Elcogen Solid Oxide Fuel Cell User Manual

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Fuel cell technology elcogen

1 General information

Elcogen cells are efficient electrochemical conversion devices working at intermediate to high temperature (600-750 ˚C). Electrical efficiency of SOFC system may achieve over 70 %, and the total efficiency may rise over 90 % in case of heat utilization. In electrolysis mode (SOEC), the combined efficiency may achieve 99%.

These solid oxide cells consist of anode made by ceramic-metal composite (green before reduction; grey after reduction), where the fuel (H2, CH4, CO, syngas etc) oxidation occurs, and cathode made by ceramic material (black), where the oxygen (air) reduction occurs (if operated at SOFC mode, to produce electricity). They are separated by thin ceramic electrolyte and barrier protective layer (Fig. 1). Our cells may be used also as electrolysers (if operated at SOEC mode, to produce H2 or syngas) by changing polarity and anode fuel composition (H2O, CO2 etc).

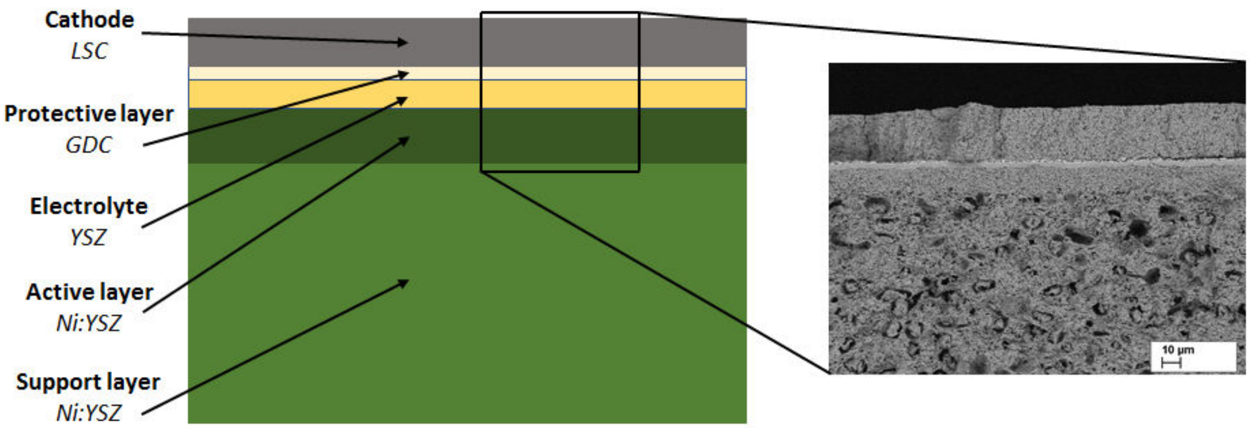

Figure 1. *Schematic structure of Elcogen's cells (left) with SEM photo (right).*

Elcogen cells may be used for different purposes at different conditions in single cell or in stack configuration (system consisting of numerous cells to increase power output). Depending on the needs and equipment, different protocols may be applied. Here, you find general recommendations based on our experience how to use Elcogen cells, that ensure correct functioning and high performances at the most of test systems.

Combining high efficiency, small size, silent functioning and environmental friendliness, our cells are very attractive energetical solution for future, helping you to build your own system for your needs, whatever energy generation from various fuel types or fuel production using electrolysis process (***Fig. 2***).

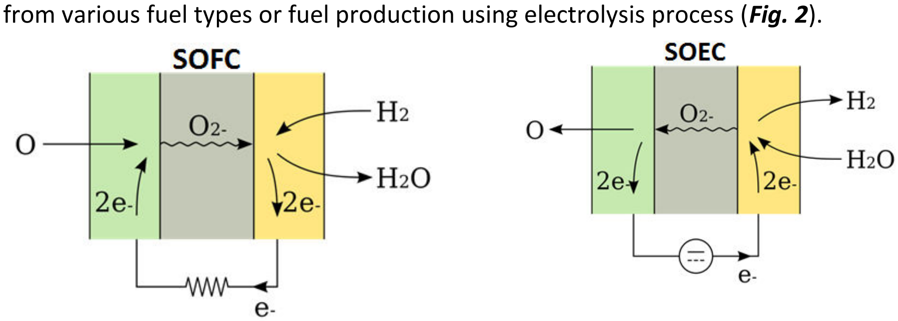

Figure 2. *Functioning of solid oxide cells in electricity generation (SOFC, left scheme) and electrolysis (SOEC, right scheme) modes, in case of H_2/H_2O use.*

In case of questions, do not hesitate to contact us. We are always opened to help our customers in case of problems!

