Nanoscale Horizons

EDITORIAL

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Nanoscale Horizons Emerging Investigator Series: Dr Siwen Zhang, Liaoning University, China

Our Emerging Investigator Series features exceptional work by early-career nanoscience and nanotechnology researchers. Read Dr Siwen Zhang's Emerging Investigator Series article 'PVP pre-intercalation engineering combined with the V^{4+}/V^{5+} dual-valence modulation strategy for energy storage in aqueous zinc-ion batteries' (DOI: https://doi.org/10.1039/D5NH00236B) and read more about him in the interview below.

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Dr Siwen Zhang has been engaged in research on electrochemical energy storage, including supercapacitors and aqueous batteries. To date, he has published over 60 SCI-indexed papers in the field of electrochemical energy storage. Among these, he has authored more than 30 SCI papers as first author or corresponding author in internationally renowned journals such as *Advanced Materials*, *Angewandte Chemie International Edition*, *Energy & Environmental Science*, *Advanced Functional Materials*, *Energy Storage Materials*, *Nano Energy*, *Nano-Micro Letters*, *Journal of Materials Chemistry A*, and the *Chemical Engineering Journal*. His papers have been cited over 3000 times, with an H-index of 29. Additionally, four of his publications have been recognized as ESI Highly Cited Papers (top 1% worldwide), and one paper has been identified as an ESI Hot Paper (top 0.1% worldwide). He holds 5 authorized invention patents and has over 10 patent applications under review. In 2024, he was awarded the Second Prize of the Natural Science Academic Achievement Award of Shenyang City, among other honors. He has served as principal investigator or participant in more than 10 national and provincial-level projects. Additionally, he is a young editorial board member for six journals, including *Battery Energy* and *Carbon Neutralization*. He also acts as an independent reviewer for over 20 journals such as *Nature Communications*, *Advanced Materials*, *Advanced Energy Materials*, *Advanced Functional Materials*, and *InfoMat*.

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NH: Your recent Nanoscale Horizons Communication describes PVP pre-intercalation engineering combined with the V^{4+}/V^{5+} dual-valence modulation strategy for energy storage in aqueous zinc-ion batteries. How has your research evolved from your first article to this most recent article and where do you see your research going in future?

SZ: Our research journey has been a continuous exploration of overcoming the intrinsic challenges in aqueous zinc-ion batteries, particularly focusing on improving energy density, cycling stability, and rate performance. In our earliest work, we concentrated on understanding the fundamental electrochemical mechanisms of zinc-ion intercalation in layered cathode materials, emphasizing the structural stability during cycling.

Building upon this foundation, our recent communication in *Nanoscale Horizons* introduces a novel PVP pre-intercalation engineering strategy combined with V^{4+}/V^{5+} dual-valence modulation. This approach not only stabilizes the host structure by pre-embedding polymer molecules but also leverages the redox activity of high-valence vanadium states to enhance capacity and reversibility. The synergy between these modifications results in significantly improved electrochemical performance, highlighting the importance of interfacial and electronic structure engineering in aqueous systems. Looking forward, I envision my research expanding in three key directions: First, developing intelligent electrode architectures that can self-adapt to different charge states through dynamic interface engineering. Second, leveraging AI-driven material design to accelerate the discovery and optimization of novel electrode and electrolyte materials, unlocking unprecedented performance and facilitating the rapid translation of aqueous zinc-ion batteries from lab to market. Third, advancing our understanding of zinc-ion solvation chemistry to design next-generation electrolytes with extended temperature windows and enhanced safety profiles. Ultimately, I aim to bridge the gap between laboratory innovations and industrial applications, contributing to the development of truly practical aqueous zinc-ion batteries for grid-scale energy storage applications.

NH: How do you feel about Nanoscale Horizons as a place to publish research on this topic?

