POLYURETHANE, SILICONE AND EPOXY RESINS

FOR FUEL CELLS, ELECTROLYSERS AND OTHER ENERGY STORAGE DEVICES

UL webinar, 4 April 2023, Andreas Arlt

AGENDA

1. Company introduction
2. Solutions for fuel cells and electrolysers
3. Solutions for batteries and supercaps
4. Sealants, coatings and adhesives for flow battery manufacturing
5. Takeaways

01

COMPANY INTRODUCTION

WEVO-CHEMIE

AN INDEPENDENT FAMILY-OWNED COMPANY WITH AN INTERNATIONAL PRESENCE

We are the experts for all encapsulation applications and for special-purpose bonding and sealing applications.

Our customised resin systems are mainly used in electrical and electronic components.

COMPREHENSIVE PROTECTION

RESIN SOLUTIONS FROM WEVO PROTECT SENSITIVE COMPONENTS AGAINST:

Chemicals

Vibrations

Particles

Temperature

Dust

Humidity

WEVO SOLUTIONS FOR YOUR INDUSTRY

Automotive
Mobility

Wevo gets
things moving

Energy · Industry
Safety

Wevo secures
energy systems

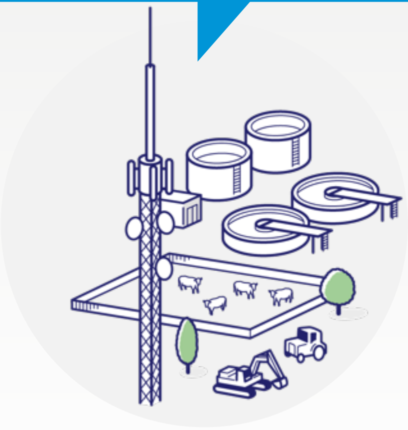
Lighting

Wevo
provides light

Home/Consumer
Health/Medical

Wevo is
home

Infrastructure
Environment · Agriculture



Wevo stands
for safety

WEVO IN FIGURES

1^{st}
ISO/TS 16949 certified
(since 2017: IATF 16949)
supplier in our sector

>50
export countries served
by Wevo

>75
years of experience in
product development
and application technology

>500
Wevo resin formulations
available worldwide

1250
customers use our systems

>2 bn
components casted,
bonded or sealed with
Wevo products every year

PRODUCT PORTFOLIO

THREE PRODUCT CHEMISTRIES FOR CUSTOMISED SOLUTIONS – FOR EVERY REQUIREMENT

WEVOPUR

Balanced systems with
highly configurable profile

WEVOPOX

High-strength systems with
high thermal stability

WEVOSIL

High-elasticity systems with
high thermal stability

02

SOLUTIONS FOR FUEL CELLS AND ELECTROLYSERS

FUEL CELL DEFINITION

A fuel cell is a technical device that generates electrical energy: it converts the chemical reaction energy of a continuously supplied fuel and an oxidising agent into electrical energy.

A fuel cell often means a hydrogen-oxygen fuel cell. Certain fuel cell types use other fuels instead of hydrogen, in particular methanol, butane or natural gas. Together with batteries, fuel cells belong to the galvanic cells.

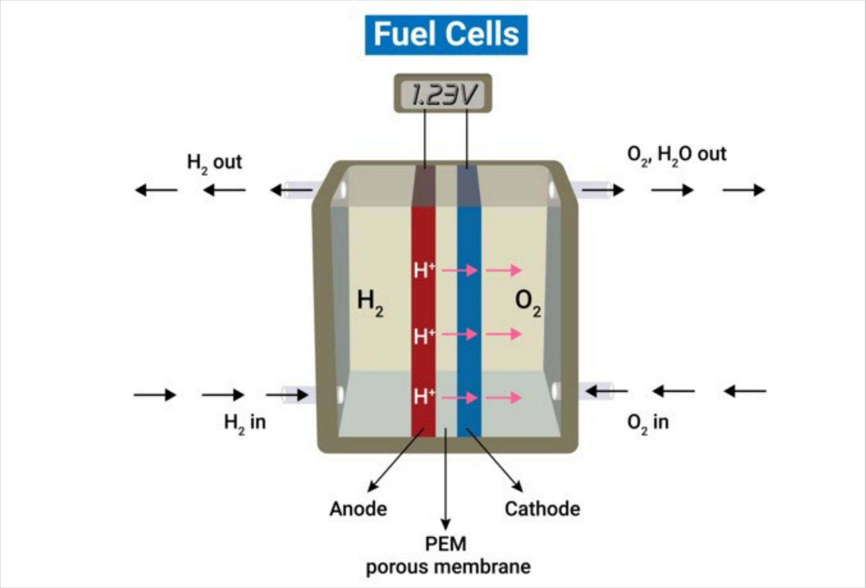
However, fuel cells are not energy storage devices, but energy converters.

The mechanism is based on the following redox reaction:

Anode: $2\ H_2 + 4\ H_20 \rightarrow 4\ H_3O^+ + 4\ e^-$ (oxidation)

Cathode: $O_2 + 4\ H_3O^+ + 4\ e^- \rightarrow 6\ H_20$ (reduction)

Reaction: $2\ H_2 + O_2 \rightarrow 2\ H_20$ (redox/cell reaction)



The most important type of fuel cell for many applications today is the proton exchange membrane fuel cell (PEMFC). Such a fuel cell usually uses hydrogen as fuel. This is generated either by steam reforming from methanol or methane and in the future from renewable energy by electrolysis (green hydrogen).