2 Handling

After receiving, the cells need to be stored in a dry place at room temperature in the original packaging.

While manipulating, use of clean gloves (not powdered latex / nitrile, ESD or cleanroom gloves) is mandatory. Do not touch the active cell surface. Avoid contact with any liquid or solid substances.

Cells are brittle, do not bend/compress/drop/scratch it. Before using, no mechanical load allowed.

3 Test housing

Before installing cells in test fixture, verify that the cells were not damaged during shipping/storing.

There are different test housing geometries (circular, rectangular), types (open perimeter, with open cell edges; closed perimeter, with isolated anode and cathode chambers), materials (ceramic, metal alloys) etc., depending on type of analysis and desirable result. For correct functioning, we advise our customer to use fuel and air feeding from the centre to outside for circular geometry, or co-flow for rectangular test housing (Fig. 3). It helps to minimize thermal gradient from inhomogeneous electrochemical reaction and inlet gases temperature.

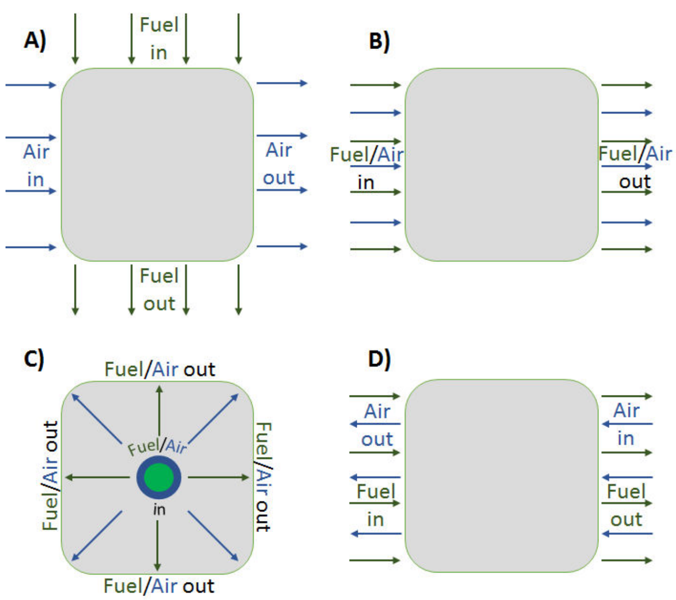

Figure 3. Representation of (A) cross-flow, (B) co-flow, (C) round flow and (D) opposite flow for fuel and air in cells that are commonly used in SOC.

During functioning, cells need to be connected to external electrical circuit. For this, current collectors are used. They are in direct contact with anode and cathode active area surface.

To ensure a good electrical contact between cell and current collectors, cells need to be pressed perpendicularly between two plates. the optimal external load is 300-600 g/cm² (depending on current collectors and system design). The load must be distributed homogeneously on the active cell surface, and the contact must be smooth enough to avoid local cell overloads (Fig. 4).

