PRESS RELEASE

GIST Researchers Optimize the Performance of Novel Organic Electrochemical Transistors

Using poly(diketopyrrolopyrrole)-based polymers as active materials results in high charge carrier mobility and volumetric capacitance values

Organic electrochemical transistors (OECTs) are biocompatible, amplify ionic–electronic signals, and efficiently detect ions and molecules. To further improve their novelty, researchers from Gwangju Institute of Science and Technology developed and optimized OECTs based on poly(diketopyrrolopyrrole) (PDPP). They found that PDPP with four ethylene glycol side chains resulted in a remarkable figure-of-merit mobility–volumetric capacitance product value of over 800 F V^{-1} cm^{-1} s^{-1}.

Image title: Optimizing the Performance of Organic Electrochemical Transistors (OECTs)
Image caption: Molecular design and structural alignment to optimize the performance of OECTs produces a product of charge carrier mobility and volumetric capacitance equal to 702 F V^{-1} cm^{-1} s^{-1} through spin casting and 804 F V^{-1} cm^{-1} s^{-1} when fabricated using unidirectional floating film transfer method.
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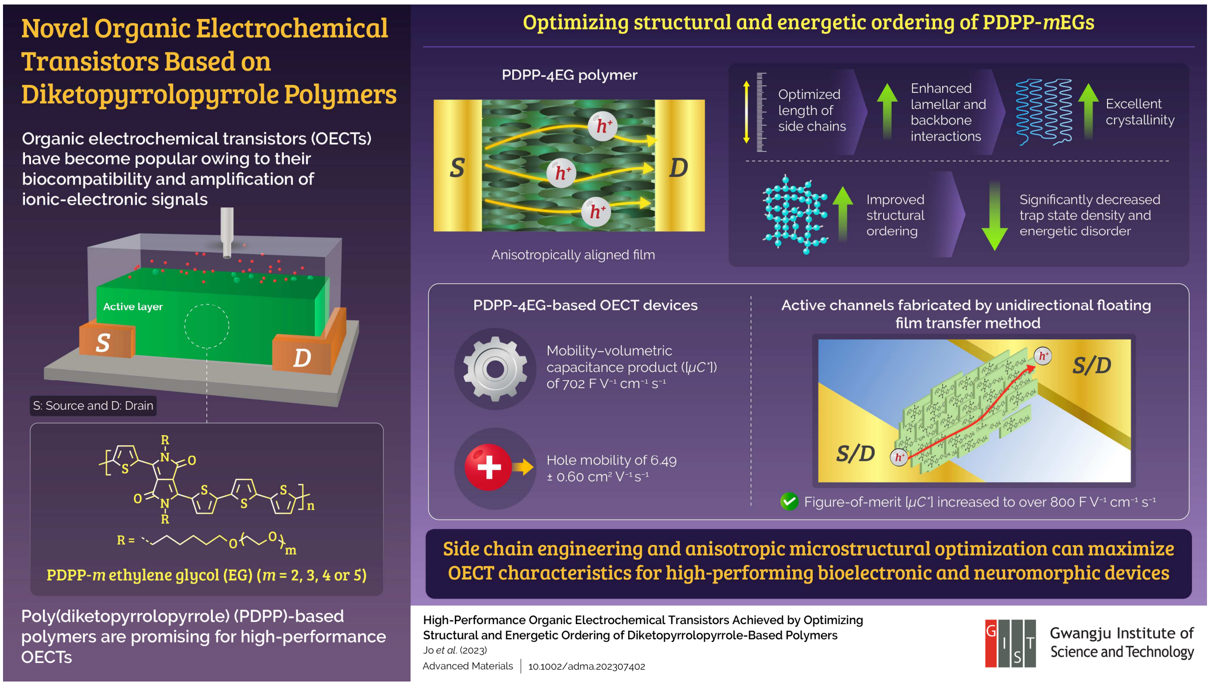

Organic electrochemical transistors (OECTs) have recently received a lot of interest and attention in the research community, not only for their biocompatibility but also for other novel characteristics like the amplification of ionic–electronic signals and the detection of ions and molecules. To achieve these characteristics, semiconductors comprising OECTs must be able to transport both ions and electrons efficiently. Conjugated materials grafted with hydrophilic glycol chains have shown the desirable levels of efficiency, while also being soft and allowing ions to permeate through their surfaces. However, they exhibit imperfect semicrystalline characteristics and disordered fractions when converted into solid films.

