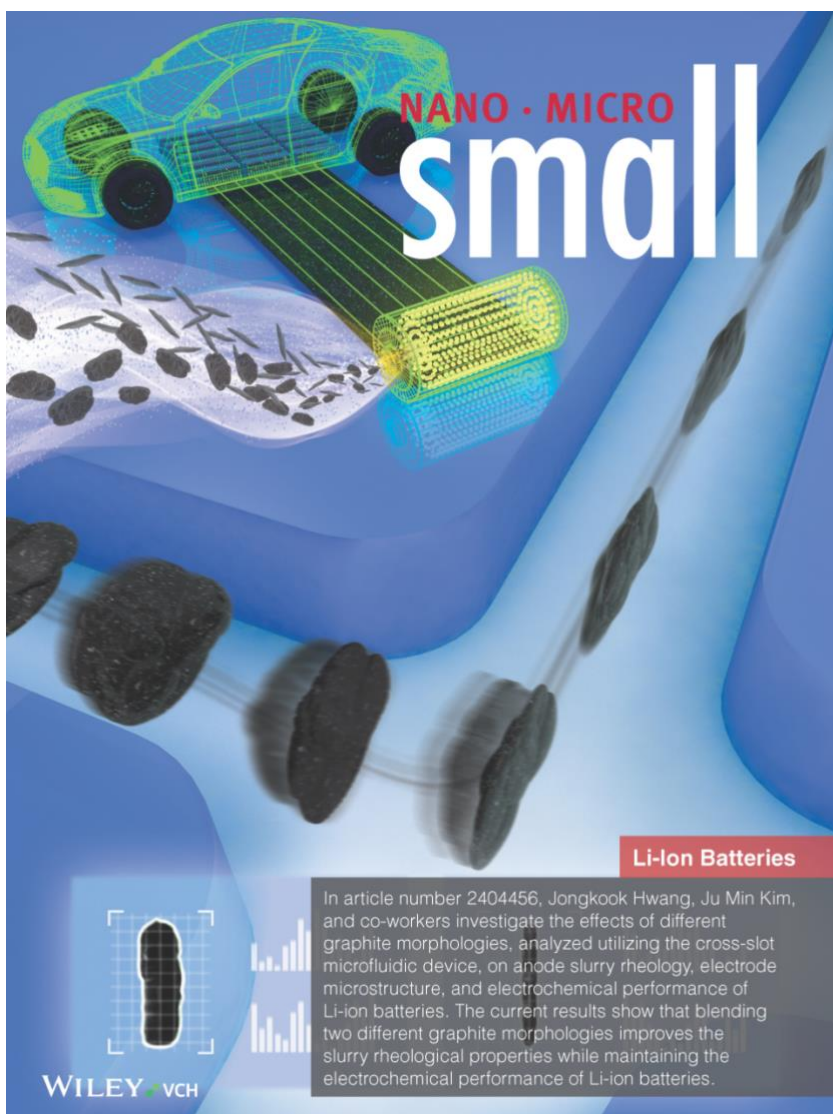


The Research Group of Professor Ju min Kim Developed a Precision Measurement Technology for Graphite Particles Utilizing Secondary Battery Materials



Researchers at Ajou University have developed a technology to precisely measure non-spherical graphite particles utilized as secondary battery materials using microfluidic channels. The innovation suggests that battery performance and yield can be enhanced through particle shape control, without complex chemical treatments.

The research team led by Professor Ju min Kim (Department of Chemical Engineering and Graduate Department of Energy Systems) and Professor Jongkook Hwang (Department of Chemical Engineering) announced they have developed a technology that quantitatively measures the morphology of non-spherical graphite active materials using cross-shaped microfluidic channels. Additionally, the team proposed an anode morphology composition that improves the stability of electrode slurry used in battery mass production processes while simultaneously satisfying battery charging and discharging characteristics.

The research was featured as the November frontispiece in *Small*, a prestigious international journal in nanoscience and materials science, titled "Microfluidic Shape Analysis of Non-spherical Graphite for Li-Ion Batteries via Viscoelastic Particle Focusing." The study was led by the research team at Ajou University, with collaborations from Seoul National University, Hankyong National University, and Georgia Institute of Technology. Professors Ju min Kim and Jongkook Hwang from Ajou University served as co-corresponding authors, with Ajou University master's student Jiin Park as the first author.