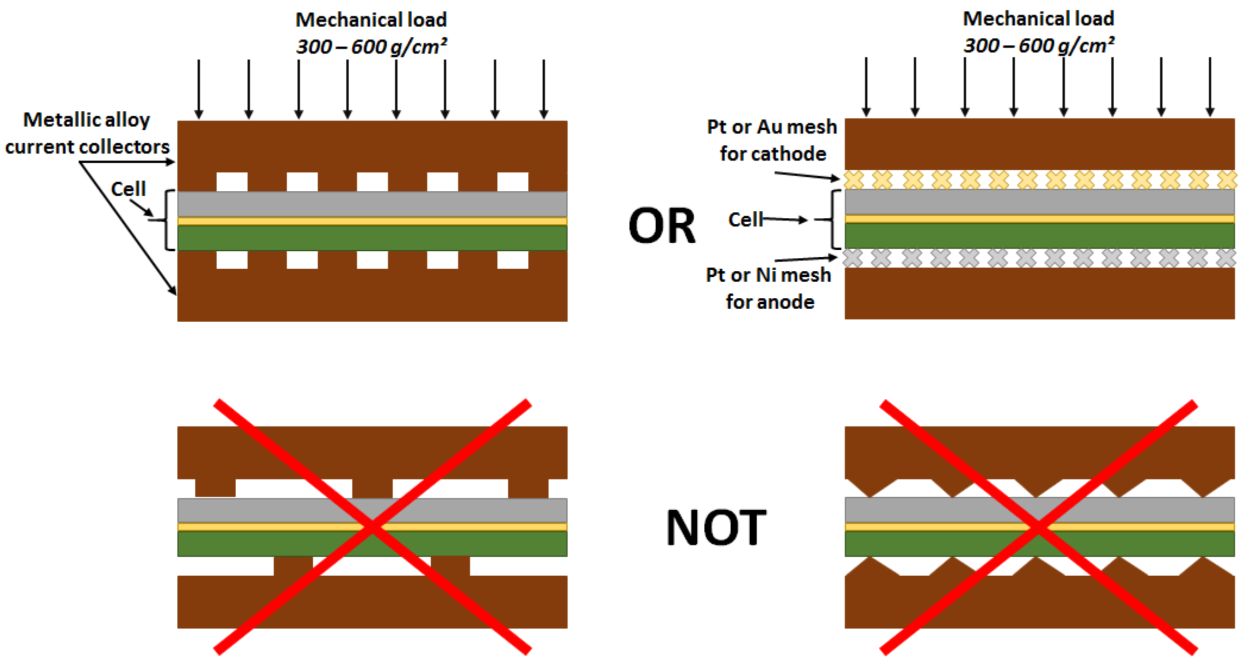

Figure 4. Current collector and mechanical load.

As current collectors, the best materials are fine metallic meshes (≤ 100 meshes/cm²) of Ni or Pt for anode side, and Au or Pt for cathode side. In case of other metallic alloys, metal protection covering, or electrode paste are desirable to protect the active surface of cells from metal vapours at high temperature.

Make attention to homogeneous current distribution at whole current collector area. At high current density, inhomogeneous current may provoke local overheating and decrease performance.

If closed perimeter test system is used, make attention to cell dimensions and coefficient of thermal expansion (CTE). Elcogen cells has CTE around 13.2·10-6 K-1, that means that cells are expanding while increasing temperature (Fig. 5). For example, cell of 120×120 mm at 650 ˚C has dimensions of 120.84×120.84 mm, and even small lateral load from rigid housing may break it. It needs to be taken into account also in case of single cell or stack tests for quick-start and shut-down durability, where the cells are heated/cooled rapidly several times.

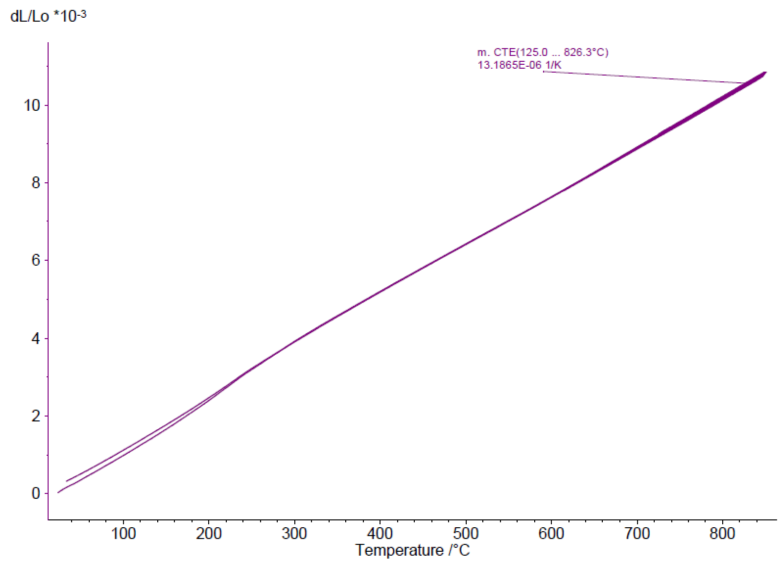

Figure 5. Thermal expansion curve of Elcogen's cell before reduction.

