ADVANCED MATERIALS AND STRUCTURES FOR SOLAR FUELS

This focus issue of the Journal of Materials Research contains peer reviewed articles that were accepted in response to a call for manuscripts.

Introduction

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"For nature is not in a hurry and mankind is."
– Giacomo Luigi Ciamician

The world's hunger for energy is increasing, and there is no indication this trend will stop. The sun is the earth's primary energy source. After all, in the next few hundred years, mankind will exhaust all of the fossil fuels the sun has created over 4 billion years, while the sun itself will generate renewable solar power for another 4 billion years to come.

Solar energy as electricity from photovoltaic cells (PV) has become a commodity, and its share of the energy market is steadily growing,[1] challenging current electric grid technology. Cheap sunlight-generated energy undercuts the business models of utility companies that capitalize on high demand for electric power at peak daytime hours by with hydroelectric power plants.

Less than 20% of the world's energy consumption is in the form of electricity. In principle, this could be produced with solar PV. The other 80% of energy is produced via a variety of more expensive, limited, and problematic fuels: fossil fuel, nuclear fuel, biomass.[2] One can only imagine the global social impact possible if 80% of energy requirements were met using renewable solar fuels?[3]

In the 19th century, the consensus on photochemistry was that light acts as a catalyst. A paradigm shift occurred in the very early years of the 20th century when light itself began to be considered as a primary energy source.[4] Ciamician saw the significance of this paradigm shift 100 years ago in his article on the future of photochemistry published in *Science*[5]: *"On the arid lands there will spring up industrial colonies without smoke and without smokestacks; forests of glass tubes will extend over the plains and glass buildings will rise everywhere; inside of these will take place the photochemical processes that hitherto have been the guarded secret of the plants, but that will have been mastered by human industry which will know how to make them bear even more abundant fruit than nature, for nature is not in a hurry and mankind is. And if in a distant future the supply of coal becomes completely exhausted, civilization will not be checked by that, for life and civilization will continue as long as the sun shines!"*

Cast in the 21st century, we materials scientists are aware of the responsibilities and opportunities of our time, because, after all, the challenges are still the same.[6] In 2009, when the HELIOS project at Berkeley Lab became known to the public, we spanned the bridge from photocatalysis to photo electrochemical cells, which can produce solar hydrogen by water splitting.[7] A *Journal of Materials Research* Focus Issue was published, highlighting promising research avenues in the field of solar fuel generation,[8] and including a review paper that has become a PEC analysis standard work cited over 300 times.[9]

Since then, countless research groups on every continent have started their own work on solar water splitting, CO_2 reduction, artificial photosynthesis, and solar fuel research. New research centers have been built for that purpose, for example the Joint Center for Artificial Photosynthesis in California to name one of the largest. Meanwhile, a new branch of solar energy research is emerging which aims at producing fine chemicals by artificial photosynthesis. It seems the loop closes again and solar fuel research is not alone anymore at the forefront of solar research.

In the same period, it has become a growing interest to the Materials Research Society at large. With this Focus Issue in 2016, we decided to review this short golden age of solar fuel pioneering, specifically focusing on recent advancements in materials, components and devices. The traditional fields of materials synthesis and processing are

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covered here; moreover, the trend of making PEC components from complex heterostructure photo- and nano-architectures is reflected.

Now, with all necessary materials and components readily available, the time is ripe that PEC devices and reactors should be featured in publications, and to the general public, in the interest of how tax money has been spent and a perspective on future investment opportunities.[10] For the materials scientists working on solar energy storage, research and development then gain a higher leverage.

The Guest Editors are indebted to the many authors and peer reviewers who have made this Focus Issue possible.

ON THE COVER:

Zinc oxide semiconductor – imposing its hexagonal structure on a photoelectrode heterostructure.

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