A EUROPEAN JOURNAL

CHEMPHYSCHEM

OF CHEMICAL PHYSICS AND PHYSICAL CHEMISTRY

06/2014

ChemPhysChem, European in origin but international in scope, deals with all aspects of the overlapping areas between chemistry, physics, biology, and materials science. It is co-owned by Chemistry Publishing Society Europe (ChemPubSoc Europe) and published by Wiley-VCH. Contributions in *ChemPhysChem* cover a wide range of topics including atmospheric science, hard and soft matter, femtochemistry, nanoscience, complex biological systems, single-molecule research, clusters, colloids, catalysis, and surface science; experimental and theoretical studies can be published. *ChemPhysChem* publishes short Communications and long Articles, as well as Reviews, Minireviews, Highlights, Concepts, Essays, Book Reviews, and occasionally Conference Reports. Authors can submit manuscripts to *ChemPhysChem* online through our homepage (see left) by clicking on "Submit an Article" and following the simple instructions.

CHEMICAL PHYSICS & PHYSICAL CHEMISTRY

http://www.chemphyschem.org

Full text:

Wiley Online Library
wileyonlinelibrary.com

Most of the articles in this issue have already appeared online on wileyonlinelibrary.com. See www.chemphyschem.org under EarlyView®.

DOI: 10.1002/cphc.201400098

Hybrid Organic–Inorganic Photovoltaics

Shahzada Ahmad,*[a] Mohammad Khaja Nazeeruddin,*[b] and Juan Bisquert*[c]

The remarkable increase in our planet's energy consumption and dwindling fossil-fuel resources drive current research on alternative energy sources and conversion pathways. The use of chemistry for energy is currently one the most important research topics for the sustainability of our society. Prof. Michael Grätzel is known for his invention and development of dye-sensitized solar cells (DSSCs), aptly called "Grätzel" cells. The excellent price-to-performance ratio of these novel devices earned him the Millennium Technology prize in 2010. Grätzel cells are likely to have an important role in low-cost, large-scale solutions for renewable energy. Besides photovoltaics, the concepts of Grätzel cells can also be applied to batteries, hydrogen production, and a diverse portfolio of components for future energy requirements.

Michael Grätzel was appointed as a Professor of Physical Chemistry in 1977 at the Ecole Polytechnique Federale de Lausanne (EPFL), where he directs the Laboratory of Photonics and Interfaces. He pioneered the studies of electron- and energy-transfer reactions in mesoscopic systems and has an outstanding track record while maintaining the leadership on the global scale. His seminal work put forward an entirely new research front providing the basis for a whole set of important fundamental scientific discoveries. They have revolutionized the approach of energy generation and storage. Grätzel is the inventor of the mesoscopic solar cell and was the first to introduce nanostructured electrodes for the photogeneration of hydrogen by solar photolysis of water and in lithium-ion batteries. His work has been described in over 1000 publications and has widespread international recognition. Today, he is one of the most highly cited chemist in the world.

In the early 80's, he made remarkable inputs to the field of photodissociation of water into hydrogen and oxygen and discovered a process for low-temperature methanation of carbon dioxide. From 1985 onwards, he shifted his work towards fundamental studies of the mechanisms and dynamics of interfacial electron-transfer processes in nanodispersed systems and became interested in molecular photovoltaics. His seminal work on nanostructured DSSCs at the beginning of the 90's had an exceptional repercussion. He showed for the first time how a photoelectrochemical device was able to compete with classical semiconductor-based p–n junction photovoltaic (PV) cells—but with a much cheaper and less energy-demanding manufacturing process, in a similar fashion as natural photosynthesis in plants. His revolutionary approach was to sensitize mesoscopic materials in which a sensitizer absorbs sun light, creating electric charges that are transported separately through electron- and hole-conducting interpenetrating networks. This opens up a whole realm of new opportunities for realizing low-cost PV devices and building integrated photovoltaics. Several companies are currently producing modules and flexible cells on a manufacturing line with a variety of products in the market. The development and understanding process of DSSCs has complemented a very broad area of science by providing crucial information for interfacial electron-transfer dynamics, interfacing molecules and electrodes, charge transport, and materials synthesis.

His fundamental studies also laid the ground for the development of semiconductor quantum dots showing size-quantization effects in their absorption and emission properties. In mesoscopic solar cells, the electron- and hole-conducting materials form an interpenetrating network, in contrast to conventional p–n solar cells which employ flat junctions.

