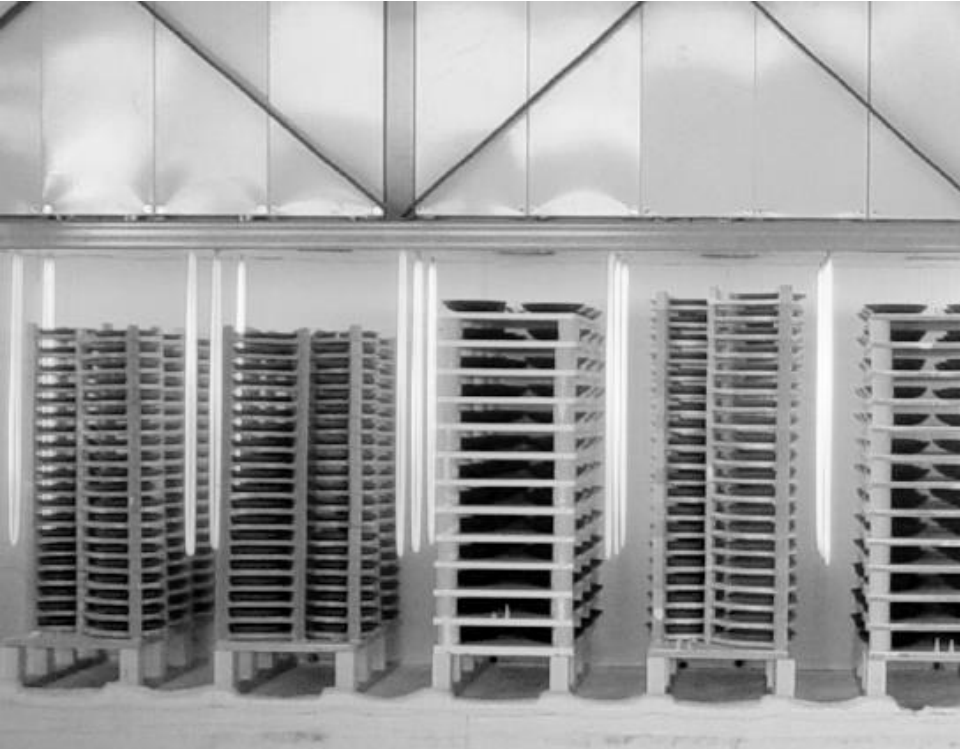




THERMPROCESS-TECHNOLOGY

FUEL CELLS

Solid Oxide Fuel Cell (SOFC)





Periodic furnace systems

100°C – 1600°C

and process-complementary systems
in prototype/sample construction of SOFCs



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THERMCONCEPT high-performance Furnaces
in the ceramic manufacturing process

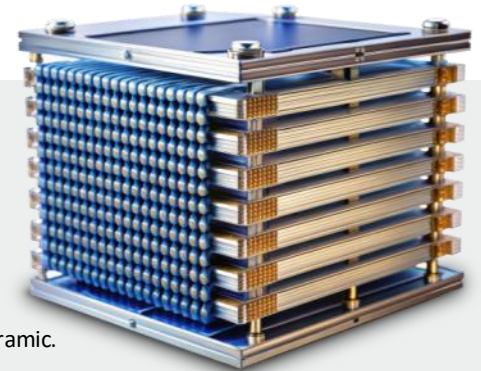
Thermal processes in fuel cell production

Definition of SOFC (Solid Oxide Fuel Cell)

One of the most promising technologies for generating and using hydrogen is the solid oxide fuel cell (SOFC). So-called high-temperature fuel cells (HT-SOFC) use an oxide ceramic material as the base material for the individual cells. These cells are manufactured at sintering temperatures of up to 1600 °C.

In recent years, however, SOFCs that can be operated in the temperature range from 600 °C to 700 °C have also gained in importance. A metallic base material is used in these cells. In addition, the materials of the functional thin films have been optimised so that the sintering temperatures in the manufacturing process can be limited to a maximum of 1100 °C. This represents a clear advantage in terms of energy and manufacturing technology compared to the ceramic-based HT-SOFCs mentioned above.

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While the operation of SOFC systems is climate-neutral, their production is energy intensive due to the complex extraction and refinement of oxide ceramic.

Currently, the necessary furnace systems are still often powered by fossil fuels or natural gas. Optimising the manufacturing processes is essential to minimise the ecological footprint.

THERMCONCEPT supports the transformation process with highly efficient, discontinuous furnace systems whose design is consistently geared towards reducing the energy requirement per kW of SOFC power produced.



Thermal processes in fuel cell production

The process chain

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The production of the individual cells required for SOFCs involves up to 10 or more thermal processes before a fuel cell can be manufactured from a so-called stack, the electrochemical components of an SOFC.