In case if glass sealing used, attention should be made to the glass melting temperature, its chemical composition and deposition on the cell. Sealing of the cell occurs at temperature at least 50-100 ˚C higher than operational temperature, when the glass is enough soft to cover properly all the leakages. When temperature is decreased, the glass become rigid, and anode and cathode compartments of the cell are supposed to be isolated. Otherwise, the sealing is not considered to be enough hermetic, and it can damage the cell during operation, but also have influence on neighbouring cells in stack. To avoid higher degradation from glass chemical composition, we recommend using special design glass e.g., from Schott.

Use of compressible or metallic seals may give an optimal solution between glass sealing and open perimeter, but attention needs to be made to chemical stability at high temperature.

4 Test conditions

Working with SOFC requires special equipment and knowledges. During operation, do not touch hot surfaces and electrical wires.

Elcogen cells belong to IT-SOFC with optimal working temperature between 600 and 750 ˚C. Higher temperature increase cell performances, but it may provoke faster degradation of the cell materials.

Heating/cooling processes needs to be slow enough to ensure homogeneous temperature increase in whole cell, and generally is limited by system design and materials. Optimal rate for the most of tests should not be over 5 ˚C/min. For example, to heat the cell from 20 to 650 ˚C at 2 ˚C/min, the time needed is 5 hours and 15 minutes. In case of 5 ˚C/min, it takes 2 hours and 6 minutes.

After sealing (or just after heating, if opened perimeter is used), cells need to be reduced from anode side to transform NiO to metallic Ni. Because of the different volume occupancy between nickel oxide and metallic nickel, during the reduction process cell shrinks at around 1 %. For example, cell of 120×120 mm after reduction has dimensions of 118.8×118.8 mm. This means, that during heating cells are expanding (become bigger), and during the reduction process cells shrink (become smaller). This size change needs to be taken into account for correct sealing (Fig. 6).

