第218回フロンティア材料研究所講演会

「Thermo-iono-electronic (TIE) materials: Unified perspectives of thermoelectrics and ceramic gas-transporting membranes and recent performance improvements through texturing」

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主催： フロンティア材料研究所

要旨

In addition to ionic and/or electric charge carriers, it is proposed to consider entropy as further basic quantity being transported through a thermo-ionic-electronic (TIE) material. Conversion of energy is easily understood as the loading of energy from entropy current (thermal energy) to ionic current or electronic current (both electrochemical energy). Analogies between the Soret coefficient, the Seebeck coefficient and the ionic transfer number become evident. The latter plays an important role in the context of the mixed ionic-electronic conductor (MIEC), which can be considered as TIE under isothermal conditions. If the TIE is simultaneously placed in gradients of temperature and electrochemical potential (ionic and/or electronic), currents of entropy, ionic charge carriers, and electronic charge carriers are observed (i.e. Soret diffusion or thermoelectrics). In the basic transport equation, the TIE material appears as tensor, which is a major advantage over the concept of the so-called thermodynamics of irreversible processes. The role of energy and its conversion is easily understood by the flux of entropy, ionic charge carriers, and electronic charge carriers at their respective local potentials, which are the temperature, the ionic electrochemical potential, and the electronic electrochemical potential.

An overview of the activities of our group in the context of the subsets of TIE materials, thermoelectric (TE) materials and MIEC for oxygen-transporting membranes (OTMs) is given with some emphasize on the utilization of anisotropic transport properties in layered oxide systems (e.g. “$Ca_3Co_4O_9$” = $[Ca_2CoO_{3-\delta}]_{0.62}CoO_2$, $La_2NiO_{4+\delta}$, and $Nd_2NiO_{4+\delta}$) in (nano)structured bulk ceramics with texture. Together with our cooperation partners, we have applied a variety of techniques for ceramic texturing, including electrospinning of nanofibers and nanoribbons, spark plasma sintering (SPS), spark plasma texturing (SPT), magnetic grain alignment, and crystal facet engineering via reverse microemulsion synthesis. Substantial performance improvements were realized.

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Speaker biography

Prof. Armin Feldhoff holds the venia legendi for Physical Chemistry. His research interests are in thermo-iono-electric (TIE) materials for energy conversion and chemical separation. His activities link materials synthesis with the microstructure, as obtained by scanning and transmission electron microscopy as well as x-ray diffraction, and functionality. Aim is always a knowledge-based approach to bring new functionality into materials and devices.

Armin Feldhoff received his diploma in physics from the University of Münster (Germany) and his PhD degree from the Martin-Luther University Halle-Wittenberg (Germany). He was pre- and post-doctoral researcher at the Max Planck Institute of Microstructure Physics in Halle (Germany). He was postdoctoral associate at the Department of Materials Science and Engineering at Cornell University in Ithaca (NY, USA) and at the Centre d'Études de Chimie Métallurgique of the CNRS in Vitry sur Seine (France).

He has published more than 200 papers in peer-reviewed journals. He has more than 17,000 citations with an h-index of 65 and an i10-index of >170. He has been the 2019-2021 inaugural chair of the Energy Materials and Systems Division of the American Ceramic Society. In the German Society for Electron Microscopy, he served in the editorial team of Elektronenmikroskopie (i.e. Electron Microscopy) from 2012 to 2025. He is editorial board member of Entropy with MDPI and served as Guest Editor for 200 Years Anniversary Special Issue of "Sadi Carnot, Réflexions Sur La Puissance Motrice Du Feu". As Associate Editor of the Journal of Electronic Materials with Springer Nature, he handled more than 200 manuscripts. Since 2023, he has been Associate Editor of the Journal of the American Ceramic Society. In 2022, he was honored by the American Ceramic Society with the D.T. Rankin Award and recognized as a Global Ambassador. He was inducted as a Fellow of the American Ceramic Society in 2025.