FUEL CELL TYPES

Fuel cell type		Operating temp.	Electrolyte	Fuel	Oxidant	Applications
Alkaline	AFC	80–90 °C	KOH	Hydrogen	Oxygen	Aerospace
Polymer electrolyte	PEMFC	80–120 °C	Polymer	Hydrogen, methanol	Oxygen, air	Mobility
Phosphoric acid	PAFC	200 °C	Phosphoric acid	Natural gas	Air	Combined heat and power plant
Molten carbonate	MCFC	650 °C	Lithium and potassium carbonate	Natural gas	Air	Power plant
Solid oxide	SOFC	1,000 °C	Zirconium oxide	Natural gas	Air	Power plant

02—1

ADHESIVES AND GASKETS FOR STACK MANUFACTURING

HYDROGEN APPLICATIONS

Mobility applications:
Fuel cell systems

Stationary applications:
Green hydrogen production/electrolysers

STACK PRODUCTION FOR FUEL CELLS AND ELECTROLYSERS

Application:

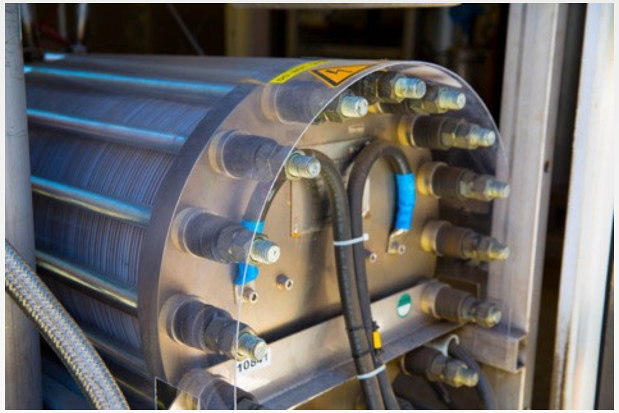
2-component addition curing adhesives and sealants for the stack production of fuel cells and electrolysers based on polyurethanes, silicones and polybutadiene resins

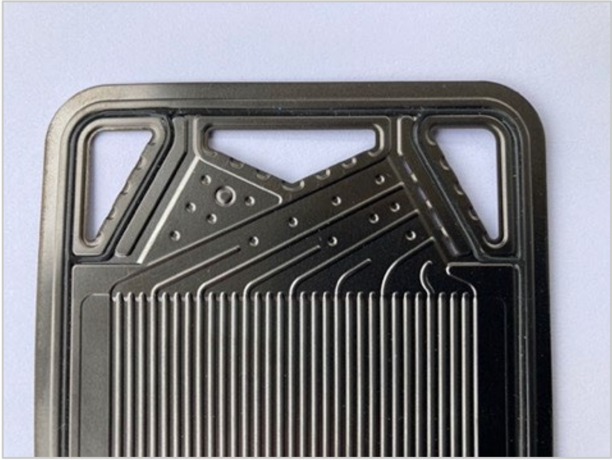
Properties:

- Fast curing
- Good adhesion to metallic and polymer/composite bipolar plates and membranes
- Good chemical and hydrolysis resistance under both acidic and alkaline conditions (pH 0–14)
- High ionic purity (ion elution test)

Possible solutions:

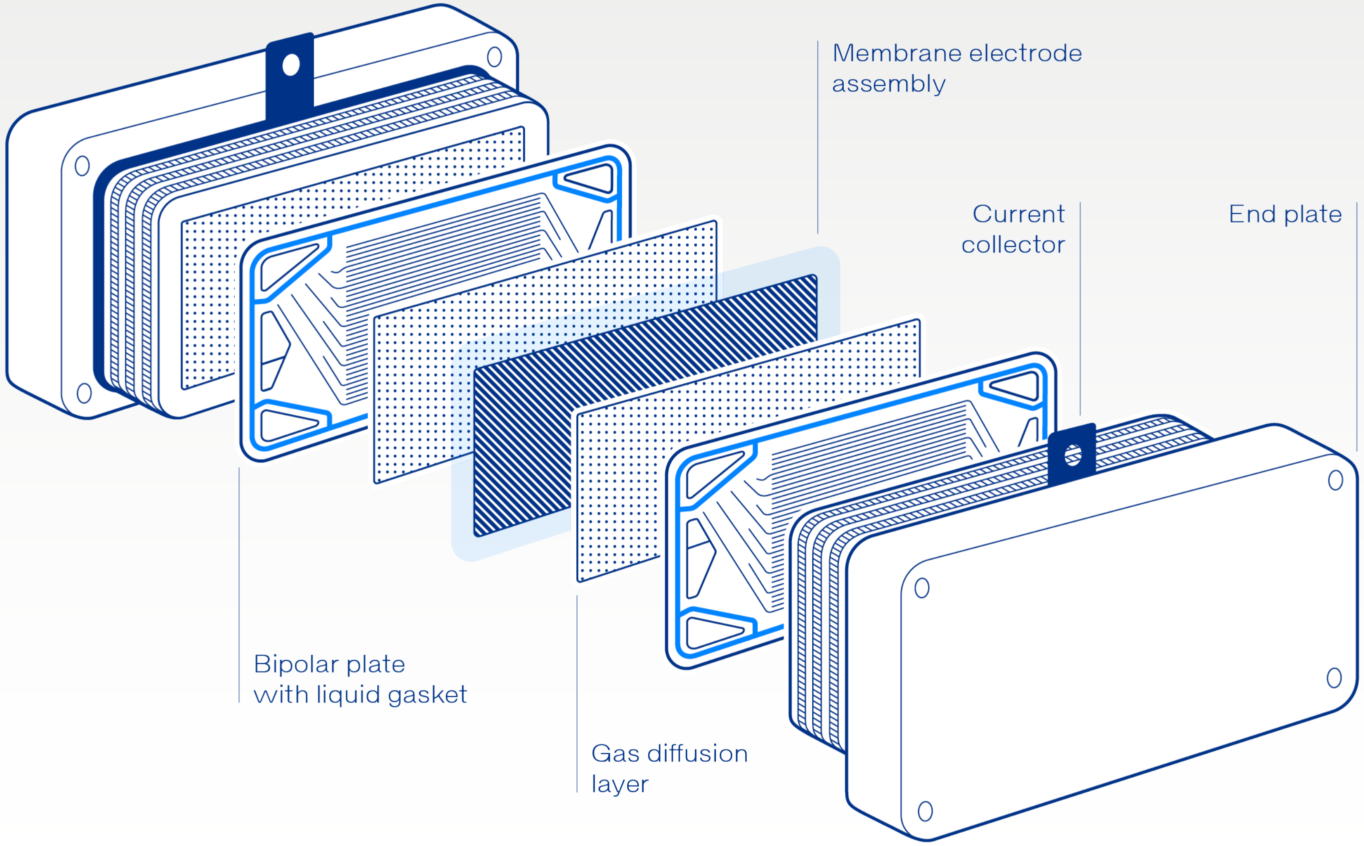
- WEVOPUR 79954/15; WEVOPUR 78901; WEVOPUR 79086 T
- WEVOSIL 28001 A/B; WEVOSIL 28002 A/B
- WEVOPOX 30010; WEVOPOX 389





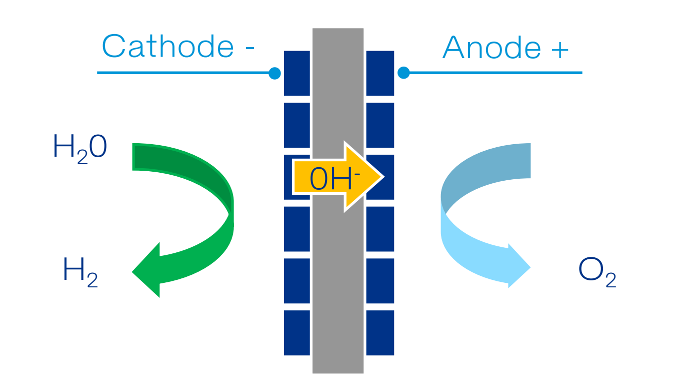
THE STACK:
HEART OF THE FUEL CELL SYSTEM

Setup of a PEM fuell cell with liquid gaskets applied



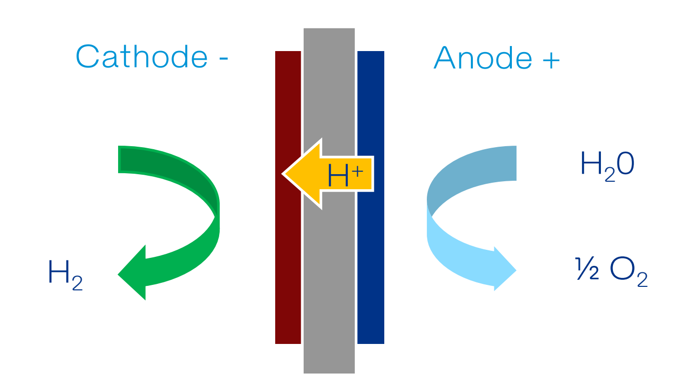
COMPARISON OF ELECTROLYSER TYPES

Alkaline Electrolyser



Technical framework	
Optimal cell temperature °C	60–80
Cell pressure (bar)	< 30 (< 200)
Current density / A cm^{-2}	0.2–0.4
Cell voltage (V)	1.8–2.4
Power density (W cm^{-2})	< 1
Lifetime stack (h)	> 90,000
Lifetime system (y)	20–30

