measurements obtained from the symmetric cells with the configuration of BLF /SDC/YSZ/SDC/ BLF reveal that polarization resistance of BLF (001) thin films (100 nm) is as low as ~0.1 Ω cm^2 at 700 °C and 0.21 atm oxygen pressure. The polarization resistances of BLF are lower than those of other perovskite electrodes, e.g., $La_{0.6}Sr_{0.4}Co_{0.8}Fe_{0.2}O_{3-\delta}$. Furthermore, our computational results, including density functional theory and molecular dynamics simulations, show that the BLF is characterized by low vacancy formation energy and fast oxygen transport.

[1] D. Chen, C. Chen, F. Dong, Z. Shao, F. Ciucci, J. Power Sources, 250, 188-195 (2014)
[2] C. Chen, D. Chen, Y. Gao, Z. Shao, & F. Ciucci. J. Mater. Chem. A, 2, 14154-14163 (2014)

SESSION A8: SOEC
A: Solid Oxide Fuel Cells and Electrolyzers
Chair: Steven McIntosh
Thursday Morning, June 18, 2015
Keystone Resorts, Longs Peak

10:30 AM **A8.01
Prospects and Challenges of Solid Oxide Electrolysis Peter V. Hendriksen[1], Ming Chen[1], Ragnar Kiebach[1], Xiufu Sun[1], Karsten Agersted[1], Yi-Lin Liu[1], Sebastian Molin[1], Sune D. Ebbesen[1], Christopher Graves[1], Anne Hauch[1], Karen Brodersen[1], Mogens B. Mogensen[1], Johan Hjelm[1], Soren H. Jensen[1], Christodoulos Chatzichristodoulou[1] and Brian V. Mathiesen[2];[1]Department of Energy Conversion and Storage, Technical University of Denmark, Roskilde, Denmark; [2]Department of Development and Planning, Aalborg University, Copenhagen SV, Denmark.

Concerns to reduce future adverse effects on the global climate have led to increased focus on means to reduce anthropogenic CO_2 emission. The amount of electricity generated from renewable and intermittent energy sources (e.g. wind and sun) is consequently likely to increase globally in the coming decades. High temperature electrolysis of CO_2 and/or H_2O using solid oxide electrolysis cells (SOECs) has the potential to become a key technology in enabling reduced emissions by providing an energy efficient way to "store" electricity from periods of surplus production. The energy can, in the form of gaseous or liquid hydrocarbon fuels produced from the electrolysis products, be transferred to the transport sector, where emission reduction is especially difficult.

In this presentation we discuss the prospects of the SOEC technology for enabling larger shares of intermittent electricity production in the energy system and give examples from scenario analyses of its role in a future energy system based on 100 % renewable energy.

Whereas state of the art SOFCs have been shown to be fully reversible, there are important differences between SOFC and SOEC operation in terms of degradation phenomena. Highlights from the technical SOEC R&D at DTU Energy will be presented including a status on achieved cell durability and cell operation under high pressure. Problems in terms of life time limiting degradation phenomena during SOEC operation will be discussed in detail based on own findings and literature. This will cover both microstructural degradation phenomena at electrode and cell level as well as phenomena occurring in stacks, specifically related to the interconnects. It will be illustrated how detailed modeling of the chemical potential profiles over the cells and interconnects can be useful in unravelling which processes contribute to the observed performance degradation during long term operation.

11:00 AM A8.02
Surface and Bulk Properties of Polarized Mixed Conducting LSF Electrodes: An in-situ Study in H_2/H_2O and O_2 by Simultaneous near-Ambient Pressure XPS and Impedance Spectroscopy Alexander K. Opitz[1], Andreas Nenning[1], Sandra Kogler[1], Christoph Rameshan[2], Raffael Rameshan[3, 4], Raoul Blume[4, 5], Michael Haevecker[4, 5], Axel Knop-Gericke[4], Guenther Rupprechter[2], Bernhard Kloetzer[3] and Juergen Fleig[1]; [1]Insititute of Chemical Technologies and Analytics, Vienna University of Technology, Vienna, Austria; [2]Institute of Materials Chemistry, Vienna University of Technology, Vienna, Austria; [3]Institute of Physical Chemistry, University of Innsbruck, Innsbruck, Austria; [4]Department of Inorganic Chemistry, Fritz Haber Institute of the Max Planck Society, Berlin, Germany; [5]Catalysis for Energy, Group E-GKAT, Helmholtz-Zentrum Berlin fuer Materialien und Energie GmbH, Berlin, Germany.

