Michael Grätzel

Professor at the École Polytechnique Fédérale de Lausanne (EPFL), Head of the Laboratoire de photonique et interfaces (LPI)

2009 Balzan Prize for the Science of New Materials

For his many contributions to the Science of New Materials, and in particular for his invention and development of a new type of photovoltaic solar cell, the Dye Sensitized Cell, commonly known as the Grätzel Cell.

Institution Administering Research Funds:
École Polytechnique Fédérale de Lausanne (EPFL)

Adviser for the Balzan General Prize Committee: Nicola Cabibbo †

Improving the Performance of the Dye Sensitized Solar Cell (DSC)

The overall goal of the Balzan research project proposed by Professor Michael Grätzel is to improve the performance of the Dye Sensitized Cell (DSC), commonly known as the Grätzel Cell. An increase in the overall efficiency of this kind of photovoltaic cell from its present 12.3 to nearly 15 percent is predicted, which would strongly contribute to making the DSC a widely used method for electricity production from sunlight.

With the second half of the 2009 Balzan Prize for the Science of New Materials, the Laboratory of Photonics and Interfaces at the École Polytechnique Fédérale de Lausanne (EPFL), directed by Michael Grätzel, acquired an Atomic Layer Deposition System for the Laboratory and hired Dr. Aswani Yella as a postdoctoral fellow for two years. Aswani Yella finished her thesis with Professor Wolfgang Tremel at the Johannes Gutenberg-Universität Mainz in Germany. A sum has also been set aside to support visits of students and researchers from Italian universities within a framework of collaboration on the research project.

Adopting an experimental approach to the design of the Grätzel Cell, the Balzan research project has focused its attention on the interface that separates the materials used in the device for transporting the negative charge carriers (electrons) and positive charge carriers (called holes). The electron transporting material is constituted by a network of very small titanium dioxide (TiO_2) particles whose size is in the nanometer range (a nanometer is one million times smaller than a millimeter), while the hole transporting medium is either an electrolyte or a solid p-type semiconductor. These electric charges are generated by dye molecules that are anchored as a monomolecular layer at the surface of the nanocrystalline TiO_2 film. Following excitation by sunlight, the dye molecules inject electrons in the TiO_2 particles and holes in the electrolyte or solid p-type conductor. In order to reach high conversion efficiencies with the solar cell, it is very important to collect these photo-generated charge carriers as electric current before they recombine. In order to achieve this goal, the charge carrier collection has to be significantly faster than their recombination. Contrary to conventional photovoltaic devices where electrons and holes are generated – and recombine – in the same semiconductor solid, in the Grätzel Cell their recombination has to take place across the interface that separates the electron transporting material from the hole transporting material. This offers the opportunity to retard the charge carrier recombination by judicious engineering of this interface.

The Balzan research project is exploring several new strategies to retard the interfacial charge carrier recombination rate. The dye molecule itself is a molecular insulator and hence should impair the electron-hole recombination on its own. However, the molecular dye layer formed by adsorption on the TiO_2 nano-particles is usually disordered, leaving part of the surface exposed to the electrolyte or hole conductor. Hence, research will be conducted to improve the self-assembly of the dye molecules in order to form more compact films at the surface. Thus, Grätzel's research group is modifying the chemical structure of the dye molecules to endow them with long alkyl chains enhancing their lateral attraction. This is expected to increase the packing of dye molecules retarding the unwanted interfacial recombination of negative and positive charge carriers. They are also attempting to use additives in the electrolyte that will promote the formation of dense monolayers of dye molecules. Finally, the atom layer deposition (ALD) system acquired with the second half of the Balzan Prize is a powerful tool to modify the titanium oxide surface by depositing a very thin overlayer of a semiconducting oxide in a contiguous and conformal manner. The goal here is to eliminate defects such as oxygen vacancies that are present at the nanocrystal surface. These defects, called electronic surface states, are known to accelerate the interfacial electron-hole recombination. Judicious engineering of the interface will retard the interfacial charge carrier recombination increasing the open circuit voltage and cell efficiency.

The work on introducing the ALD overlayers on the surface of the mesoscopic titania films to stop interfacial charge recombination was carried out by Aravind Kumar Chandiran. He is a very gifted graduate student from India, with previous experience in material science. Dr. Aswani Yella has now started to test the films prepared by Dr. Chandiran to realize gains in voltage output and overall efficiency as foreseen in the proposal.

Researchers:
Aravind Kumar Chandiran
Aswani Yella

Publications:

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