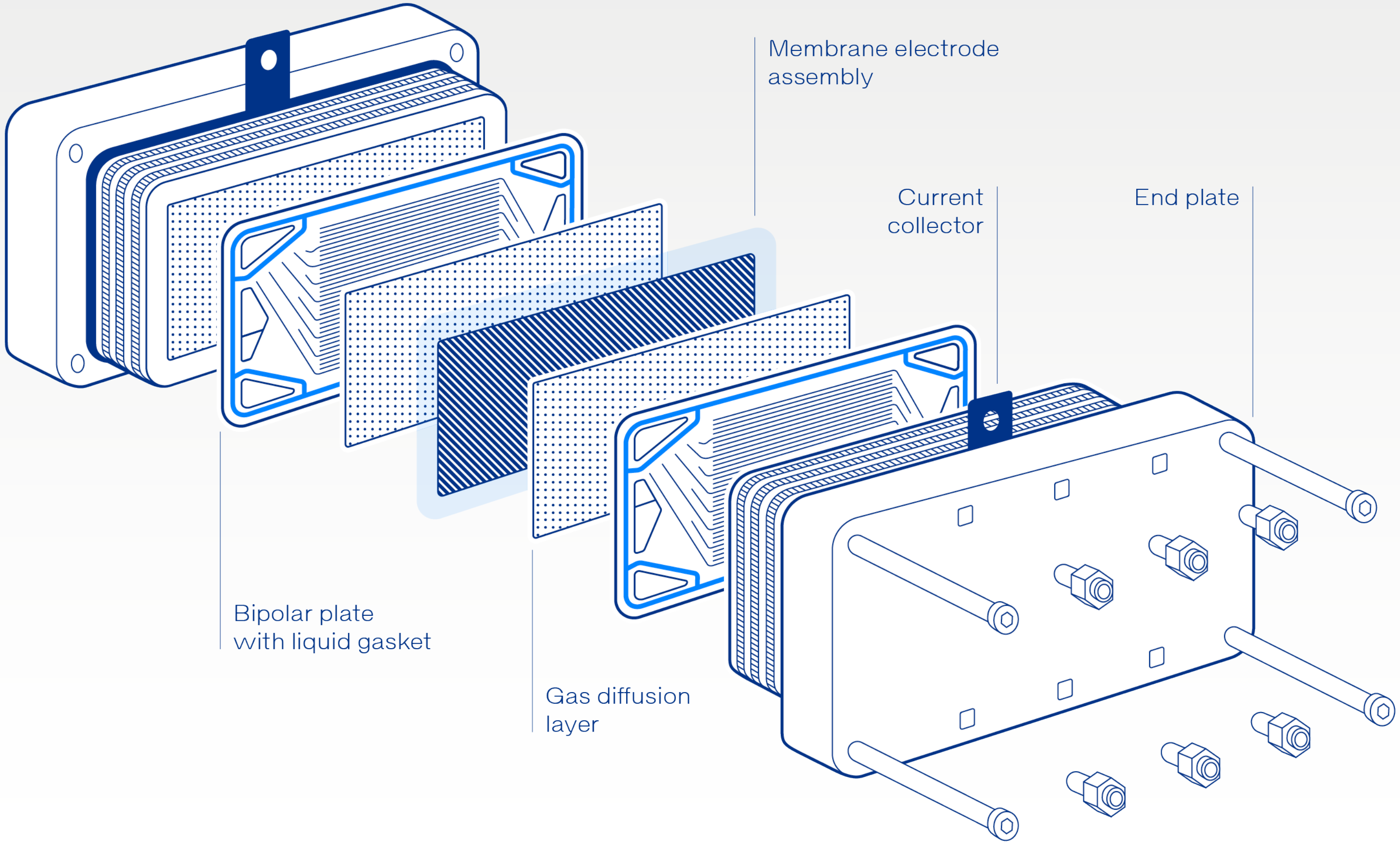
PEM Electrolyser



Technical framework	
Optimal cell temperature °C	50–80
Cell pressure (bar)	< 50
Current density / A cm^{-2}	0.6–2.0
Cell voltage (V)	1.8–2.2
Power density (W cm^{-2})	< 4.4
Lifetime stack (h)	> 80,000
Lifetime system (y)	> 20

PEM ELETROLYSER STACK

Setup of a PEM electrolyser stack



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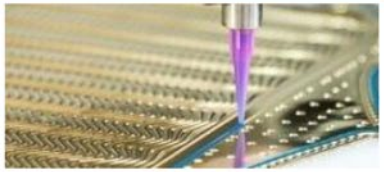
GASKET TECHNOLOGIES

Premanufactured

Seal on Plate



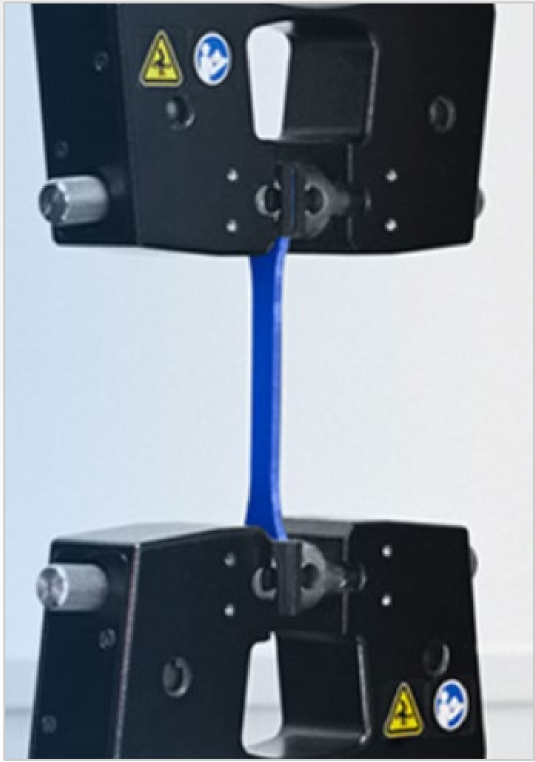
Seal on GDL

Key performance indicator (KPI)	
Temperature resistance	-70 to 200 °C
Thickness	0,2 – 0,5 mm
Weight	5 - 50 g
Resistance	Chemically inert

