Optimizing Direct Carbon Solid Oxide Fuel Cells (DC-SOFCs) performance.

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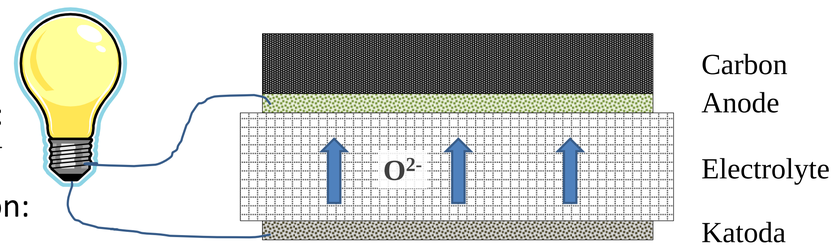
Direct Carbon - Solid Oxide Fuel Cells

Direct Carbon – Solid Oxide Fuel Cells are devices that convert carbon fuel directly to electricity utilizing an electrochemical reaction. The thermodynamics of DCFC devices is very promissing:

Summary reaction:
$C + O_2 \rightarrow CO_2$

Anode half-reaction:
$C + 2\,O^{2-} \rightarrow CO_2 + 4\,e^-$

Cathode half-reaction:
$O_2 + 4\,e^- \rightarrow 2\,O^{2-}$



For the above reaction (25°C):

Enthalpy: $\Delta H = -393{,}51\ \frac{kJ}{mol}$

Gibbs free energy: $\Delta G = -394{,}373\ \frac{kJ}{mol}$

Entropy: $\Delta s = 2{,}895\ \frac{J}{mol\ K}$

Theoretical Open Circuit Voltage:

$$E^0 = \frac{-\Delta G \times 10^3}{n \times F} = \frac{-(-394{,}373) \times 10^3}{4 \times 96485} = 1{,}022\ V$$

Thermodynamic efficiency: $\eta = \frac{\Delta G}{\Delta H} = \frac{-394{,}373}{-393{,}51} = 100{,}22\ \%$

The reaction is almost temperature independent.

Why the subject is important?

DC-SOFC-based power plant will convert coal to electricity with about 60 % efficiency (compared to average 30 % of conventional coal-fired steam power plants)

Globally – there is a need for a technology that convert fossil coal to electricity with high efficiency to limit the resources utilization and emissions to the atmosphere. The technology must be Carbon Capture and Sequestration ready.

Locally – coal utilization provide to Poland energy safety, but the present technologies used for coal-to-electricity conversion have the efficiency limit of 45 %.

Scientifically – there is a need to improve power density, reliability of the cells and deepen the knowledge of the processes occuring in a DC-SOFC. Also the tests on fossil coals have not been conducted broadly.

The content of the project

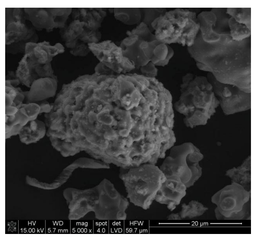
Investigation of DC-SOFC laboratory cell of planar geometry using electrochemical methods:

(cyclic voltametry (CV), electrochemical impedance spectroscopy (EIS), chronoamperometry (CA), interruption pulse method and others)

Effects on DC-SOFC performance of:

- electrode and electrolyte materials
- carbon fuel type, including fossil coals

Processing of coals and composite fuels preparation for improving the performance of DC-SOFC

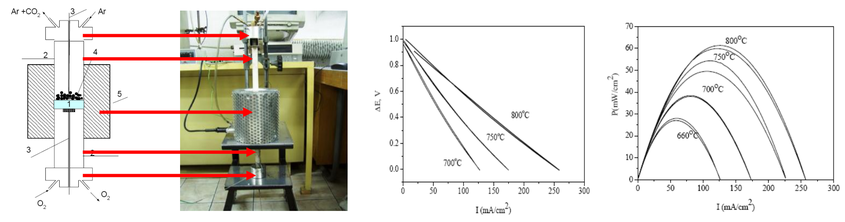


SEM diagram of investigated carbon fuel

Optimizing design and construction of DC-SOFC laboratory cell

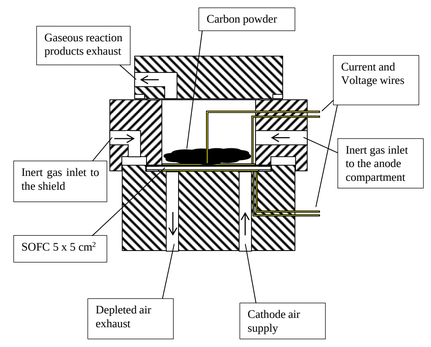
Parties in the programme:

AGH – University of Science and Technology, Cracow



Cell area: 1 cm²

IEn – Institute of Power Engineering, Warsaw



Cell area: >10 times higher than in AGH

Planned research activities

Carbon fuel preparation
- Ball milling
- De-ashing with acids
- Activating with catalysts
- Mixing with ceramic powders

Carbon fuel investigation
- SEM
- XRD
- XPS/ESCA
- DTA/TG

Tests of cells with various anodes composition

Investigation of the scale-up factors
- AGH testing facility: circular 1 cm2 cells
- IEn testing facility: square >10 times higher area cells

Testing the same configuration (fuel cells, fuel and testing conditions) in different scales

Laboratory test stands improvements

Expected results of the project

- Determination of the influence of carbon fuel preparation on DC-SOFC performance
- Determination of the influence of anode composition on DC-SOFC performance
- Laboratory test stands improvements
- Succesful (minimalized performance loss) scale-up of the technology

Innovative aspects

- Improvements in DC-SOFC performance
  Lowering cost of future power-plant construction and operation costs
- Improvements in carbon preparation techniques
  Lowering future fuel processing costs
- Scale-up of the DC-SOFC technology
  A step towards further scale-up of the technology
- AGH and IEn belong to DCFC Consortium with PGE as one of the financing parties