# Professor Michael Graetzel

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## 1. Education and Positions Held

*Education:*
Habilitation (Dr.habil.) Physical Chemistry, 1976, Free University of Berlin.
Dr.rer.nat. in Physical Chemistry, 1971 (summa cum laude), TU Berlin.
Diploma degree in Chemistry, 1968 (summa cum laude), Free University of Berlin.

*Positions Held:*
Since 1981: Full Professor, Director of the Laboratory of Photonics and Interfaces at EPFL. Head of the Chemistry Department from 1991-1993, and 1983-1985. Since 2017: External Scientific Member of the Max Planck Institute for Solid State Research Stuttgart, Germany. Since 2019 Invited Professor at Nankai University, 2011 - 2018 Guest Professor and NTU Singapore, Chair of the Scientific Board of the Energy Research Institute (ERIAN), 2005-2009 Distinguished Invited Professor National University of Singapore. 2004 Invited Professor, Delft University of Technology. 1998: Invited Professor Ecole Polytechnique Supérieure de Paris-Cachan. 1988: Invited Professor at the University of California at Berkeley. 1977 -1981: Associated Professor of Physical Chemistry at EPFL. 1974-1976: Senior Staff Scientist, Hahn-Meitner Institute Berlin, Germany. 1974 -1976: Lecturer of Photochemistry and Physical Chemistry, Free University of Berlin. 1972-1974. Petroleum Research Foundation Post-Doctoral Fellow, University of Notre Dame, USA. 1969-1972 Research Associate, Hahn Meitner Institute Berlin.

## 2. Selected Major Honors and Awards (since year 2000)

2021 BBVA Frontiers of Knowledge Awards in Basic Science.
2020 Materials Today Innovation Award, USA.
2020 Diels - Planck Medal and Lecture, Kiel, Germany.
2018 August Wilhelm von Hofmann Memorial Medal, German Chemical Society.
2017 Global Energy Prize, St. Petersburg, Russian Confederation.
2017 Zewail Prize and Medal in Molecular Science. Elsevier.
2017 RUSNANO Prize, Moscow, Russian Confederation.
2016 Centenary Prize of the Royal Society of Chemistry (UK )
2016 Paracelsus Prize and Medal of the Swiss Chemical Society
2016 Elected Member of the National Academy of Inventors, USA
2015 Ordre de mérite du canton de Vaud, Switzerland
2015 King Faisal International Science Prize, Saudi Arabia
2014 Samson Prime Minister's Prize for Innovation in Alternative Fuels, Israel
2014 First Leigh-Ann Conn Prize in Renewable Energy, University of Kentucky USA
2013 Leonardo da Vinci Medal of the European Academy of Science
2013 Marcel Benoist Prize (Switzerland)
2012 Albert Einstein World Award of Science, World Cultural Council.
2012 Swisselectric Research Award
2011 Wilhelm Exner Medal, Vienna Austria
2011 Paul Karrer Gold Medal, University of Zurich, Switzerland
2011 Federation of the European Material Societies (FEMS) Innovation Award.

2011 Gutenberg Research Award, University of Mainz, Germany
2010 Galileo Galilei Award, Padova Italy,
2010 Millenium Technology Grand Prize, Technology Academy Finland
2010 City of Florence Award of the Italian Chemical Society
2009 Balzan Prize , Balzan Foundation, Milano, Zurich.
2009 Galvani Medal of the Italian Chemical Society.
2008 Harvey Prize in Science and Technology, The Technion Haifa, Israel.
2007 Received offer (call) on the Kroll endowed Chair, University of Cornell, Itaca,,USA.
2007 First International Prize, Japanese Society of Coordination Chemistr.y
2006 World Technology Award in Materials San Francisco, USA .
2005 Gerischer Prize of the Electrochemical Society.
2005 Winner, Scientific American Top 50, ranked amongst 50 leading scientists worldwide
2003 ENI-Italgas Price in Science and Environment.
2002 IBCInternational Award in Supramolecular Chemistry and Technology.
2001 Havinga Award, Lecture and Medal, Leiden, The Netherlands.
2001 Faraday Medal of the Royal Society of Chemistry, United Kingdom.
2000 European Grand Prix of Innovation and Technology, Monaco.
1998 Eurel Price of the European Society of Electrical Engineers.
1997 Calveras Award in Photovoltaics, National Renewable Laboratory Golden, USA.
1993 Best Publication Award, The American Society of Mechanical Engineers.
1985 R.A.Plane endowed Chair offered ,Clarkson University, Potsdam USA..
1984 Japanese Society for the Promotion of Science Fellow, Tokyo, Japan.
1981 Chair of Physical Chemistry, Free University of Berlin offered.

