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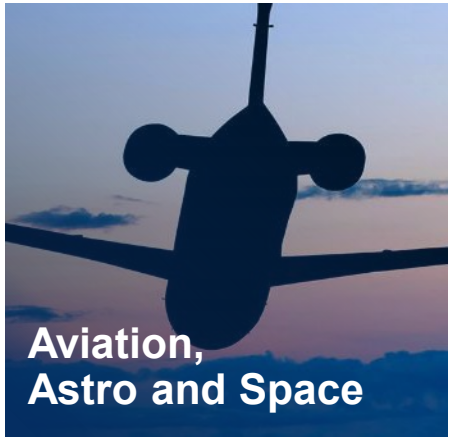
Scaling SOE/FC production with SCHOTT glass sealing solutions

U.S. DoE High-Temperature Electrolysis (HTE) Manufacturing Workshop

Dr. Jens Suffner

SCHOTT offers a broad product portfolio of specialty glass materials and components for various markets



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One of the world’s leading specialty glass suppliers

FY 2020/21

17,300
Employees

2.52 billion EUR
Global sales

- More than 130 years of specialty glass and glass-ceramics expertise
- More than 650 people in R&D
- 3,700+ patents worldwide

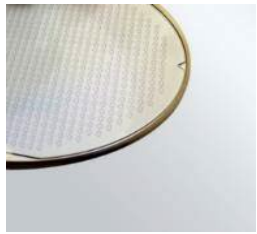
SCHOTT Electronic Packaging is vertically integrated from materials science to materials processing

Specialty Glass for Electronics and Life Science

Material Science and processing know-how for a variety of material formats, from (sintered) glass powders to tubes and substrates

Glass Powder Technology

Tubing Technology



Wafer Technology

Hermetic Sealing & Packaging

Glass-to-Metal Sealed (GTMS) components for the long-term protection of sensitive electronics

