Laudatio del Prof. Dr. Michael Graetzel

con motivo de la imposición de la

Medalla de Académico Correspondiente de la

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Manuel Doblaré

Sr. presidente, Sres. académicos, Sras. y Sres.

It is for me a pleasure and a privilege to have been appointed to impart the welcome Laudatio to Prof. Dr. Michael Graetzel as honorary member of the Royal Academy of Engineering. I want to start thanking him for accepting the invitation of our Academy, unanimously approved in plenary session, and supported by a very large group of Academicians.

And this is because today, it is not just the entrance of another member in the Academy, but it joins us one of the most brilliant scientists of our generation. Recognized worldwide for fundamental contributions to the knowledge of electron transfer reactions in mesoporous and nanocrystalline materials, Graetzel is not only an extraordinary scientist, but one of those rare examples that combines, in a single person, the complete cycle of successful research. From generation of basic knowledge to the conception of devices for the production and storage of clean and cheap energy, which have given rise to a complete industrial sub-sector. Very much like an engineer.

Prof. Michael Graetzel was born in Dorfchemitz, Germany, in 1944. He graduated in Chemistry in 1968 at the Free University of Berlin and obtained the doctorate in Natural Sciences from the Technical University of the same city in 1971. After short period at the Hahn-Meitner Institute of Nuclear Research also in Berlin and a postdoctoral stay at University of Notre Dame, in US, he obtained the habilitation as professor of Physical Chemistry in 1976 at the Free University of Berlin. Almost immediately, in 1977, he moved to the Federal Polytechnical School of Lausanne in Switzerland, one of the most prestigious in Europe, where after four years as Associate Professor, he was appointed as Full Professor of Physical Chemistry in 1981. There he continues today as director of the laboratory of Photonics and Interfaces that he founded.

He has also spent long periods in multiple universities around the world, building an impressive network of collaborators and students with whom he continues working intensely. As examples and not to bore the audience, he has been Visiting Professor at Cornell, California Berkeley, KAUST and École Nationale Supérieure de Cachan, Distinguished Visiting Professor at Delft, Huazhong University in China and the National and Technical Universities of Singapore and Albert Einstein Professor at the Chinese Academy of Sciences. He has also been guest scientist at the US National Renewable Energy Laboratory in Colorado and guest lecturer in the most prestigious universities in Europe, Asia and America, as well as in companies such as Kodak and DuPont.

Humanity faces enormous challenges that can alter the very essence of the human being and of our Society. The growing world population, together with the progressive urbanization and the increase in the average standard of living and of life expectancy, are causing such a strong pressure on the resources (water, energy, raw materials) and on the planet as a whole (massive waste, pollution of seas, rivers and atmosphere, climate change), that some scientists see near the point of no return with catastrophic consequences for future generations.

It is therefore necessary not, imperative, to make structural changes in the way we generate, consume and recycle goods, although we must guarantee the rights of the most unfavored, and the long-term sustainability of our small, and, for the moment, only habitable planet.

One of the most important challenges in this direction, as will be remarked by our guest in his talk, is changing the way in which we convert energy, from the current one, essentially based on fossil fuels, to another that uses clean and renewable sources, affordable in all locations and sufficiently cheap even for less wealthy countries.

It seems clear today that the future is using solar energy directly. In fact, the energy that arrives from the sun to the earth in two hours would be roughly sufficient to cover the world demand of all classes of energy for one whole year. An enormous amount of energy, but otherwise diffuse and difficult to concentrate with reasonable efficiency.

This has been precisely the area in which the research of our new Academician has been focused. In the late eighties, and taken as model the process of photosynthesis, by which green plants convert light energy and carbon dioxide in carbohydrates, Graetzel developed photo-systems based on small nanoparticles of organic dyes, capable of efficiently collecting sunlight and converting it into electricity. In 1991 he published in Nature, with Brian O'Reagan, the article entitled "A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO2 films" in which he presented a new type of photovoltaic solar cell based on photosensitive semiconductors that absorb sunlight, generating electrons that are collected by a nanostructured mesoporous titanium dioxide scaffold. This article, according to Google Scholar, has got more than 25,000 citations and was the starting point for a whole family of new cells called "Dye-sensitized solar cells" (DSSC) or more commonly in the scientific and technological community "Graetzel cells".

These cells have opened up new perspectives on photovoltaic devices, since they have a reasonable efficiency, up to 15%, are low cost, may have arbitrary color, use very small quantities of abundant materials and are easy to manufacture. In addition, they are flexible, very light and have a good performance in diffuse light, making them ideal for indoor applications like their integrations in windows or powering electronic appliances.

The commercial manufacture of these cells started only in 2009, and although at their initial stages they had poor efficiency and stability, today have been improved to the point that are sold by different companies in the world at a scale of megawatt/year.

Over the next 20 years, multiple research groups, led largely by Graetzel, worked to replace the original liquid electrolyte with a solid organic semiconductor. In 2009, perovskite was identified as a suitable material for this purpose. The new cell had a high theoretical potential in terms of efficiency and immediately got the interest of researchers, companies, and the media. This led to an explosive growth in the efficiency of these cells never seen before for other solar cell concepts, passing in only seven years from 9.7% to more than 22%, comparable to the most efficient cells in the market made of polycrystalline silicon. it is believed that, when the problems they yet have of degradation and large-scale manufacturing will be solved, they will lead to a paradigm shift in solar energy conversion, due to their good efficiency at low radiation, insensitivity to temperature, manufacturability on flexible substrates and again its very low cost and ubiquity and abundancy of their components.

