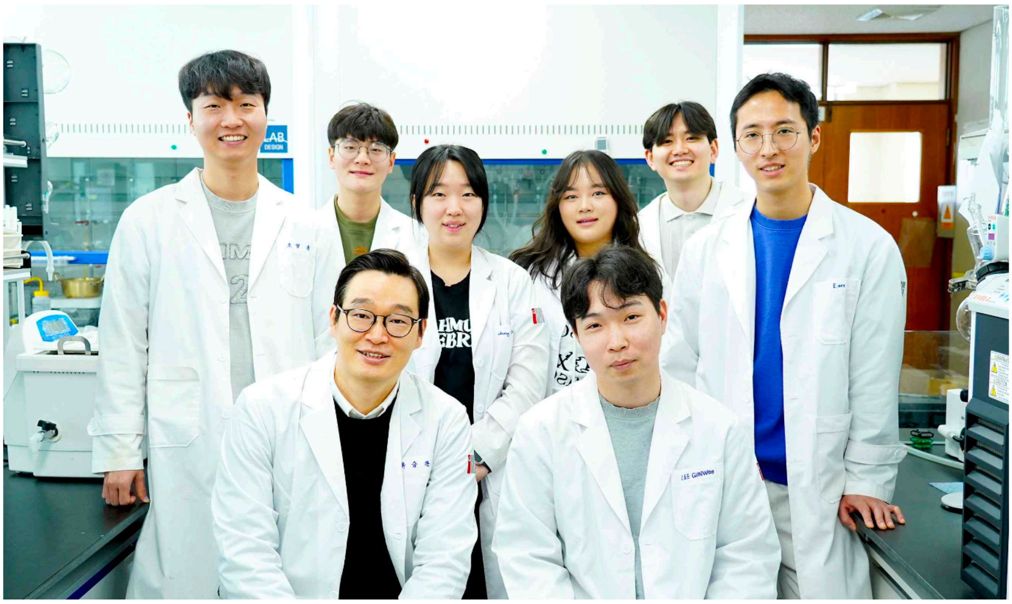
"Large-capacity and high-performance batteries without risk of explosion or fire are emerging" GIST develops next-generation electrolyte that takes only the strengths of aqueous and organic systems

- Professor Seung Joon Yoo's research team developed a high-performance zinc-bromine battery that solved both the problems of the cathode (generation of zinc dendrites) and the anode (self-discharge of bromine active material)... Expected to develop battery technology for large-sized and commercialized ESS
- Published in <EnergyStorageMaterials>, a top international academic journal in the field of materials engineering



▲ GIST School of Materials Science and Engineering Professor Seungjun Yoo's research team

Recently, as major construction companies have begun targeting new and renewable energy markets such as solar power, green hydrogen, and wind power generation, interest in energy storage devices* is growing to compensate for the unstable power supply and demand problem of new and renewable energy.

Among these, lithium-ion batteries, which are mainly used in small electronic devices, have a risk of ignition because they use flammable organic solvents, so 'aqueous electrolyte-based batteries' that replace organic solvents with water are attracting attention.

* energy storage system: A device that stores electricity produced by solar and wind power in large quantities and releases it when needed. It is essential for the expansion of new and renewable energy.

The Gwangju Institute of Science and Technology (GIST, President Kichul Lim) announced that Professor Seung Joon Yoo's research team in the School of Materials Science and Engineering has developed a 'non-flow zinc-bromine battery' with the world's highest level of performance and efficiency using a next-generation electrolyte that has the advantages of both aqueous and organic electrolytes.