Mixed ionic and electronic conductors (MIECs) find applications in a wide range of oxygen partial pressures and in numerous electrochemical devices. For example, in solid oxide electrolysis cells (SOEC) reduction stable MIECs are an attractive alternative to the presently used Ni/YSZ SOEC cathodes.

In this study the acceptor doped mixed conductor $La_{0.6}Sr_{0.4}FeO_{3-\delta}$ (LSF) was investigated as an SOEC cathode in H_2/H_2O atmosphere and electrochemical properties such as surface exchange resistance are compared to those of LSF in air. Model-type LSF thin film electrodes were prepared on YSZ and the relatively poor electronic conductivity of LSF under reducing conditions was compensated by Pt current collectors beneath the MIEC thin film.

On these model-composite electrodes the relation between surface chemistry and electrochemical surface activity was investigated by means of simultaneous synchrotron-based near-ambient-pressure XPS and impedance spectroscopy. Special focus was laid on the effect of electrochemical polarization on the composition and valence states of near surface cations of the LSF electrodes. Cathodic polarization (i.e. water splitting conditions) caused the evolution of metallic iron on the LSF surface, which was accompanied by a strong decrease of the electrode polarization resistance for the water splitting reaction [1]. This correlation suggests a fundamental difference in the water-splitting mechanism on LSF with and without near-surface metallic iron and may provide new paths in the search for novel mixed conducting SOEC electrode materials. Moreover, the XPS binding energy shift of different cations under electrochemical polarization is discussed in terms of bulk defect chemistry of LSF.
[1] A. K. Opitz et al., Angewandte Chemie International Edition 54 (2015), p.2628–2632.

11:20 AM A8.03
Infiltrated Double Perovskite Electrodes for Proton Conducting Steam Electrolysers Einar Vollestad, Ragnar Strandbakke and Truls Norby; Department of Chemistry, University of Oslo, Oslo, Norway.

The oxygen side electrode remains a major challenge in the development of cost efficient and durable high temperature ceramic proton conducting fuel and electrolyser cells. This is due to the scarce availability of mixed proton electron conductors with high conductivities, high catalytic activity, and chemical stability. Composite electrodes comprising a proton conducting phase and an electronically conducting active electrode component are therefore necessary to increase the active area and the amount of triple phase boundaries
.
In this contribution, we present structures of porous $BaZr_{0.7}Ce_{0.2}Y_{0.1}O_3$ (BZCY72) backbones applied using both spray coating and brush painting, infiltrated with the double perovskite $BaGd_{0.8}La_{0.2}Co_2O_{6-\delta}$ (BGLC) as the active electrode component. The infiltrated structures form a percolating nanoscopic layer of BGLC, finely distributed throughout the electrode structure. The electrodes are tested as oxygen side electrodes by impedance spectroscopy as a function of temperature and pO_2. The electrodes display area specific resistances of ~1 Ωcm^2at 600 °C in wet air. Extracted polarization resistances are fitted to a model resolving partial polarization resistances for protons and oxide ions in a system of multiple charge carriers [1]. From these resistances combined with parameterized morphology of the backbone structure, we can identify how the electrode microstructure influences both ohmic and polarization resistances and thus find various routes for further improvement of the electrode performance.

References:
[1]: R Strandbakke, V Cherepanov, A Zuev, D. S. Tsvetkov, C Argirusis, G Sourkouni, S Prünte, T Norby: Gd- and Pr-based double perovskite cobaltites as oxygen electrodes for proton ceramic fuel cells and electrolyser cells (under publication).