It was precisely in this period when I met Michael Graetzel. During my visit to Lausanne in 2012 to discuss possibilities of collaboration between his group and the company Abengoa Research that I was heading at that time. Introduced by his former student, Dr. Shahzada Ahmad that I had the luck to recruit in Seville, I was immediately impressed by his accessibility, his openness to our proposals and the interest he showed in our project. After several mutual trips to Lausanne and Seville, I had the opportunity to meet his best collaborator, Prof. Nazeeruddin and his lovely Carole, who unfortunately could not be with us today due to a health problem and whom I wish a soon recovery. We then started a collaboration, which developed more than satisfactorily and that, unfortunately, broke

down due to the problems of our company. This ratified my strong conviction that long-term strategic partnership between first-level research groups and companies, not biased by immediate objectives, although requires a period of adaptation and getting confidence, gives rise to much greater returns for both players and is a necessary condition for keeping technological leadership.

Today Michael Graetzel remains fully active, traveling around the world, and still being one of the leaders in new improvements and concepts for perovskite-based photovoltaic devices where his group has been responsible of several efficiency records. He also works in other applications such as the production of hydrogen by direct photolysis of water, the storage of electricity in high-power Li-ion batteries and new proposals related to artificial photosynthesis for CO2 capture and for production of hydrogen and carbohydrates.

His bibliometric data are overwhelming. He has three books published by international publishers, about 1200 articles, with dozens of them in the most prestigious journals like Nature or Science, 60 book chapters and innumerable presentations at conferences where, in the majority, he has been "plenary speaker". All this has resulted in more than 180,000 citations and an H-index of 222 according to Google Scholar, being today one of the three most cited chemists in the world.

Participating in hundreds of public and private funded projects, suffice it to cite the prestigious European Research Council's Advanced Grant he was awarded in 2010 for the Mesolight project "Mesoscopic Junctions for Light Energy Harvesting and Conversion".

But in addition, and as mentioned before, its labor of technology transfer is equally impressive. He is the author of more than 50 patents that are currently being exploited by giants such as Panasonic, Siemens or Samsung. They have been the basis for the creation of several companies directly in the United Kingdom, Italy, Switzerland, Germany or Japan, in many of which, Michael Graetzel is scientific adviser.

As it cannot be otherwise, this enormous work of research, teaching and technology transfer has been recognized by multiple international awards and distinctions. Stand out their ten doctorates "Honoris Causa" in universities of Asia and Europe and the most important prizes of the research world. Among them, I shall only mention some of the most important such as: the Paracelsus Prize of the Swiss Chemical Society, the King Feisal International Science Prize, the Samson Award for Innovation in Alternative Fuels, the Leigh-Ann Conn Prize in Renewable Energies, the Wilhelm Exner Medal, the Innovation Award from the Federation of European Material

Societies, the World Technology Award in Materials, the Eurel Prize of the European Society of Electrical Engineers, the Paul Karrer Gold Medal, the Gutenberg Research Prize, the Balzan Prize, the Galvani Medal, the Faraday Medal awarded by the Royal British Society, the Harvey Prize, the Galileo Galilei Prize, the ENI-Italgas Award, the Leonardo da Vinci Medal. And finally, the most prestigious, the European Grand Prize of Innovation, the Albert Einstein World of Science, the Marcel Benoist Prize, considered the Swiss Nobel, the Millennium Technology Grand Prize, and only a few days ago the Global Energy Prize. And these, besides his several candidatures to the Nobel Prize in Chemistry.

As other indicator of its impact in world science, Michael Grätzel has been appointed as member of the editorial boards of the leading scientific journals in the field, such as Langmuir, Angewandte Chemie, Advanced Functional Materials, Nanostructured Materials or Chemical Physics Letters among many others, and has been elected member of the Swiss Chemical Society, of the German Academy of Science (Leopoldina), of the European Academy of Science, and Honorary member of the Royal Society of Chemistry, the Max Planck Institute and the Bulgarian Academy of Science.

If a scientist is someone who unravels hidden laws in Nature, Michael Graetzel is one of the greatest, having been selected by Scientific American as one of the 50 best scientists in the world. If an engineer uses such mechanisms to design new products and processes that improve our quality of life and sustainability of our planet, Prof. Graetzel has proven himself to be one of the best. But even more important, like most geniuses, Michael Graetzel is an affordable person, generous, close, and always ready to help. Not in vain the number of those who admire and love him is measured in hundreds.

I am, we are, completely sure that his appointment as new Honorary member of our Academician will enlarge the many existing professional and personal relations between him and several of our members, will improve the links in science and engineering between Switzerland and Spain and will contribute to the better knowledge and recognition of our Academy. It is therefore a privilege and an honor for the Royal Academy of Engineering of Spain to receive Michael Graetzel as Honorary member and, frankly, I hope that, from now on, Michael will consider this building and what it represents as his home. Be very welcome!