Solar cell **research**

A team of scientists is exploring extremely thin absorber (ETA) solar cells, their usage and commercial viability. Here, **Drs Martin Loeser** and **Laetitia Philippe** discuss their complex work and obstacles that have so far prevented solar cells from large-scale market penetration

To begin, what are the aims and objectives of your current research into solar cells?

ML: Our project focuses on understanding and improving the optical properties of nanostructured thin film solar cells. Our goal is to contribute to solar cell research and help design more efficient solar cells.

LP: We hope to understand the charge collection and transfer within extremely thin absorber (ETA) solar cells by modelling the light diffusion of the nanostructured semiconductors.

What tools or methods do you use to produce the solar cells and measure their optical characteristics?

LP: We use electrochemical deposition techniques, controlled by potentiostat and electrodes, for the production of all the nanomaterials composing ETA devices. We measure the optical properties (transmission and reflection) by means of a spectrophotometer connected with an integrating sphere.

How do you see global usage of solar power developing in the future? What is needed to encourage the public and governments to make greater use of solar power?

ML: During the last decade especially, globally-installed solar power has increased tremendously and this explosive growth can, at least partly, be attributed to both ecological concerns and increasing fossil fuel prices. Germany is a prime example of this. Here, the total installed photovoltaic power increased more than tenfold within seven years. Furthermore, from 2000-10, the globally installed solar power capacity averaged 40 per cent annual growth and ranged around 67 GW at the end of 2011. Still, only a tiny fraction of global power consumption is covered by solar power today.

In my eyes there will be an increasing demand for green and affordable energy in the near future, and solar cells are one possible option which could meet such demands. To keep up the high pace at which the use of solar power is currently growing, two hurdles need to be addressed – one is its poor efficiency, the other its high price. I am convinced, however, that solar technology can mature to a point where it is not only an ecologically, but also an economically interesting alternative. Developing inexpensive and efficient solar cells is one step in this direction. If governments are to encourage the general public to use more solar power I believe that adequate feed-in tariffs play a major role here.

LP: The future use of solar power strongly depends on political decisions, which in turn are influenced by many unpredictable parameters – such as nuclear catastrophes, petrol crises and so on. In order to encourage both governments and the general public to make greater use of solar power, long-term education on the usage of fossil energy and its impact on the planet is desperately needed.

Who is involved in this research and what range of backgrounds and expertise do they represent?

ML: In general, solar cell research is quite a complex task and combines a broad variety of disciplines, such as semiconductor physics, chemistry, materials science, engineering, and – especially when computer programmes are being utilised as analysis or design tools – mathematics and computer science. It is this interdisciplinary approach that makes solar cells such an interesting field of research.

LP: Research in solar power requires a large panel of experts, from engineers to researchers, in material science, optics, physics and chemistry. The multidisciplinary aspect of the research is essential for its success.

To what extent does the project utilise partnerships? Have you identified potential industrial partners for future collaborations?

ML: Today, efficient scientific research can only be conducted if partnerships are employed. As already mentioned, solar cell research comprises a multitude of different disciplines, and cutting-edge research requires the cooperation of different experts in their respective fields. In our project, we combine expertise in the field of device production and experimental characterisation with profound experience in numerical modelling and optical simulations. We consider it a major asset of our approach that we combine both experimental and numerical aspects. To better understand the market needs we are in close contact with the industry and, in the future, it would be very exciting for us to closely collaborate with both academic and industrial partners.

LP: This project is an excellent example of experimental and simulation collaborative work. We are still looking for some potential industrial partners and are enthusiastic to move forward to this step.

The future of **solar power**

An interdisciplinary research team led by the School of Engineering at the **Zurich University of Applied Sciences** is currently making headway in the design and production of efficient and inexpensive thin film solar cells. However, such a feat of engineering is not always easy

IN RECENT YEARS, the world has become both disenchanted and disinclined to rely upon fossil fuels. Indeed, even if the environmental hazards surrounding fossil fuel usage does not concern individuals, companies and countries, their increasing price is certainly a deterrent to their use. With these concerns in mind, it is unsurprising that over the last decade the development and installation of 'greener' energy provisions has substantially increased.

