

A Molecular Design towards a Highly Amphoteric and Polar Molecule (HAPM) to Assemble Novel Organic Solid-State Structures

Naoki Sato, Ikuo Kawamoto, Taro Sakuma and Hiroyuki Yoshida

A molecular design towards a highly amphoteric and polar molecules (HAPM) to fabricate a novel molecular assembly with notable electronic properties is proposed. This design stresses the combination of electron-donating and accepting segments with a pseudo-delocalized π -electron system. To examine the suggested contrivance, 2-(4-dicyanomethylenecyclohexa-2,5-dienylidene)-4,5-ethylenedithio-1,3-dithiole, **1**, was designed and synthesized as a test molecule. Results from semiempirical MO calculations and several kinds of experiments imply most characteristics expected for HAPM in principle.

Keywords: Amphoteric molecule/ Intramolecular charge transfer/ Intermolecular charge transfer/ Dipole moment/Molecular packing

A single molecule which works as both an electron donor (D) and an electron acceptor (A) is called an amphoteric molecule. The amphotericity is connected with, *e.g.*, a small energy gap between HOMO and LUMO and is noteworthy in organic materials science. Nevertheless, only a few studies to produce a highly amphoteric molecule have been reported so far, *e.g.*, an approach with tuning electronic levels of a polycyclic aromatic hydrocarbon (PAH) to stabilize its LUMO and also to destabilize its HOMO as demonstrated by pentaleno[1,2,3-*cd*:4,5,6-*c'd'*]diphenalene (PDPL), while they have not taken the control of molecular aggregation form into account as such a molecule has no peculiar clue for intermolecular interaction.

Here we propose another approach based on the combination of D and A segments with a pseudo-delocalized electron system to realize an amphoteric nature with controllability of molecular arrangements via charge transfer interactions leading to novel electronic

properties. A molecule thus-designed is expected to have a high polarity, however, is different from the conventional 'push-pull' type of molecules.

This molecular design of a highly amphoteric and polar molecule (HAPM) lays stress on the choice of a chemical link between D and A segments; this is influential to both intramolecular and intermolecular charge-transfer degrees [1]. When a non-conjugated bonding like a saturated hydrocarbon chain is applied, two segments are fixed at both ends with no through-bond interaction. Conversely, an intramolecular charge transfer will rigorously be induced to form nearly zwitterionic charge distribution in the molecule when an efficiently delocalized π -electron system such as a charge resonance one is employed; this could depress a controllability of molecular arrangements by a balance between intramolecular and intermolecular charge-transfer interactions.

Thus, a bonding system permitting a moderately high degree of π -electron delocalization is expected to keep

INTERFACE SCIENCE — Molecular Aggregates —

Scope of research

The research at this subdivision is devoted to correlation studies on structures and properties of both natural and artificial molecular aggregates from two main standpoints: photoelectric and dielectric properties. The electronic structure of organic thin films is studied using photoemission and inverse photoemission spectroscopies in connection with the former, and its results are applied to create novel molecular systems with characteristic electronic functions. The latter is concerned with heterogeneous structures in microcapsules, biopolymers, biological membranes and biological cells, and the nonlinearity in their dielectric properties is also studied in relation to molecular motions.



Professor
SATO, Naoki
(D Sc)



Associate Professor
ASAMI, Koji
(D Sc)



Instructor
KITA, Yasuo
(D Sc)



Instructor
YOSHIDA, Hiroyuki
(D Sc)

Students

SAKUMA, Taro (DC)
TSUTSUMI, Kiyohiko (DC)
TAKAHASHI, Ryo (MC)
YOKOI, Tomoko (MC)
OKAZAKI, Takashi (MC)

the electronic nature of each segment nearly unchanged, so that intermolecular charge-transfer interactions could further work in the condensed phase. Besides, not only electronic factor above but also steric one should be considered to choose the system to realize a variety of molecular packing manners. HAPM fulfilling these requirements may be crystallized with gross polarization due to molecular dipole moments arranged in the same direction if the resulting electrostatic instability is suppressed by the intermolecular interaction; such a specific structure could exhibit notable electronic properties.

