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High Temperature Electrochemistry Preface

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高温电化学专辑序言

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基于无机固体氧化物电解质的电化学过程可在发电、电解以及电化学合成等领域起到重要作用. 由于固体氧化物晶格中离子的迁移活化能高,这类电化学过程需要在高温下(400 ~ 800 ℃)进行,故一般称为高温电化学过程. 较之传统的电化学,高温电化学过程具有一些特别的优势:首先是动力学过程快,无需贵金属催化剂;其次,电解质中一般只有一种导电离子,目标产物选择性好,且涉及到的多数反应为气固两相催化反应,反应器结构简单,副产物少;此外,由于氧化物电解质一般具有稳定性好、电化学窗口宽等特点,高温电化学反应器可大电流、高电位下运行.

虽然固体氧化物电解质的导电离子种类多样,但近年来,基于氧离子导体和质子导体电解质的高温电化学及其相关应用发展特别迅速,其发展动力来源于当今世界对节能减排和大力发展可再生能源的迫切需求.

在发电方面,固体氧化物燃料电池(SOFC)展现出其高效和使用燃料范围广的优势,高温运行不仅可减少动力学过程损失,产生的高质量余热还可用于推动涡轮机发电,从而进一步提高电转化效率;其燃料除氢气外,来源广泛的碳氢化合物、甚至固体碳都可通过重整、或直接用作 SOFC 的燃料,使 SOFC 的运行成本降低. 这些优势使得 SOFC 有望在分布式电站和高效清洁地使用煤炭发电等领域得到广泛应用.

在电解方面,通过 SOFC 的逆过程构成的固体氧化物电解器(SOEC),可高效地电解水和二氧化碳,得到氢气、合成气和纯氧等产品,通过对水和二氧化碳进行共电解,还可直接生产甲烷. 与传统的电解技术相比,高温电解的效率可增加一倍,有望发展成大规模储能技术,助力可再生能源的高效利用.

随着人们对高温电化学过程的研究和认识逐步深入,目前已很难将相关过程仅仅划分到发电和电解范畴,越来越多的研究致力于利用高温电化学反应,同时实现发电和获得目标产物的目的. 例如,对含碳燃料进行部分电化学氧化实现气电联产,对乙烷进行电化学脱氢反应制乙烯并同时发电,等等. 这些新型高温电化学反应,为低能耗低污染地获得高价值化学品提供了新的选择途径.

作为一种实现化学能和电能相互转化的过程,高温电化学是在传统电化学基础上的拓展,但其涉及到的无机固体电解质相关的材料及反应机理与传统的基于液体电解质的电化学完全不同,迫切需要针对无机固体电解质中离子的快速传输机制、温场和电场的共同作用对电极催化剂表面电子态的影响、电极过程与电极结构及其周边环境的相互作用关系等,建立新的理论体系和方法,用于指导高性能材料和器件的研制和开发. 而这些新理论和新方法的建立,又依赖于当今应用需求引领的实验研究所积累的数据和经验.

本专辑搜集了国内高水平研究团队的 8 篇论文,内容涵盖了高温电化学的一些热门研究领域,包括单气室和直接碳固体氧化物燃料电池、水和二氧化碳的高温电解、通过质子导体电解质实现乙烷脱氢反应制乙烯、阳极燃料原位重整、阴极催化剂等,论文介绍了相关领域的基础知识和国内外研究现状,重点介绍了各团队的工作. 本专辑在一定程度上反映了我国在高温电化学领域的研究现状, 将为促进高温电化学领域的交流和发展、帮助初学者和其他领域的感兴趣者了解高温电化学领域、加速相关技术的产业化进程起到积极的作用.

最后,衷心感谢所有作者和审稿人的支持和付出,感谢编辑及相关工作人员的耐心细致和高度负责.

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High Temperature Electrochemistry Preface

The electrochemical process based on an inorganic solid oxide electrolyte is promising to play an important role in electricity generation, electrolysis, and electrochemical synthesis. Such a process is often called as high temperature electrochemical process because high temperature (400 ~ 800 ℃) is needed for the ions, strongly bonded with the lattice sites of the oxide electrolyte, to overcome the migration activation energy. Compared to conventional electrochemical process, high temperature electrochemical process has several advantages: First, its kinetic process is fast and it does not need any noble metal as catalyst. Second, the electrolyte is generally single ion conducting, leading to high selectivity of target product. Usually, only gas-solid catalytic reactions are involved, thus the reactor configuration is simple and there are few byproducts. At last, a high temperature electrochemical reactor can operate under large current and high potential because of good stability and wide electrochemical window of solid oxide electrolytes.

While there are many kinds of solid oxide electrolytes, conducting a variety of ions, the electrolytes conducting oxygen ions and protons are attracting special attention because their application may meet the urgent demands of the world for energy conservation and emission reduction as well as sustainable energy application.

Regarding to electricity generation, the solid oxide fuel cell (SOFC) performs well in terms of efficiency and fuel flexibility. Its high efficiency comes from high operating temperature which not only reduces activation loss but also enables high quality exhaust heat to run a turbine to generate more electricity. Except hydrogen, more readily available hydrocarbons and even solid carbon can be used as the fuels of SOFCs, resulting in reduced operating cost. These superiorities make SOFC a potential clean and efficient technology for distributing electrical power station and coal to electricity conversion.

Regarding to electrolysis, the solid oxide electrolysis cell (SOEC), operating in the reverse process of SOFC, can efficiently split water and carbon dioxide to produce hydrogen, syngas, and oxygen. It can also directly produce methane through co-electrolyzing water and carbon dioxide. The efficiency of high temperature electrolysis can be over twice of that of a conventional electrolysis technology. It is a promising technology for large scale energy storage which is essential to efficient application of sustainable energy.

With the development of high temperature electrochemistry, it is hard to classify all the areas only by electrical generation and electrolysis. There are increasing interests in applying high temperature electrochemical process in co-generation of electricity and value-added products. For instance, gas-electricity cogeneration through partial electrochemical oxidation of carbon-contained reactants and producing more valuable ethane by electrochemically dehydrogenation of ethane through a reactor with proton conducting electrolyte. These high temperature electrochemical reactions provide new pathways for producing chemical products with high energy efficiency and low pollution emissions.

Focusing on the interconversion between chemical energy and electrical power, high temperature electrochemistry is an expansion field of electrochemistry. However, its processing principles involving the inorganic solid electrolytes are rather different from those of conventional electrochemistry, which are mainly based on liquid electrolytes. Novel theoretical systems and methods should be built up for research to provide insight into fast transportation of ions in inorganic solid electrolytes, co-effects of temperature and electrical fields on the surface electronic states of electrode catalysts, and correlations between the electrode process and its microstructure, as well as the surroundings. While the new theories and methods are important for guiding developing high performance materials and devices, their establishment needs data accumulated from experimental research promoted by the urgent application demands.

Here, we have collected 8 papers from some excellent research teams. The content covers several hot topics of high temperature electrochemistry, including direct carbon and single chamber SOFCs, water and carbon dioxide electrolysis by SOECs, electrochemical dehydrogenation, *in situ* reforming of fuels, and cathode catalysts, etc.. To some extent, this issue reflects the national status of high temperature electrochemistry research. It may be helpful to those interested in high temperature electrochemistry, either for fundamental research or for practical application development.

I highly appreciate the excellent contributions of all the authors and reviewers. Also, I would like to give my special thanks to the editors for their kind patience and effective hardworking.

Guest editor
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