A1 Electric current from solar cells – We build a dye-sensitized solar cell

1 Building a dye-sensitized solar cell

1.6 Questions

a) State reasons for the different power output of the individual cells.

Answer: Different dyes have their absorption maximum at different wavelengths. The various light sources also have different spectral compositions of the emitted light wavelengths. Because of this, the dyes that are attuned to the spectrum of the emitted light will work best. For instance, if you shine a red light on a red dye, the light will be reflected and not absorbed. However, if you shine a green light on this red dye, it will be completely absorbed, and in the case of a dye-sensitized solar cell, it will mostly be converted into electrical energy. In addition, the concentration of the dye and the concentration of the electrolyte (iodine tincture in this case) play a role. Either way, too low concentrations will yield a reduced output of electricity.

b) A brief review of electricity basics: Explain why the power determined from the no-load voltage and short-circuit current is not equivalent to the actual power when a load is connected.

Answer: For the maximum power of a current source to be transmitted to a load, the internal resistance of the current source and the load resistance must be equal. If this is not the case, the maximum power will not be achieved. For example, if we measure the no-load voltage of the solar cell, the load resistance is enormous (10 MOhm), but the current that flows approaches zero. The measured no-load voltage is thus greater than the voltage at optimal power. If we measure the short-circuit current, the load resistance is extremely low compared with the solar cell's internal resistance; this means that nearly all the voltage drops at the internal resistance, and the useful voltage is very low. Thus, measured at optimum useful load conditions, the no-load voltage and the short-circuit current are too high and the calculated power cannot be realized. The power calculated from the short-circuit current and no-load voltage is, however, a reference point and can be compared with the power of other solar cells that has been calculated in the same way. To determine the real power, you must conduct a series of current-voltage measurements under variable load resistance (see experiment A5, subexperiment 6).

c) If you have already discussed photosynthesis in class: Compare the processes in the dye-sensitized solar cell with photosynthesis processes in plants.

Answer: The similarity between the two processes is that the radiant energy of light is absorbed; the difference is in how the light energy is used.
Solar cell: Radiant energy is converted into electrical energy (solar electricity)
Photosynthesis: Radiant energy is converted into chemical energy (ATP, or reaction of H_2O with CO_2 to form glucose).

Even though, in the case of a dye-sensitive solar cell, the light energy causes electrons to be transferred between atoms or molecules, this transfer is a chemical reaction and not electric power generation, since it does not produce a usable external circuit.

2 Power output of the dye-sensitized solar cell at different illuminance

2.6 Questions

a) Select the best light source for generating power with a dye-sensitized solar cell and give reasons for your choice.

Answer: The three available light sources are indirect (diffuse) sunlight indoors (here referred to as indirect daylight for short), direct sunlight outdoors without clouds, and the light from an artificial light source (overhead projector or lamp with a halogen light bulb). Not only is indirect daylight less bright than direct sunlight (by a factor of up to 10,000!), but its spectral composition also differs from that of direct sunlight because it is filtered through the window panes and absorbed and reflected by the walls.
Indirect daylight will thus generally yield lower electricity output than direct sunlight. Whether the artificial light source is better than indirect daylight also depends on the brightness.
Due to the shorter distance, however, the illuminance can be intensified to such a strong degree that the electricity output is much better with artificial light than with indirect daylight. In short, if the dye-sensitized solar cell is far away from the artificial light source or if the indirect daylight is weak, the resulting illuminance on the solar cell is so low that there is hardly any current flow.
In addition, the result depends on whether the dye is attuned to the light source's spectrum. Halogen light bulbs are normally well suited; fluorescent lamps are not. Since direct sunlight is very bright and emits the complete light spectrum, it normally provides the best results.

b) Explain what influence the brightness of sunlight has on plant growth. Take into account the varying illuminance from the sunlight over the course of a day and year.

Answer: For a plant to grow, its cells need energy. Plants obtain this energy by absorbing sunlight using chlorophyll (a dye) and producing sugar from carbon dioxide and water. This sugar contains more energy than the starting substances. Through additional chemical reactions (depending on temperature), the plant's cells can then convert this sugar into substances required for growth, such as cellulose and proteins. Provided that enough water and heat is present and the plants tolerate high heat and light intensity, the following principle applies: The more intense the light is (duration and brightness), the more the plant grows. This is why plants grow best in daylight and in the summer.

3 Higher voltages through several dye-sensitized solar cells

3.6 Questions

a) Come up with applications in everyday life for which dye-sensitized solar cells could be used.

Answer: Dye-sensitized solar cells can be used whenever conventional semiconductor solar cells made from silicon, cadmium telluride, CIS, etc. can be used. However, a disadvantage of dye-sensitized solar cells today is that they are still less efficient (large cells only about 3%).
Two advantages of dye-sensitized solar cells are that the materials and production cost less and the materials are relatively environmentally friendly. Another advantage is that they produce proportionately more electricity in relatively diffuse, weak light than, for example, silicon cells. This means that for single-use applications (disposable articles), they are already clearly better suited than silicon cells. If efforts to extend their service life are successful, it would make sense to use dye-sensitized solar cells where large areas are available, such as on building facades. The larger surface area would then compensate for the lower output. They would then be cost-efficient despite the lower efficiency, provided that they cost only about 20% to 25% of what semiconductor solar cells cost.

b) Describe what you would change in the dye-sensitized solar cell to improve the useful life and power output of the cell.

Answer: You can optimize the spectral sensitivity of a cell by choosing other dyes or combining several dyes. The main problem is the service life, which is contingent upon the rate of bleaching and oxidation of the dyes. The primary objective is to develop more stable dyes, which will probably be possible only with synthetic dyes. In addition, attempts can be made to find an electrolyte that is less sensitive to temperature fluctuations (research is currently being conducted on this). Another suggestion for improvement is to optimize the cells' contacts for collecting the current.