GIST presents efficient bioelectronic system design strategy

Electricity production through enzyme fuel cells, such as blood sugar measurement biosensors, is expected to be applied to enzyme-based material conversion

- Professor In Seop Chang's research team from the School of Environment and Energy Engineering presents a review paper that presents design guidelines and the latest protein engineering technology introduction methods necessary for enzyme-electrode system development

- "It will be a practical technology that can be used for monitoring biomarkers or environmentally hazardous substances, biofuel cells, and material biosynthesis" Published in the international academic journal 《Trends in Biotechnology》



▲ (From left) Professor In Seop Chang, Dr. Hyeryeong Lee, and Dr. Stacy Simai Reginald

Biosensors that detect and measure biological signals or substances generally interact with specific enzymes, antibodies, DNA, or RNA, such as biomolecules, to generate signals or detect changes.

A Korean research team has presented design guidelines for an 'enzyme-electrode system*' that is applied to electricity production through enzyme fuel cells or enzyme-based material conversion, such as a blood sugar measurement biosensor.

* enzyme-electrode system: A system that converts biomolecules into electrical signals or induces enzymatic reactions using electrical signals by combining the specific catalytic action of enzymes and the electrochemical properties of electrodes.

The Gwangju Institute of Science and Technology (GIST, President Kichul Lim) announced that a review paper by Professor In Seop Chang's research team in the School of Environment and Energy Engineering presented design guidelines for an 'enzyme-electrode system' and a method for introducing the latest protein engineering* technology to improve efficiency was published in 《Trends in Biotechnology》, a sister journal of the international academic journal 《Cell》.

* protein engineering: Engineering that creates proteins with new functions and their replacement polymers through genetic recombination based on knowledge of protein structure and function.

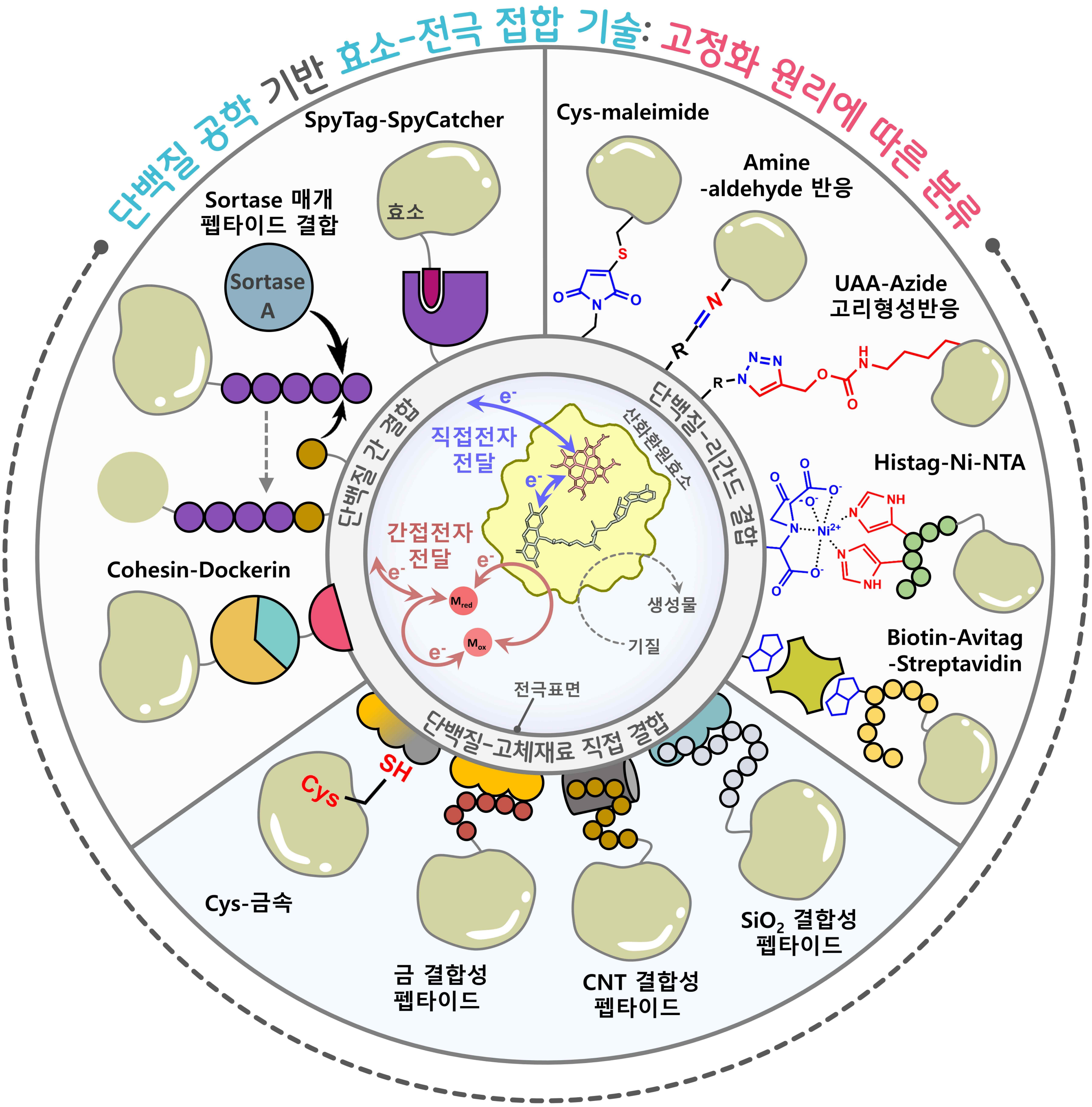
The ‘enzyme-electrode system’ that combines the specific catalytic action of enzymes and the electrochemical properties of electrodes converts biomolecules into electrical signals or induces enzymatic reactions with electrical signals. This is attracting attention as a key element of biomimetic technology for electricity production or material synthesis using enzymes.

