

**Section of
Public Affairs**Hyo Jung Kim
Section Chief
(+82) 62-715-2061Nayeong Lee
Senior Administrator
(+82) 62-715-2062**Contact Person
for this Article**Professor Bong-Joong Kim
School of Material Science and Engineering
(+82) 62-715-2341**Release Date**

2019.12.26

Professor Bong-Joong Kim's joint research team develops nonvolatile organic memory material using reversible phase change in room temperature

- Gwangju Institute of Science and Technology (GIST, President Kiseon Kim) School of Material Science and Engineering Professor Bong-Joong Kim (corresponding author) and Professor Kwanghee Lee (joint corresponding author) have for the first time in the world brought about 100,000 times more resistance change and thermal hysteresis * through the reversible phase of organic unity due to fine temperature changes in room temperature to develop the next generation of non-volatile organic memory materials.

* thermal hysteresis: a phenomenon in which a physical state, physical quantity is not determined by the physical conditions at that time but depends on the process of change of the state previously experienced by the substance

- In addition, the experimental results of both real-time grazing-incidence wide-angle x-ray scattering (GIWAXS) * and real-time transmission electron microscope ** observations with temperature changes are compared with the theoretical model using density functional theory ***. The correlation between single crystal structure, molecular rotation, and electrical properties was established and the nonvolatile memory mechanism was identified.

* in-situ grazing-incidence wide-angle x-ray scattering (GIWAXS): x-rays and neutron diffraction measurements that occur in crystal structures can be made highly sensitive to incoming x-rays or neutron beams by using small angle of incidence on the surface. This information is used to study the fine expansion, contraction, twisting, or rotational changes of molecular crystal structures.

** transmission electron microscope: a beam of electrons is transmitted through a specimen to form an image

*** density functional theory: It is one of the theories for calculating quantum mechanics and the shape of electrons in a substance or molecule. This allows us to predict which molecules can exist in the world and the shape and nature of certain molecules. It is one of the most widely used computations of quantum mechanics among computer-based scientific calculations.

□ Non-volatile organic memory materials are lightweight, transparent and flexible, making them a key material for next-generation electronics applications. Despite the importance of such nonvolatile organic memory materials, the development and commercialization of materials have been delayed because organic semiconductors have low charge mobility and no materials have rapid resistance change in room temperature (less than 30 degrees Celsius).

- Recent studies on the development of ferroelectric polymers * materials and devices development have been underway to implement nonvolatile organic memory, but the on/off ratio has shown a limit of ~ 100 due to the inability to obtain rapid resistance changes.

* ferroelectric polymers: polymers that maintain a polarizing effect without an electric field being applied from outside

□ In this study, in order to secure the high electrical characteristics of organic semiconductor, non-conductive additive polystyrene having different molecular weight is mixed with C8-BTBT (Benzothienobenzothiophene) material, a high-performance monomolecular organic semiconductor, to form a thin film. A single crystal rod was produced by solvent vapor phase heat treatment.

- X-ray photoelectron spectroscopy results showed stable C8-BTBT single crystals that reach equilibrium when the molecular weight of the polystyrene is very high. However, when the molecular weight is relatively small, the C8-BTBT molecules are slightly misaligned. It was found that metastable crystals were formed. The stable C8-BTBT single crystal showed no change in electrical properties with temperature, but the metastable C8-BTBT crystalline material decreased resistance by more than 100,000 times as the temperature dropped to -20 degrees from room temperature. It recovered to its original resistance, and this phenomenon was found to have very high reproducibility and to operate stably up to 20 volts.
- Although the crystal structure and molecular structure of the stable C8-BTBT single crystal through the GIWAXS measurement method and the transmission electron microscope analysis according to the real-time

temperature change do not vary with temperature, the metastable C8-BTBT crystalline material has a temperature of -20 degrees at room temperature. The crystal structure remained the same as it was, but the molecules changed from 9 degrees to -15 degrees. As a result, it can be seen that the electrical property change with temperature is due to the rotation of the C8-BTBT organic molecules. To verify this, the researchers calculated the charge mobility according to the rotational change of molecules by introducing the density functional theory. At that time, the orbital interactions * increased, indicating that the charge mobility increased.

* orbital interaction: phenomenon where the pi orbitals present in the organic semiconductor molecules interact with the pi orbitals of adjacent molecules to spatially expand or contract

- Professor Bong-Joong Kim said, "The latest findings are of the greatest significance as the first development of non-volatile organic memory materials that can be operated under room temperature and low voltage conditions, and this is expected to invigorate the development of transparent, flexible multi-function electronic systems or highly integrated non-volatile memory development in the future."

- This research was led by School of Material Science and Engineering Professor Bong-Joong Kim (corresponding author) and Professor Kwanghee Lee (joint corresponding author), School of Material Science and Engineering Dr. Min-Woo Kim, Research Institute for Solar and Sustainable Energies Dr. Sooncheol Kwan, and Pohang Accelerator Laboratory Researcher Jehan Kim and was supported by the National Research Foundation of Korea and their paper was published on December 20, 2019, and selected as the cover paper by *Small*, the world's leading journal in nanotechnology.

⌘