Glass-to-Metal Sealing (GTMS) Technology

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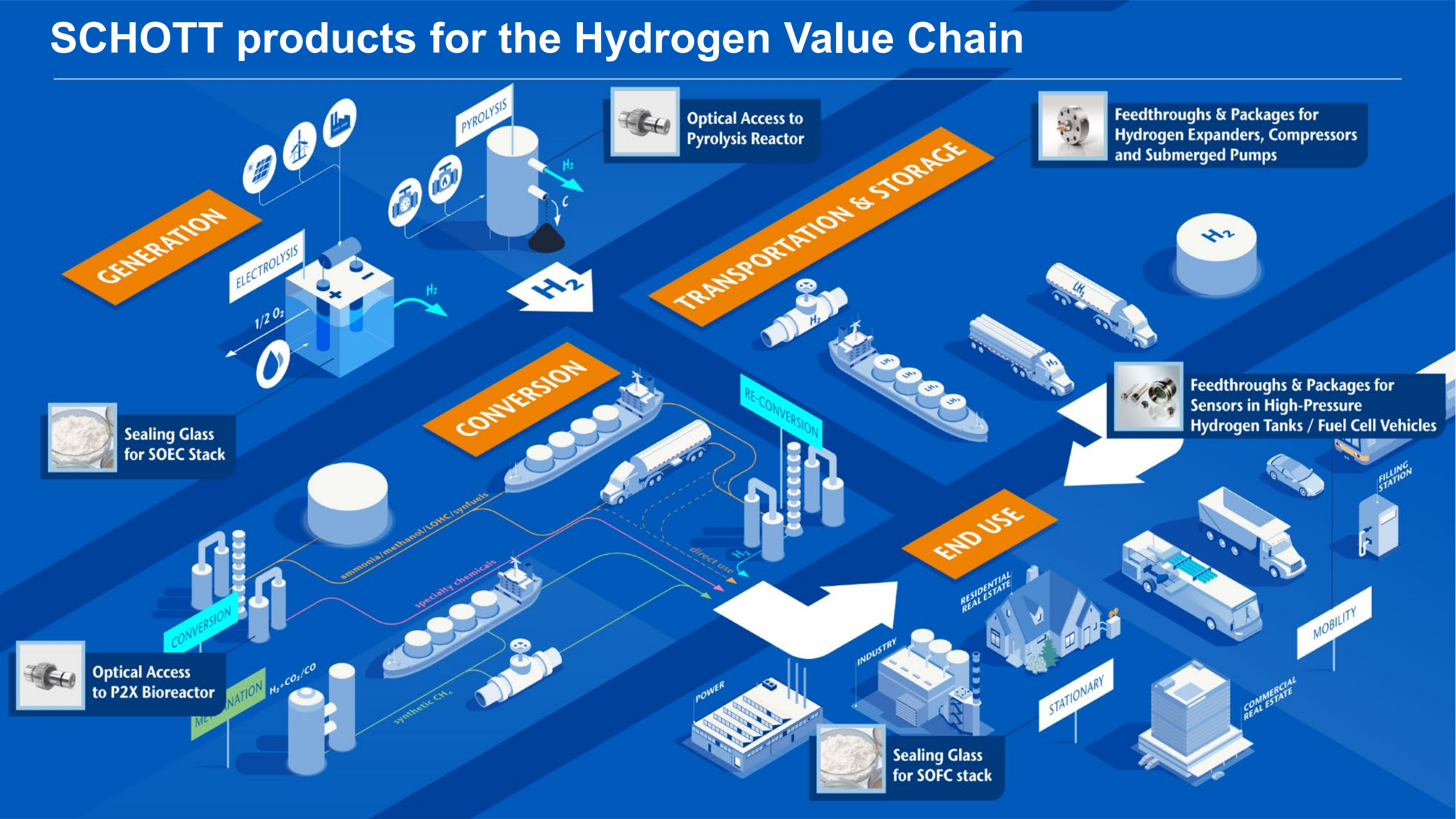
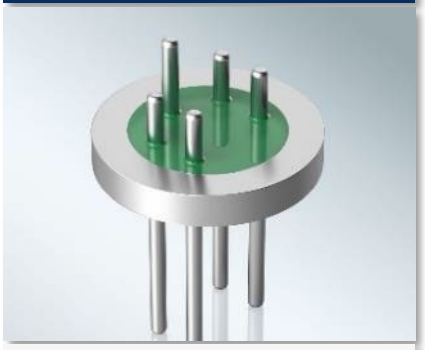
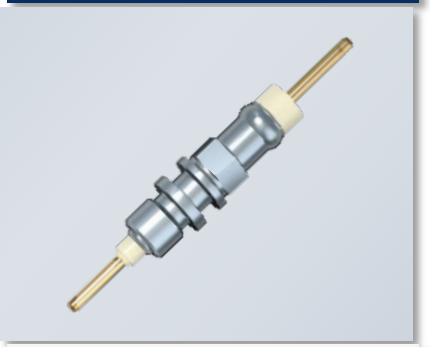
SCHOTT products for the Hydrogen Value Chain



Glass-to-metal seals are versatile – they can be designed to specific product requirements and endure extreme application environments

Non-aging inorganic	Hermetically sealed vacuum-tight	Temperature resistant	Pressure resistant	Chemically robust
				

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SCHOTT has been a supplier to the SOFC and SOEC industry for more than 25 years

- **Long-term experience** – development of SOFC sealing materials since the **early 90's**
- **Reliable supplier** to the SOFC industry for more than 25 years
- **Large variety** of standard and customized glasses available:
  - Glasses available with viscosity curves adjusted to the particular operating temperature of different SOEC/FC designs from 600 to 1000°C
  - Glasses available for all relevant commercial interconnect alloys
  - Glasses available with different crystallization behavior
- **Reproducible high purity** glasses through **dedicated melting and grinding** facilities
- SCHOTT SOEC/FC sealing glasses are available as **powders, pastes, sintered preforms or green sheets**

