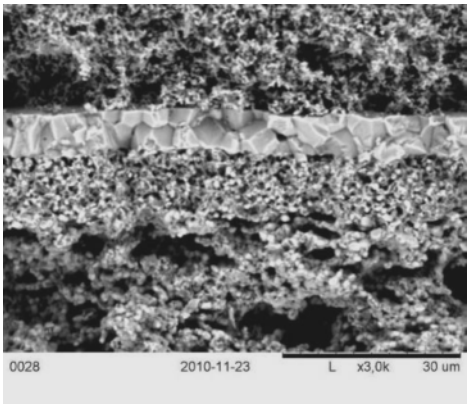
Efficient and robust fuel cell with novel ceramic proton conducting electrolyte (EFFIPRO)

Proton ceramic fuel cells (PCFCs) can operate at intermediate temperatures due to a modest activation energy of migration of dissolved protons. Water appears on the cathode side and does not dilute the fuel or constitute a danger of oxidising the anode in PCFCs, contrary to regular solid oxide fuel cells (SOFCs). Thus, fuel utilisation can approach 100% and the overall efficiency in principle surpass SOFCs by at least 10%.

Proton conducting oxides have traditionally been acceptor-doped $BaCeO_3$ or $BaZrO_3$ which suffer from reactivity towards CO_2 or high sintering temperatures and high grain boundary resistance. **EFFIPRO** explores novel stable proton conducting oxides, firstly Ca-doped $LaNbO_4$ (LCN), and investigates thin film electrolytes and compatible electrodes. It leaves a complete cell to a next stage, and instead defines separate goals for the supported anode-electrolyte thin film assembly and for the electrolyte-cathode half-cell. In the long term the electrolyte and electrodes are each required to be less than 0.1 Ωcm^2 at operating temperature, withstanding acidic gases and thermal cycles. The target values for EFFIPRO are 0.2 Ωcm^2 (0.5 Ωcm^2 at midterm). Sub-goals are defined for electrolyte thickness and conductivity.

Initial problems of manufacture of the **electrolyte** were found to stem from negligible cation non-stoichiometry of LCN, accompanied by difficulties related to certain secondary phases. A remedy was developed in integrated action with national projects. The potential of using a mischmetal strategy to lower the **cost** of raw materials has been demonstrated for LCN. However, neither co-doping nor grain boundary engineering enabled LCN to reach the conductivity target. Other candidate proton conductors have been evaluated, and it was found that $La_{5.6}WO_{12-d}$ (LWO) meets the midterm targets, and takes over for LCN in EFFIPRO.

Thin film electrolytes have been deposited using various techniques on anode supports (LCN-Ni cermet or metallic) with fine-grained thin functional anode layers of LCN-Ni cermet in between. The electrolyte is then sintered, a counter electrode is applied, and the NiO phase reduced to Ni, all of which strain the electrolyte. The midterm target of 5 μm for the electrolyte film has been reached by two methods, and polarisation resistances better than target values have been obtained for LCN-NiO anodes. Modelling of electrodes suggests that the proton conductivity in the electrolyte phase of the cermet is critical.



Fracture cross-section of thin dense LCN electrolyte between substrate (bottom) + functional anode layer and counter-electrode (top) (all LCN+Ni).

A matrix of electron conductors has been investigated as cathodes for various proton conductors, as monophase or cercer (ceramic-ceramic) composites. Half cells with overpotential resistance better

than midterm target were obtained with certain oxide cathodes on lanthanum oxoborate and LWO. Studies of **interface kinetics** support the finding that LWO exhibits relatively good electrode kinetics.

Impact: EFFIPRO forms a base for follow-up projects which will lead PCFC technology to a sound competition with the now ever more successful polymer fuel cells and SOFCs. PCFCs are in principle 10-20% more efficient than SOFCs because of the better fuel efficiency, provided a hydrogen rich fuel. The impact is even higher as pure H_2 becomes available e.g. in infrastructure for fuel cell vehicles.

Dissemination, IPR, and related technologies: The results are being disseminated through international talks and publications. There is high innovation and IPR generation around the new LWO electrolyte, expectedly soon also in EFFIPRO. The project contributes indirectly to the possible use of LWO in membranes for hydrogen separation: A Norwegian SME recently won a national prize for innovation for such a membrane in a catalytic reactor to produce diesel components from natural gas.

Status at midterm is that 4 of 5 milestones are met, the 5th expectedly caught up by introducing LWO as electrolyte. The targets for EFFIPRO thus remain at 0.2 Ωcm^2 area specific resistance for anode, electrolyte, and cathode. It is expected that the long term targets of 0.1 Ωcm^2 for each component can be met in a follow-up project, that this kind of PCFC technology will contribute to the efficiency and introduction of fuel cells by 2020, and in the long run thereby reduce power consumption and CO_2 emissions in Europe by 10%.

http://www.kjemi.uio.no/effipro/

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