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Introduction to the themed issue on liquid-based materials: novel concepts from fundamentals to applications

Xu Hou *[abc] and Jungmok Seo *[d]

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The preliminary research on liquid-based materials aims to transcend the limitations of traditional solid materials by leveraging the unique characteristics of liquids. These characteristics include rapid dynamic responsiveness, soft interfaces, and structural plasticity. Recent advancements in liquid-based material development focus on integrating various liquid materials—such as aqueous liquids, organic liquids, ionic liquids, and liquid metals—with different solid frameworks, including non-supporting, soft-supporting, and hard-supporting structures. This integration has led to the development of innovative technologies and materials like hydrogels, ionic liquid-based materials, liquid metal-based materials, liquid-infused surfaces, and liquid-based membranes. These advancements offer significant advantages, including adaptability, anti-fouling, anti-icing, anti-fogging, self-healing, defect-free surfaces, and high interfacial transport efficiency.

As research progresses, liquid-based materials are finding applications in various fields, from environmental protection to biomedicine, with their potential continuously being explored and expanded. In separation processes, the integration of functional liquids into porous membranes facilitates efficient molecular sieving and separation, which is extensively utilized in water treatment and gas separation. In sensor technology, liquid-based materials are employed to develop highly sensitive biosensors, which are crucial for medical diagnostics and environmental monitoring. Additionally,

[a] *State Key Laboratory of Physical Chemistry of Solid Surfaces, College of Chemistry and Chemical Engineering, Xiamen University, Xiamen 361005, China. E-mail: houx@xmu.edu.cn*
[b] *Department of Physics, Research Institute for Biomimetics and Soft Matter, Fujian Provincial Key Laboratory for Soft Functional Materials Research, Jiujiang Research Institute, College of Physical Science and Technology, Xiamen University, Xiamen 361005, China*
[c] *Innovation Laboratory for Sciences and Technologies of Energy Materials of Fujian Province (IKKEM), Xiamen 361102, China*
[d] *School of Electrical and Electronic Engineering, Yonsei University, Republic of Korea. E-mail: jungmok.seo@yonsei.ac.kr*

Xu Hou

Xu Hou is a Professor and the Director of Institute of Electrochemical Science and Engineering of Xiamen University and the Associate Director of the State Key Laboratory of Physical Chemistry of Solid Surfaces. He focuses on bioinspired smart porous systems, particularly in Liquid Gating Technology and Bioinspired Nanofluidic Iontronics. In 2020, his leading "liquid gating technology" was selected as one of the 2020 Top Ten Emerging Technologies in Chemistry by IUPAC. In 2024, he was elected as a Fellow of the Chinese Chemical Society and a Fellow of the Royal Society of Chemistry.

Jungmok Seo

Jungmok Seo is an associate professor in the School of Electrical and Electronic Engineering at Yonsei University. His research focuses on developing functional systems for biointegrative applications using a nature-inspired approach. He is currently working on bioelectronic devices based on liquid-based electronic materials to overcome existing limitations in solid-based bioelectronics, including longevity, infection, and immune-related side effects. In 2024, he received two Innovation Awards in the categories of Digital Health and Human Security at CES for his translational research on liquid-based materials and their product.

these materials show significant potential in energy conversion and storage, where optimizing interfaces and material properties can lead to more efficient energy utilization and storage.

Despite their exceptional performance, liquid-based materials face challenges, particularly regarding stability, which limits their long-term applications. Harsh environments such as high temperatures, pressures, or corrosive conditions can degrade their performance and lifespan. Additionally, the complex interactions at solid–liquid interfaces present challenges in optimizing these interfaces to enhance overall material performance. Therefore, continued efforts are necessary in molecular design and interface engineering. By integrating emerging concepts and methods such as artificial intelligence and big data, researchers can advance preparation theories and technologies, develop diverse soft and functional liquid materials, and further explore solid–liquid interactions for efficient coupling. Additionally, it is worth noting that this emerging interdisciplinary field of liquid-based materials has been developing rapidly in recent years, with the introduction of many new terms and concepts. These new concepts are often initially difficult for most people to accept due to differing perspectives and approaches stemming from various disciplinary backgrounds. Overcoming traditional thinking and encouraging the creation of comprehensive new terminology in this field will facilitate its rapid development. This is why we believe our thematic issue will make a significant contribution to this specialty. For example, the development of these materials has led to the emerging 'liquid gating technology' being recognized as one of the top ten emerging technologies of 2020 by the International Union of Pure and Applied Chemistry (IUPAC). Moreover, anti-fouling characteristics of liquid-based materials have received great attention in medical devices, leading to the development of liquid-infused endoscopic lenses. This research and its product were awarded two Innovation awards at the Consumer Electronics Show (CES) 2024 in the categories of Digital Health and Human Security.

We express our sincere appreciation to the guest contributors for their invaluable insights into liquid gating systems, liquid-based electronic materials, multi-component liquid-infused systems, and the regulation of hydrophilicity and hydrophobicity. We believe that the prospects for liquid-based materials are highly promising, with the potential to revolutionize intelligent applications across various domains. These domains include ecological environments, manufacturing technology, resource and energy management, agricultural science and technology, life sciences and healthcare, and aerospace technology. This encompasses substance detection, interface transport phenomena, energy conversion and storage mechanisms, advancements in microfluidics, and the development of artificial organs and wearable devices.

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