Educational Concept for Hands-On Energy Science Workshops

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Abstract

Achieving a sustainable energy future is a tremendous challenge for society that requires broad education in its importance as well as in the underlying science. We present here a workshop that has been developed by the Collaborative Research Center (CRC) 1073 at the University of Göttingen for school students on the topic of renewable energy. The goal of the workshop is to pass an appreciation of the science behind renewable energy conversion on to school students. By educating our youth in the science and technology of energy conversion, we aim to empower them to evaluate political and social discussions about renewable energies and to actively shape our future.

The workshop introduces the students to the broad concept of the "hydrogen economy", and then to the interdisciplinary sciences needed to understand hydrogen generation and storage. These include semiconductor physics and redox chemistry, which are both important topics in German school curricula. The students first isolate TiO_2 nanoparticles from commercial sunscreen, measure the particle size with scanning and transmission electron microscopes and then build a solar cell with them. The effect of the particle size on both the solar cell and the sunscreen is discussed. Second, they demonstrate hydrogen generation by electrolysis using commercial solar cells and by photocatalysis using zinc sulphide nanoparticles. Finally, the students calculate and compare the efficiency of solar cell electrolysis and photocatalysis for hydrogen generation from water. The comparison reveals the high potential of photocatalysis, but at the same time the need for further research.

Keywords: *Energy, research, hydrogen, photocatalysis, solar cell;*

1. Introduction

The Collaborative Research Center in Göttingen entitled "Atomic Scale Control of Energy Conversion" (CRC 1073) is one of many CRCs funded by the German Research Foundation (DFG). The CRC consists of three project groups dealing with energy losses (A), energy conversion of optical excitations (B) and energy storage (C). Both physicists and chemists work together in the three groups to gain a fundamental understanding of energy conversion, with the eventual goal of developing tactics to improve conversion and storage efficiency [1]. In this way, the CRC 1073 aims to contribute to the urgently needed energy revolution. The reason is not simply the limited fossil fuels like mineral oil or natural gas, but also the climate change caused by greenhouse gas emission and the fine dust pollution associated with health risks for human beings. The German decision to stop using nuclear energy by 2022 makes an increase in the use of environmentally friendly renewable energies even more urgent. Nonetheless, non-renewable hard and brown coal, mineral oil, natural gas and nuclear energy are still the main energy sources in Germany.

2. Educational concept

A sustainable energy future can of course not be achieved by the CRC alone. Everyone and in particular the next generation need to contribute. For this reason, the CRC researchers have joined with Chemistry Education students to develop a concept for public outreach (s. fig. 1) to connect the CRC with school students and the general public. The outreach activities should educate both male and female school students in energy science and attract them to physics and chemistry Bachelor programs in order to guarantee the next generation of energy-conscious scientists. The final goal is that students acquire the skills and motivation to actively contribute to shaping a sustainable future.

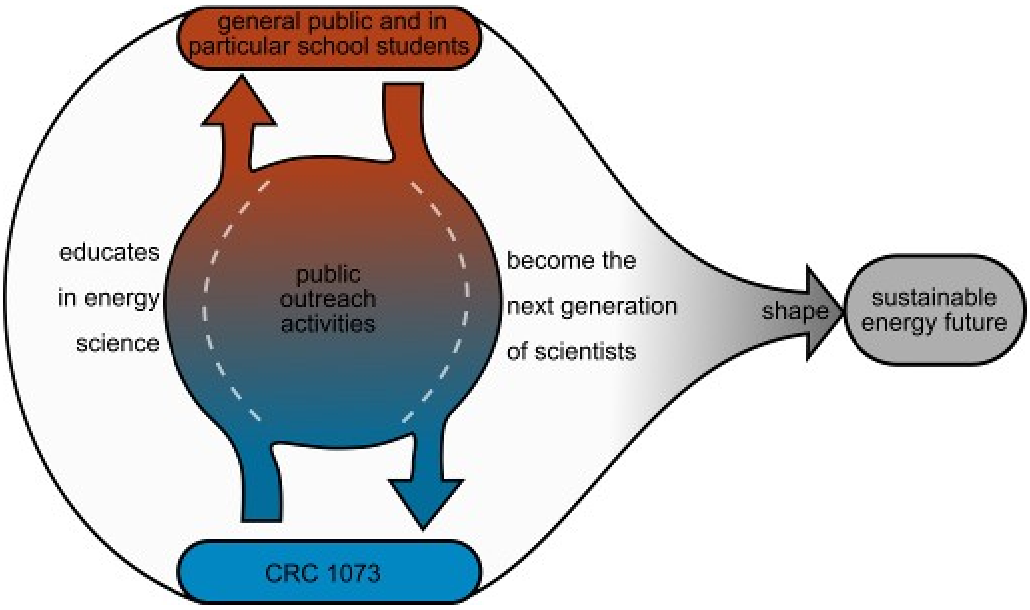

Fig.1. Concept for public outreach of the CRC 1073.

