Molecular design for highly efficient organic solar cells

Hiroshi Imahori[1]
[1] Department of Molecular Engineering, Graduate School of Engineering,
Kyoto University, Kyotodaigaku-katsura, Nishikyo-ku, Kyoto 615-8510, Japan
E-mail; imahori@scl.kyoto-u.ac.jp

Recently, ecological considerations linked with CO_2/global warming problem have prompted us to utilize photovoltaic solar energy. However, the present cost of electricity from silicon-based photovoltaics is much higher than the current commercial prices of electricity generated by hydraulic power and nuclear and fossil fuels. Therefore, it is necessary to develop low-cost solar cells with high power conversion efficiency (η). Organic solar cells would be promising candidates if they fulfil the requirements.[1] It should be noted here that they bear unique advantages over inorganic solar cells (*i.e.*, flexibility, lightness, and colorfulness). Since the beginning of the 1990s, substantial advances in power conversion efficiency have been made in molecular photovoltaics including dye-sensitized solar cells (up to η=7-11%) and bulk heterojunction solar cells (up to η=3-6%).

In this context, extensive efforts have been made in recent years to explore the photovoltaic and photoelectrochemical properties of electrodes modified with various donor and acceptor components toward the realization of highly efficient organic solar cells. In the design of organic solar cells we consider the following criteria: i) extensive light-harvesting in the visible region, ii) efficient energy transfer to an interface of heterojunction (if necessary) and subsequent charge separation, and iii) efficient injection of separated electron and hole into respective electrodes, minimizing undesirable charge recombination. Accordingly, it is of vital importance to select suitable donor and acceptor and organize the donor and acceptor on the electrode surface in nanometer scale for fulfilling the requirements.

In this talk, we will present versatile approaches to organize donor and acceptor molecules on electrodes. In particular, various donors and acceptors and their composites have been successfully deposited electrophoretically onto nanostructured SnO_2 and TiO_2 electrodes which exhibit photocurrent generation.[2-5] For instance, bottom-up self-organization of porphyrin and fullerene molecules onto the nanostructured SnO_2 electrodes has led to highly efficient photocurrent generation with an incident photon-to-current efficiency (IPCE) of up to ~60%. Cell performance with η=4.6% has also been obtained for the TiO_2 cell modified with *meso*-tetraphenylporphyrin with large steric hindrance around the porphyrin. Such examples will give a deep insight for the design of organic molecular electronics including solar cells, organic transistors, and light-emitting devices.

[1] *"Organic Photovoltaics"*, ed. S. S. Sun and R. S. Sariciftci, CRC: Boca Raton, 2005.
[2] H. Imahori, *Org. Biomol. Chem.* (Perspective), **2**, (2004) 1425.
[3] H. Imahori, *J. Phys. Chem. B* (Feature Article), **108**, (2004) 6130.
[4] H. Imahori and S. Fukuzumi, *Adv. Funct. Mater.* (Feature Article), **14**, (2004) 525.
[5] T. Hasobe, H. Imahori, P. V. Kamat, T. K. Ahn, S. K. Kim, D. Kim, A. Fujimoto, T. Hirakawa, and S. Fukuzumi, *J. Am. Chem. Soc.*, **127**, (2005) 1216.
[6] S. Kang, T. Umeyama, M. Ueda, Y. Matano, H. Hotta, K. Yoshida, S, Isoda, M. Shiro, and H. Imahori, *Adv. Mater.*, **18**, (2006) 2549.
[7] H. Imahori, *J. Mater. Chem.* (Future Article), **17**, (2007) 31.
[8] H. Imahori, *Bull. Chem. Soc. Jpn.* (Award Accounts), **80**, (2007), in press.