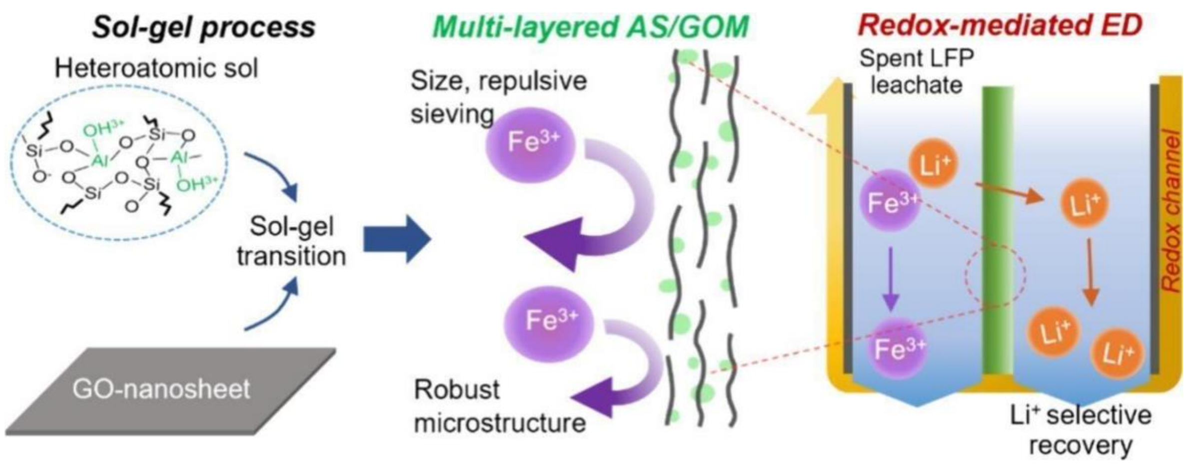
The Research Group of Professor Jongkook Hwang Developed a Novel Lithium Recovery Technology for Waste Batteries, Promising Environmental and Safety Solutions



A research group led by Professor Jongkook Hwang of Ajou University has achieved a breakthrough in the development of a high-performance lithium-ion exchange membrane that enables selective recovery of precious metals from spent batteries. This development addresses a critical need in the expanding electric vehicle sector, where technologies for waste battery processing and recovery are urgently required and show promise in contributing to environmentally sustainable, cost-effective approaches to battery waste resource utilization.

Professor Hwang's research team from the Department of Chemical Engineering at Ajou University, working in conjunction with Professor Choonsoo Kim's research group from the Department of Environmental Engineering at Kongju National University, has reported the development of a high-performance lithium-ion exchange membrane capable of selective recovery of valuable lithium ions from spent batteries.

The findings have been published in the December issue of *Desalination*, a prominent international journal, under the title "Swelling-resistant graphene oxide membranes reinforced by heteroatomic inorganic dots for electrochemical lithium recovery from aqueous solution."

The study was conducted under the joint correspondence of Professor Jongkook Hwang from the Department of Chemical Engineering at Ajou University and Professor Choonsoo Kim from the Department of Environmental Engineering at Kongju National University, with doctoral candidates Taenam Kim (Ajou University) and Hyunjin Kim (Kongju National University) contributing as co-first authors.

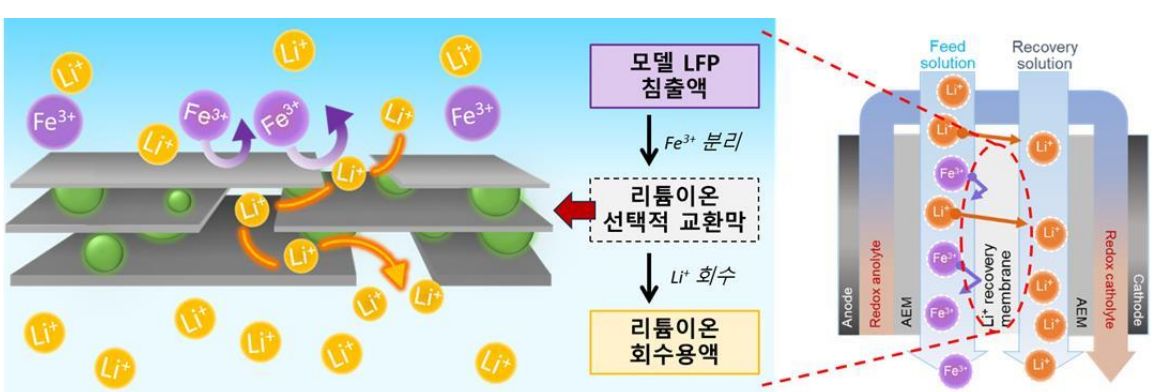
Lithium-ion batteries, a representative secondary battery, have achieved widespread implementation across various applications, ranging from consumer electronics such as smartphones, tablets, laptops, and wearable devices to electric and hybrid vehicles. With the recent growth of the electric vehicle market, a substantial increase in lithium-ion battery waste is anticipated. This situation calls for the development of both environmentally friendly and safe disposal methods, as well as resource recovery technologies capable of extracting lithium from battery cathode materials.

