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EDITORIAL

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Oxygen ionic and mixed conductors: recent developments

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To continue the publication of thematic issues and surveys highlighting the state-of-the-art developments in key areas of solid state electrochemistry, it is our pleasure to introduce this special issue focused on the transport, thermodynamic, and interfacial phenomena in oxygen ion-conducting solid electrolytes and mixed ionic-electronic conductors. In the future, a series of special issues and invited reviews is planning to expand in other important fields, particularly in batteries and fuel cell technologies. The increase in the cost of primary energy sources, such as hydrocarbon fuels, has created a demand for the development of a more efficient power generation and energy storage systems. The substantial commercial interest promoted the intense activity related to both technological and fundamental aspects. One important goal of the present and subsequent special issues is to introduce the reader to these areas of research and to provide a critical overview of novel experimental and theoretical achievements, problems, and trends. Although the scope of each issue is limited and there cannot be an exhaustive analysis of all developments related to a given field of solid state electrochemistry, the editorial team hopes that by drawing attention on the experience of many established groups in the electrochemical community, the newcomers will be inspired to pursue an interest in this rapidly developing science. Another aim relates to the discussion of critical factors determining industrial applications, future developments, and theoretical understanding of the electrochemical processes involving solid state.

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In this issue, emphasis is centered on the ion-conducting materials for solid oxide fuel cells (SOFCs), oxygen-separation membranes, membrane reactors for the conversion of natural gas, and interfacial processes in these electrochemical devices. Technologies based on the use of high-temperature electrochemical cells with oxygen ion-conducting solid electrolytes have important advantages with respect to conventional industrial processes. In particular, SOFCs are considered among most promising alternative power-generation systems due to high efficiency, fuel flexibility including the prospects to operate directly on natural gas and biogas, and environmental safety. The ceramic membrane technologies also provide potential economic and environmental benefits, particularly for liquefying gas fuels, electrocatalytic synthesis of methanol and various value-added chemicals, and production of high-purity gases. Applications of these technologies are expected to significantly decrease capital investments for gas-to-liquid plants and for distributed hydrogen, to increase energy efficiency of oxygen-based combustion processes, and to recover and to use remote gases that would otherwise be flared or reinjected. At the same time, practical use of the oxygen-ion and mixed conductors is limited, to a considerable extent, by the materials science- and electrochemistry-related problems. Many of these problems are addressed in the present issue, and in previous volumes of the Journal which has a tradition in this area of solid state electrochemistry. Since the foundation at 1997, a number of reviews, original research papers, and letters were systematically published with a particular target to cover most promising topics in the research on oxygen ion-conducting materials. One may note that in parallel with an overview of historical aspects [1, 2], substantial attention is permanently given to the studies of SOFC cathodes [3–11], various solid electrolytes and their derivatives [12–23], electrocatalytic processes [24], and mixed conducting ceramics [25–29]. Serious emphasis is also given to closely related fields, such as protonic conductors [30, 31] and redox and oxygen intercalation behavior of perovskite-related compounds in liquid media [32–36]. This clarifies the theme selection for the first issue composed of invited state-of-the-art works.

This issue consists of 18 papers contributed by scientists from 16 countries. As an introduction, the review by A. Petrov et al. analyzes phase relationships and transport in cobaltite-based solid solutions, the promising parent compounds of intermediate-temperature (IT) SOFC cathodes and oxygen-separation membranes. Consideration is also given to the oxygen nonstoichiometry and defect formation mechanisms, which are the subjects of numerous debates in literature up to now. The results collected by the authors during 30 years make it possible to predict the behavior of Co-containing mixed conductors in electrochemical cells, thus serving as an important tool in designing of materials performance. Another promising family of cathode and membrane materials, namely the systems based on Ruddlesden–Popper type lanthanum nickelates, are addressed in the comprehensive survey contributed by G. Amow and S. Skinner, who studied selected phase relationships, oxygen ion diffusion, and electrochemical properties of Ni-containing mixed conductors. The developments of new solid-electrolyte and cathode materials, electrochemical reaction mechanisms, mechanisms, and the results of reassessing known compositions in IT SOFCs, are discussed in contributions from Dalslet et al., Sansom et al., Abraham et al., Mebane and Liu, and Bronin et al.; the contribution by Chi et al. presents an electron microscopy study of $LaCrO_3$-based protective films assessed for potential applications in IT SOFCs. The remaining ten contributions are original research papers related to the ceramic membrane developments. Much of the research effort in this direction is focused on the selection of mixed-conducting materials, evaluation of the oxygen transport mechanism and stability, and studies of thermomechanical properties and kinetic demixing phenomena. Finally, having presented a brief overview of this special issue, the editorial team trusts that the readers may find the contents stimulating and interesting.

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