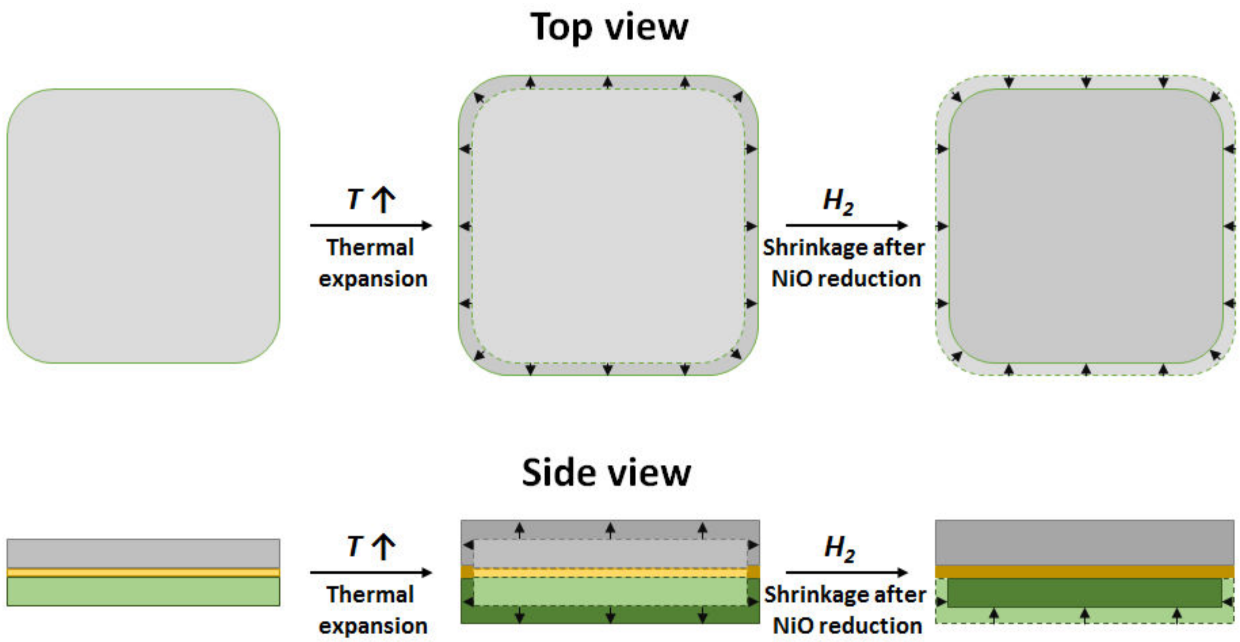

Figure 3. *Thermal expansion and shrinkage of cells anode affected by increase of temperature and reduction of NiO to Ni during H_2 supply at high temperature.*

The inlet gases should be preheated close to furnace temperature before contacting with cell to decrease thermal shock. Make attention to inlet gases purity and excessive humidity of air from cathode side, it can poison the catalytical activity of cells. In order to decrease degradation, you should pay attention on water, lubricant, heavy hydrocarbons and Sulphur compounds.

Necessary amounts of fuel and air should be calculated from desired fuel (FU) and oxygen (OU) utilization (generally, comprised between 20 and 40 % for open perimeter housing and up to 80 % for closed perimeters), but it need to be enough high to avoid back-flow of exhaust gases to electrodes surface. For example, for a cell with effective area of 80 cm², applied load of 32 A (0.4 A/cm²) and 20 % of both FU and OU, the gas flows are 1114 ml H2/min to anode and 2650 ml air/min to cathode.

It is recommended to operate under standard or slightly elevated pressure. Working at different fuel/air pressures requires equipment and working protocol optimizing.

Standard reduction process consists of several steps. Firstly, the cell is heated till the sealing or operational temperature is achieved and left at this temperature for several hours. It helps to stabilize the internal strengths in the cell, improve sealing and to enhance contact with current collectors. Then, 5 % of hydrogen mixture with Nitrogen is introduced to anode side with the same flow rate used in the test and left for 2 hours to reduce the nickel oxide. After that, the hydrogen content should be increased every time by 10 % just after open circuit voltage (OCV) stabilization reaches till 100 % of hydrogen at anode side. The system is in steady state conditions if the OCV value do not show a variation bigger than +/- 5mV/3h.

During heating /cooling of the reduced cells at the temperature higher than 200 ˚C, the anode side should be fed with dry nitrogen or a mixture of 5 % H2 in nitrogen. The cathode side is always fed by purified air. Do not heat cells to high temperature without gas supply, it may damage active electrode materials.

If closed perimeter is used, in case of dry hydrogen at 20 % of FU and OU, the OCV should be higher 1.2 V. Lower value of OCV significates problems in sealing or in fuel purity. If 3-5 % of H2O in hydrogen is used, the OCV value is lower, but cell performance under the electrical load is the same.

Elcogen cells can work under current up to 1 A/cm² and even more (Fig. 7). But it is recommended to operate under the values close to 0.5 A/cm² to have optimal performance/durability properties. The allowed current density like FU/OU depends on housing structure and flow type. FU should not exceed 80% in any points of the cell. If there is not enough gas supplied, do not apply electrical load. In case of high current density, pay attention to even temperature distribution along the cell.