Through his highly innovative and painstaking research, Grätzel has maintained a leading position in the domain of mesoscopic solar cells since its inception. Through innovative chemistry, his group was able to molecularly engineer transition-metal sensitizers which can give panchromatic light absorption. Performing in-depth kinetic studies, he discovered that the electron injection from the excited sensitizer into the conduction band of titanium dioxide occurs on a femtosecond timescale. His group later developed organic dyes that show a near-infrared response enhancing the efficiency in these systems apart from the use of organic hole conductors and ionic liquids to replace the redox electrolytes in DSSCs.

For many of the contributors to this special issue, Grätzel has been a collaborator, colleague and/or mentor. His dedications, restless approach, and enthusiasm have brought a tsunami-like wave into this field, which has ignited many young minds across the globe. These distinct effects will pave the way for global technological innovation.

We thank Grätzel for his groundbreaking contributions to physical chemistry and wish him a happy 70th birthday. We dedicate the collection of results in this special issue of *ChemPhysChem* to him. This date also marks the coming age of the Hybrid and Organic Photovoltaics (HOPV) Conference, which celebrates the 6th edition. This conference was conceived to unite in a single and specific forum for the growing number of scientists interested in hybrid, nanostructured, and low-cost solar cells. The conference was established around the DSSC as a central topic, and the leadership of Grätzel, who has participated as Keynote Speaker in all the previous editions (Benidorm, Assisi, Valencia, Uppsala, and Sevilla), has been a major driving force to establish the conference as an indispensable meeting point in the calendar of many researchers in this field.

In this special issue of *ChemPhysChem*, 28 papers related to contributions presented at the HOPV14, dealing with hybrid organic–inorganic photovoltaics on different aspects—and including minireviews, reviews, synthesis, properties, and applications of DSSCs, organic solar cells, solid-state DSSCs, and the newly invented perovskite-based solar cells—have been assembled, showing a broad overview of the variety of third-generation devices. The contributions are highly relevant and come from leading laboratories worldwide, covering almost all geographical regions. The topics cover, for example, photoanode engineering, new sensitizers and their interactions, device architects, transport properties, one-dimensional structures of semiconductors for devices, quantum dots, small molecules as donor materials, bulk-heterojunction solar cells, and the industrial adaptability of these devices as well as theoretical aspects of the dyes. It can be easily understood that a single issue of this type can hardly cover all the areas that are currently being investigated in third-generation solar cells; this themed issue gives an overarching view of the contemporary hot research area around these solar cells. These authoritative articles can also act as a path guider for more detailed information within individual sub-areas. It will allow us to visualize the dynamics of this diverse field, which is growing rapidly, and to understand how nanotechnology, physics, chemistry, and materials science are integrated into one device.

This also leads to some open questions that need to be answered concerning device integration and stability: Will these cells be stable enough to compete with existing technologies? We need to understand better how these materials will impose environmental hazards in the case of leakage of the devices. By keeping these facts in mind, we need to continue focusing our efforts on developing environmentally friendly materials through facile synthesis routes, which can be easily scaled up and penetrate the market.

Grätzel has made influential contributions and devoted his whole life to advocating and showing new paths to energy conversion through mesoscopic systems, which he invented. Over the years, his work has been characterized by excellent basic and applied research, as well as by multidisciplinary collaborations in the field. By permission of all the authors whose works are gathered in this special issue, we wish to dedicate it to Grätzel for the marvelous innings he has played during his career. We are convinced that this compilation improves our understanding of the fascinating physical chemistry, as well as the device physics and integration, involved in this research field. There cannot be a better occasion other than Grätzel's 70th birthday to bring out this special issue, where over 500 scientist and technologists gathered here in Lausanne to witness this moment, and the HOPV community will remember this for years to come. The Ecole Polytechnique Federale de Lausanne (EPFL) is also celebrating this occasion by inaugurating a new conference hall integrated with Grätzel cells.


Dr. Shahzada Ahmad


Dr. M. K. Nazeeruddin


Prof. Juan Bisquert

[a] Dr. S. Ahmad
Abengoa Research, C/Energía Solar no 1
Campus Palmas Altas-41014, Sevilla (Spain)
E-mail: shahzada.ahmad@research.abengoa.com

[b] Dr. M. K. Nazeeruddin
Institute of Chemical Science and Engineering
Faculty of Basic Science
Ecole Polytechnique Federale de Lausanne
CH-1015 Lausanne (Switzerland)
E-mail: mdkhaja.nazeeruddin@epfl.ch

[c] Prof. J. Bisquert
Grup de Dispositius Fotovoltaics i Optoelectrònics
Departament de Física
Universitat Jaume I (Spain)
E-mail: bisquert@fca.uji.es