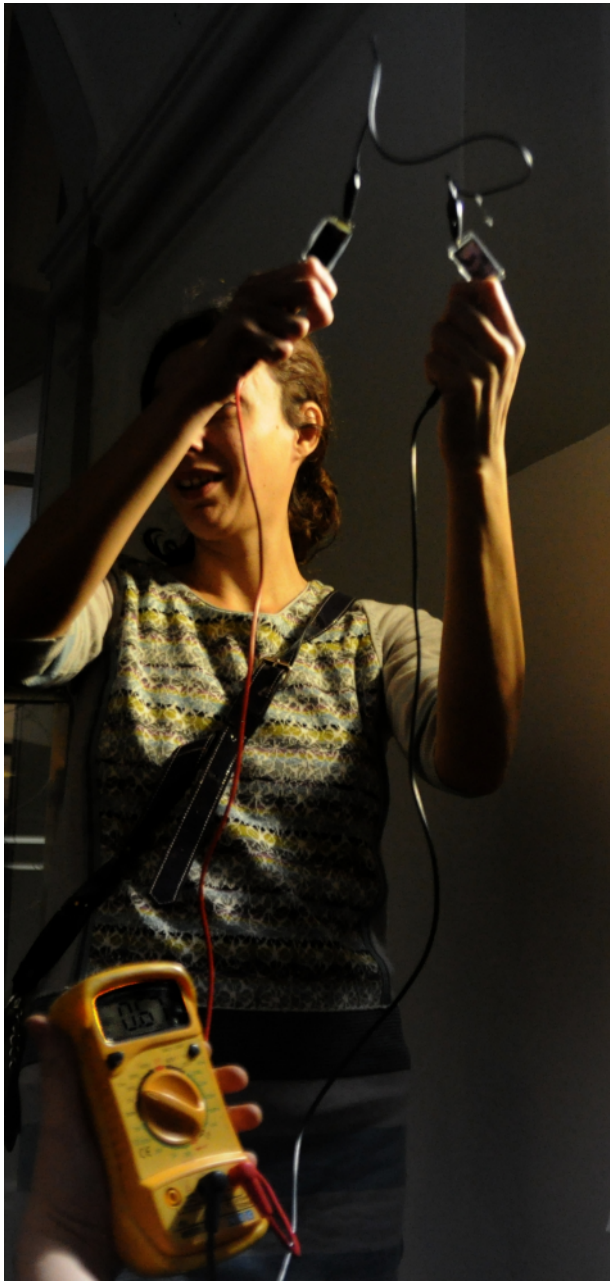
Solar workshop at Make me Eclectic, Vienna
January 2012

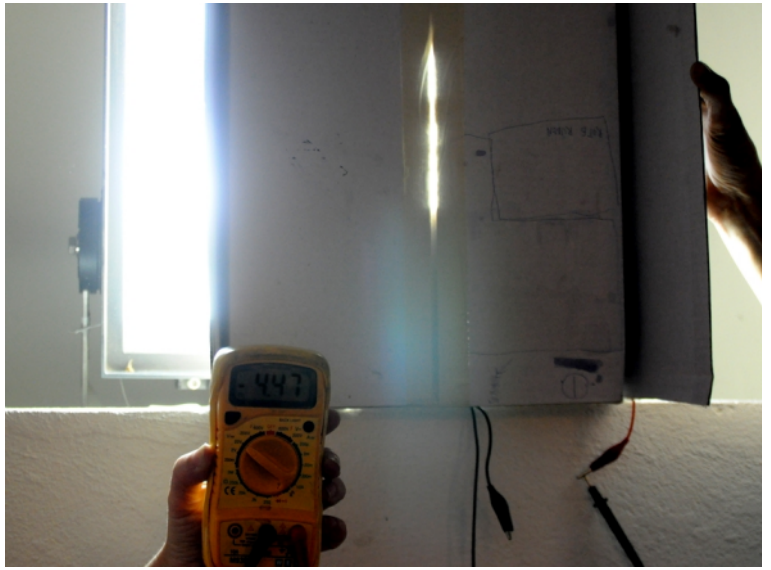
Using industrial conductive glass, with precoated TiO2 layer;
Dye: Hibiscus tea and Red Beets;
Sealing with hot glue (falls off too easily, doesn't stick to dirty or wet surfaces)

measurements:

Each cell gave about 0.4V when exposed to the light of a very strong reflector;
Connected in series, all 11 cells gave 4.47V;