Source: FCI Center Fuel Cell Industrialisation

PROPERTIES OF POLYURETHANES

- Hardness/elasticity can be adjusted in a wide range from soft-elastic (Shore A 25) to rigid (Shore D 90)
- Very good adhesion on metals, incl. stainless steel, and various plastics
- Polyurethanes may act as an adhesive and sealant at the same time
- Modified polyurethane types can be adjusted with a low Tg of –60 °C and high elasticity and therefore may replace silicone elastomers
- Compared to silicones significantly lower gas permeability, therefore the H_2 permeation rate is much lower
- Lower hydrogen losses and therefore higher safety
- Viscosity can be adjusted from low viscous to thixotropic (application of sealings)
- Reactivity can be adjusted, fast curing is possible, curing can be accelerated by heat or IR



OVERVIEW OF POLYURETHANES

	WEVOPUR 79086 T WEVONAT 600	WEVOPUR 79954/15 WEVONAT 385	WEVOPUR 78901/40
Type	2-component addition curing polyurethane	2-component addition curing polybutadiene	2-component addition curing polyurethane
Operating temperature [°C]	–40 to +130	–40 to +125	–60 to +110
Mixed viscosity @ 23 °C [mPA·s]	thixotropic	15,000–30,000	10,000–20,000
Pot life @ 23 °C [min.]	30	15	30–40
Curing	room temperature, can be accelerated by heat or IR	room temperature, can be accelerated by heat or IR	room temperature, can be accelerated by heat or IR
Shore hardness A/D	--/45–50	--/25–35	65–75/--
Elongation at break [%]	84	120	96
Glass transition temperature [°C]	25	–56	< –55
Water absorption 30 d @ 23 °C [%]	0.6	0.8	
Permittivity @ 50 Hz, 23 °C	n/a	3.67	4.43
Dissipation factor @ 50 Hz, 23 °C	n/a	0.063	0.078
Hydrogen permeation coefficient [10E-8 cm²/s]	3	approx. 30	approx. 60
Advantages	Tough-elastic properties, low VOC, very low gas permeability (incl. water vapour and H_2), good adhesion on various plastics and metal substrates	Silicone-like properties, low VOC, high ionic purity (ion elution 90 °C, 168 h: 3–4 ppm total cation elution, low gas permeability (incl. water vapour and H_2), good hydrolysis resistance against water (85/85) and hot aqueous KOH (35%)	Elastic properties, low VOC, high ionic purity, high chemical resistance
Applications	Adhesive for fuel cell stacks, filters and humidifiers	Adhesive and sealant for fuel cell stacks, alkaline electrolysers, filters and humidifiers	Adhesive and sealant for fuel cell stacks, filters and humidifiers
Variations	• Low viscosity versions • Various thixotropic versions for bead application • Various pot-life versions (5,20, 30 min)	• Low viscosity version for potting (PD 79952) • Thixotropic version (79954 T) for bead application • Various pot-life versions	• Fast pot life (5 min.) for dispensing application • Softer version (WEVOPUR VP 408), Shore A 40–50

WEVOPUR 78901/40 WITH WEVONAT 385

Modified 2-component addition curing polyurethane with a hydrophobic polybutadiene backbone

Product features:

- Softer version of WEVOPUR 79952 (Shore A 60–65)
- The material acts as an adhesive and sealant at the same time
- Due to its low Tg of < –60 °C and the high elasticity, the material has similar properties to a silicone elastomer
- Longer pot life (approx. 40 min,), therefore suitable for screen-printing application

Varieties:

- WEVOPUR 78901: 5 min. pot life for dispensing application
- WEVOPUR VP 408: softer version, suitable as sealant

Source: FCI/Fraunhofer IPT

OVERVIEW OF SILICONES

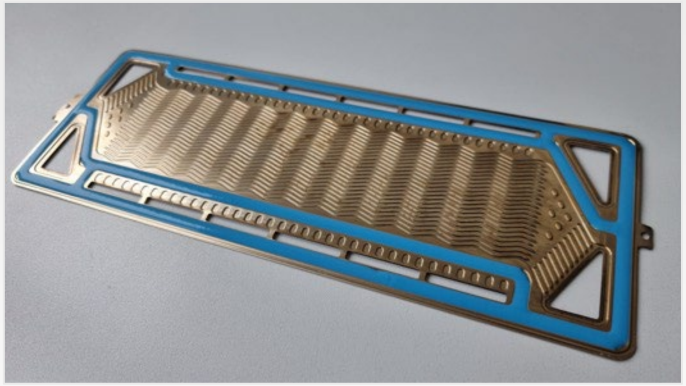
	WEVOSIL 28001 A/B	WEVOSIL 28002 A/B
Type	2-component addition curing silicone	2-component addition curing silicone
Operating temperature [°C]	–60 to +200	–60 to +200
Mixed viscosity @ 23 °C [mPA·s]	30,000–60,000	100,000 – 150,000
Pot life @ 23 °C [min.]	60–90	60–90
Curing	Room temperature, can be accelerated by heat or IR	Room temperature, can be accelerated by heat or IR
Shore hardness A/D	60–70/--	30–40/--
Elongation at break [%]	100	300
Glass transition temperature [°C]	< –55	< –45
Water absorption 30 d @ 23 °C [%]	< 0.2	
Permittivity @ 50 Hz, 23 °C	3.06	2.86
Dissipation factor @ 50 Hz, 23 °C	0.013	0.008
Hydrogen permeation coefficient [10E-8 cm²/s]	approx. 500	approx. 130
Advantages	Elastic properties, low VOC, high ionic purity, high chemical resistance	Very elastic properties, low VOC, high ionic purity, high chemical resistance, low gas permeability compared to common silicones
Applications	Adhesive and sealant for fuel cell stacks, filters and humidifiers	Adhesive and sealant for fuel cell stacks, filters and humidifiers
Variations	Higher viscosity version (WEVOSIL 28002)	Lower viscosity version (WEVOSIL 28001)