The public outreach activities consist of multimedia work through the CRC homepage, newspapers, TV and YouTube, the participation in public events, the collaboration with the XLAB which is a laboratory for young students and "Hands-On Energy Science" workshops. The workshop on the subject of the hydrogen economy exemplifies the educational concept of the CRC public outreach. It targets upper secondary level school students who already have basic knowledge in semiconductor physics and redox chemistry. Building on their school knowledge, students learn how fascinating technologies like solar cells work. They thereby understand the value of their school knowledge, which can motivate them. At the same time, they acquire a deeper understanding of the basic concepts "energy" and "donator/acceptor" that are part of the German school curricula. Moreover, they learn to reflect on and evaluate science with regard to socially relevant issues like technological development and a clean and safe environment. During several discussions, they additionally learn how to use scientific language and to argue based on well-founded knowledge.

In order to reliably inform students about climate change, which is often the subject of contradictory media reports, the workshop starts with statistics of the German Federal Statistical Office which verify global warming and point out the acute need for action. It is a good "warm-up introduction" for the workshop, as it activates and clarifies students' knowledge about the problem the CRC tries to tackle. Afterwards, the workshop is divided into two units related closely to the CRC project groups B and C. They deal with solar cells as an example for an environmentally friendly way to generate electric energy and with hydrogen as an example for a sustainable way to store energy.

In the first unit, students learn how a solar cell works, thereby acquiring required German physics curriculum content about the band model, band gaps, doping and pn junctions. They learn that commercial solar cells convert only a small part of the captured sun energy into electrical power and thus understand why the CRC project group B works on new, more efficient ways to convert light to electricity. In addition, they are introduced to other research approaches like tandem, thin-film and polymer solar cells. In the experimental part of the first unit, students build a dye solar cell with TiO_2 nanoparticles. They isolate the nanoparticles from sunscreen, measure their size with a scanning electron microscope (SEM) (s. fig. 2) and with a highly advanced transmission electron microscope (TEM) which is capable of resolving atoms. The high resolution microscopes are usually quite impressive for the students and arouse their interest in science.

In the second unit, student engagement is in high demand, since the unit mainly consists of discussions that evaluate the efficiency and environmental impact of different energy storage methods. Students first learn that renewable energies require storage, in contrast to coal and nuclear energy, because they depend on weather and seasonal fluctuations. Afterwards, they learn about using hydrogen to store energy, about the hydrogen economy and about current political and corporate strategies for its advancement. But they also learn that hydrogen is currently generated by steam reforming. They are asked to evaluate this method. The expectation is that they argue that steam reforming is neither sustainable nor environmentally friendly due to the use of natural gas and the emission of CO_2. Following discussions about alternatives, they are guided towards the next experiment which is water splitting using solar cells. But calculating the efficiency of hydrogen generation by water splitting using electricity generated by solar cells reveals that it is quite low. A promising alternative is photocatalytic water splitting where the sun energy is directly converted into hydrogen. This research approach is investigated in the CRC project group C and included as the final experiment of the workshop. The idea is that direct conversion is more efficient than a two-step conversion of sun energy to electrical power in a first step and then to hydrogen in a second step. However, the photocatalytic experiments reveal that photocatalytic and solar cell water splitting currently have approximately the same efficiency. Thus, the final conclusion is that more research is required to develop efficient and environmentally friendly ways to store energy and generate electricity.