Tested with an arduino > the current was still not strong enough to run it; tried also connecting some in parallel and some in series to increase both ampers and volts;

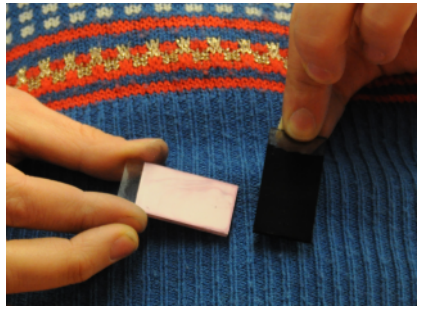


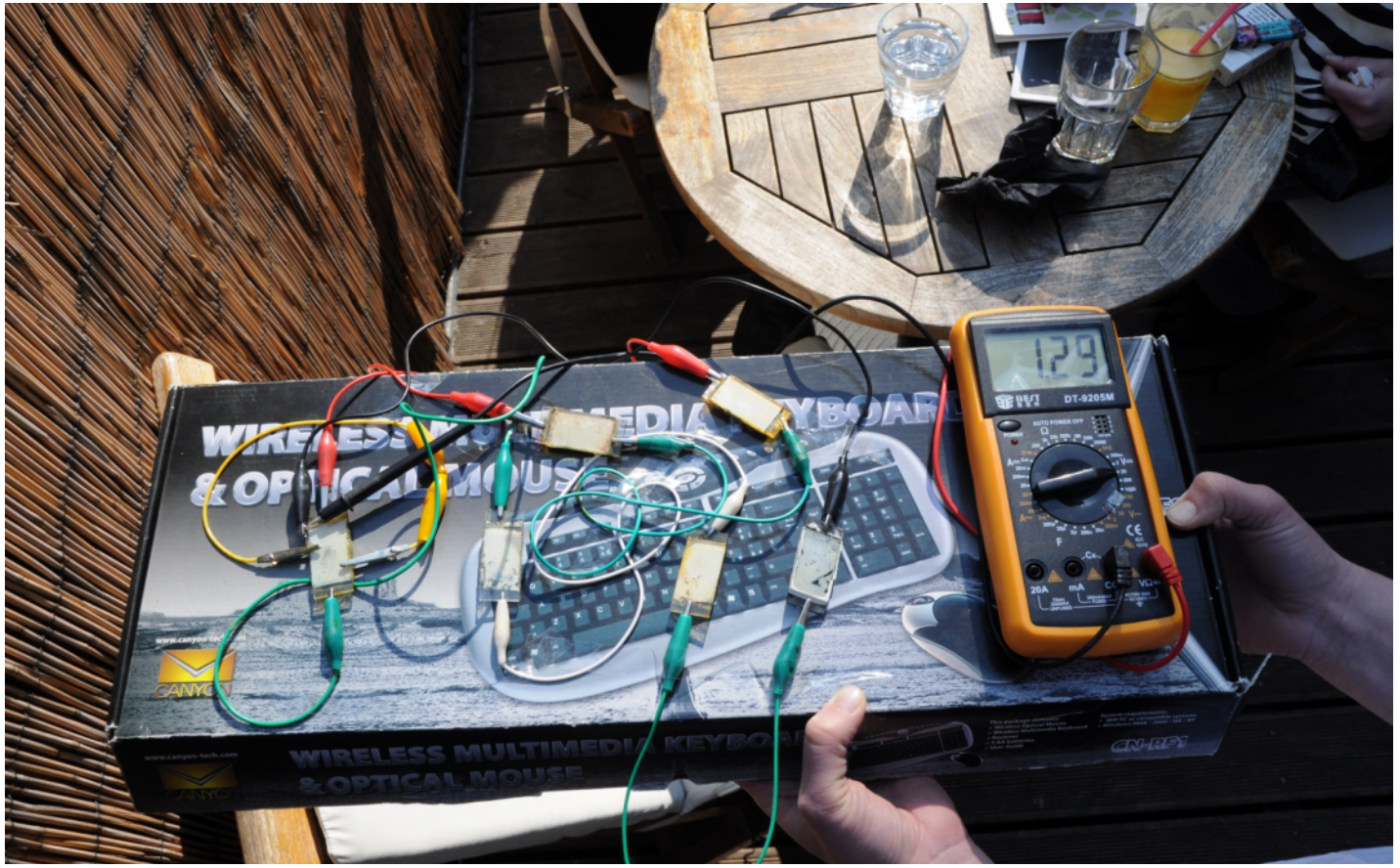


Results

Solar workshop at Eclectic Tech Carnival, Ljubljana
March 2012

Using industrial conductive glass;
Making two types of TiO2 coating (vinegar+detergent and aceton+laxative+water)
Baking the coating with a heat gun;
Dye: Hibiscus tea (didn't absorbe too well);
Sealing with hot glue (cleaned and dried all surfaces before)