WEVOSIL 28001 A/B

2-component addition curing silicone adhesive

Product features:

- The material has a wide operating temperature range: –60 °C to +200 °C
- It cures without shrinkage and release of volatile by-products and is free of low molecular weight VOC
- The material is flame resistant acc. to UL 94 V-1
- The material shows good adhesion on many substrates after short heat exposure (100–120 °C). Tensile shear strength in accordance with ISO 527-2:
  - AlMg3/AlMg3: 7.0 N/mm²
  - V2A/V2A: 6.5 N/mm²
  - PA 6.6 / PA 6.6: 6.5 N/mm²
  - PBT / PBT: 5.0 N/mm²
- Like all silicones, the material exhibits higher gas permeability and a H_2 permeation coefficient in the same range as common silicones



Source: WätaS

WEVOSIL 28002 A/B

2-component addition curing silicone sealant

Product features:

- Elastic material (Shore A 30–40, elongation at break: > 300 %)
- The material has a wide operating temperature range: –60 °C to +200 °C
- It cures without shrinkage and release of volatile by-products and is free of low molecular weight VOC
- The material is flame resistant acc. to UL 94 V-1
- The material shows good adhesion on many substrates after short heat exposure (100–120 °C). Tensile shear strength in accordance with ISO 527-2:
  - AlMg3/AlMg3: 1.0 N/mm²
- Very low gas permeability for a silicone elastomer and a very low H_2 permeation coefficient of approx. 130 E-8 cm²/s

Source: FCI/Fraunhofer IPT

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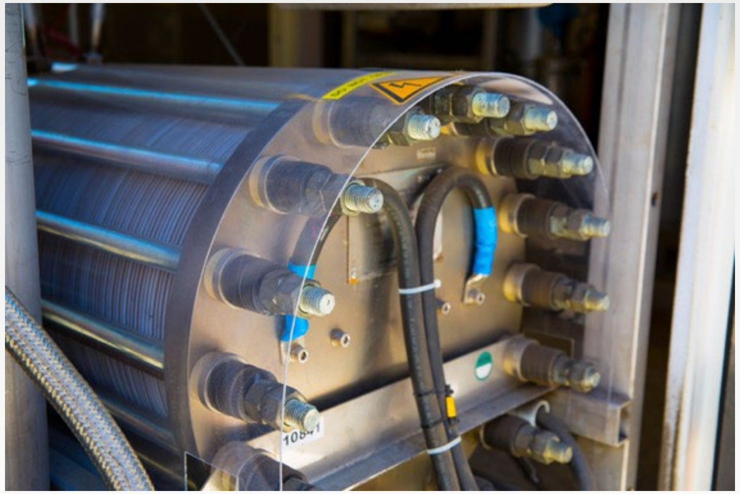
WEVOPOX 30010 WITH WEVODUR 5007

2-component addition curing epoxy resin

Product features:

- The material shows very good adhesion on various plastics, metals, including stainless steel, glass and ceramics
- Good chemical and hydrolysis resistance
- Resistant to hot aqueous KOH (35 %), therefore suitable as adhesive in alkaline electrolyser stack assembly:
  - Change in Shore D hardness and weight: < 1 % after 1 week exposure



Varieties:

- WEVOPOX VP 414 with WEVODUR VP 415: thixotropic version for dispensing of beads