The steady-state performance of OECTs can be optimized by using both molecular design and structural alignment together to reduce the energetic and microstructural disorders in the films. With this forethought, a group of researchers led by Professor Myung-Han Yoon from Gwangju Institute of Science and Technology, Korea, has recently undertaken a study to create high-performance OECT devices based on poly(diketopyrrolopyrrole) (PDPP)-type polymers as active layers. They modulated the number of repeating units of ethylene glycol (EG) side chains in PDPP from two to five and chose the figure-of-merit as the product of the charge carrier mobility and the volumetric capacitance. Their study was made available online in *Advanced Materials* on November 21, 2023.

Talking to us about the rationale behind conducting this study, Prof. Yoon says, *"Using mixed conductors in electrochemical transistors makes it difficult to expect significant performance improvements, even when applying conventional microstructure control processes. This is due to the strong intermolecular cohesion owing to the flexibility and hydrophilicity of the molecular structure side chains. Our new mixed conductor material solves this problem by introducing alkyl-EG hybrid side chain structure, which can provide appropriate hydrophobicity and structural stability to the molecule."*

In their study, ultraviolet-visible (UV-vis) absorption spectroscopy confirmed the formation of J-aggregates in the three, four, and five EG polymers. Moreover, cyclic voltammetry measurements demonstrated a gradual decrease in oxidation onset values with an increase in the number of EG polymers. Furthermore, since electrochemical impedance spectroscopy revealed similar volumetric capacitance values for all polymers in the present PDPP family, the researchers utilized charge carrier mobility to primarily distinguish their performance.

The OECT device based on PDPP-4EG fabricated via spin casting showed optimal performance — a figure-of-merit value of 702 F V^{-1} cm^{-1} s^{-1}, charge carrier mobility of 6.49 cm^2 V^{-1} s^{-1}, and a transconductance value of 137.1 S cm^{-1}. The subthreshold swing values were as low as 7.1 V dec^{-1}, and the number of interface trap states were only 1.3×10^{13} eV^{-1} cm^{-2}. Furthermore, PDPP-4EG also exhibited the lowest degree of energetic disorder and well-developed crystalline domains with the least microstructural disorder.

To optimize structural alignment along the OECT channel, the researchers utilized the unidirectional floating film transfer method (UFTM). The J-aggregates underwent unidirectional compression when the polymer film was added to a hydrophilic liquid. The UFTM PDPP-4EG film-based OECTs yielded a remarkable figure-of-merit value of over 800 F V^{-1} cm^{-1} s^{-1}.

Highlighting the long-term implications of this study, Prof. Yoon says, *"In the era of artificial intelligence, neuromorphic devices are expected to be developed. Organic mixed conductors are among the most promising materials in this field, with high potential for advancement. Our research forms a part of the efforts to overcome the low performance of organic materials."* In the long-term, the development of organic mixed conductors with high reliability can be applied to various fields such as next-generation wearable sensors, computers, and healthcare systems, thus contributing to the enhancement of human convenience.

We surely hope that the research and development on OECTs propels the world towards a brighter future!

Reference

Title of original paper:	High-Performance Organic Electrochemical Transistors Achieved by Optimizing Structural and Energetic Ordering of Diketopyrrolopyrrole-Based Polymers
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About the institute

The Gwangju Institute of Science and Technology (GIST) was founded in 1993 by the Korean government as a research-oriented graduate school to help ensure Korea's continued economic growth and prosperity by developing advanced science and technology with an emphasis on collaboration with the international community. Since that time, GIST has pioneered a highly regarded undergraduate science curriculum in 2010 that has become a model for other science universities in Korea. To learn more about GIST and its exciting opportunities for researchers and students alike, please visit: http://www.gist.ac.kr/.

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About the author

Prof. Myung-Han Yoon is a full Professor in the Department of Materials Science and Engineering at GIST (Gwangju Institute of Science and Technology). Before coming to GIST, he completed his postdoctoral training at Prof. Hongkun Park' lab at Harvard University. In 2006, Myung-Han Yoon received his Ph.D. in Materials Chemistry from Northwestern University. His group is developing bio interface integrated devices using organic and inorganic electronic materials for bioelectronic device technology. Prof. Yoon's group is also developing biodegradable composite materials for sustainable electronic devices.