ACCOUNTS
of chemical research

GUEST EDITORIAL

Organic Photovoltaics

Earlier this year marked the 40th anniversary of a feat that deeply struck the imagination of mankind. In July 1969, men safely landed and walked on the moon! The challenge put forward by President Kennedy in 1961 had been met within less than a decade. Nowadays, mankind faces a challenge with major implications for its future that will require an even greater level of dedication and technological breakthroughs than the race to the moon: the energy challenge. By most accounts, provided every inhabitant on our planet is able to enjoy the same level of energy resources as that available in the most developed countries, the energy needs by 2050 will reach some 45−60 TW, that is, will triple or quadruple with respect to the current needs. In addition, this increase will have to be met by clean, sustainable energy sources, because power generation relying on fossil fuels and linked to greenhouse-gas emission has to come to an end quickly. With sunlight bathing our planet with 120,000 TW, solar energy is bound to play a critical role in meeting the global energy challenge. Chemists must be part of the solution by creating new materials and new combinations of materials that can efficiently transform solar light into usable, storable power at low cost.

The photovoltaic effect represents the conversion of light into electrical power. It was first described over 150 years ago and can be traced back to Becquerel's pioneering studies on liquid electrolytes. It has since been investigated in a wide range of inorganic, organic, and hybrid materials. The development that transformed photovoltaics from a laboratory curiosity into a technology was the report by Chapin and co-workers in 1954 of a silicon-based single p−n junction device with a solar power conversion efficiency of 6%. Fifty-five years later, solar technologies remain dominated by wafer-size single-junction solar cells based on crystalline silicon and assembled into large area modules. However, other semiconductor materials and devices are under active evaluation in order to further reduce the cost of electricity production by increasing power conversion efficiency, reducing the amount and energy content of absorbing material, and lowering the assembly cost of modules. In particular, since the discovery of conductive polymers in the 1970s, which led to the Nobel Prize in Chemistry awarded to Heeger, MacDiarmid, and Shirakawa in 2000, the science and engineering of organic semiconducting materials have advanced rapidly, resulting in the emergence of the fields of organic electronics and photonics. Building on fundamental studies in the 1960s on the optical and electronic properties of model organic molecules such as oligoacenes and on the advent of high-purity small organic molecules that can be processed into thin films at room temperature using physical vapor deposition, Tang fabricated in 1986 single heterojunction organic photovoltaic cells with a power conversion efficiency of about 1%. Following this breakthrough, in the early 1990s, Grätzel and co-workers showed that the use of nanostructured metal oxide electrodes allowed the fabrication of dye-sensitized photoelectrochemical solar cells with promising device efficiencies. Moreover, the development in the 1990s of high-purity conjugated polymers allowed the fabrication of organic photovoltaic cells with materials simply processed from solution. These developments have led to the rapid growth of a new field of "organic" or "excitonic" solar cells, solar cells whose function is based upon light absorption by molecules to generate relatively localized excited states. The first examples of these technologies are already moving from the academic to the commercial arenas, while at the same time rapid progress is being made on the underlying scientific challenges to enable further advances in materials and device performance.

The possibility of processing organic electronic materials from solution at low temperature and organic small molecules from the vapor phase underlines a significant advantage of organic semiconductors over inor-

10.1021/ar900238j CCC: $71.50

ganic semiconductors. Indeed, it expands the range of substrates on which the semiconductors can be deposited to include flexible plastic substrates. This feature opens the way to applications and consumer products with lower cost, highly flexible form factors, and lighter weights. In addition, the ability that the chemists have to modulate nearly at will the physical properties of organic (macro)molecules by fine-tuning their chemical structure constitutes another driver that boosts research and industrial interest in organic photovoltaics.

The organics-based approaches do not rely on conventional single p−n junctions for their function but are based rather upon charge separation at a donor/acceptor interface. They include the types of solar cells on which the Accounts in this special issue focus, that is, the all-organic solid-state solar cells, the dye-sensitized cells, and hybrid technologies such as those based upon inorganic quantum dots blended into a semiconducting polymer matrix. The Accounts that follow highlight the complexity of the issues facing scientists and engineers involved in organic photovoltaics research and development. The various electronic and optical processes that eventually produce the transformation of sunlight into electricity are intertwined in such a way that their respective optimizations require opposing criteria to be fulfilled. Finding the optimum balance among these criteria is the name of the game in organic photovoltaics and will be achieved only via large-scale, multidisciplinary research, in which chemists have to play a central role.

Jean-Luc Bredas
Georgia Institute of Technology

James R. Durrant
Imperial College London
Guest Editors

AR900238J