02—2

HYDROGEN PERMEABILITY

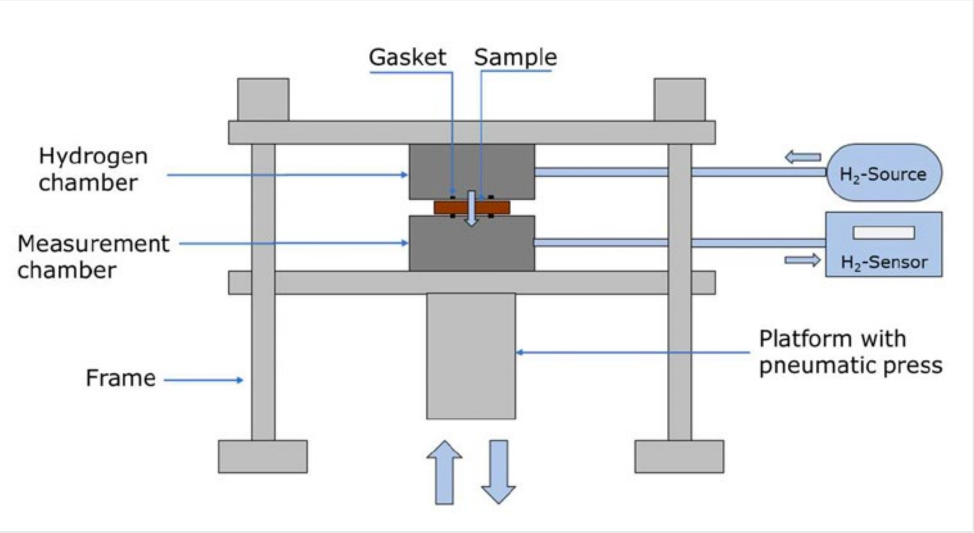
H_2 PERMEATION MEASUREMENT: TEST SET-UP

Measurement parameters:

- Calibration point: 10 ppm
- Highest accuracy: 10 ppm ± 5 ppm
- Time periods: 1 min., 10 min., 1 h, 16+ h
- Hydrogen pressure: 1 bar_{rel}

Measured values:

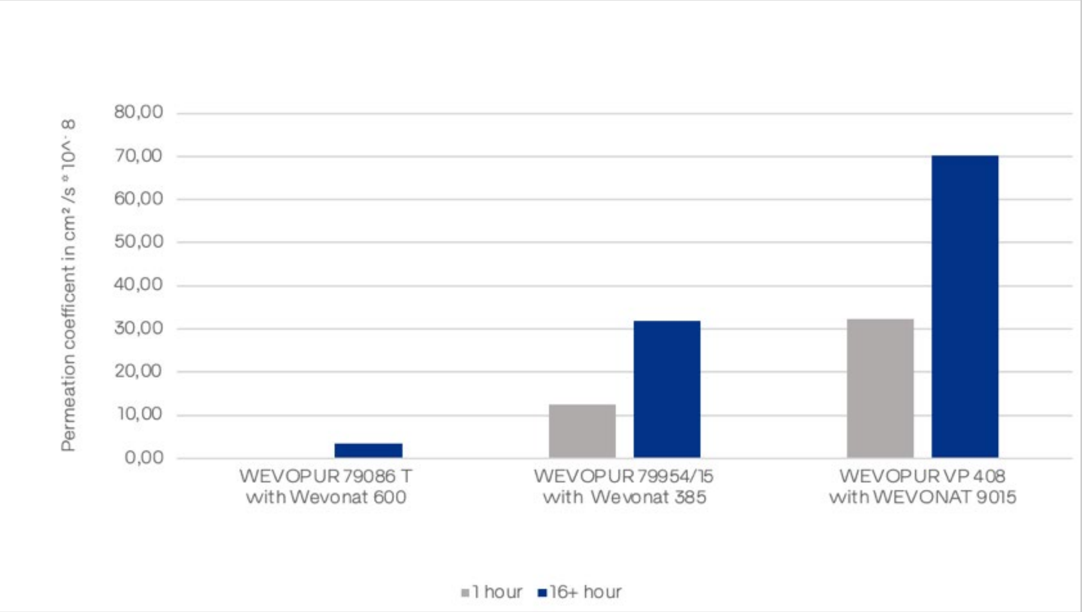
1. pV throughput [mbar·l/s]
   - Change in product of pressure and volume per unit time
2. Gas permeation rate [cm/s]
   - Including the partial pressure difference to the measurement chamber as well as the permeation area
3. Permeation coefficient [cm²/s]
   - Gas permeation rate related to sample thickness

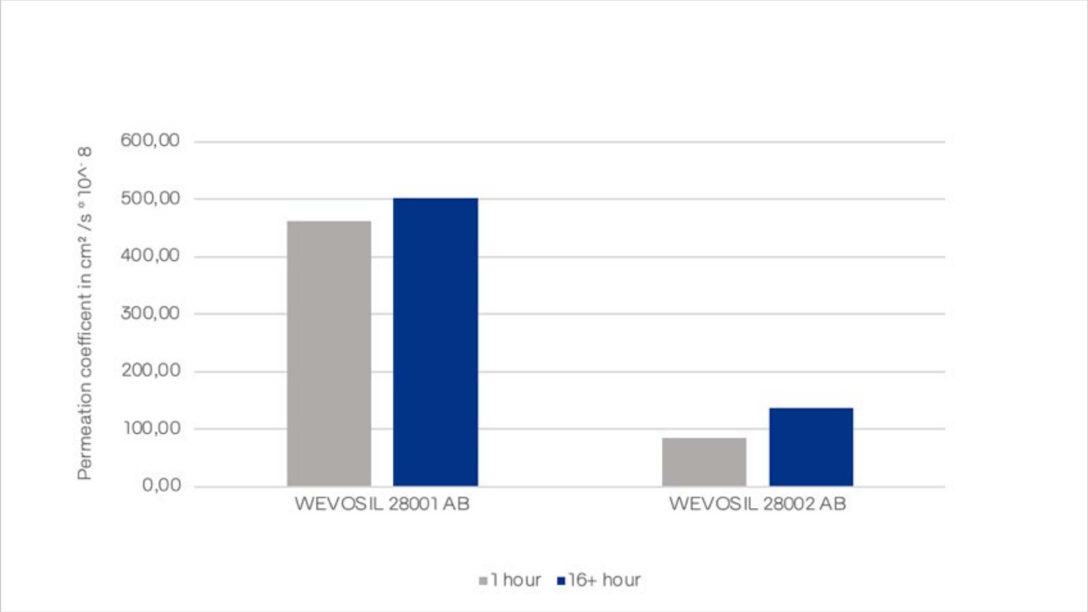


Source: ZBT

Rating	Excellent	Very good	Good	Acceptable	Only silicone material
Perm. coeff. [10E-8 cm²/s]	< 0.1	< 1	< 10	< 100	< 1,000

