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Preface

Michael Graetzel Festschrift, a tribute for his 60th Birthday

The World's conventional energy supplies (oil, natural gas, and coal) have a finite lifetime as our major source of energy and current forecasts suggest that alternatives must make a major contribution in the near future. Though nuclear power was once regarded to be a solution for increasing energy demand and the depletion of fossil fuels, sincere concerns about the storage of nuclear waste led scientists to explore alternative and renewable sources of energy. Most renewable energy options must rely on a net input of energy into the earth and since the sun is our only external energy source, harnessing its energy, which is clean and infinite is the main objective of all alternative energy strategies. It is remarkable that a mere 10 min of solar irradiation onto the Earth's surface is equal to the total yearly human energy consumption. Therefore, if we could accomplish harvesting merely a tiny fraction of the solar energy reaching the Earth, we would solve many of our problems not only in energy, but global environmental and political.

Prof. Michael Graetzel at EPFL invented a novel technology based on dye sensitized nanocrystalline TiO_2 films that mimic photosynthesis in the conversion and storage of solar energy. A sensitizer molecule anchored to a rough titania surface provides a way to successfully trap solar radiation in a fashion analogous to the light-absorbing chlorophyll molecule found in nature. Dye sensitized solar cell technology has been a major triumph during the past decade in many laboratories, because of its high efficiency and potentially low cost. Several groups have obtained white light conversion efficiencies of over 10% based on the dye-sensitised solar cells. The chapters in this special issue provide a flavour of the many scientific opportunities and challenges of this new evolving technology. In the same way that key discoveries made several decades ago have shaped today's life; present discoveries such as the dye-sensitized solar cell will have the potential to shape the life of future generations.

In addition to his many publications and patents, Professor Michael Graetzel has trained many students, and been the recipient of many awards. In addition to dye sensitized solar cells, he has had a significant impact in many fields of chemistry including catalysis, colloids, thin films, electrochemistry, membranes, bioelectronics, solid oxide fuel cells, Li-intercalation batteries, molecular sensors, photophysical and photochemical studies involving supramolecular complexes, photodegradation of toxic industrial wastes and artificial photosynthesis.

I would like to express my sincere gratitude to the authors and Prof. Barry Lever for making this Festschrift Issue possible, and the reviewers who are responsible for the high quality of the manuscripts contained here. It is a great pleasure to handle the responsibilities of this Festschrift Issue honoring Professor Graetzel's 60th birthday.

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Biography

Michael Graetzel's formative years were spent in a devastated Germany, being born in Dresden, that crucible of

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physical destruction. However the destruction was not only physical, with burnt-out cities and fractured infrastructure; it was moral, academic, intellectual. The ruins of Dresden were soon to fall under Soviet domination as part of that division of Germany and of Europe which was to last for a half century. A total reconstruction of the fabric of the nation and a rediscovery of its due place in Europe were required, and it was Michael Graetzel's generation which inherited, met and ultimately fulfilled that challenge, restoring their country's credibility, renewing the links with its historic culture and values. That this was possible is due to those of an older generation who had maintained their values and integrity through the cataclysm, two of whom deserve mention here for their influence on Michael Graetzel the student. The first, Armin Henglein, directed his doctoral thesis, with the degree awarded summa cum laude at the Technical University of Berlin in 1971, for work on pulse photolysis methods in physical chemistry, investigating short-lived free radicals by polarography on mercury drops. The interest in photoelectrochemical processes, with which his name is primarily associated and which then provided the central orientation of his research career was first stimulated by contact with Heinz Gerischer, one of the great names of that German renaissance, in the context of his Habilitation at the Free University of Berlin (1976). Like many young European scientists of that generation, the obvious next step was to experience wider horizons through the opportunity of working in the United States, in his case at the University of Notre Dame under a Petroleum Research Foundation Fellowship. Photoredox reactions in micellar systems were investigated there under the direction of John Kerry Thomas, thus initiating his career engagement in biomimetic photosystems in which technology is modelled on nature. In this case the bilayer structure of the micelle simulates the plant cell as an encapsulated microreactive environment for photochemistry. Another positive long-term consequence was his contact with a group of young and enthusiastic physical chemists who were later to form the nucleus of his team when eventually, in 1977, he became Associate Professor, and later in 1981 was promoted to a Chair in Physical Chemistry, in the Ecole Polytechnique Fédérale de Lausanne, Switzerland.