Below is an overview of the process chain for thermal methods used to manufacture cells that are installed in LT-SOFCs and HT-SOFCs

LT-SOFC – low-temperature cell production

≤ 400 °C

Drying & Burnout

- Removal of solvents
- Pyrolysis of organic binders
- Preparation of layer porosity

600–700 °C

Calcination

- Decomposition of inorganic precursors
- Phase formation of oxides

800–950 °C

Oxidation

- Adjustment of stoichiometry
- Oxidation of substrates & inter-connectors

800-1100 °C

Sintering processes

- Compaction of electrolyte, anode and cathode layers
- Adhesion of interfaces

HT-SOFC – high-temperature cell production

Pre-processes similar to LT-SOFC

≈ 1600 °C

High-temperature sintering

- Full sintering of ceramics
- Mechanical strength
- Gas-tight electrolyte structure

The SOFC stack manufactured from the individual components is subjected to at least one further thermal process in the temperature range of 600 to 700°C, which is necessary for the shrinkage and sintering of the sealing material, usually layer minerals, in order to ensure the gas tightness of the cells between each other.

THERMCONCEPT Areas of expertise



Engineering

Conflicting objectives

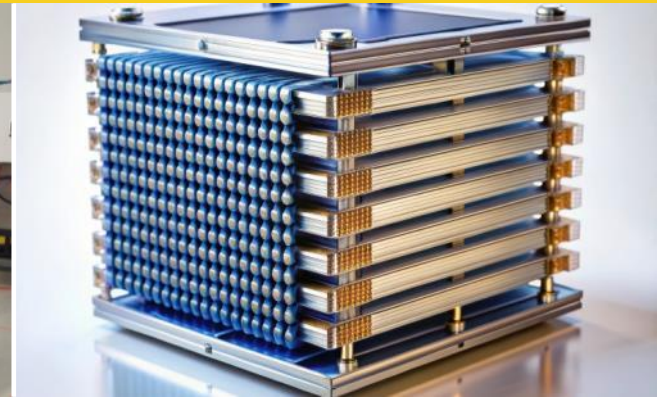
- Product quality and costs
- High demands due to product dimensions and large formats
- High furnace load vs. temperature homogeneity
- Thermal stress vs. limited service life of firing aids

What we offer

- Support right from the early planning phase
- Many years of expertise in furnace construction and charge design
- Holistic coordination of furnace, charge structure and process parameters
- Design of firing aids, including load-bearing structures
- Optimisation of heating/cooling gradients for stable processes and long service life

What we do

- Engineering, including selection of furnace types and sizes based on the production environment and quantity
- Selection of suitable furnace types and sizes
- Provision of quotations for refractory structures
- Defining temperature-time profiles
- Optimisation potential for large-scale production, support with scale-up for large-scale production



THERMCONCEPT Areas of expertise

Prototypes / sample production



Example of the design of a prototype

Premises:

- Electrical SOFC output: 10 kW
- Number of cells per 10 kW SOFC stack: 300..400
- Capacity of prototype construction: 1 stack / working day
- Space requirement ("footprint") for furnaces and auxiliary equipment: Minimal



Required furnace system

| Process | Furnace type | T max (°C) | Volume (l) | Number |
|------------------------------------------------------|-------------------|------------|------------|--------|
| Drying /de-binding with post-combustion | Convection | 50 | 800 | 2 |
| Calcination Stack gas-tight | Recirculating air | 700 | 800 | 2 |
| Oxidation | Chamber furnace | 1000 | 600 | 2 |
| Sintering | Chamber furnace | 1150 | 600 | 2 |
| De-binding / sintering combined with post-combustion | Chamber furnace | 1150 | 600 | 2 |

Design variants and space constraints may require the use of other furnace types, such as bottom-loaders and / or bogie hearth furnaces. THERMCONCEPT supplies a wide range of different furnace types for a variety of applications.



THERMCONCEPT Areas of expertise

Furnace systems for the thermal process chain



Overview

THERMCONCEPT supplies batch furnaces for the thermal processes in the SOFC-manufacturing process chain. The focus in the design of the furnaces is on reducing the electrical energy required to operate the furnaces per kW of SOFC output produced.

THERMCONCEPT furnace systems operate in a temperature range from 100 °C to 1600 °C.

The range includes chamber furnaces, bogie hearth furnaces and bottom-loaders (hood furnaces). The different designs are essential for optimally adapting the furnace systems to the process.

The design of the firing aids and their adaptation to the respective furnace geometry is another decisive prerequisite for efficient technical implementation and automatability of the thermal process chain.