Current waste battery recycling technology employs hydrometallurgy, with a primary focus on high-value NCM (Nickel-Cobalt-Manganese) batteries. This is owing to the high economic efficiency of recovering and reusing lithium, nickel, cobalt, and manganese components. On the contrary, the more economical LFP (Lithium-Iron-Phosphate) batteries present limited utility value for non-lithium components, resulting in low cost-benefit ratio for recycling. This economic constraint has historically limited comprehensive research initiatives in this domain. Consequently, it has limited comprehensive research in this area. However, with the projected rapid growth in market share of affordable LFP batteries, the lack of proper recycling measures for spent LFP batteries could lead to severe environmental consequences within the next 5 to 10 years. This scenario underscores the urgency for developing advanced processing and resource recovery technologies for LFP waste batteries.

Recently, the electro-membrane separation process has garnered attention as a method for selectively separating and recovering lithium ions from waste batteries. This technology, which leverages electrochemical forces and was initially developed for lithium-ion extraction from brine solutions, demonstrates significant advantages over conventional refining processes in terms of reduced installation and operational costs while enabling selective high-concentration recovery of target ions. The ion exchange membrane represents a critical component in this process, with its performance characteristics determining the speed of lithium recovery and purity.

However, current polymer membranes employed in ion exchange applications have substantially low lithium recovery rates. Furthermore, they significantly decrease the lithium's purity as they can't effectively block the passage of multivalent ions such as nickel and iron contained in cathode materials of waste batteries. The highly acidic nature of waste battery leachate presents stability issues due to the oxidative degradation of polymer membranes during extended operational periods.

To address these limitations, the research team at Ajou University developed an innovative ion permeation channel that is larger than the size of lithium ion's hydrated ion (0.76 nanometers) to selectively separate only lithium ions from batteries, while suppressing the passage of other multivalent ions.



Structural diagram of the high-performance, highly stable graphene oxide ion exchange membrane developed through collaboration between Ajou University and Kongju National University research teams

This approach is promising for recovering valuable lithium ions from waste batteries and contributes to environmental sustainability.

The research team noted that despite graphite-derived graphene oxide membranes possessing ion permeation channels of approximately 1 nanometer and excellent chemical resistance, their utilization has been significantly limited due to hydration effects in water. Addressing this challenge, the team developed a HARD (heteroatom-reinforced dot) strategy, which leverages Electrostatic attraction to introduce silica-alumina (aluminosilicate) nanoparticles as cross-linking agents between layers of graphene oxide. The silica-alumina nanoparticles not only electrically neutralize the graphene oxide interlayers to precisely control ion permeation channel size at the 0.1-nanometer level but also significantly improve the structural stability of the ion exchange membrane. As a result, they were able to produce a graphene oxide-nanoparticle composite membrane with substantially improved stability and lithium-ion selectivity compared to conventional ion exchange membranes.

The Ajou University research team applied their newly developed highly stable, high-performance graphene oxide ion exchange membrane to an eco-friendly continuous electrodialysis system designed by the Kongju National University team to conduct lithium recovery experiments using LFP waste battery leachate. Through this, the joint research team achieved approximately 4 times faster lithium recovery rate and 95% lithium purity while using only 65% of the energy compared to previously reported electrochemical lithium recovery processes.

Professor Jongkook Hwang of Ajou University stated, "The significance of this research lies in securing the core technology to develop high-performance graphene oxide-nanoparticle composite membranes," and explained that "with the ability to control channel size at the 0.1-nanometer level, it can be applied to various separation processes including ion separation, hydrogen gas purification, and lithium-sulfur battery separators."

Professor Hwang added, "This research is a collaborative achievement between Ajou University's Department of Chemical Engineering and Kongju National University's Department of Environmental Engineering, analyzing waste battery resource utilization technology from multiple angles through interdisciplinary cooperation," and noted that "follow-up research on large-scale production methods for the composite membrane is required in the future."

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