Perhaps due to his formative experiences, the research interests of Michael Graetzel have had an applied orientation, with a vision of a technical contribution to a sustainable society and equilibrium with the environment. The great challenge of the present age is the management of depletable resources and the replacement of extractive procedures by recycling technologies. The specialty of the Institute which he formed and now directs has been electrochemistry and photochemistry for energy and environment, with a renewed expression of the biomimetic theme. Nature has expressed processes which have proven rugged and sustainable over geological time scales. In contrast our extractive technologies have existed only momentarily, and are already reaching obsolescence. Life on earth has been sustained throughout its existence by photochemistry, specifically the process of photosynthesis dependent on the organometallic molecule chlorophyll. Animal life including human life, being dependent on the hemoglobin system, is functionally parasitic on the vegetable world. Nature has an unlimited flexibility in the configuration of life forms, but all remain dependent on these two complexes of Mg and Fe. Porphyrins are therefore obvious candidates for biomimetic chemical photoconversion systems for the exploitation of solar energy. It was therefore logical that after some attention to photoreactions of colloids and recognizing that narrow-gap semiconductors alone, while sensitive to the visible spectrum, are in general unstable in contact with electrolytes, Michael Graetzel should assess porphyrin photochemistry in chromophores for energy and environmental applications.

Photosensitization of semiconductors has a long history, being pioneered in the photographic process by Vogel in Berlin in 1873, and for semiconductors by Moser in Vienna in 1887. The mechanism of this photosensitization was only much later determined, by Gerischer and Tributsch in Munich in the 1960s. Sensitization technology in the German lands has very long roots! By 1980 ruthenium-based dyes had been identified by the Dare-Edwards group in England. The groundwork was in place for what would become known as the Graetzel cell. His specific breakthrough was the realization that highly disordered wide-bandgap semiconductor electrodes could be efficiently photosensitized with these ruthenium complexes and their later developments. Recombination losses are suppressed in this system, in which the semiconductor has a majority-carrier function. Excited charge carrier loss can therefore only occur by transfer across a phase interface, from the semiconductor to the contacting electrolyte, an intrinsically slow process. At the same time the extended surface area presented to the electrolyte by the disordered semiconductor permits the chemisorption of a sufficient quantity of the sensitizing dye to ensure a high level of optical absorption. The resulting device is the only proven alternative to the conventional solid state semiconductor junction solar cell, and as such has been a significant stimulus to photovoltaic research and development over the past ten years. Even for the silicon engineers a significant incentive is the awareness that other systems are possible! At the same time there is developing industrial interest in the dye-sensitized cell, both here in Europe and elsewhere, particularly in Japan and in the United States.

A notable aspect of Michael Graetzel's career, as expected of a Professor of a leading Technical University, is the provision of a fertile environment within his Institute to nurture a new generation of professionals devoted to studies in electrochemistry for energy applications. Some 40 doctorates have been granted within the Institute, and its fertility as represented by publications and patents has been consistently maintained. Of particular relevance are the contributions to textbooks and reference works as key components in the task of technical communication and formation. Current work extends across the whole domain of electrochemistry and photochemistry: dye and semiconductor synthesis methods including molecular engineering and nano-scale self-structuring, solid, gel, organic and molten salt electrolytes, electrodes and electrocatalysis, and photochemical kinetics are some of the procedures used, with application in environmental photochemistry, batteries and fuel cells, as well as in the photovoltaic field. The activity within this Institute is an ongoing story; long may it continue in the spirit of Michael Graetzel, its founder.

Augustin McEvoy (Adjoint scientifique)
EPFL, Lausanne, Switzerland

Brief Curriculum Vitae

Personal

Date	11 May 1944
Place of birth	Dorfchemnitz, Germany
Family	Married, three children

Education

1950–1964	Primary & Secondary Schools in Germany
1964–1968	Free University of Berlin, Germany, Major in Chemistry
1968–1970	Technical University of Berlin & Hahn-Meitner Institute, Berlin
	Doctoral Thesis, Physical Chemistry; Ph.D. Supervisor: Prof. Dr. Armin Henglein
	Pulse Radiolysis and Polaographic Studies of Short Lived Transients, Fast Electrochemical Methods
1975	Free University of Berlin, Germany: Habilitation for Physical Chemistry with the thesis “Laser Photolysis Studies and Fluorescence Studies in Micellar Systems and Homogeneous Solutions”

Professional Activities

1968	Research Associate, Max-Planck Institute, Berlin, Germany
	Diploma Thesis: Kinetics of Crystallization of Polymers
1969–1972	Research Associate, Hahn-Meitner Institute, Berlin, Germany
1972–1974	ACS Petroleum Fund Research Fellow, University of Notre Dame, Notre Dame, Indiana, USA
	Applications of Photochemical Techniques for the Study of Micelles, Membranes, Photoionization and Electron Transfer Reactions Across Lipid–Water Interfaces
1974–1976	Senior Staff Scientist, Hahn-Meitner Institute Berlin, Germany & Privat-dozent, Free University of Berlin
1977–1981	Prof. Extraordinaire, Ecole Polytechnique Federale, Lausanne, Switzerland
1981–till date	Prof. ordinaire, EPFL, Lausanne, Switzerland
1980–1982	Director, Institute of Physical Chemistry, EPFL
1983–1985	Head, Department of Chemistry, EPFL
1987–1988	President (Chemistry Section) Sociéte Vaudoise des Sciences Naturelles
1991–1993	President (Chemistry Section) Sociéte Vaudoise des Sciences Naturelles