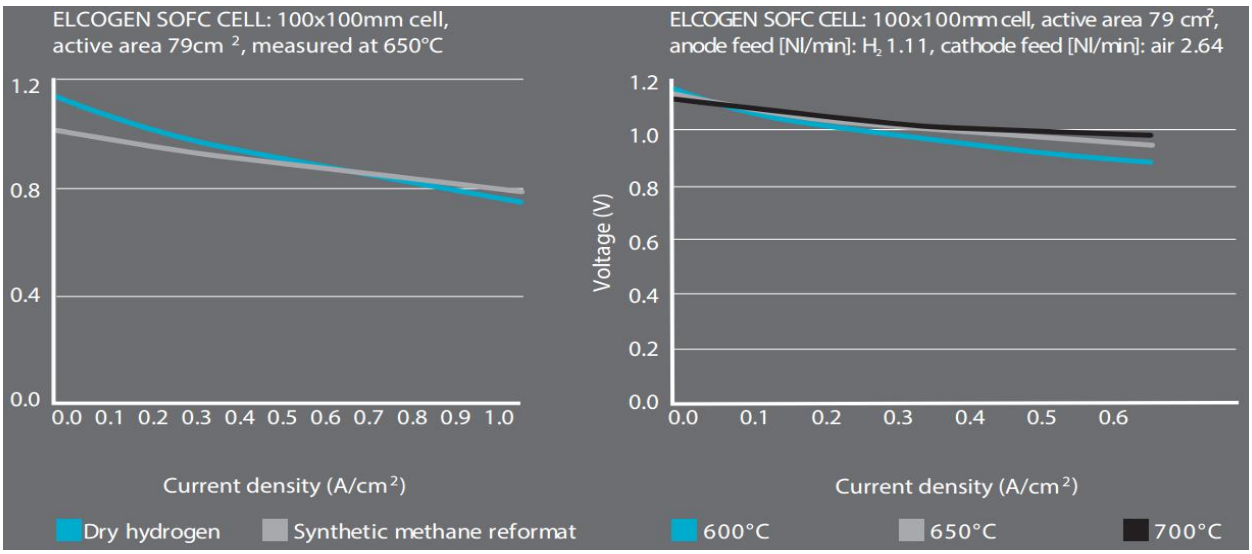

Figure 4. *Example of I-V polarization curves of Elcogen's cells using different fuels (left); using H_2 as fuel at different temperature (right).*

The polarization curve test should be conducted so the cell voltage never falls under the value of 700 mV. For proper EIS analyses, smaller active surface area is favourable. It helps to minimize any pressure/ current/temperature oscillation in cell due to non-homogeneous heating, current collection of gas supply. Current or voltage oscillation should be as small as possible to be close to linear state observed at I-V curve. It is recommended to use four electrodes set-up (two electrodes for current and two other electrodes for potential) with short contact wires to current collectors having enough cross-section to decrease ohmic losses.

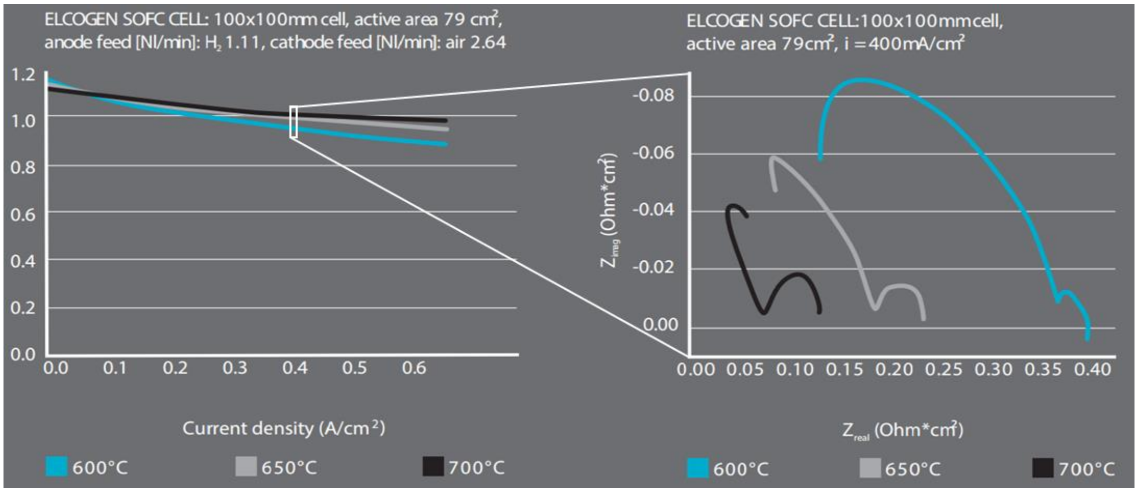

Figure 5. *Example of EIS curves of Elcogen's cells at different temperature (right) taken at anodic polarization (left).*

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