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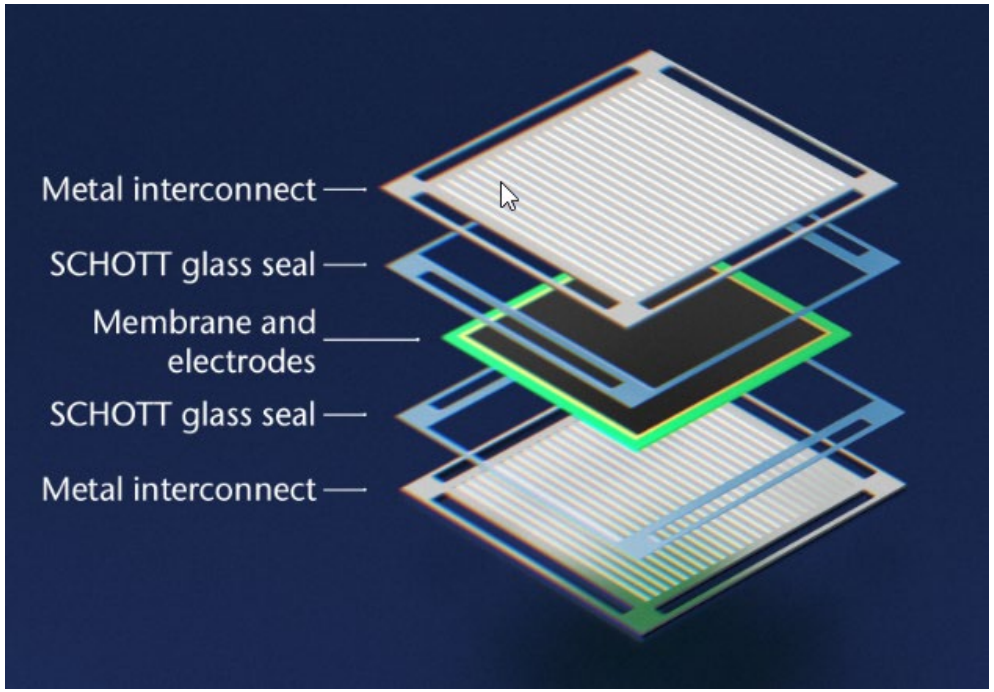
Using glass to hermetically seal SOEC/FC interconnects has numerous advantages:



- **Gas-tightness** at **high temperatures**
- Stability / gas-tightness **after thermal cycling**
- **Electrical insulation / resistance** (achievable with alkaline free glasses)
- **Chemical stability** under reducing and oxidizing atmospheres

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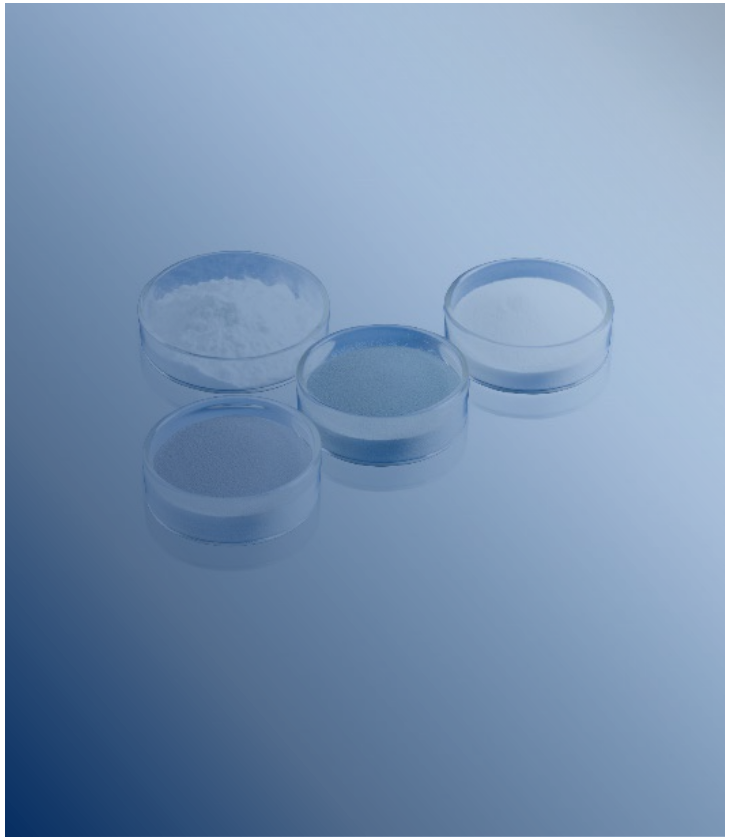
SOFC vs. SOEC – Implications for sealing glasses



12 standard glasses on a production and pilot level available for SOFC operation that can also be used for electrolysis applications

But additional constraints apply for SOEC:

- SOEC are mostly operated at higher temperatures
- Stronger volatilization of glass components with steam:
  - Evaporation of Boron: $3\ B_2O_3 + 3\ H_2O \rightarrow 2\ B_3O_3(OH)_3$
    [Zhang et al. Journal of the American Ceramic Society, 2018, 91(8):2564 – 2569]
  - Evaporation of Zinc: Reduction of ZnO to Zn
  - Formation of other hydroxides possible but volatility (respective vapor pressure) is much lower

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Large variety of standard glasses available

	Low temp.	Intermediate temperature			High temperature			
SCHOTT SOEC/SOFC sealing glass	**GM31107**	**G018-311**	**G018-354**	**G018-391**	**G018-281**	**G018-381**	**G018-385**	**G018-394**
Suitable for typical SOEC/FC operating temperatures [°C]	600-700	650-750	650-750	700-800	800-1000	800-1000	800-1000	800-950
Sealing temperature [°C]	700	850	850	900	1000	950	870	900-950
Coefficient of thermal expansion $\alpha_{20\text{-}300}$ (10^{-6}/K)	9.8	9.9	9.2	9.8	12.1	12.1	8.0	8.7
Compatibility with	ITM, Crofer®,StS	ITM, Crofer®,StS	ITM, Crofer®,StS	ITM, Crofer®,StS	CFY	CFY	CFY	CFY

Crofer® = Trademark of Thyssen Krupp; CFY, ITM = Trademark of Plansee
StS = Stainless Steel

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SCHOTT is your industrial partner to scale up your glass solution

7 glasses in production stage, 5 glasses in pilot stage

> 200 R&D stage compositions formulated in the SOF/EC context including variants without and with low boron content

SCHOTT can cover all required volume scenarios from initial product development to full industrialization.

Stage	Volume	Production	Quality control
Early stage samples	0,1 – 10 kg	Melting: Lab Grinding: Lab	Target values
Pilot production	10 – 200 kg	Melting: Lab Grinding: Production	Preliminary specification
Series production	> 200 kg	Melting: Production Grinding: Production	Specification

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The effects of material costs should be considered right from the beginning of product development

Cost oriented		**Engineering requirements**
Off the shelf material	VS.	**Customized solution**
Materials selection		**Design-based solution**

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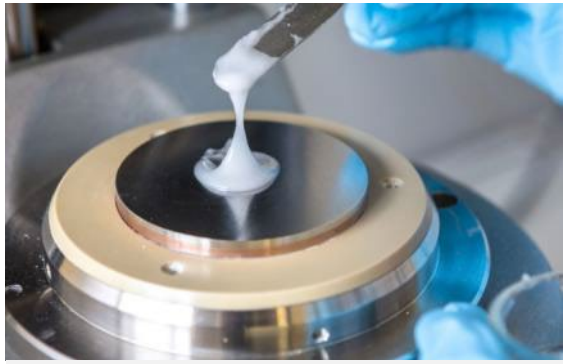
SOEC/FC sealing glasses scalable in different application forms

Powders

\+ Flexible application form for lab testing
\+ Starting point for all other forms

\- Cannot be applied for mass production



Pastes

\+ Flexible / free choice of geometry
\+ Screen printing and dispensing
\+ Easily scalable/large volumes
O Customized paste viscosity
\- Requires removal of organics
\- Shrinkage to be considered

Sintered Preforms

\+ Easy to apply
\+ Easily scalable to highest volumes
\+ No shrinkage
\+ No debindering required
O Customized tooling needed
\- Low flexibility in dimensions and designs/complexity
\- Only small parts possible (< 50 mm)

\+ Application via pick and place
\+ Scalable
O Customized dimensions
\- Low flexibility in dimensions
\- Waste recycling to be tested
\- Requires removal of organics
\- Shrinkage to be considered

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Get in touch with us to discuss your sealing solution!

SCHOTT offers 12 industry proven standard glasses for fuel cell and electrolyzer cell production in four supply formats.

Customized modification and production is possible. A large number of compositions are available as a starting point.

Design for manufacturability: Rethink the necessity of costly, possibly over-engineered materials and designs.

Chemical stability and component evaporation is only one factor to be considered when looking at electrolyzer sealants. Consider the complete picture for scale up.

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