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Editorial

Introduction: Manufacturing Science and Metrology Development

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Manufacturing science and metrology development is vital for producing complex, high-precision components required by modern technology. Rechargeable batteries based on lithium chemistry are indeed such components. With innovations in manufacturing, the typical ten step process of lithium ion battery production—1. Slurry mixing, 2. Coating, drying and calendaring, 3. Slitting of the electrode sheets, 4. Identification for traceability, 5. Stacking, 6. Foil-to-Tab welding, 7. Electrolyte filling, degassing and sealing, 8. Formation and aging, 9. Bonding of module and pack components, 10. Tab-to-busbar laser welding—can be done more efficiently and more reliably. Even before the manufacturing steps, measurements and qualifications of materials vendors require deep metrology development of the active materials, electrolytes, current collectors and any other parts of the battery to ensure the ultimate quality of the battery products.

At its core, metrology is ***the scientific study of measurement***. Metrology specialists (usually they are materials scientists or chemists) apply various characterization methods to confirm measurement standards in the field of manufacturing. Throughout the manufacturing process, vendors differ or change, and tools consistently wear down, causing parts to differentiate and produce flaws in final products. The practice of metrology lessens such risks and enables better yields in manufacturing. Metrology makes a significant difference in the accuracy and dependability of production. It is particularly essential for industries relying on crucial precision, like aerospace, battery and semiconductor sectors of manufacturing.

In this collection, we received seven contributions from authors who are leading the measurement science for various parts of a battery. From atomistic understanding to materials level characterization, to operando monitoring of a battery, scientists demonstrate the exciting progress in recent years: "Emerging Multimodal/Multiscale Characterization Techniques for Advanced Battery Development" by Zhao Liu et al. depicts the collaboration between industry and academic institutions to push the boundary between fundamental science and applied research. "From Ab Initio to Instrumentation: A Field Guide to Characterizing Multivalent Liquid Electrolytes" by Marshall, Schroeder, et al. gives a comprehensive framework where the "secret sources" of the battery, a.k.a. electrolytes, are deciphered, understood and measured quantitatively. Two papers on an advanced characterization toolset such as *in situ* transmission electron microscopy by Miaofang Chi et.al. and Haimei Zheng et.al. unravel both materials synthesis in the chemical environment, and materials behaviors *operando* in an electrochemical cell, respectively, giving insights otherwise difficult to observe and analyze. "Characterizing Electrode Materials and Interfaces in Solid-State Batteries" by Matthew T. McDowell et al. demonstrates the new insights about all solid-state batteries and the challenges presented by this next generation battery type. Another topic of next generation battery type "Lithium−Oxygen Battery", authored by Shao-Horn Yang et al., brings back a challenging topic—the oxygen reduction reaction (ORR) may be tackled with new theories and new scientific tools. Last but not least, "Advancing Battery Manufacturing: Synchrotron Characterization for Industry" by Kelsey Hatzell et al. showcases the power of synchrotron-based tools, such as computed tomography (CT) in combination with machine learning (ML) on data processing; such a toolset will no doubt accelerate domestic advanced battery manufacturing in years to come.

Through collaboration among universities, private companies and national laboratories, we are working as one team to enrich the science of measurements—either with photons, electrons or neutrons, opening a new chapter on how manufacturing science enters the center stage of our community.

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Notes

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Biography

Ying Shirley Meng is the Liew Family Professor at the Pritzker School of Molecular Engineering, University of Chicago. She serves as the faculty director for the Energy Technology Initiative for the Institute for Climate and Sustainable Growth (ICSG). Dr. Meng is the director of Energy Storage Research Alliance (ESRA), an innovation hub funded by Office of Science, US Department of Energy. Dr. Meng is the elected Fellow of Electrochemical Society, Materials Research Society and American Association for the Advancement of Science. Dr. Meng received several prestigious awards, including Shep Wolsky Battery Innovation Award (2025), Lifetime Achievement Award of NATTBatt (2025), ACS Research Excellence in Electrochemistry (2024), ECS Battery Division Research Award (2023), the C3E technology and innovation award (2022), the Faraday Medal of Royal Chemistry Society (2020), and International Battery Association IBA Research Award (2019). She has over 345 peer-reviewed publications and 12 issued patents.

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