The key factor that determines the performance of such an ‘enzyme-electrode system’ is efficient electron transfer at the interface between the enzyme and the electrode. Existing enzyme conjugation* strategies designed do not sufficiently consider protein structure, surface charge, and cofactor characteristics, and thus have limitations in maintaining the catalytic activity of the enzyme continuously and forming a precise interface between the enzyme cofactor and the electrode.

* enzyme wiring: A technology that attaches an enzyme to a specific support such as an electrode so that it can be used electrocatalytically

The research team compared and analyzed various enzyme-electrode interface conjugation technologies such as solid-binding peptide method, enzyme-mediated peptide conjugation method, and ligand interaction utilization method, and presented the latest protein engineering technology and introduction method that can improve the efficiency of the enzyme-electrode system according to the electron transfer mechanism.

The research team classified protein engineering-based enzyme-electrode bonding technology into the broad framework of ▴ protein-protein, ▴ protein-ligand, and ▴ protein-solid material interactions based on the principles of immobilization at the interface between enzymes and electrodes, and compared enzyme bonding methods that have been developed and mainly used in academia to date.



▲ Innovative protein engineering approach for enzyme-electrode junctions. Enzyme immobilization strategies based on protein engineering are classified into three types of interactions based on the principles at the enzyme-electrode interface: 1) protein-protein interactions utilizing the affinity of host-guest protein molecules; 2) protein-ligand interactions utilizing click chemistry between amino acid residues and ligands; and 3) protein-solid interactions directly binding to the electrode via solid-binding peptides.

In particular, it is expected to serve as a standard manual for the development and utilization of enzyme-based bioelectronic systems in the future by suggesting a design strategy for a highly efficient enzyme-electrode system through enzyme conjugation utilizing the latest protein engineering techniques.

The research team, which has focused on research to implement effective enzyme-electrode interfacial electron transfer by fusing biological protein engineering and non-biological electrochemical system elements, has achieved excellent research results by publishing more than 10 papers in SCI-level international academic journals related to ▲ enzyme-electrode conjugation utilizing solid-bonded peptides and ▲ various enzyme-electrode systems utilizing them ▲ and construction of a chain reaction-type enzyme-electrode system.

Professor In Seop Chang said, "This paper presents the design direction of enzyme-based bioelectronics by deeply discussing enzyme immobilization technology, which is an important technology for improving the interfacial electron transfer efficiency in enzyme-electrode systems, from the perspective of protein engineering. If the enzyme-electrode platform is further developed in the future, it will become a practical technology that can be used in various fields such as monitoring of biomarkers or environmental pollutants, biofuel cells, and material biosynthesis."

This study, led by Professor In Seop Chang (corresponding author) of the School of Environment and Energy Engineering at GIST and jointly conducted by graduate students of the lab, Dr. Hyeryeong Lee and Dr. Stacy Simai Reginald, was supported by the Basic Research Program (Mid-career Researcher) of the National Research Foundation of Korea and was published online in the international journal 《Trends in Biotechnology》 on December 14, 2024.

Meanwhile, co-first authors Dr. Hyeryeong Lee and Dr. Stacy Simai Reginald have been selected for the Postdoctoral Fellowship of the Marie Skłodowska-Curie Actions (MSCA) hosted by the European Commission. Dr. Hyeryeong Lee has been conducting research at the University of Cambridge in the UK since last year, and Dr. Stacy Simai Reginald has been conducting research at the Technical University of Munich in Germany from 2023.

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