The 18th Brdička Lecture

Professor Michael Graetzel

(Ecole Polytechnique Federale de Lausanne, Switzerland)

"Mesoscopic Electrodes for Generation and Storage of Electric Power from Sunlight"

June 5, 2008 at 2:00 pm

J. Heyrovsky Institute of Physical Chemistry,v.v.i.
Academy of Sciences of the Czech Republic
Prague 8, Dolejškova 3.

Professor Michael Graetzel (1944)

directs the Laboratory of Photonics and Interfaces (LPI) at the Ecole Polytechnique Federale de Lausanne.

Prof. Graetzel pioneered research on energy and electron transfer reactions in mesoscopic-materials and their optoelectronic applications. He discovered a new type of solar cell based on dye sensitized mesoscopic oxide particles and pioneered the use of nanomaterials in lithium ion batteries. He was a frequent guest scientist at the National Renewable Energy Laboratory (NREL) in Golden Colorado, was a fellow of the Japanese Society for the Promotion of Science. He has received numerous awards including the Millenium 2000 European innovation prize, the 2001 Faraday Medal of the British Royal Society, the 2001 Dutch Havinga Award, the 2004 Italgas Prize, two McKinsey Venture awards in 1998 and 2002 and the 2005 Gerischer Prize. Prof. Graetzel is holding a doctors degree from the TU Berlin and honorary doctors degrees from the Universities of Uppsala and Turin. He was elected honorary member of the Société Vaudoise des Sciences Naturelles and an invited professor at the University of California at Berkeley, the Ecole Nationale Supérieure de Cachan (Paris) and is presently part-time distinguished visiting professor at the Delft University of Technology.
Prof. Graetzel is an author of over 600 publications, two books and inventor or co-inventor of over 40 patents.

Research Area
LPI pioneered research on semiconductor nanocrystallites and mesoscopic oxide films. These new materials have found important applications in a variety of fields, particularly in dye sensitized solar cells (DSC) lithium insertion batteries and electrochromic displays. By covering the surface of the mesoscopic oxide films with a suitable molecular chromophore efficient harvesting and conversion of sunlight into electricity can be achieved. The overall power conversion in full sunlight reaches presently over 11 %. Current research focuses on optimization of key parameters such as spectral response, photocurrent, photo-potentials and long-term stability. Fundamental studies concern electron and energy transfer reactions in these mesoscopic systems. Ultrafast interfacial electron transfer down to the femtosecond time domain and lateral charge percolation processes on the surface of insulating oxide nanoparticles are being investigated. Electrochemical studies currently underway include those on oxygen reduction in solid oxide fuel cells and the use of mesoscopic oxide films in lithium insertion batteries as well as in electroluminescent and bioelectronic devices. Photo-electrochemical studies concern visible light induced water oxidation on semiconductor oxides and the combination of the latter with a dye-sensitized solar cell in a tandem device to split water into hydrogen and oxygen by sunlight. The photo-degradation of toxic industrial wastes and pollutants is also being investigated. Finally LPI pioneered the development of new ionic liquids, which are used as "green" electrolytes in solar cells and other electrochemical devices.

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The lecture covers our recent research on mesoscopic electrodes that made up of a network of nanometer-sized particles such as titanium dioxide, zinc oxide, tungsten trioxide, Fe_2O_3 or $LiMnPO_4$. The pores between the particles are filled with an electrolyte or p-type semiconductor, in this way interpenetrating bicontinuous network composites are formed which are phase-separated by a hetero-junction. Electrons can percolate rapidly across the network of nanoparticles allowing the huge junction area to be addressed electronically. Intriguingly, cross surface electron and hole transfer in self-assembled monolayers (SAM) of redox-active molecules has also been observed. These mesoscopic oxide electrodes show great promise for a number of applications, such as high power lithium insertion batteries photo-electrochemical cells for solar hydrogen generation and dye-sensitized solar cells (DSCs). The DSC achieves currently a conversion efficiency of over 11 percent and exhibits excellent long term stability, rendering it a credible alternative to conventional silicon based devices. These new cells offers opportunities for applications in building integrated photovoltaic device and light weight solar power supplies. Recently large-scale production of flexible DSC modules has started.

