

NATURE INSPIRED WELL-DEFINED DISCOTIC LIQUID CRYSTAL PORPHYRYNS FOR ORGANIC PHOTOVOLTAICS: NEW OPPORTUNITY AND NEW CHALLENGE

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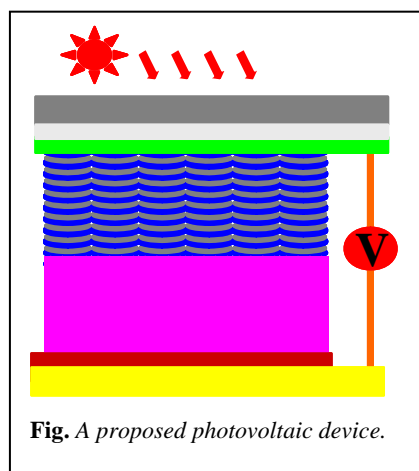
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The crystalline silicon photovoltaic cells, though efficient, appear too expensive to compete with primary fossil energy. The organic photovoltaic (OPV) technology would hold a promise for cost reduction since the OPV materials are potentially cheap, easy to process, and capable of being deposited on flexible substrates and bent while their inorganic competitors, e.g. crystalline silicon, would crack. However, currently widely used OPV materials, e.g. polycrystalline Cu phthalocyanine, suffer from the scattering of electron/exciton at the grain boundaries resulting in poor charge mobility. A challenge for OPV with the possibility of significant cost reduction is to make them in a desired macroscopic order to improve charge transportation.¹ One route to accomplish this goal is to induce liquid crystal (LC) phase in efficient OPV materials since LCs can respond easily to external stimuli and their alignment can be manipulated by external fields and surface effects. Among all LCs, the discotic LCs having superior absorption in solar energy bands as well as capable of being homeotropically aligned (i.e. the columns formed by intermolecular strong π - π self-assembly are perpendicular to the electrode surface) would be the desirable candidate to meet this challenge. Unfortunately, such discotic LCs are difficult to achieve their homeotropic alignment due to high viscosity although the alignment technology of rod-shaped LCs is well established in the Liquid Crystal Display industry. In order to make the discotic LC with more efficient absorption of sunlight, it is logical to use porphyrin as the building block of discotic materials since it is the basic structure of the best photoreceptor in nature, chlorophyll. Porphyrin and its derivatives have many desirable features such as highly conjugated disc plane, high stability,

efficient absorption of sunlight, and the small gap between the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) energy levels.²

Here I will present a new class of nanoscale discotic LC porphyrins, which can be exceptionally homeotropically aligned into a highly ordered nanostructure in which the columns formed by intermolecular π - π stacking are spontaneously perpendicular to the film substrate. The homeotropic alignment is important for photovoltaic applications since the favorable molecular arrangement can provide the most efficient path for holes and/or electrons along the columnar axis, and the light-harvesting molecules are arranged with the largest area toward the coming light. This work shows the essence of nanotechnology in which core issue is self-assembly due to the big conjugation system of



porphyrin together with the unique properties of liquid crystals. The results provide new insights on the development of organic photovoltaics by using homeotropically aligned crystalline thin films.

References

- [1] Basic Research Needs for Solar Energy Utilization. Report on the Basic Energy Sciences Workshop on Solar Energy Utilization, chaired by N.S. Lewis, G. Crabtree, April 18-21, 2005, Office of Science, DOE.
- [2] H. Eichhorn, *J. Porphyrins Phthalocyanines*, 2000, **4**, 88; B. A. Gregg, M. A. Fox, A. J. Bard, *J. Am. Chem. Soc.*, 1989, **111**, 3024; B. A. Gregg, *Mol. Cryst. Liq. Cryst.* 1994, **257**, 219.
- [3] L. Li, S. Kang, J. Harden, Q. Sun, X. Zhou, L. Dai, A. Jakli, S. Kumar, Q. Li, *Liquid Crystals*, 2008, **35**, 233; X. Zhou, S. Kang, S. Kumar, R. Kulkarni, S. Z. D. Cheng, Q. Li, *Chemistry of Materials*, 2008, **20**, 3551; Q. Sun, L. Dai, X. Zhou, L. Li, Q. Li, *Applied Physics Letters* 2007, **91**, 253505/1; S. Kang, Q. Li, B. D. Chapman, R. Pindak, J. O. Cross, L. Li, M. Nakata, S. Kumar, *Chemistry of Materials* 2007, **19**, 5657; "Photoconducting discotic liquid crystals", Q. Li, L. Li, Chapter 11, *Thermotropic Liquid Crystals*, A. Ramamoorthy Editor, Springer, 2007, ISBN: 978-1-4020-5327-6.