Although a large variety of solar cell technologies have emerged over recent years, the development of an economically viable source of solar energy is still to come into fruition. Two vital parameters which can determine the economic success of a specific solar cell design are the production cost and the cell's efficiency. It is in these key areas that Dr Martin Loeser's team in Zurich, who wish to develop more efficient solar cells, are focusing their attention.

A BRIEF HISTORY OF SOLAR CELLS

Roughly speaking, there are three different generations of solar cells. The first generation employs crystalline silicon, which is based on well-established production technologies and can boast high efficiency. Yet despite these apparent benefits, the production process for this high-purity silicon is intricate and energy consuming, which ultimately results in high prices and prevents such devices from large scale market penetration.

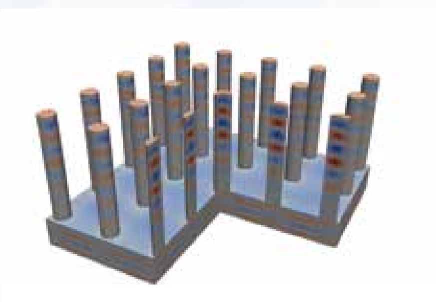

FIGURE 1. Result of a numerical simulation: light propagation inside a solar cell featuring nanowire light absorbers.

As a consequence, the second generation, thin film solar cells, emerged. Among the main advantages of these devices are the greatly reduced demand of semiconductor material, the use of cheaper materials (such as amorphous silicon), the employment of inexpensive production techniques and the possibility to grow these cells on flexible substrates. Furthermore, in spite of the materials' poorer electronic and optical properties, which result in significantly lower efficiencies, their low price has gained thin film solar cells a significant market share.

Unsurprisingly, it was in order to boost the efficiency of thin film devices, that the third generation solar cells started to be developed. It is this type of solar cell that is presently under intensive research. This new generation is based on thin film technologies, but takes attempts to improve the cell's performance. Typical examples of third generation solar cells would be multi-junction cells, low-dimensional quantum dot devices, organic solar cells, and nanostructured solar cells.

THE PROJECT

Loeser's current research into solar cells is centred around the overarching aim of improving the optical properties of nanostructured thin film solar cells. His team hopes that by combining both experimental and numerical techniques they can successfully develop more efficient and inexpensive thin film solar cells.

The group's research focuses on nanowire thin-film solar cells with cadmium selenide (CdSe) lightabsorbers. Loeser believes that by combining both numerical and experimental tools his team will be able to establish a framework for thin-film solar cells with nanowire or other nanostructured absorbers, which will boast efficient analysis and design.

However, it is not a completely straightforward process. "The challenge for us," explains Loeser, "is that optical processes in such devices are hard to model and understand, and we address this issue by combining experimental and numerical tools to gain a better insight into these processes." The routine that the group is currently following works by firstly producing the solar cells and measuring their optical characteristics – of particular interest is the cells' ability to trap and convert the incident sunlight. Secondly, the team makes computer models of these cells and coordinate numerical simulations, so as to analyse and explain their previous experimental findings. The ultimate goal would be using computer software as a powerful tool to accelerate and facilitate the solar cell design process.

RESULTS AND CHALLENGES

To speak of specific, significant findings and results of the project to date would be too narrow a frame of reference. The research being conducted in Zurich can best be described as a continuous process, where new insights are gained step by step. However, within the modular, trial-based study, the team has learned that their specifically developed 3D optical simulation software is well applicable. Furthermore, by comparing simulations with experimental results, it is easier to understand the optical processes in nanostructured solar cells. These developments do, of course, point towards a future of more efficient solar cells.

