Artificial Photosynthesis, Following the Footsteps of Parsifal

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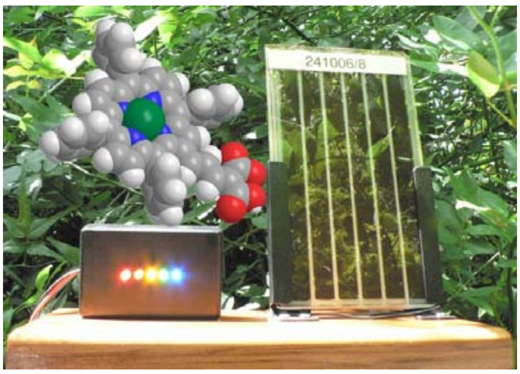
Photosynthesis, the foundation of almost all energy generation and transfer on the planet, tantalises us with one of the great scientific challenges or ‘Holy Grails’, the efficient and sustainable production of energy from the sun using renewable materials. The replication of photosynthetic processes in devices could not only provide a new generation of economical photovoltaic devices but also lay the foundation for sustainable hydrogen production as well as fuel and food production through carbon dioxide fixation.

In the dye-sensitised solar cell (DSSC) or Grätzel photoelectrochemical cell, light is harvested using a large surface area of dye (that may be a chlorophyll-like molecule) bound to a mesoporous thin film of nanostructured titanium dioxide. This has often been likened to the light harvesting component of photosynthesis. However, in the exquisitely structured photosynthetic light harvesting process, light is absorbed by a 3-dimensional non-covalent array of up to three hundred chlorophyll "dyes" that make up the light harvesting antenna, and the energy transferred to the "special pair" of bacteriochlorins in the Reaction Centre, within which charge separation occurs. In other words, in photosynthesis, the energy absorption and transfer, and charge separation processes are somewhat isolated from each other. This limits oxidation of the light harvesting dyes, as occurs in the Grätzel cell, and the bacteriochlorins that are oxidised in the reaction centre are sited close to the reducing species (thus allowing efficient water splitting). Consequently, recombination is minimised and destructive redox processes largely avoided, problems that beset the DSSC, significantly diminishing cell efficiency. Emulating the photosynthetic light harvesting structure in the titanium dioxide solar cell would offer the potential to improve cell efficiency both through enhanced light harvesting as well as control of the energy and electron transfer processes.

In this lecture, I will outline the oft-fraught journey to find the "Holy Grail" of artificial photosynthesis. I will present our achievements in porphyrin light harvesting in DSSCs and other photovoltaic devices as well as discuss aspects of our attempts to create new electromaterials for such devices.



A vision of the "Holy Grail", a porphyrin-based dye-sensitised solar cell