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Ionic Liquids: Technology Integration and Function

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This special issue highlights current endeavors that employ ionic liquids in developing technologies. The interplay between *properties* and *application* underscores the historical development of ionic liquids over the past century and continues to be a driving force for onwards exploration. As new ionic liquids being synthesized, unique properties are discovered and then applied to new applications. The reverse is also true, where the stringent requirements of some applications force the discovery of new compounds. On the molecular level, the synthesis of ionic liquids containing conventional alkyl imidazolium, ammonium, and phosphonium cations have led to the development of task-specific cations with tailored functionalization or completely new organic cations or anions with ever increasing applicability.

The most salient features of ionic liquids are their low melting points, charged nature, and non-volatility. More broadly though, a liquid that is functionally non-volatile and displays excellent solubilizing properties is sufficiently unique in comparison with conventional solvents/liquids, which find niche applications. One early example was their use as molten electrolytes in the 1960s/1970s for use in batteries to replace conventional molten salts, which broadened the potential for these intriguing molecules beyond curiosities. A review in this special issue by Nakamura *et al.* presents an overview of the effect dielectric response of ionic liquids to distinguish them from common organic salts and the underlying reasons. Drawing upon a combination of theory and experimental data, they show that ionic liquids may be distinguished from conventional inorganic salts by their high dielectric responses and hydrogen bonding. Their use as tailored solvents became popularized over the past few decades and was broadened from small-molecule chemistry to applications in biopolymer processing. For example, an application-oriented review by Amarasekara *et al.* discusses the recent developments of ionic liquids in lignocellulosic biomass treatment. This includes depolymerization, biodiesel synthesis, and carbohydrate dehydration, among other chemical transformations. While ionic liquids do perform well, the practical challenges related to their high cost, toxicity, and recycling complexities leaves room for further exploration.

Applications of ionic liquids beyond their use as solvents or battery electrolytes harness their other features such as tailor-made quality, non-volatility, and binding to small-molecules of interest. Often the introduction of ionic liquid improves a technology by increasing the effectiveness of a given mechanism, thus leading to boosted performance. For example, Shaplov *et al.* provides some original work on the synthesis of silyl-functionalized ionic liquids and their incorporation within a polymer supported ionic liquid membrane (SILM) to determine their CO_2/N_2 permselectivities. The introduction of different atoms in the ionic liquid structure is an active research frontier with the potential to further broaden the property profile of ionic liquids for such applications. The SILM strategy seeks to compensate for the low melting point of ionic liquids, which makes their integration within functional devices problematic. The polymer itself does not fulfill any chemical function but instead acts as a support that can be impregnated with ionic liquid whose chemical properties dominate the function of the material. The functionalization of solid-supports is another approach to harness useful properties. Dedzo *et al.* presents a review on the improvement of kaolinite clay minerals by functionalization with ionic liquids to fabricate nanohybrid materials. Modification of clay with a variety of different organic cations has the potential to intercalate between clay sheets and improve dispersability or increase adsorptivity of small-molecules.

One significant development in applying ionic liquids in technology has been the conversion of ionic liquids from a small-molecule in to a macromolecule. Such polymers combine useful properties of ionic liquids with the mechanical stability of macromolecule. This significantly broadened the applicability of ionic liquids into new domains and helped attracting attention among engineers and polymer chemists. In particular, polymerized ionic liquids became a route towards the fabrication of highly tunable cationic polyelectrolytes and have found use in porous materials with high surface areas. In such cases, the material takes advantage of the adsorption and exchange properties of the constituent cationic units. Hesemann *et al.* have demonstrated a facile approach to generate porous ionosilica from aminomethylsilanes for chromate adosprtion. The combination of high-surface area and anion-exchange capabilities of the material led to impressively high amounts of chromate adsorption (up to 2.5 mmol/g). The

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ability to fabricate these materials on a large scale makes them particularly attractive for such anion-exchange applications. Yu and coworkers explored in an in depth review the use of ILs as a platform for CO_2 separation. They describe progress in selecting ILs that can either be supported in to membranes or used as building blocks to fabricate membranes that separate CO_2 from gas mixtures.

As guest editor, my colleagues and I have contributed our efforts in bridging ionic liquids with polymer science, batteries, and electrolytes. In one review, we describe the niche application of ionic liquids as monomers for photopolymerization. Light initiated polymerization methodologies provide a streamlined avenue for the preparation of electrolyte-containing polymer coatings and materials. This approach circumvents the innate difficulties in processing polymeric ionic liquids as melts and instead forms a crosslinked substance directly where it will be used. Materials fabricated using this approach can be used to create robust antibacterial coatings, gas separation membranes, patterns by photolithography, and even 3D printed materials. In another review in collaboration with Prof. Robert Dominko at the National Institute of Chemistry in Ljubliana, Prof. Patrik Johansson at Chalmers University, and Dr. Marian Stan at WWU Münster, we display the broad applicability of ionic liquids in lithium-sulphur batteries and discuss current trends and future outlook.

We hope that this special issue will help connecting disparate disciplines of chemistry and engineering in the years to come and facilitate further discussion. We also thank Prof. Ehud Keinan for his guidance and support and the authors for their contributions.

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Guest Editor