However, there are significant challenges facing this area of study. One of the main challenges is the numerical simulation of nanostructured thin-film solar cells. To put this in context, there is general agreement that numerical simulations are of paramount importance when analysing or designing novel semiconductor devices, and this also holds for solar cells. When numerically analysing the optical characteristics of third generation solar cells, which feature sub-

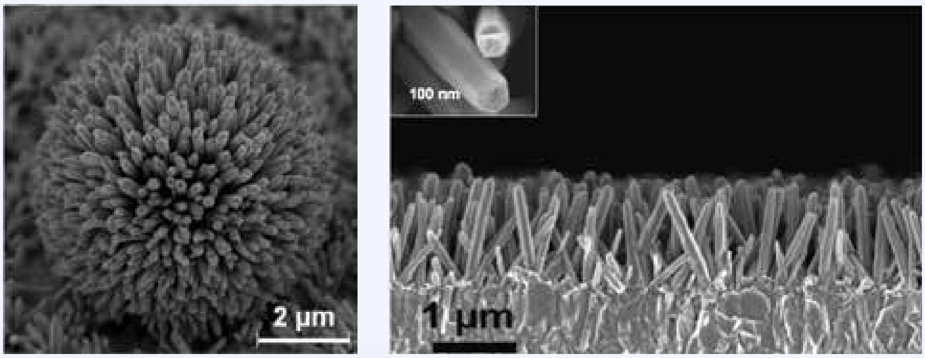

FIGURE 2. (Left) Urchin absorber (Right) Nano absorber

wavelength nano-structures, there is a broad consensus in the research community that this step requires the rigorous solution of Maxwell's equations.

The problem is, while there are several well-established and proven numerical approaches for solving these equations, it is computationally expensive to do so, and both computation time and memory consumption strongly increase with the greater size of the simulation domain. This is why, for solar cells, only a small fraction of the entire solar cell is being modelled. Although efforts have been made to alleviate the computational constraints, the high computational costs are still a limiting factor when simulations are to be run on medium-sized computer servers.

It is clear, therefore that the team still has a long way to go in order to resolve these issues. Loeser's work has uncovered, however, that the employment of a novel Finite-Element based formalism – the Ultra-Weak Variational Formulation (UWVF) – is well suited for the optical simulation of third-generation solar cells. So far, by employing this method, the team has been allowed to numerically investigate larger domains at significantly reduced computational cost; a success that certainly needs to be build upon.

HOPES FOR THE FUTURE

Overall, by combining numerical and experimental techniques the project members strongly believe that a better understanding of the light diffusion and charge separation will be achieved, which will ultimately lead to higher solar cell efficiencies.

In order to branch out and continue their success, the researchers want to ensure and obtain good agreement between simulated and measured data. The next steps of their project, therefore, will include the analysis of a larger class of devices and further analysis of techniques. Furthermore, the fact that most of the success of solar power is normally rated in power efficiency can sometimes lead to a general lack of clear and systematic investigations into the influence of each individual parameter in solar cell efficiency. For this reason, Loeser's group is determined to combine experiments and simulation in all future work.

Thus, it is hoped the ultimate impact of this research will make a contribution to the advancement of a third generation solar cell technology. In other words, they want to learn during the course of the project how to design and produce efficient and inexpensive solar cells.

The team hopes that their project will make a contribution to the advancement of a third generation solar cell technology

INTELLIGENCE

NUMERICAL SIMULATION, DESIGN AND FABRICATION OF EXTREMELY THIN FILM ABSORBER SOLAR CELLS

OBJECTIVES

By combining both experimental and numerical techniques the project aims to develop efficient and inexpensive thin film solar cells.

KEY COLLABORATORS

Dr Laetitia Philippe, EMPA Thun, Switzerland; **Dr Martin Loeser**, Zurich University of Applied Sciences

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MARTIN LOESER studied Electrical Engineering at the Munich University of Technology, Germany, and the University of Sydney, Australia. After obtaining a Master's degree he joined ETH Zurich as a PhD student. During his research – carried out in close collaboration with industrial partners – Loeser focused on the numerical modelling and simulation of optoelectronic semiconductor devices. Since 2009 he has been with the Zurich University of Applied Sciences where he is currently a lecturer and research project leader. Loeser also holds a Master's degree in economics and management.

LAETITIA PHILIPPE obtained her PhD in electrochemistry from the University of Manchester in 2002. She then worked as a postdoc at TU Delft. She then moved to the Swiss Federal Laboratories for Materials Science and Technology (EMPA) where she became Group Leader for material synthesis by electrochemical methods. Her research interest lies in use of electrochemical means to create well-ordered nanostructured materials, compact layers and micro-devices, featuring exquisitely defined geometry, controlled surface chemistry, and tuneable physical/mechanical properties.

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