Visiting Appointments

1981–1982	Solar Energy Research Institute (now NREL)
1986	Golden, Colorado, USA (Visiting Professor)
1988	Lawrence Berkeley laboratory, University of California, Berkeley, California, USA (Visiting Professor)
1993	Ecole Nationale Superieure de Cachan, Paris (Invited Professor)
1995, 1997	National Renewable Energy Laboratory (NREL)
1998	Golden, Colorado, USA (Guest Scientist)

Honors/Awards/Honorary Lectureships

1966	Studienstiftung des Deutschen Volkes Fellowship
1979	British Council Lecturer (London, Oxford, Southampton, Port Sunshine)
1981	GOP Invited Lecturer (Des Plaines, IL, USA)
1981	Chair of Physical Chemistry (offered), Free University of Berlin, Germany
1982	University of Texas, Austin, TX, USA (Visiting Lecturer)
1984	Japanese Society for the Promotion of Science (Visiting Professor)
1985	Chinese Academy of Science Lecturer (Peking, Dalian, Lanshou, Shanghai)
1985	R.A. Plane Endowed Chair Lectureship, Clarkson University, Potsdam, NY, USA
1992	US Popular Science Magazine Grant Award
1993	Irish Chemistry Society Inaugural Lecturer, Dublin, Ireland

1993	American Society of Mechanical Engineers—Best Publication Award
1994	Prix de la Ville de Lausanne—International Festival of Films on Energy
1995	US Air Force Award Lectureship (Boston, Durham, Gainseville, USA)
1995	Debye Lecturer, Utrecht, The Netherlands
1995	Ars-Oeko Foundation Award (Ars-Oeko Foundation), Basel, Switzerland
1996	Dr. honoris causa, Faculty of Science, University of Uppsala, Uppsala, Sweden
1997	Calaveras Award in Photovoltaics, Denver, Colorado, USA
1997	US Department of Energy Council on Chemical Science—invited panelist
1997	Volkswagenstiftung, Germany—Member, Evaluation Board
1998	Venture 98 McKinsey Award
1998	Eurel Prize—European Society of Electrical Engineers
1998	Helmholtz Foundation—Member, Evaluation Board of Photovoltaic Research
1999	Weissberger Williams Distinguished Scientist Lecturer, Eastman Kodak, Rochester, NY, USA
1999	National Institute of Minerals and Chemicals, Tsukuba, Japan—Member Evaluation Board
2000	Van der Waals-Zeeman Lecturer, University of Amsterdam, The Netherlands
2000	European Prize of Innovation and Technology, European Council of Appl. Sciences and Engineering
2000	Millenium European Prize of Innovation and Technology
2001	Havinga Lecture Award and Medal, Leiden, The Netherlands
2001	Institute of Scientific Information—ISL List of Most Highly cited Chemists 1981–1999 Publications
2001	Faraday Medal, Royal Society of Chemistry, UK
2002	IBC International Award in Supramolecular Chemistry and Technology
2002	Venture 2002 McKinsey Award, Zürich, Switzerland
2002	Nominated Honorary Member—Societe Vaudoise de Sciences Naturelles
2004	Laurea Honoris Causa, University of Torino, Italy
2004	ITALGAS 2003 Prize for Science & Environment

Professional Engagements

1983	Chair, UNESCO Conference on Renewable Energy through Chemistry, Lausanne
1989	Co-editor for the special issue of New Journal of Chemistry on Fractals in Chemistry
1993	Chair, Erice Symposium on Nanocrystalline Photovoltaic Systems, Ericy, Silicy (conference sponsored by World Laboratory)
1997	Co-Chair, SPIE International Symposium on Optical Sciences and Engineering, San Diego, California, USA
2001	Chair, International Conf on Unconventional Photoactive Systems, Les Diablerets, Switzerland

Past & present — Member, Editorial Board for the following scientific journals:

- Chem. Phys. Chem. (Wiley-VCH)
- Journal of Molecular Catalysis (Elsevier)
- Langmuir (American Chemical Society)
- Chemistry of Materials (American Chemical Society)
- Handbook of Nanostructured Materials and Nanotechnology (Academic Press)
- Advances in Photochemistry and Photophysics (CRC)
- Solar Energy Materials and Solar Cells (Elsevier)
- Renewable and Sustainable Energy Reviews (Elsevier)
- Advanced Functional Materials (Springer)
- Nanostructured Materials (Elsevier)

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