Membrane Technologies for recovery and separation of metal ions

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Recovery and separation of metal ions are essential for both pollution mitigation and resource reutilization. The research topic has recently attracted increasing attention in Taiwan because metal ions are widely used in several important industries, including manufacturing of semiconductors, batteries, electric motors and 3C (computer, communication, and consumer electronics) products. Surely, worldwide attention to rare earth metals has also enhanced the need for technologies for ion recovery and separation. In the presentation, three membrane-related processes for ion recovery and separation will be introduced, including ultrafiltration with ion precipitation, liquid membrane processes and nanofiltration.

For electroplating surface treatment (metal coatings) industries, ion precipitation is widely used to remove metal ions from wastewater. However, to effectively separate ion precipitates from water, addition of flocculants is usually needed and thus generates toxic sludge to be treated. To reduce the amount of toxic sludge, it has been proposed to separate the ion precipitates from wastewater by using ultrafiltration. However, decline in filtration flux, caused by the precipitates, limits the application of such a process. In the presentation, we will discuss how a MBR (membrane bioreactor) filtration scheme can help to solve the problem of flux decline, making the practical application of the process possible. Several examples of the application of the process to recover ions will be introduced.

Liquid membrane is a separation process combining extraction and stripping for recovery of ions. Though the technique has high separation selectivity for ions, its practical application is limited because of the difficulty in maintaining the long-term operation stability. One useful operation scheme to improve the stability of liquid membrane is the supported liquid membrane (SLM) process, in which hydrophobic porous membrane are introduced to stabilize the oil-water interface for extraction and stripping. The presentation focuses on the application of SLM to recover and separate rare earth metal ions. An interesting point to be discussed is the role of aquoions (metal-water complexes). We will show how the stability of aquoions can be used to efficiently separate rare earth metal ions and other trivalent impurity ions.

The last part of the presentation is related to the recovery of tetramethylammonium hydroxide (TMAH), a widely used chemical for lithography in semiconductor manufacturing. To reuse TMAH, separation of tetramethylammonium (TMA^+) and sodium (Na^+) ions are needed. However, the separation is challenging because both ions are monovalent and their sizes are similar. We will show how the separation can be achieved by properly tailoring the structure and surface charge of polyamide nanofiltration membranes. The results demonstrate that TMA^+, the larger cation, can be rejected mainly by size exclusion, while the permeation of Na^+ is regulated by the membrane surface charge. Overall, our study demonstrates that strategic tuning of membrane structure and surface charge provides an effective route for separation of two cations with the same charge.

Sustainable Advanced Materials and Technologies for Energy and Environmental Applications

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The growing need for sustainable solutions to address global energy and environmental challenges has accelerated the development of advanced materials and integrated technologies. This lecture presents a holistic perspective on the utilization of renewable and waste-derived resources for multifunctional applications in energy and environmental systems. Various material platforms, including biomass-based carbon, nanostructured materials, and membrane technologies, are discussed for their versatility in applications such as energy storage, water purification, and pollutant removal. The integration of innovative approaches, including nanotechnology, advanced separation processes, and oxidation-based treatments, further enhances system efficiency and performance. This work highlights the importance of bridging material development with practical applications, supporting circular economy principles and sustainable development. Overall, the lecture will provide insights into how advanced materials and hybrid technologies can contribute to resilient and environmentally responsible solutions for future energy and water systems.