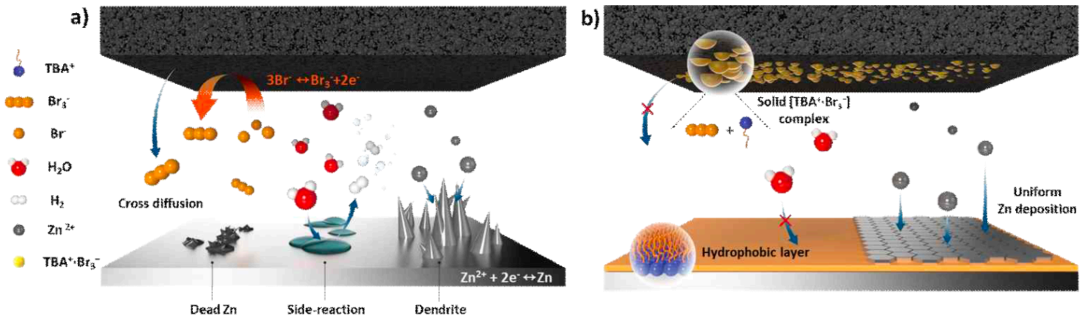
Among various water-based battery technologies, zinc-bromine batteries, which use zinc and bromine as active materials*, have high driving voltage and energy density and have been continuously developed since the 1970s. In particular, the 'no-flow zinc-bromine battery' has the advantage of securing price competitiveness through a simplified cell structure by eliminating the electrolyte storage and pump that are essential for driving existing redox flow zinc-bromine batteries.

* active material: An active material that produces electrical energy by chemically reacting at the anode and cathode of the battery.

On the other hand, zinc-bromine batteries have the fatal disadvantage of generating dendrites* and by-products from water decomposition reactions because the interfacial energy between zinc metal and aqueous electrolyte at the cathode is unstable. In addition, self-discharge occurs at the anode due to cross-diffusion of bromine*, resulting in low efficiency, making commercialization difficult.

* dendrite: A tree-shaped crystal that is formed when metal ions are electrodeposited on the surface of a metal electrode.

* self-discharge due to cross-diffusion: A phenomenon in which the battery's charging capacity spontaneously decreases as bromine dissolved in the anode electrolyte diffuses unwantedly to the cathode after charging.



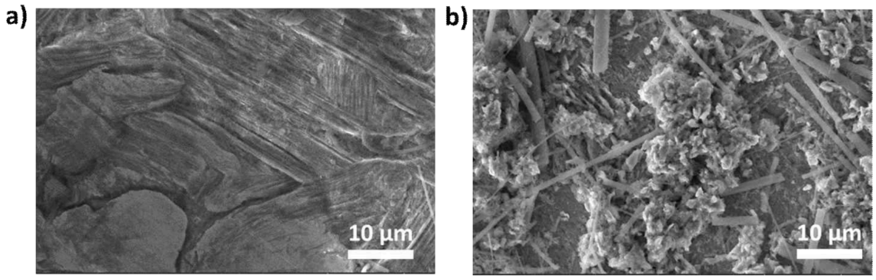
▲ Schematic diagram of a) the problems of aqueous electrolyte and b) the effect of using hydrated deep eutectic solvent electrolyte in a non-flow zinc-bromine battery: dendrite formation and cross-diffusion of bromine, which are problems with existing zinc-bromine batteries. The problem can be solved simultaneously with a hydrated deep eutectic solvent electrolyte.

The research team proposed and used a strategy to simultaneously solve the problems of the anode and cathode by using multifunctional 'bromine complexing agents', which can form solid complexes with bromine, suppress cross-diffusion, and block dendrite formation.

Until recently, its use was limited by the very low solubility of bromine complexing agents in zinc-based electrolytes. To solve the solubility problem, the research team developed a "hydrated deep eutectic solvent* electrolyte" that tripled the amount of zinc ions and optimized the water content to 30%.

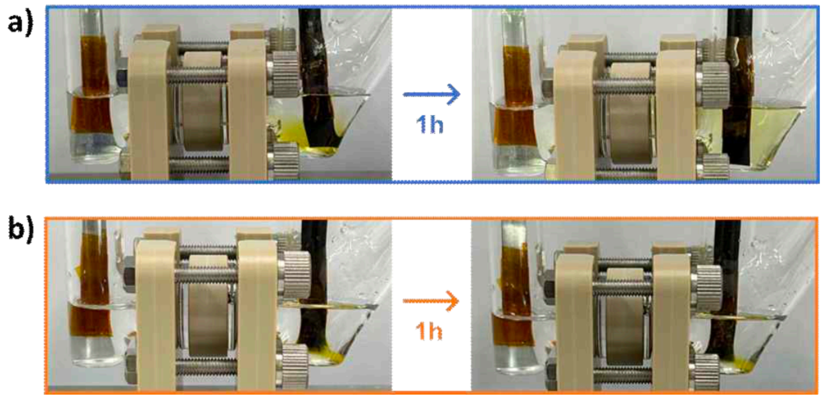
* hydrated deep eutectic solvent: A system in which water is added to a deep eutectic solvent that has a lower melting point than theory when two or more chemical substances are mixed in a specific ratio.