**3. Honorary Doctors Degrees (Dr.honoris causa):**

Ecole Nationale Supérieure de Paris-Cachan, France; Université de Liège; Belgium, Roskilde University, Denmark; Huazhong University of Science and Technology, Wuhan, China; NTU (Singapore); University of Lund, Sweden; University of Nova Gorica, Slovenia.; University of Hasselt, Belgium; Delft University of Technology, Netherlands; University of Turin, Italy; University of Uppsala, Sweden.

**4. Academy Memberships**

2019 Elected Member of the Swiss Academy for Technical Sciences
2016 Elected Member of the Royal Spanish Academy of Engineering
2014 Elected member of the German Academy of Science (Leopoldina)
2014 Elected Honorary Fellow of the Royal Society of Chemistry (UK)
2012 Elected Member of the European Academy of Science
2005 Elected Honorary Member of the Bulgarian Academy of Scienc
1998 Elected Honorary Member of the Société Vaudoise de Sciences Naturelles

**5. Endowed Named Lectures** (past 12 years only)

**2021** Diels Planck endowed lecture University of Kiel Germany. **2020** Förster endowed lectures Munich and Cologne, Germany. **2019 :** *Aun Lecture* POSTECH**,** Pohang, South Korea, **2018***: L. E. Tannas Jr. Lecture*, UCLA, California, USA, *Siemens Foundation Lecture***,** *Theodor Förster Memorial Lectures* Munich and Cologne, Germany, *Peiyang Lecture* Tianjin University China*, Betts Lecture* University of Manitoba, Canada, **2016:** *Shipley Lecture* Clarkson University Potsdam NY (USA). **2014**: *Argonne National Laboratory Director's Lecture,* USA*, Barré lectures University of Montreal. William Mong lecture* University of Hong Kong. **2013:** *O.Hassel Lecture,* University of Oslo Norway. *Nanqiang Lecture*, University of Xiamen China, *Los Alamos National Laboratory Director's Lecture,USA.* **2012**: *Dr. R. A. Mashelkar Endowment Lecture,* National Chemical Laboratory Pune, India, *Oersted Lecture* University of Copenhagen (DK),

*Kolthoff Lecture,* University of Minnesota, Minneapolis, USA, *Meloche Lecture*, University of Wisconsin-Madison, USA. *Irvin Shain* Lecture, University of Wisconsin-Madison, USA. **2011:** *Klaus Römer Lecture*, Maximilian University, Munich, Germany, *Albert Einstein Lectures,* Chinese Academy of Science, China. *Max Planck Lecture,* MPI Stuttgart Germany. *47th Shiram Institute Founder Memorial Lecture*, New Delhi, India. *Louis Pasteur Lecture*, Paris France. **2010:** *COPE Distinguished Lecture* Georgia Tech, Atlanta Georgia, USA. *European Chemical Society Lecture*, Nuremberg Germany. *European Science Foundation Lecture*, Paris, France. *CNR Rao Award Lecture*, Indian Institute of Sciene Bangelore India. *Michael Faraday Lecture*, J.Nehru Center for Advanced Scientific Research, Bangalore, India. **2009:** *Patrick S. Ncholson Memorial Lecture*, Lake Louise Canada. *John C. Bailar Lectures and Medal* University of Illinois. 2008 *18th Brdicka Lecture,* Karl's University Prague, Czech Republic. **2008:** *AD Little lectures*, MIT Boston, USA. 2008 *"Lecture at the Leading Edge",* University of Toronto, Canada, *Earl L. Muetterties Memorial Lectures*, University of California at Berkeley, USA. **2007:** *William Lloyd Evans Lectures and Award,* Ohio State University. Columbus, USA, *6th Distinguished Gouq-Jen Su lecturer*, University of Rochester, Rochester USA.

## 6. Professional Assignments, Selection Committees, Advisory and Editorial Boards

Since 2020: Chairman of Panel 8, selecting recipient for ERC Advanced Research Grants. Since 2018: European Research Council (ERC) Panel for selecting recipients of Advanced Research Grants in the Physical Science and Engineering. Since 2015: Scientific Commission for ENI Energy Award. Since 2014: Election Panel for Fellows and Advanced Investigator of the National Research Foundation Singapore. Scientific Advisory Board Member for the Presidents of: DGIST (Daegu South-Korea 2012-2014) KTH Stockholm (2010-2011) and University of Helsinki (2010-2013), Weizmann Institute of Science, Israel (2006). UK Engineering and Physical Sciences Research Council (EPRC) Review College Evaluation Board of the NIMC Institute, Tsukuba, Japan (1999-2006). Invited panelist, US Department of Energy Council on Chemical Science, 2005 and 1997. Expert witness for the Royal Court of Justice, London (2002-2004). *Evaluation Board*: Scientific Committee of the French CNRS, Photovoltaic Research Helmholtz Foundation Germany (1998), and Volkswagenstiftung, Hannover Germany (1997-2003). *International Editorial Board* (past and present): eScience (Elsevier) Angewandte Chemie (Wiley), ChemPhysChem. (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 &Sustainable Energy Reviews (Elsevier), Advanced Functional Materials (Springer), Nanostructured Materials (Elsevier), Progress in Photovoltaic Science and Technology. Chemical Physics Letters (Elsevier). Topical Editor, New Journal of Chemistry, 1989: Fractals in Chemistry.

