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University of Applied Sciences

Fachbereich Chemieingenieurwesen
Department of Chemical Engineering

Lab Work Advanced Inorganic Chemistry

Experimental description

Grätzel Cell

Version 11/2023

1. Task:

1.1 Sketch the structure of a Grätzel dye-sensitised solar cell.

1.2 Describe the functioning of a Grätzel dye-sensitised solar cell.

(These two papers must be submitted before the start of the experiment).

1.3 Make Grätzel dye-sensitised solar cells with two different dyes.

1.4 Determine from each of the cells you have made:

- the open-circuit voltage
- the short-circuit current
- the U-I brightness characteristic and
- the fill factor at maximum power
- the efficiency

1.5 Discuss the results

2. Basics

Grätzel cells are named after their inventor Michael Grätzel and are also known as dye-sensitised solar cells (DSSC or DSC). They are a cost-effective method of converting light into electricity and can be manufactured with little effort. Their structure and the materials used differ greatly from solar cells made of silicon and other semiconductors. The way the Grätzel cell works also differs from semiconductor-based cells. In solar cells made of semiconductor materials, the necessary charge separation is generated in the space charge zone around the p n junction. In contrast, in a Grätzel cell electrons are excited from dye molecules with the help of light. The separation of the electron from the dye molecule then occurs by kinetic processes as also found in photosynthesis. Due to their variability, Grätzel cells are very popular. This is because a variety of substances can be used as the dye, which is the active component of the Grätzel cells. In the experiment carried out here, raspberry juice, tea made from rose hips and a specially produced dye are used as the active material.

The aim of this experiment is to characterise self-produced Grätzel cells and to compare the different dyes used to stain the cells.

3. Assembly of the Grätzel cells

Glass substrates with dimensions of 5 x 5 cm are used in this experiment. The substrates have a conductive transparent oxide (ITO) on one side and are coated with a porous titanium dioxide layer. Each cell is made of one ITO glass substrate and one simple glass substrate with a graphite layer.

a. TiO_2-film deposition

The glass slides coated with ITO are cleaned with Ethanol and a fluffless cloth. The ITO is masked at two opposite lying sides with a 5 mm wide strip of Scotch tape.

1. Slurry : 6,0 g TiO_2 (Degussa TiO_2 P25)
   20 ml H_2O
   2-3 ml TritonX
   2 ml PEG 20000 (0,1 g /ml H_2O)
   1 ml Acetylacetone

2. Apply a few drops of the slurry on the conductive side of the ITO and spread it to a transparent film with the help of a glass bar.

3. Remove the tape and heat the ITO at 460 °C for 30 min. starting at room temperature..Let it slowly cool down in the furnace.

b. Dye preparation

Tea dye:

First, a tea is prepared from rose hips. For this, two tea bags of rose hip tea are poured into a beaker with about 100 to 200 ml of boiling water. Leave to steep for about 15 minutes.

Fruit dye:

The dye solution is prepared from fresh raspberries and ethanol. 50 g raspberries are carefully crushed with about 50 ml ethanol in a mortar. The paste is now filtered to obtain a solution.

Ruthenium dye:

The dye solution consists of a ready-made ruthenium complex solution in ethanol and is provided by the supervisor.

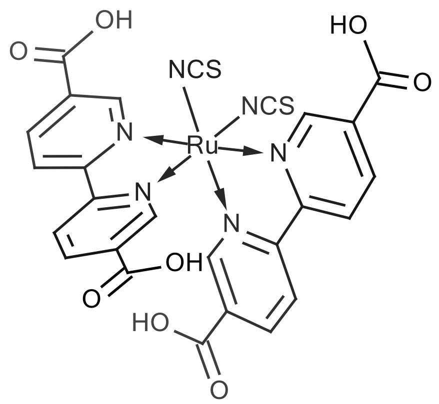


Figure 1: cis-Ru(dcbpy)$_2$(NCS)$_2$ · 2 H_2O

c. Dye application

Drop the dye onto the TiO_2 film and dry it carefully with a hairblower.

d. Graphite electrode

An ITO-sized white paper is coated with a graphite pencil and cut out.

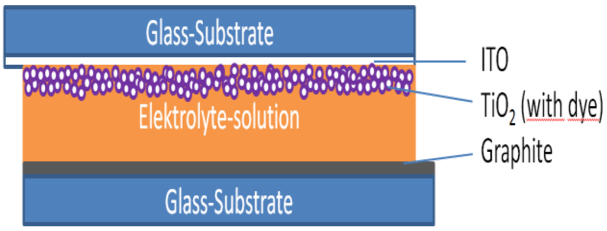
e. Electrolyte application

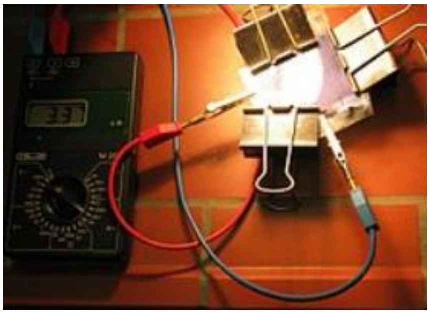
Solution: 4,15 g KJ
0,51 g I_2 in 50 mL H_2O

Sprinkle the solution on both sides of the graphite electrode and also 1-2 drops on the TiO_2 film.