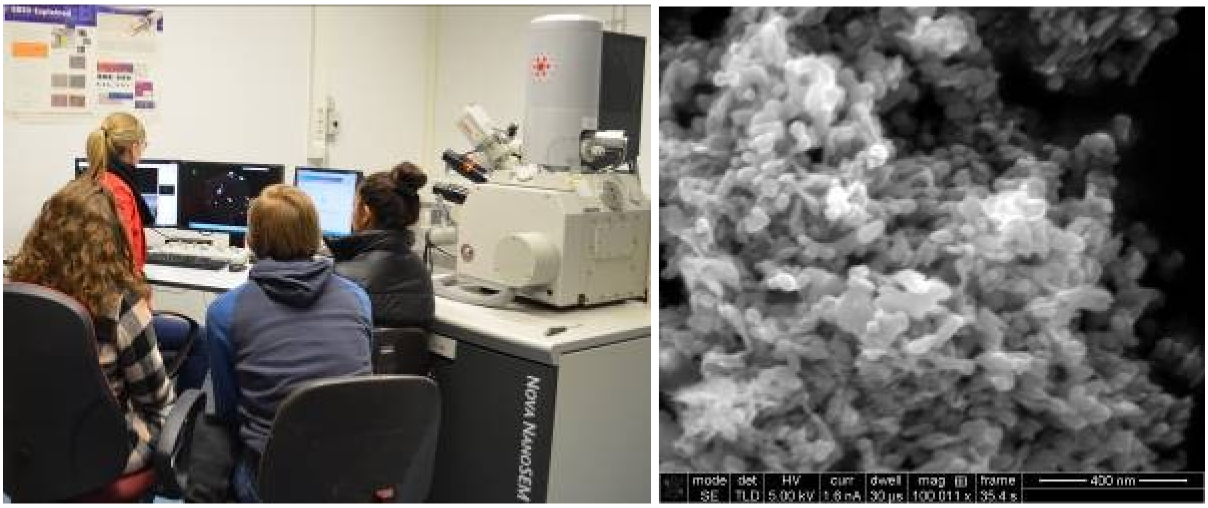

Fig. 2. Left: School students at the SEM. Right: SEM image of TiO_2 nanoparticles isolated from commercial sunscreen.

3. Hands-On Experiments

The workshop experiments aim to inform about the research projects of the CRC and to transfer both process-related and content-related skills to students. The latter are mainly experimental skills, but students also learn the scientific workflow.

3.1 Building a dye solar cell

The CRC project B02 has the long-term objective to develop a new, more efficient type of solar cell. By analogy students build dye solar cells using different dyes [2] and attempt to identify the best one. Thereby, they:

- apply their acquired knowledge about the operating principle of solar cells,
- practice basic electrochemical measuring techniques.

3.2 Working with electron microscopes

Students measure the TiO_2 nanoparticle size with the professional electron microscopes of the CRC. The educational objectives are that students:

- understand why the size of the TiO_2 particles is important in sunscreen and transfer this knowledge to solar cells,
- learn how an electron microscope works and explain similarities to light microscopes,
- experience the everyday life of a scientist by operating the SEM themselves.

3.3 Electrolytic water splitting

The CRC project C02 aims to understand and control the elementary steps of water splitting at the atomic scale. In fact, the scientists have observed how a water molecule is split at the surface of a catalyst in the exact same TEM used by the students to measure the nanoparticles. During the workshop students perform in principle the same experiment as the researchers. They:

- apply their school knowledge about the galvanic series and overvoltage,
- hypothesize and prove how many solar cell modules are necessary to split water,
- hypothesize which gas is generated at which electrode and prove their hypotheses with detection reactions for H_2 and O_2,
- learn the scientific workflow.

3.4. Photocatalytic hydrogen evolution

Hydrogen is generated by illuminating ZnS nanoparticles in a Na_2S/Na_2SO_3 solution (s. fig. 3) [3]. Students

- tackle the problem of finding the right LED for the photocatalytic hydrogen evolution,
- understand the relation between light wave length and band gap by problem-oriented learning.

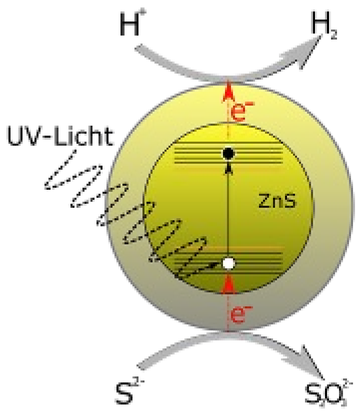

Fig. 3. Illustration of photocatalysis.

4. Conclusion and Outlook

The CRC 1073 has developed an educational workshop in which students learn the basics of energy science and reflect on and evaluate science with regard to its role in society. The workshop empowers and inspires students to contribute to a sustainable energy future. By repeating the workshop at regular intervals, the Göttingen CRC hopes to make a difference in how our society uses and thinks about energy. In the next phase of the CRC, we hope to measure the impact of the workshop using a survey study of participants.

References

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