## 7. Brief Summary of Prof. Michael Graetzel's Research Achievements

Michael Graetzel was the first to conceive and realize mesoscopic photosystems that convert sunlight very efficiently to electricity and chemical fuels mimicking natural photosynthesis.. By now the new generation of solar cells that emerged from his research can rival and even exceed the performance of conventional photovoltaics. He is credited with creating molecular photovoltaics by moving the photovoltaic field beyond the principle of light absorption via diodes to the molecular level. His revolutionary cell design presented a new paradigm since it features a three-dimensional mesoscopic junction, in contrast to the planar p-n architecture used in conventional solar cells. The prototype of this new photovoltaic family is the dye-sensitized

solar cell (DSC), also referred to as “Graetzel cell”, which employs dye molecules, pigments or quantum dots as light harvesters. These are surface-bound on a support formed by an array of colloidal nanocrystals of a wide band gap semiconductor, such as $TiO_2$ or $SnO_2$ as key electron capturing substrate. The mesoporous film is infiltrated with a redox electrolyte or a solid-state hole conductor to effect charge transport to the back contact of the cell. They are the first and only photovoltaic system that achieves the separation of light absorption from charge carrier transport mimicking the light reaction of natural photosynthesis in solar energy harvesting. DSCs are simple and inexpensive to manufacture and possess unique practical advantages including their flexibility, aesthetic appeal, transparency and bifacial photon collection. They reach currently a power conversion efficiency of over 15 % in full sunlight and 35% in ambient light. These features along with excellent long-term stability have fostered commercial applications on the industrial scale. By now, large-scale DSC production and commercial sales have been launched for applications as semitransparent glass panels for production of electricity from production or in flexible photovoltaics providing electric power from ambient light as battery replacements for electronic devices.

Graetzel played a pivotal role in the development of perovskite solar cells (PSCs) that directly emerged from the DSC. Their meteoric rise to reach a solar to electric power conversion efficiency of 25.5% in 2020 has stunned the PV-community and attracted enormous research interest with close to 20’000 papers being published on the subject over the last 8 years. Interest in these materials was further heightened by cost projections that show that the levelized cost of electricity (LCOE) produced by PSCs could be substantially lower than that of conventional photovoltaics. This prediction attracted enormous attention and spurred large research efforts, ear-marking these extraordinary materials as a key thin film solar cell candidates of the future.

Graetzel also applied his mesoscopic design concept to enhance the power and charging rates of lithium on batteries and to create photoelectrochemical cells that generate chemical fuels from sunlight, opening up a new path to provide future sources of renewable energy that can be stored. His group achieved very high solar to chemical conversion efficiencies for the solar light driven decomposition of water into hydrogen and oxygen and the reduction of carbon dioxide by to carbon monoxide or ethylene and ethanol. Graetzel’s 1750 publications have received some 378’000 citations and his h-index is 259 (Web of Science, May 2021). A recent ranking issued by Stanford University places Graetzel in the first position on a list of 100,000 top scientists across all fields.

## 8. Twenty Selected Publications


1) J. Desilvestro, **M. Grätzel,** L. Kavan, J. Moser and J. Augustynski Highly Efficient Sensitization of Titanium Dioxide **J.Am.Chem.Soc**., 107, 2988 (1985).

2) B.O’Regan and **M. Grätzel** , A Low Cost, High Efficiency Solar Cell based on the Sensitization of Colloidal Titanium Dioxide, **Nature**,1991, 353, 7377-7381.

3) ) U.Bach, D.Lupo, P.Comte, J.E.Moser, F.Weissörtel, J.Salbeck, H.Spreitzer and **M.Grätzel,** Solid-state dye-sensitized mesoporous $TiO_2$ solar cells with high photon-to-electron conversion efficiencies, **Nature** 1998, 395, 550.

4) A. Hagfeldt and M. **Grätzel,,** Molecular Photovoltaics, **Acc. Chem. Res**. 2000, 33 , 269.