Literature

1) B. O'Regan and M. Graetzel, "A Low Cost, High Efficiency Solar Cell" *Nature*, London, **353**, 737 (1991).

2) U. Bach, D. Lupo, P. Comte, J. E. Moser, F. Weissörtel, J. Salbeck, H. Spreitzert and M. Graetzel, "Solid State Dye Sensitized Cell Showing High Photon to Current Conversion Efficiencies" *Nature* **395**, 550 (1998).

3) M. Graetzel, "Photoelectrochemical Cells " *Nature*, London, **414**, 338, 2001.

BRDIČKA LECTURES

1. ***(1991)*** *Edgar **HEILBRONNER** (Eidgenossische Technische Hochschule, Zürich)*
"**The old Hűckel formalism**"

2. ***(1992)*** *Kamil **KLIER** (Lehigh University, Bethlehem, Pennsylvania)*
"**Physical chemistry in two dimensions**"

3. ***(1993)*** *Joshua **JORTNER** (Tel Aviv University, Tel Aviv)*
"**Clusters – a bridge between molecular and condensed matter chemical physics"**

4. ***(1994)*** *David J. **SCHIFFRIN** (The University of Liverpool)*
"**Electrochemistry in two-dimensional systems**"

5. ***(1995)*** *Josef **MICHL** (University of Colorado, Boulder, Colorado)*
"**Molecular kit for new materials**"

6. ***(1996)*** *Gerhard **ERTL** (Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin)*
"**Self-organization in surface reactions**"

7. ***(1997)*** *Roger **PARSONS** (University of Southampton)*
"**Electrochemistry in the last 50 years: from Tafel plotting to scanning tunnelling**"

8. ***(1998)*** *G. Barney **ELLISON** (JILA and University of Colorado, Boulder, Colorado)*
"**The chemical physics of organic reactive intermediates in combustion and atmospheric processes**"

9. ***(1999)*** *Henry F. **SCHAEFER III** (University of Georgia, Athens, Georgia)*
"**The third age of quantum chemistry**"

10. ***(2000)*** *Alexis T. **BELL** (University of California and Lawrence Berkeley Laboratory, Berkeley, California)*
"**Progress towards the molecular design of catalysts –lessons learned from experiments and theory**"

11. ***(2001)*** *Mario J. **MOLINA** (Massachusetts Institute of Technology, Cambridge, Massachusetts)*
"**The Antarctic ozone hole**"

12. ***(2002)*** *Jean-Marie **LEHN** (Université Louis Pasteur, Strasbourg a Collége de France, Paris)*
"**Selforganization of supramolecular nanodevices**"

13. ***(2003)*** *Helmut **SCHWARZ** (Technische Universität Berlin)*
"**Elementary processes in catalysis: looking at and learning from** "**naked**" **transition ion**"

14. ***(2004)*** *Rudolph A. **MARCUS***
(California Institute of Technology, Pasadena)
"Strange isotope effects in stratospheric ozone and in the earliest minerals in the solar system"

15. ***(2005)*** *Avelino **CORMA***
(Instituto de Tecnología Química, Valencia)
" Supramolecular Entities Based on Molecular Sieves for Catalysis and Synthesis of New Materials

16. ***(2006)*** *Paul **CRUTZEN***
(Max Planck Institute for Chemistry, Mainz):
„Atmospheric Chemistry and Climate in the ´Anthropocene´ ".

17. ***(2007)*** *Harry B. **GRAY***
(California Institute of Technology, Pasadena)
"The Currents of Life: Electron Flow through Metalloproteins"

Rudolf BRDIČKA
(1906-1970)

Professor of physical chemistry at Charles University, founding member of the Czechoslovak Academy of Sciences, founder and first director of the Institute of Physical Chemistry of the Czechoslovak Academy of Sciences.

An outstanding electrochemist renowned in particular by his pioneering work on kinetic polarographic current and on applications of polarography in medicine. A brillant university teacher, author of an internationally recognized textbook of physical chemistry. He has crucial merits for development of modern physical chemistry in this country.

To commemorate his work and personality, the Institute of Physical Chemistry of the Academy of Sciences of the Czech Republic has organized since 1991 annually a festive Brdička Lecture. Invited speakers have been eminent scientists active in some field relating to the research currently pursued in the Institute.