SEMINAR SERIES

International Institute for Carbon-Neutral Energy Research
Kyushu University

Title Mixed conduction in oxides at high electric fields focussing on yttria stabilized zirconia

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Date & Time Tueday, November 15, 2016 4:00 p.m.
Place I²CNER Hall, Ito campus, Kyushu University

Abstract

Exemplified for Yttria stabilized Zirconia (YSZ) transport phenomena in oxides exposed to large electric fields are discussed as occurring in solid oxide electrolysis cells (SOEC) and during flash sintering of oxides. The effect of high fields is twofold. First it generates large differences of oxygen activity within the sample leading to electron and hole generation or n- and p-type regions. Second it determines the characteristic time for attaining steady state transport. By assuming that this time is a measure of the onset of rapid sintering, yields onset temperatures as a function of the electric field strength which are in good agreement with experimental results. If YSZ is able to interact with surrounding oxygen gas, electrons are produced at regions near the positive electrode and vice versa holes near the negative electrode by desorption or absorption of oxygen molecules from the gas phase. To maintain charge neutrality a current of double charged oxygen ions has to be transported from the p- to the n-region which is accomplished by polarizing the oxide. For oxygen exchange with the environment being suppressed leads either to the formation of oxygen gas at interfaces or in voids leading to failure of SOECs. At high electric fields the electrodes start to react with the oxide as shown for a Ni/YSZ/Ni cell, where NiO is formed at the positive electrode and the intermetallic compound Ni3Zr is formed at the negative electrode by decomposition of YSZ. In this case the charge transfer number of oxygen is very small. This may be explained by the formation of single charged oxygen ions counteracting the transport of double charged oxygen ions, thus leading to an internal short circuit.

About the Speaker

Prof. Dr. Reiner Kirchheim received his PhD in Physics from the University of Stuttgart in 1973. Until 1993 he worked as a senior research scientist at the Max-Plank-Institute for Metals Research in Stuttgart. He joined the faculty of Physics at the Georg-August-University Gottingen, where he became full professor in Materials Physics in 1993. From 1979 till 1998 he was visiting for longer periods of time Rice University, University of Illinois, Ohio State University and NIST as a post doc and visiting professor. In 1991 he co-chaired the Gordon Research Conference on Hydrogen-Metal Systems. Since 2009 he has become a Professor of the state of Lower Saxony continuing his work at the University of Gottingen. In 2010 he was elected a member of the Max-Planck-Society and an external Member of the Max-Planck-Institute for Iron Research in Dusseldorf. Since 2011 he is also Principal Investigator at the International Institute for Carbon-Neutral Energy Research, Kyushu University, Japan. He is known for his research in the field of thermodynamics and kinetics of materials with special emphasis on hydrogen in metals. He has published more than 250 papers and was announced a “highly cited author” in Materials Science by ICI. He is an elected member of the Gottingen Academy of Science and the German Academy of Technical Sciences and has been a recipient of several other awards, including the Carl-Wagner-Price from the Bunsengesellschaft, the Honda Memorial Award from Tohoku-University, the Heyn-Memorial Medal (highest award of the German Society of Materials) and the Lee Hsun Lecture Award from the Chinese Academy of Sciences. He is a recipient of a Reinhart Koselleck-Project of the German National Science Foundation and an honorary member of the German Society of Materials.

Host: Prof. Petros Sofronis

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