With bearing these discussions in mind, to test the promise of HAPM by our approach the following molecule has been designed and synthesized: 2-(4-dicyanomethylenecyclohexa-2,5-dienylidene)-4,5-ethylenedithio-1,3-dithiole, **1**, by connecting a 4,5-ethylenedithio-1,3-dithiolydene group as D segment and a dicyanomethylene group as A segment with a quinoid structure, which is expected to show a possible heterovalent resonance through the electron conjugation resulting in a moderately high degree of intramolecular π -electron delocalization. This is largely predicted by semiempirical MO calculations.

The electronic absorption spectrum of **1** in a chloroform solution exhibits an intense band at $\lambda_{\max} = 670$ nm ($h\nu \approx 1.85$ eV) with the oscillator strength $f = 0.75$. Such a

large value can be understood by considering the intramolecular charge transfer to be enhanced by optical excitation; this is consistent with the calculated results of the dipole moments in the ground and excited states. It is notable that the λ_{\max} value is much larger than that calculated by the ZINDO/S method, 406 nm (3.05 eV), even if a possible influence by solvent is taken into account.

Cyclic voltammetry gives the difference between the first oxidation potential and the first reduction one, $\Delta_1 E$, which indicates the magnitude of electrochemical amphotericity. Although $\Delta_1 E = 1.615$ V for **1** is larger than that of PDPL (0.99 V), it is slightly smaller than that (1.65 V) of a derivative of bis[1,2,5]thiadiazolo-*p*-quinobis(1,3-dithiole) known as a single-component organic semiconductor with a remarkably narrow energy gap. It should be noted that it is much smaller than that of dibenzo[*cd,lm*]perylene (2.29 V), a PAH with a similar size to PDPL.

Thus, the above results can support feasibility of our molecular design towards HAPM, while aggregation forms of its test molecules are to be examined.

This work has been performed partly in cooperation with the late Professor E. A. Silinsh and Dr. A. J. Jurgis.

Reference

1. Sato N, Kawamoto I, Sakuma T, Silinsh E A and Jurgis A J, *Mol. Cryst. Liq. Cryst.*, **333**, 243 (1999).

Real-Time Monitoring of Cell Cycle Progression by Dielectric Spectroscopy

Koji Asami, Eugen Gheorghiu^{†1} and Takeshi Yonezawa^{†2}

A dielectric technique has been developed for monitoring of cell cycle progression in synchronized culture, which would be a promising tool for cell cycle analysis in cell biology and biotechnology.

Keywords: Dielectric relaxation/ Yeast/ Synchronized culture/ Septum formation/ Cdc mutant

Synchronized cell culture is an indispensable technique in cell cycle research. In order to assay synchronous cell growth, cells are sampled at a regular interval over a few cell cycles, and the changes in morphology and DNA content are examined by optical microscopy and flow cytometry, respectively. Unfortunately, the examinations are time-consuming and laborious task, and therefore alternative methods capable of real-time and in situ measurement become increasingly important for precise analysis of cell cycle progression and for screening mutants. Dielectric spectroscopy can be a most suitable method for this purpose because of the non-invasive and rapid measurement sensitive to the morphological and electrical properties of cells.

We have applied dielectric spectroscopy to real-time monitoring of cell cycle progression in synchronized yeast cell culture [1]. The dielectric monitoring is based on the electromagnetic induction method, regarded as a non-

electrode method, which has resolved the problems encountered in measurements with metal electrodes, namely, electrode polarization and bubble formation on electrodes. In the synchronized culture with temperature-sensitive cell division cycle mutants, the permittivity of the culture broth showed cyclic changes at low frequencies below 300 kHz. The increase and decrease in the cyclic permittivity changes correspond to the increase in cell length and bud size (S-phase to M-phase) and to the septum formation between mother and daughter cells (M-phase to G1-phase), respectively.

^{†1}NIB-UNESCO Center of Biodynamics, Calea Plevnei 46-48, 77102 Bucharest 1, Romania. ^{†2}Production Division I, Suntory, Shimamoto-cho, Osaka 618-0001.

Reference

1. Asami K, Gheorghiu E and Yonezawa T, *Biophysical J.*, **76**, 3345 (1999).