5) 5) **M. Grätzel**, Photoelectrochemical Cells, **Nature** 2001, 414, 332.
6) **M.Grätzel**, Recent Advances in Sensitized Mesoscopic Solar Cells, **Acc. Chem. Res**. 2009, 42, 1781.

7) 7 A.Yella, H.-W. Lee, H. N. Tsao,1 C. Yi, A.Kumar Chandiran,Md.K. Nazeeruddin,1 E. W.-G.Diau, C.-Y. Yeh, S. M. Zakeeruddin and **M. Grätzel,** Porphyrin- based Solar Cells Exceed 12 % Efficiency, **Science** 2011, 334, 629-634.

8) J.H Delcamp, A. Yella, T.W. Holcombe, and **M.Grätzel**, The Molecular Engineering of Organic Sensitizers for Solar-Cell Applications, **Angew. Chem. Int. Ed**., 2012, 52, 376-380.

9) ) H.Snaith and **M.Grätzel**, Light-Enhanced Charge Mobility in a Molecular Hole Transporter,**Physical Review Lett.** 2007, 98, 177402 – 177402

10) M. Freitag, J. Teuscher, Y. Saygili, X. Zhang, F. Giordano, P. Liska, J. Hua, S.M. Zakeeruddin, J.-E. Moser, **M. Grätzel**, A. Hagfeldt, Dye-sensitized solar cells for efficient power generation under ambient lighting, **Nature Photonics**, 2017, 11, 372-378.11) H.S.Kim, C.R.Lee, J.H.Im, K.B. Lee, T. Moehl, A. Marchioro, S.J.Moon, R. R.Humphry Baker, J.H.Yum, J.E. Moser, M. **Grätzel,** N.G. Park, Lead Iodide Perovskite Sensitized Mesoscopic Solar Cell with Efficiency Exceeding 9% **Scientific.Reports** 2012, 2, article 591.

11) J. Burschka, N. Pellet, S.-J. Moon, R.Humphry-Baker, P. Gao, M K. Nazeeruddin and M. **Grätzel**, Sequential deposition as a route to high-performance perovskite sensitized solar cells, **Nature** 2013, 499, 316-319.

12) G.C. Xing, N. Mathews, S.Y. Sun, S.S. Lim, Y.M. Lam, **M. Grätzel**, S. Mhaisalkar and T.C. Sum "Long-Range Balanced Electron- and Hole-Transport Lengths in Organic-Inorganic $CH_3NH_3PbI_3$, **Science** 2013, 342, 344-347.

13) **M. Grätzel**, Light and shade of perovskite solar cells, **Nature Materials** 2014, 13, 838-842 .

14) 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** 2014, 345, 1593-1596.

15) M. Saliba, T. Matsui, K. Domanski, J.-Y. Seo, A. Ummadisingu, S.M. Zakeeruddin, J.-P. Correa-Baena, W. Tress, A. Abate, A. Hagfeldt, **M. Grätzel**, Incorporation of rubidium cations into perovskite solar cells improves photovoltaic performance, **Science**, 2016, 354, 206-209.

16) X. Li, D. Bi, C. Yi, J.-D. Décoppet, J. Luo, S.M. Zakeeruddin, A. Hagfeldt and **M.Grätzel**, A vacuum flash–assisted solution process for high-efficiency large-area perovskite solar cells, **Science**, 2016, 353, 58-62.

17) A.Ummadisingu, L. Steier, J.-Y. Seo, T. Matsui, A. Abate, W. Tress, **M.Grätzel** The effect of illumination on the formation of metal-halide perovskite films, **Nature** 2017, 545, 208-212.

18) N. Arora, M.I. Dar, A.Hinderhofer, N. Pellet, F. Schreiber, S.M. Zakeeruddin and M. **Grätzel,** Perovskite solar cells with CuSCN hole extraction layers yield stabilized efficiencies greater than 20 %. **Science** 2017, 358, 768-771.

19) H. Lu, Y. Liu, P. Ahlawat, A. Mishra, W.R. Tress, F.T. Eickemeyer, Y. Yang, F. Fu, Z. Wang, C.E. Avalos, B.I. Carlsen, A. Agarwalla, X. Zhang, X. Li, Y. Zhan, S.M. Zakeeruddin, L. Emsley, U. Rothlisberger, L. Zheng, A. Hagfeldt, M. Grätzel, Vapor-assisted deposition of highly efficient, stable black-phase FAPbI3 perovskite solar cells. **Science**, 20120, 370, eabb8985.

20) J.Jeong,,,MGrätzel et.al **Nature** 2021**,** 592**,** 381–385 ; https://doi.org/10.1038/s41586-021-03406-5.