In the case of the cathode, the electrolyte developed in this study succeeded in suppressing dendrite formation by forming a hydrophobic protective layer that can prevent side reactions of water on the zinc metal surface.



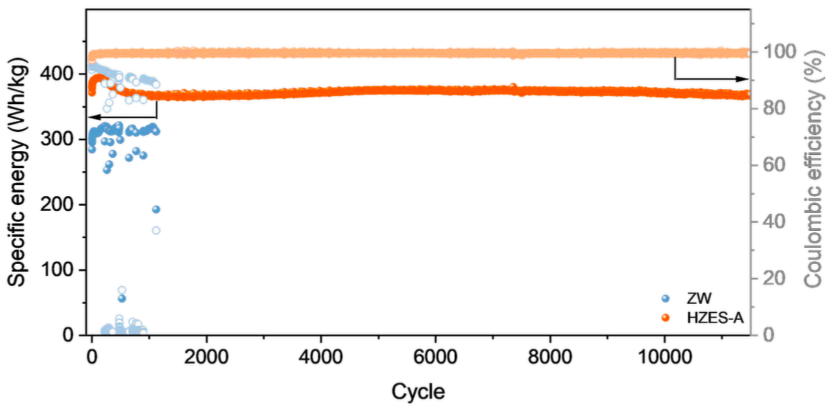
▲ SEM image of zinc metal after 50 cycles. a) Hydrated deep eutectic solvent electrolyte, b) Aqueous electrolyte: Dendrites were formed in the aqueous electrolyte (Figure 2b), but dendrite formation was suppressed in the hydrated deep eutectic solvent electrolyte (Figure 2a).

It was confirmed that cross-diffusion was suppressed through the phase change of bromine at the anode, and this succeeded in suppressing the self-discharge of the cell.



▲ H cell image 1 hour after charging completion. a) Aqueous electrolyte, b) Hydrated deep eutectic solvent electrolyte: In the aqueous electrolyte, the yellow bromine diffused to the opposite electrode. In a hydrated deep eutectic solvent electrolyte, it does not diffuse but appears clustered near the carbon electrode.

As a result, the research team succeeded in developing a next-generation zinc-bromine battery with high capacity (297 mAh/g) that can stably charge and discharge over 10,000 cycles.



▲ Comparison of cycle life performance of batteries using an aqueous electrolyte and a hydrated deep eutectic solvent electrolyte: In the aqueous electrolyte, cell operation became unstable after 1000 cycles. In hydrated deep eutectic solvent electrolytes, the cells operate reliably for over 10,000 cycles.

The new electrolyte developed by the research team ensures the stability and high efficiency of the battery, has high capacity and long-life charge and discharge performance, and eliminates the risk of explosion or fire. In addition, it is inexpensive and easy to manufacture, making it very suitable for large capacity. Therefore, it is expected that through commercialization, it will be used in energy storage devices in the future.

Professor Seung Joon Yoo said, "The next-generation electrolyte developed in this research maintains the advantages of existing aqueous electrolytes (eco-friendly, low cost, non-flammable) while maintaining low efficiency. By making up for shortcomings such as side reactions between metal electrodes and water, it is expected that it can be used as an electrolyte in various metal electrode-based batteries in the future. In addition, it will be helpful in developing battery technology for large-sized and commercialized ESS by taking advantage of the simple manufacturing process."

This research, led by Professor Seung Joon Yoo (corresponding author) of GIST's School of Materials Science and Engineering and conducted by master's student Younjee Lim and master's student Gunwoo Lee as co-first authors, was supported by the Ministry of Science and ICT, the National Research Foundation of Korea, and the Individual Basic Research Project and was published online on March 12, 2024, in ‘Energy Storage Materials’, a top journal in the materials science field (top 5% in JCR ranking, IF= 20.4).

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