THERMCONCEPT Areas of expertise

Furnace systems for the thermal process chain

KU Air-circulation chamber furnaces

With horizontal air circulation – T max. 850 °C



SOFC process

- Drying, if necessary in accordance with EN 1539
- Calcination of catalytic layers
- Baking of sealing material



Furnace design

- Double-walled housing
- Heat-resistant air duct
- High-quality heating elements
- Powerful air circulation for temperature uniformity up to +/- 3 K

Options

- Safety packages for binder or solvent discharge
- Automatic supply and exhaust air flaps
- Automatic cooling systems
- Lift door with drive
- Thermal or catalytic exhaust air purification systems



THERMCONCEPT Areas of expertise

Furnace systems for the thermal process chain

KK Chamber furnaces

T max 1200 °C



SOFC process

- Oxidation of thermally induced cell-dividers
- De-binding & sintering of functional thin films



Furnace design

- Double-walled housing
- Swing door
- 5-sided heating
- Supply and exhaust air flaps for furnace ventilation

Options

- Multi-zone control
- Safety packages for binder or solvent discharge
- Automatic supply and exhaust air flaps
- Automatic cooling systems
- Lift door with drive
- Thermal or catalytic exhaust air purification systems



THERMCONCEPT Areas of expertise

Furnace systems for the thermal process chain

HTK High-temperature chamber furnaces

T max 1600 °C



SOFC process

- De-binding
- Pre-sintering
- Sintering
- Combined "de-binding & sintering" process

Furnace design

- Double-walled housing
- Parallel swing door
- Multi-sided heating
- Exhaust air flaps for furnace ventilation



Options

- Safety packages for binder or solvent discharge
- Automatic supply and exhaust air flaps
- Automatic cooling systems
- Lift door with drive
- Thermal or catalytic exhaust air purification systems



THERMCONCEPT areas of expertise



Firing aids and carrier systems

Selecting the right furnace is not enough:

The design and materials used in the lining structure are crucial for a stable and economical process.

Controlling thermal stresses:

Temperature gradients cause thermal stress, which is why high demands are placed on the thermal shock resistance of the firing aids.

Optimised process control:

Careful design and material selection enable

- shorter furnace cycles
- lower production costs

Ensuring material compatibility:

No thermo-chemical reactions may occur between the product and the carrier plates.

Practical advice & planning:

Early, individual advice on the design and specification of firing aids, in cooperation with suppliers.

Safe commissioning:

Furnaces and combustion aids with coordinated delivery times.

Special requirements for SOFC:

Two-dimensional thin cells require high-performance charging systems for optimised loading and complex thermal processes.



THERMCONCEPT areas of expertise

Firing aids and support systems



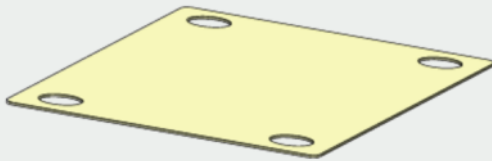
Suitable material concepts:

Monolithic high-performance materials
(e.g. for carrier plates)

Ceramic composite materials (OCMC – oxide ceramic
matrix composites) with high damage tolerance.

Rack design for efficient furnace loading:

Base frames (racks) enable simple and safe loading,
e.g. at the front of chamber furnaces using lifting
aids.



Example: Support plate (monolithic)



Filling structure/OCMC

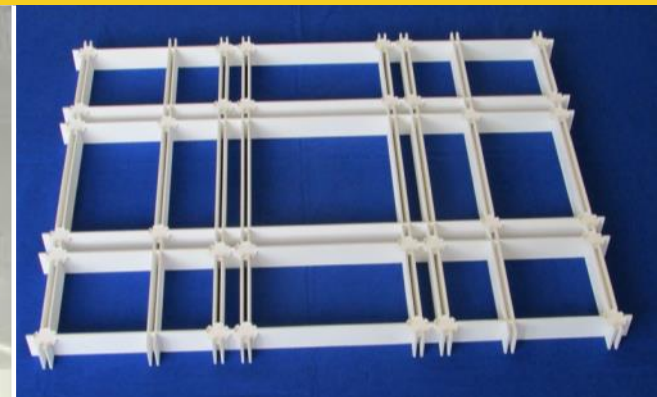
Support function of the system:

Racks support the entire superstructure

- Support plates
- Weights, if necessary
- Product

High mechanical and thermal load capacity:

Total masses up to **500 kg** per system, permanent
resistance to **thermomechanical loads up to 1100 °C.**



Substructure rack

THERMCONCEPT

High-performance furnaces in the ceramic manufacturing process

Solid oxide cells (SOC) are among the most promising technologies for efficient and climate-neutral hydrogen utilisation. These high-temperature ceramic cells achieve maximum efficiency and require minimal maintenance, but they also place high demands on materials and manufacturing processes.

THERMCONCEPT covers the entire chain of expertise: from precise dimensioning and customised furnace construction to the optimal design of firing aids. With our discontinuous furnace systems, we specifically reduce the energy requirement per SOFC output manufactured and set standards for sustainable production.



We look forward to working with you to implement efficient and future-oriented solutions.

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