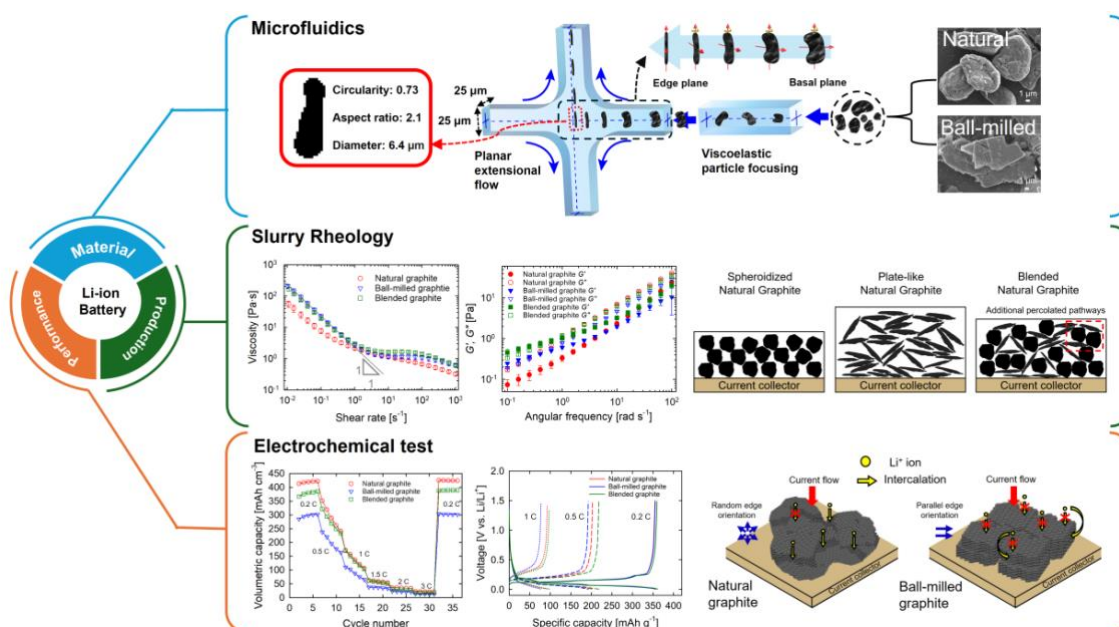
With the increasing demand for electric vehicles, lithium-ion batteries have emerged as a crucial energy storage medium. Both industry and academia are conducting extensive research to enhance battery performance, focusing on extending electric vehicle driving range and reducing charging time.

A lithium-ion battery primarily consists of an anode, a cathode, a separator, and an electrolyte. During the charging process, lithium ions and electrons migrate from the cathode to the anode to store energy. During discharge, they move from the anode to the cathode to release energy. The capacity and characteristics of the active materials used in the cathode and anode manufacturing have a direct influence on battery performance.

Graphite serves as the primary active material in anodes. Apart from the economic advantage of low unit cost, graphite has the benefits of having a low lithium-ion insertion/removal (de-/lithiation) voltage which increases battery energy density, and a relatively high theoretical capacity (372 mAh/g) that can stably accommodate large

amounts of lithium ions. Industry currently focuses on enhancing battery performance and cost-efficiency by mixing natural and artificial graphite and optimizing particle dimensions and shapes.

Consequently, it has become increasingly important to quantitatively measure and analyze graphite particle characteristics, especially the size and shape of edge planes. Since lithium ions enter between graphene layers through the lateral surfaces of graphite during battery charging (known as the staging effect), the morphology of these lateral surfaces inevitably plays a crucial role in determining the battery's charge–discharge performance.



Schematic describing the importance of quantitative shape measurement of graphite in lithium-ion battery research

However, traditional particle analysis methods have struggled with quantitative measurements of individual graphite particles. In particular, methods that rely on flat surface measurements, such as Scanning Electron Microscopy (SEM), cannot effectively observe the edge planes of non-spherical particles. This limitation has created a significant need for new measurement solutions specifically designed for non-spherical particles.

Against this backdrop, the Ajou University research team adapted microfluidic device technology, commonly used in biotech and pharmaceutical applications, to analyze non-spherical particle shapes. They conducted proof-of-concept experiments employing spherical natural graphite as the active material and ball-milled graphite with flat shapes as the control. The team analyzed individual particles using viscoelastic polymer solutions through viscoelastic particle focusing. Furthermore, using a cross-shaped channel, they induced rotation and alignment of graphite particles toward their lateral sides by utilizing a planar extensional flow field and compressive fluid flow generated within the channel, enabling observation of the lateral sides of non-spherical particles.

The research revealed that differences in graphite particle size and shape directly affect the rheological properties of battery anode slurries. Notably, they confirmed that graphite active materials approaching plate-like morphology exhibited stronger yield stress in anode slurries, maintaining slurry dispersion stability.

The rheological properties of graphite anode slurries reportedly vary with graphite size and morphology, and electrode processing can be optimized through slurry rheology control to reduce defects in electrode coating processes. Electrode coating is regarded as the most critical process affecting battery production yield. Thus, graphite edge plane morphology analysis is expected to simultaneously achieve enhanced battery charge–discharge performance and mass production capabilities. The team also discovered that different graphite shapes create varying electrode microstructures during slot-die coating processes. Through testing graphite anode half-cells, they proved these structural differences significantly impact battery energy density and charge–discharge performance.

Professor Ju min Kim of Ajou University explained, "The significant achievement lies in successfully applying microfluidic device technology, primarily used in biomedical and pharmaceutical fields, to lithium secondary battery research for measuring graphite particle edge morphology." He further elaborated, "Additionally, we were able to comprehensively evaluate the impact of graphite morphology, an aspect previously overlooked compared to electrochemical performance studies, on battery manufacturing processes and performance."

Professor Kim added, "Through quality control of graphite active materials used in lithium-ion batteries, it is expected to reduce defect occurrence rates in battery mass production processes and improve yields. Ultimately, this will serve as a cornerstone for research on higher battery performance."

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