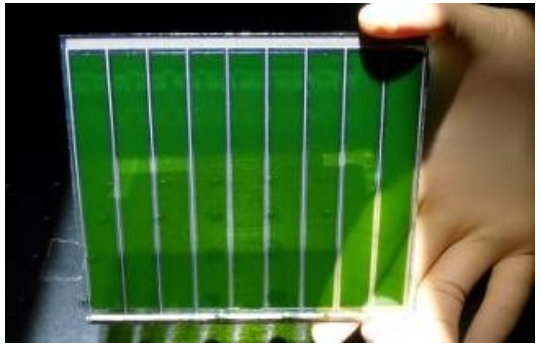


measurements:

Each cell gave about 0.2V when exposed to the sun (measured at 13:30);
Connected in series, all 6 cells gave 1.29V;

Tested the current with a synthesizer circuit > the current was still not strong enough to run it;

State fo the art research



November 2011, Dye-sensitized solar cells break a new record

Scientists in EPFL's Laboratory of Photonics and Interfaces have improved the efficiency of Grätzel solar cells to 12.3%. By changing the composition and color of the cells, the team has set a new efficiency benchmark. They replaced the standard dye components – ruthenium and iodine – with porphyrin and cobalt. This combination increases the absorption of sunlight and results in a more efficient electron exchange. The theoretical maximum efficiency of Grätzel cells is now 30%, compared with 26% for silicon.

read further:

http://actu.epfl.ch/news/solar-cells-which-exceed-12-percent-efficiency-2/

February 2012, How to turn leaves into solar panels

A long collaboration between MIT and EPFL has resulted in isolation of the protein in plants that allows for photosythesis and its engineering to produce electrical current. The PS-I molecules complex is the structure within plant cells that carries out photosynthesis. The researchers managed to chemically stabilize it and form a layer of it on glass. Andreas Merchin of MIT has adapted a substrate, similar to the one used in dye-sensetized solar cells (DSSC), to the substance PS-I, radically different from the dye normally used. Combining TiO2 nanostructure and ZnO nanowires, he created an "electric nanoforest", which carries the flow of electrons generated by the molecules, down to the supporting layer of material, from which it could be connected to a circuit.

read further:

http://actu.epfl.ch/news/how-to-turn-leaves-into-solar-panels/

Useful Links

download the instruction pdf:
http://kucjica.kucjica.org/solar-presentation-salzburg.pdf

First solar workshop in Belgrade, with step-by-step instructions:
http://belgrade011.na.pravi.me/?p=45
using regular glass and liquid silver to increase conductivity of TiO2 layer, TiO2 coating was not baked before dyeing (wrong!); red berries from the market used as dye; closing with silicon; energy conversion in bright sunshine gave about 1V for all the cells connected in series.

Solar workshop in Vienna, Make Me Eclectic
http://na.pravi.me/solar
used industrial conductive glass, precoated with TiO2; hibiscus tea and red beats as dye; sealing with a glue gun (insufficient); energy conversion under the light of a strong reflector gave 4.5V, with 11 cells connected in series;

Prof. Michael Grätzel expalining the wya the cell works and how they came up with the invention
http://www.youtube.com/watch?v=ncsNMDgngYI
"Dye-sensitized solar cells break a new record"
http://actu.epfl.ch/news/dye-sensitized-solar-cells-break-a-new-record-2/

Detailed instructions, University of Wisconsin
http://mrsec.wisc.edu/Edetc/nanolab/TiO2/#Materials
using accessible equipment and tools

Detailed instructions, Branau University
"how to make a dye sensitized solar cell HTL Braunau"
http://www.youtube.com/watch?v=qaGrHrLdRhs

Another detailed instruction, suggesting the use of a hot air gun
http://www.youtube.com/watch?v=Qbsl1NP5uZI&NR=1

Useful Links

How to make conductive glass?

Detailed instructions:
http://www.rhunt.f9.co.uk/Experiments/Conductive_Glass/Conductive_Glass_Page1.htm
Instruction video (Terra Labs)
http://www.youtube.com/watch?v=dz4YMFbVbyM&feature=related