SZ: I consider *Nanoscale Horizons* to be an ideal platform for publishing cutting-edge research in the field of energy storage, including aqueous zinc-ion batteries. The journal's strong emphasis on nanoscale science and innovative materials aligns perfectly with the core of our work, which often involves nanoscale engineering and interface modulation to enhance battery performance. Moreover, *Nanoscale Horizons* values groundbreaking and high-impact studies that push the boundaries of current technologies, providing excellent visibility among both the nanoscience and broader energy storage communities.

NH: What aspect of your work are you most excited about at the moment?

SZ: Currently, I am most excited about our breakthroughs in dynamic interfacial engineering and the application of AI-driven material design to unlock unprecedented performance in aqueous zinc-ion batteries (AZIBs). These two fronts are converging to address long-standing challenges while opening pathways toward commercialization.

NH: In your opinion, what are the most important questions to be asked/answered in this field of research?

SZ: In my opinion, the most important questions in the field of aqueous zinc-ion batteries revolve around mastering the complex interfacial dynamics and accelerating material discovery. Specifically, understanding how dynamic interfacial engineering can be precisely controlled to suppress detrimental side reactions—such as zinc dendrite growth and electrolyte decomposition—is critical to achieving long-term stability and safety. Deciphering these interfacial phenomena at the nanoscale in real time remains a significant challenge. Simultaneously, leveraging AI-driven material design presents a transformative avenue to rapidly identify novel electrode materials and optimize their structures and compositions. The question here is how to effectively integrate computational tools with experimental feedback to build predictive models that can guide the rational design of next-generation AZIBs with unprecedented performance. Addressing these questions will not only deepen our fundamental understanding of electrochemical interfaces but also accelerate the translation of lab-scale innovations into commercially viable aqueous zinc-ion batteries, pushing the field toward real-world energy storage solutions.

NH: What do you find most challenging about your research?

SZ: One of the most challenging aspects of my research lies in unraveling and controlling the intricate interfacial processes that occur within aqueous zinc-ion batteries. These interfaces are highly dynamic and complex, involving simultaneous ion transport, redox reactions, and potential side reactions such as dendrite formation and electrolyte degradation. Achieving a deep mechanistic understanding of these processes, especially at the nanoscale and during real-time operation, requires advanced characterization techniques and careful experimental design. Moreover, balancing multiple performance parameters—including energy density, cycling stability, and rate capability—often involves trade-offs that can be difficult to optimize simultaneously. Integrating novel materials and strategies, such as polymer pre-intercalation and multi-valence modulation, adds further complexity but also opportunities. Finally, bridging the gap between fundamental nanoscale insights and scalable, practical applications challenges us to consider not only scientific factors but also engineering and cost-related constraints. Despite these challenges, these difficulties drive my motivation to push the boundaries of aqueous zinc-ion battery research.

NH: In which upcoming conferences or events may our readers meet you?

SZ: I look forward to participating in several upcoming conferences and workshops related to energy storage and nanomaterials throughout the year. These events provide valuable opportunities to share research progress and engage with the scientific community. While specific plans are still being finalized, I am always open to connecting with colleagues and readers at relevant gatherings in this field.

NH: How do you spend your spare time?

SZ: In my spare time, I enjoy activities that help me recharge and maintain a sense of balance outside of scientific research. I am passionate about hiking and exploring nature, which provides both inspiration and relaxation. I also like reading outside my field—as it broadens my perspective and sparks new ideas.

NH: Can you share one piece of career-related advice or wisdom with other early career scientists?

SZ: One piece of advice I would offer to early career scientists is to embrace curiosity and resilience in equal measure. Research often involves unexpected challenges and setbacks, but maintaining a genuine curiosity about your field will keep you motivated and open to new ideas. At the same time, resilience is essential to navigating obstacles and persisting through difficult times. I also encourage early career researchers to actively seek interdisciplinary collaborations and to communicate their work clearly to diverse audiences. These experiences not only broaden your scientific perspective but also enhance the impact of your research. Ultimately, staying passionate and adaptable will pave the way for a fulfilling and successful career in science.