Waseda University

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https://oyaizu.myportfolio.com/

Top-level research and data

Development of polymer energy carrier/device

1. "All-solid-state Rechargeable Air Batteries Using Dihydroxybenzoquinone and Its Polymer as the Negative Electrode", *Angew. Chem. Int. Ed.*, **62**, e202304366 (2023).
2. "Sandwich Configuration of Zinc Anode, Gel Electrolyte, and Radical Polymer Cathode for Fully Stretch-rechargeable Battery", *Adv. Sustain. Syst.*, **7**, 2300080 (2023).
3. "Quadruply Fused Aromatic Heterocycles toward 4 V-class Robust Organic Cathode-active Materials", *Batteries Supercaps*, **5**, e202200178 (2022).
4. "Designing Ultrahigh-refractive-index Amorphous Poly(phenylene sulfide)s Based on Dense Intermolecular Hydrogen-bond Networks", *Macromolecules*, **55**, 2252-2259 (2022).
5. "Catechol End-capped Poly(arylene sulfide) as a High-refractive-index "TiO_2/ZrO_2-Nanodispersible" Polymer", *ACS Applied Polym. Mater.*, **3**, 4495-4503 (2021).

Keyword

- **Polymer synthesis**
- **Functional polymer**
- **Organic electronics**
- **Electrical / optical properties**

Deployment targets (sites, materials, etc.)

Chemicals and materials manufacturers, printing/ink materials manufacturers, battery manufacturers, electronic device manufacturers, etc.

Features (implementation means, etc.)

My research focuses on on chemistry of organic/polymeric materials with energy storage functionalities and their device technologies. Examples include high-density flexible all-organic secondary batteries made of organic electrode-active materials and ion-conducting membranes, as well as hydrogen carrier polymers that reversibly store hydrogen. The focus in recent years has been on improving the performance of hydrogen carrier polymers. Dr. Oyaizu was the first to discover hydrogen carrier polymers (newspaper article on the right, first paper published in the sister journal of *Nature* (2016)), and he has obtained/maintained a university patent (JP6402102, hydrogen carriers, and hydrogen generation method). Dr. Oyaizu has not only promoted research from a fundamental aspect but also conducted commissioned and joint collaborative research with many companies, and he has attracted social interest through online articles and numerous newspaper articles about rechargeable all-polymer fuel cells and all-solid-state air secondary batteries.

The use of hydrogen carrier polymers was demonstrated to enable a pure hydrogen storage/production system based on water electrolysis, which cannot be achieved with other hydrogen carriers, and it maintains technological superiority as a new methodology. Regarding the dynamic behavior of multiple polymers whose hydrogen storage capacity has been clarified to date, investigating the electron/proton exchange reaction mechanism and acceptor-less oxidation reaction can enable the realization of a high hydrogen storage density that is almost half that of liquefied ammonia. The bottleneck, in this case, is in lowering the voltage for electrolytic hydrogenation, but clues such as controlling the potential through molecular design and reducing voltage loss using a single-compartment cell have been obtained, and the problem is expected to be solved by utilizing accumulated expertise.

October 2016
Nihon Keizai Shimbun

水素貯蔵プラスチック
早大 ガス状態経由せず安全

早稲田大学の西出宏之教授らは、安全に水素の貯蔵や運搬に使えるプラスチック材料を開発した。液体の水からプラスチックに水素を取り込む仕組みで、そのまま長期保存できる。重量あたりの水素の密度を高めるなど改良を加え、1年後にも試作品を公開したい考えだ。

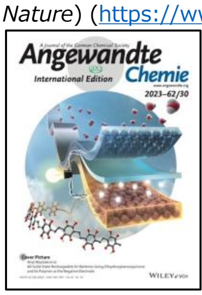
研究グループは、プラスチックのもとになるケトンポリマーを常温で水に浸してマイナス1・5ボルトの電圧をかけると、アルコールのポリマー上で水素が固定されることを見いだした。アルコールのポリマーをセ氏80度で温めると水素ガスを放出する。これにより水素の固定と放出を繰り返すことができる。

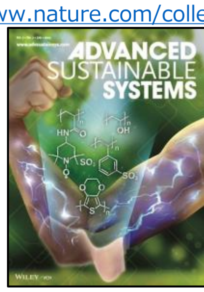
水素をガスの状態を経由せずに貯蔵できるので、水素を製造するときに爆発する危険も避けられる。プラスチック1キロに30リットルの水素を貯蔵でき、重量あたりの水素の割合は1・1%。

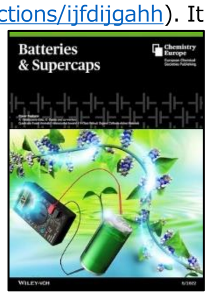
水素は爆発の危険が高く、従来は火気を避けて高圧ボンベなどで貯蔵したり運搬したりする必要があった。水素を吸収して貯蔵する吸蔵合金や、水素を多く含むアンモニアなどを利用する研究も進むが、繰り返し使える回数や揮発性などの問題がある。

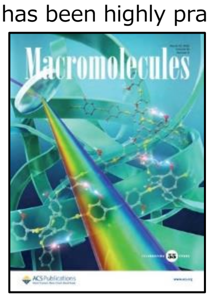
開発したプラスチックは高温高圧にする必要がなく、長期保存も可能なため、容易に水素の貯蔵や運搬が可能だ。「水素をエネルギー源のひとつとする社会が実現した際に、家庭などで安全に水素を貯蔵することもできる」（西出教授）という。

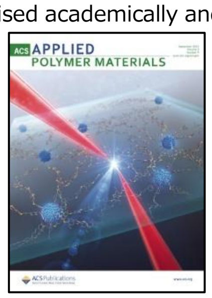
Dr. Oyanaizu's research results were selected as "One Year of Communications Materials" in the Communications Materials Collection (sister journal of *Nature*) (https://www.nature.com/collections/ijfdijgahh). It has been highly praised academically and has received international attention, such as being selected as the cover picture for numerous peer-reviewed journal including those by the American Chemical Society (recent representative papers 1–5, mentioned above from the left).











Associated proprietary technologies

Recent intellectual property list 2020-202115 : Cathode materials, power storage devices、2020-160171 : Resin composites
2020-160170 : Sulfur-containing polymer and its manufacturing methods; sulfur-containing polymer composites
2020-66681 : Polymer, electrode active material, and secondary battery

Expected outcome/ applications

New energy devices using polymers. Specifically, practical application of high-density hydrogen carrier polymer sheets, air cells, soft solar cells, etc.

Associated SDGs