

MSE-Colloquium@NTU

19 January 2017, 3.45 pm

Lecture Theatre 3, Nanyang Technological University



Mesoscopic photosystems for the generation of electricity and fuels from sunlight

Professor Michael Graetzel

Physical Chemistry at the Ecole Polytechnique Fédérale de Lausanne

Head of Laboratory of Photonics and Interfaces

About the Talk

Mesoscopic photovoltaics have emerged as credible contenders to conventional p-n junction photovoltaics [1-3]. Mimicking light harvesting and charge carrier generation in natural photosynthesis, dye sensitized solar cells (DSCs) were the first to use three-dimensional nanocrystalline junctions for solar electricity production, reaching currently a power conversion efficiency (PCE) of over 14% in standard air mass 1.5 sunlight. Remarkably the PCE increases to 26% in ambient light matching the performance of GaAs photovoltaics. By now, large-scale DSC production and commercial sales have been launched on the multi-megawatt scale for application in building integrated PV and light weight flexible power sources. Recently, the DSC has engendered the meteoric rise of perovskite solar cells (PSCs) [4,5]. Today's state of the art devices employ metal halide perovskite of the general composition ABX_3 as light harvesters, where A stands for methylammonium, formamidinium or caesium, B denotes lead or tin and X iodide or bromide. Carrier diffusion lengths in the 100 nm - micron range have been measured for solution-processed perovskites and certified power conversion efficiencies (PCEs) attain 22 %, exceeding the PCE of polycrystalline silicon solar cells. These photovoltaics show intense electro-luminescence matching the external quantum efficiency of silicon solar cells. and V_{oc} values close to 1.2 V for a 1.55 eV band gap material. This renders perovskite-based photosystem very attractive for applications in tandem cells and for the generation of fuels from sunlight mimicking natural photosynthesis [6-8].

1. B.O'Regan and M. Grätzel. "A Low Cost, High Efficiency Solar Cell based on the Sensitization of Colloidal Titanium Dioxide," *Nature* 353 (1991) pp 7377-7381.
2. M. Grätzel, "Photoelectrochemical Cells," *Nature* 414 (2001). pp 332-344.
3. A.Yella, H.-W. Lee, H. N. Tsao, C. Yi, A.Kumar Chandiran, Md.K. Nazeeruddin, EW-G .Diau,,C.-Y Yeh, S. M. Zakeeruddin and M. Grätzel, "Porphyrin-based Solar Cell with Co(II/III) Redox Electrolyte Exceed 12% Efficiency," *Science* 629 (2011) pp 334-341.
4. M. Grätzel, Light and Shade of Perovskite Solar Cells, *Nature Mat.* 13 (2014) pp 838-842.
5. J. Burschka, N. Pellet, S.-J. Moon, R.Humphry-Baker, P. Gao¹, M K. Nazeeruddin and M. Grätzel, "Sequential deposition as a route to high-performance perovskite-sensitized solar cells" *Nature* 499, (2013),pp 316-3199.
6. J. Luo, J.-H. Im, M.T. Mayer, M. Schreier, Md.K. Nazeeruddin, N.-G. Park, S.D.Tilley, H.J. Fan, M. Grätzel, Water photolysis at 12.3% efficiency via perovskite photovoltaics and Earth abundant catalysts *Science*, 345, (2014), pp 1593-1596.
7. X. Li, D. Bi, C. Yi, J.-D. Décoppet, J. Luo, S.M. Zakeeruddin, A. Hagfeldt, M. Grätzel, A vacuum flash-assisted solution process for high-efficiency large-area perovskite solar cells, *Science* 353 (2016), pp 58-62.
8. M.Schreier L. Curvat, F. Giordano, L. Steier, A. Abate, S.M. Zakeeruddin, J. Luo, M. Mayer and M:Grätzel, "Efficient photosynthesis of carbon monoxide from CO2 using perovskite photovoltaics" *Nature Commun.* 6, (2015) , pp 7326-7332.

MSE-Colloquium@NTU

School of Materials Science & Engineering

About the Speaker

Professor Michael Graetzel is a Professor of Physical Chemistry at the Ecole Polytechnique Fédérale de Lausanne, where he directs the Laboratory of Photonics and Interfaces. He pioneered research in the field of energy and electron transfer reactions in mesoscopic systems and their use in energy conversion systems, in particular photovoltaic cells and photo-electrochemical devices for the splitting of water into hydrogen and oxygen and the reduction of carbon dioxide by sunlight as well as the storage of electric power in lithium ion batteries. He discovered a new type of solar cell based on dye sensitized nanocrystalline oxide films which successfully mimic the light reaction occurring in green leaves and algae during natural photosynthesis. Dye sensitized solar cells (DSSCs) are currently produced by industry and sold commercially on the megawatt scale as light-weight flexible cells for powering portable electronic devices and as electricity producing glass panels for application in building integrated photovoltaics. The DSSC has engendered perovskite solar cells (PSCs) that have revolutionized the whole field of photovoltaics reaching over 22% efficiency only a few years after their inception.

Author of several books and over 1200 publications that received some 180'000 citations (h-factor 196) he is one of the 3 most highly cited chemists in the world. His recent awards include the Paracelsus Prize of the Swiss Chemical Society, the King Feisal International Science Prize, the Samson Prime Minister's Prize for Innovation in Alternative Fuels, the First Leigh-Ann Conn Prize in Renewable Energy, the Albert Einstein World Award of Science, the Marcel Benoist Prize, the Paul Karrer Gold Medal, the Gutenberg Research Award, the Millennium Technology Grand Prize, and the Balzan Prize. Other prestigious awards include the Galvani Medal, the Faraday Medal, the Harvey Prize, the Gerischer Award, the Galileo Galilei Award, the City of Florence Award of the Italian chemical Society, the Dutch Havinga Award and Medal, the International Prize of the Japanese Society of Coordination Chemistry, the ENI-Italgas Energy-Prize and the year 2000 European Grand Prix of Innovation.

He graduated as Doctor of Natural Science (Dr.rer.nat.) from the Technical University of Berlin and received 10 honorary doctors degrees from Asian and European Universities.



SCHOOL OF
**MATERIALS SCIENCE
AND ENGINEERING**