Organic Ferroelectronics in Liquid Crystalline Nanostructures

Department of Advanced Materials Science, Professor Masahiro Funahashi
Contact address: m-funa@eng.kagawa-u.ac.jp

In contrast to conventional solid-state electronic materials, we have paid attention to soft matter with optoelectronic functions constructing a new research filed of Soft Matter Electronics.[1,2] In nanostructures of liquid crystals and polymers, physical and chemical processes couple mutually to create new functional materials. For examples, liquid crystal molecules consisting of π-conjugated units and ionic moieties form nanosegregated structures in which electrons and ions can be transported separately, resulting in the interaction of the ionic conduction with the electronic carrier transport, resulting in the interstitial doping, anisotropic electronic conduction, and electrochromism.[3]

We synthesized π-conjugated liquid crystal compound **1** exhibiting ferroelectricity and photoconductivity (Figure 1(a)). In the ferroelectric phase, we first observed a bulk photovoltaic effect of which the driving force is the internal electric field. The polarity of this effect can be inverted by the change of that of the poling treatment.[4,5] The polarized state can be immobilized in the ordered phase to enhance the photovoltaic effect.[6] In the ferroelectric phase of compound **2**, the open circuit voltage exceeds 0.8 V in spite of the symmetrical device structure (Figure 1(b)).

Electroluminescence is also observed in the ferroelectric phase of compound **2**, due to the reduced carrier injection barriers by the internal electric field. The efficient light emission is possible in thick samples and chemically unstable cathodes are not required. From a uniaxially aligned sample, linearly polarized light is obtained and the polarized plane can be rotated in 90 degrees by the inversion of the DC bias polarity in the polling treatment (Figure 1(c)).[7]

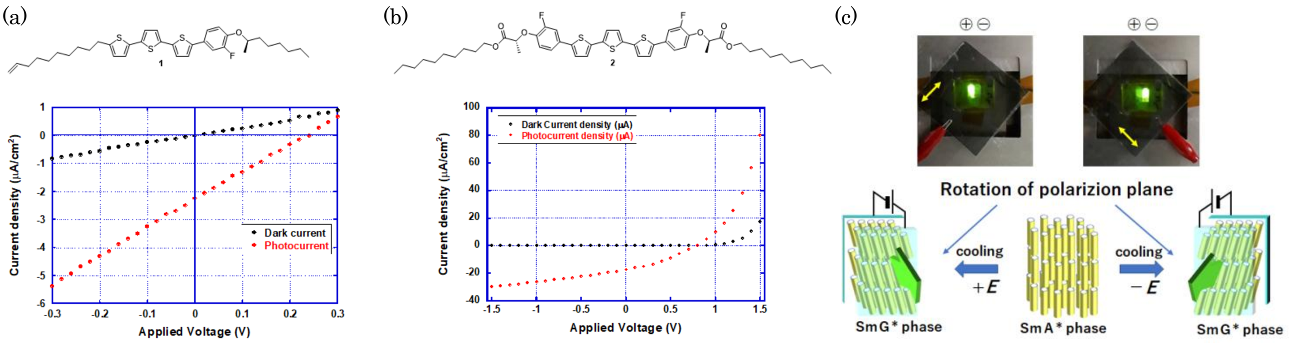

Figure 1 (a) J-V characteristics of the bulk photovoltaic effect in compounds **1** and **2** (b) Linearly polarized electroluminescence using compound **2** and rotation of the polarized plane.

Recent publications related to this topic

1. M. Funahashi, "Nanostructured Liquid-Crystalline Semiconductors - A New Approach to Soft Matter Electronics", *J. Mater. Chem. C*, **2**, 7451-7459 (2014).
2. T. Kato, M. Yoshio, T. Ichikawa, B. Soberats, H. Ohno, M. Funahashi, "Transport of ions and electrons in nanostructured liquid crystals", *Nature Reviews Materials*, **2**, 17001 (2017).
3. M. Funahashi, "Anisotropic electrical conductivity of n-doped thin films of polymerizable liquid-crystalline perylene bisimide bearing a triethylene oxide chain and cyclotetrasiloxane rings", *Mater. Chem. Front.*, **1**, 1137-1146 (2017).
4. Y. Funatsu, A. Sonoda, M. Funahashi, "Ferroelectric liquid-crystalline semiconductors based on a phenylterthiophene skeleton: Effect of introduction of oligosiloxane moieties and photovoltaic effect", *J. Mater. Chem. C*, **3**, 1982-1993 (2015).
5. A. Seki, Y. Funatsu, M. Funahashi, "Anomalous photovoltaic effect based on molecular chirality: Influence of enantiomeric purity on the photocurrent response in π-conjugated ferroelectric liquid crystals", *Phys. Chem. Chem. Phys.*, **19**, 16446 - 16455 (2017).
6. A. Seki, M. Funahashi, " Chiral photovoltaic effect in an ordered smectic phase of a phenylterthiophene derivative", *Org. Electr.*, **62**, 311-319 (2018).
7. M. Funahashi, Y. Mori, “Linearly polarized electroluminescence device in which the polarized plane can be rotated electrically using a chiral liquid crystalline semiconductor”, *to be submitted*.