4 . Grätzel cell assembly and measurement

1. Fix both glass plates with two clamps.
2. Connect the wiring to the gauge (Keithley) and contact the ITO and the graphite layer
3. Irradiate the Grätzel cell with „cold light“ and note the values.





5. Measuring instructions

Since the Grätzel cells are manufactured anew each time, they are subject to certain variations in performance. Therefore, it is not clear exactly in which range the measuring resistor is to be used. The measurements are to be carried out under the supervision of the supervisor and his instructions are to be followed at all times.

To begin with, the open-circuit voltage and short-circuit current of each cell are documented with the light source switched on and off. To do this, place the cell under the light source provided at a constant distance. A measuring device is connected directly to the contacts of the cell with crocodile clips and the measurements are taken.

Then a measuring set-up with the adjustable measuring resistor is set up according to the illustration below. A first measurement with 0 Ohm resistor serves as a check. The current intensity should correspond to the short-circuit current. Then the resistance values are increased step by step by 100 ohms until the current intensity drops to zero. Then the step size of the resistance values is adjusted at the discretion of the experimenter. This procedure is to be repeated with all the manufactured cells.

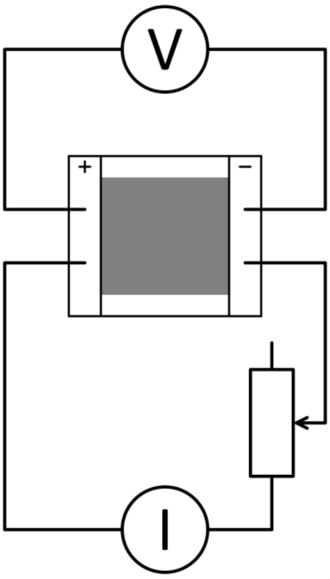


Figure 2: Measuring circuit with Grätzel cell, current and voltage measurement and adjustable resitor

6. Evaluation

For the U-I characteristics of the cells, the pairs of values found for current and voltage are now entered into a diagram. The values found for the short-circuit current and the open-circuit voltage are also plotted here. The pair of values with the highest power is to be highlighted and the area that this point spans between the voltage and current axis is to be marked. To find the maximum power of the cells, simply plot the products of current and voltage against the corresponding resistance in another diagram. From the maximum power, the short-circuit current and the open-circuit voltage, the fill factor of each cell is to be determined.

An interpretation and discussion of the I-V curves of the three cells is to be prepared. (Is the curve as expected? What can be improved? What are limiting factors?) The results of the cells are summarised in a table and compared with each other.

Finally, the efficiency of all cells is to be determined and discussed. (Assumption: The light source has an output of 80 W/m² at the given distance).

7. **Optical characterization**

a. Take an IR-spectrum of the Ruthenium complex analysing the characteristic vibrations
b. Absorbance spectra of all prepared dyes have to be measured

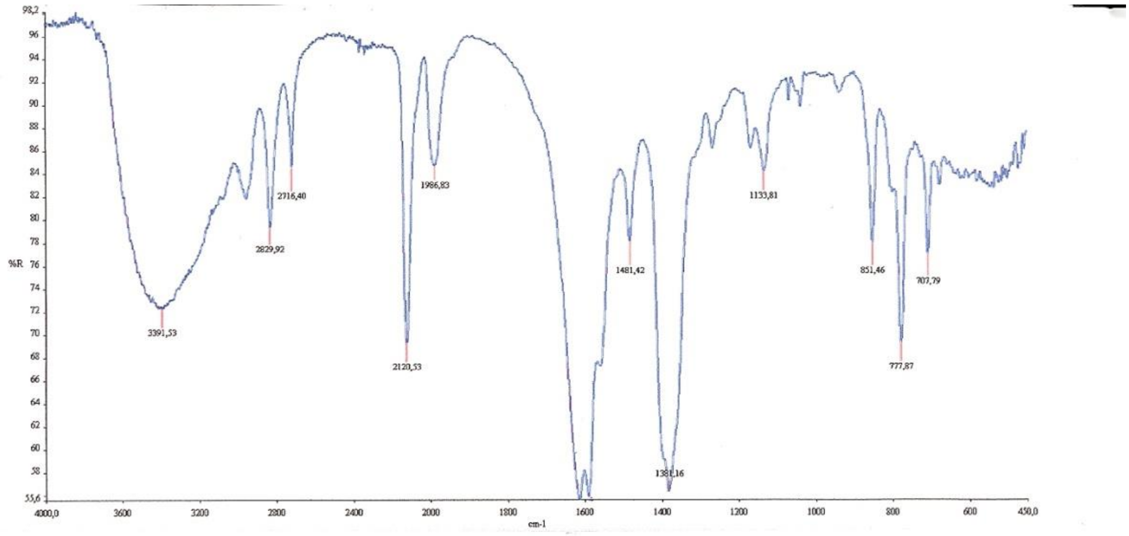


Figure 3: Reference IR-spectrum of cis $Ru^{II}(dcbpy)_2(NCS)_2$

<u>Position of the Ru- complex absorption bands depending on the solvent:</u>

Lösungsmittel	λ(π→π*)/nm	λ(MLCT)/nm	λ(MLCT)/nm
H_2O	308.1±0.4	371.8±0.9	502.8±0.8
C_2H_5OH	313.2±0.2	396.3±0.2	536.0±0.5
DMF	317.0±0.5	403.8±0.9	545.8±0.5
DMSO	319	404	549