RESULTS OF H_2 PERMEATION





- Polyurethanes have much lower hydrogen permeability compared to silicones.
- However, we have developed silicone sealants with comparably low Hydrogen permeation, especially WEVOSIL 28002 shows an exceptionally low hydrogen permeability.

02—3

BALANCE OF PLANT APPLICATIONS

BALANCE OF PLANT: AIR AND H_2 CIRCULATION SYSTEM

Application:

2-component addition curing adhesives, potting compounds and sealants for the production of air filters, coolant filters, humidifier modules and ion exchange filters

Properties:

- Fast curing
- Good adhesion to polymer membranes, non-wovens and polymeric spacer materials
- Very good chemical and hydrolysis resistance
- High ionic purity (ion elution test)

Possible solutions:

- WEVOPUR 79952 and thixotropic versions; WEVOPUR 895 and thixotropic versions; WEVOPUR 2082; WEVOPUR 78901
- WEVOSIL 28001 A/B

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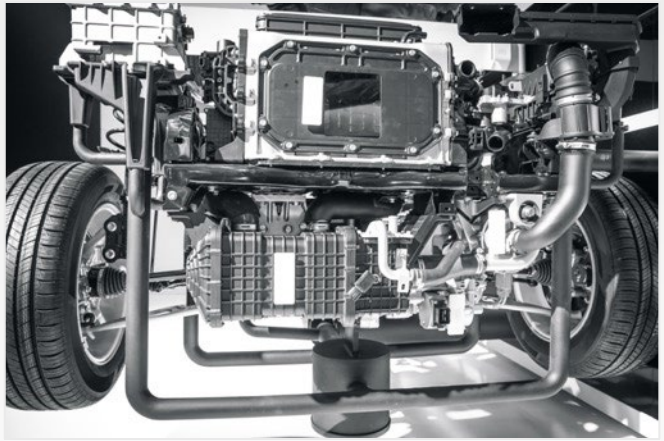
HUMIDIFIER



Application:

Efficient fuel cell drives depend on reliable membrane humidification. This ensures a perfect reaction and prevents premature degradation by drying out the polymer electrolyte. Adhesives are used to assemble the membrane and different spacer materials to form a stack in flat type membrane humidifiers. Potting materials are used to encapsulate hollow fibre bundles for hollow fibre type humidifiers.

Properties:

- Good adhesion to polymeric membranes, non-wovens and polymeric spacer materials
- Very good chemical and hydrolysis resistance
- High ionic purity (ion elution test), low volatiles, no influence on vapour permeability of the membrane

Solutions for flat type membranes:

- WEVOPUR PD 79952, WEVOPUR 78901, WEVOPUR 895 and thixotropic versions

Solutions for hollow fibre membranes:

- WEVOPUR 2082, WEVOPOX 30010

WEVOPUR 2082 WITH WEVONAT 1000

2-component addition curing tough-elastic polyurethane potting compound

Product features:

- The material shows very good adhesion on various plastics, metals, including stainless steel, glass and ceramics
- Low mixed viscosity (600 mPA·s), good penetration behaviour
- Long pot life (> 60 min.), therefore low exotherm
- Good chemical and hydrolysis resistance
- Pure raw materials
- Drinking water approval in accordance with BS 6920 (WRAS)

Application:

- Hollow-fiber based humidifiers
- Water-filter for electrolysers

AIR COMPRESSOR

Application:

In order to achieve a higher power density in the fuel cell, the inlet air is compressed in the air compressor. The requirements of the air compressor in a vehicle with an internal combustion engine are different from those in a fuel cell vehicle. These include a high pressure ratio and low mass flow. In a fuel cell vehicle, the compressor is one of the most critical components with one of the highest failure probabilities, as it runs at high speeds of up to 200,000 rpm. The stator of the motor is typically potted with thermally conductive potting compounds to increase component life.

Requirements:

- High temperature resistance (180–200 °C (min. Class H))
- High thermal conductivity, high crack resistance
- Low viscosity, good impregnation properties

Solutions:

WEVOPOX 2513, WEVOPOX 36001 FL, WEVOSIL 27015, WEVOSIL 22002 FL

H_2 RECIRCULATION BLOWER

Application:

The blower is situated behind the cell and has two major tasks. Firstly, the non-utilised hydrogen is recirculated to the hydrogen supply channel. Secondly, when the hydrogen passes through the cell, it experiences a pressure drop, which must be compensated by the blower. This is technically demanding as hydrogen is more difficult to compress than air due to its small molecule size.

Requirements:

- High temperature resistance (180–200 °C (min. Class H))
- High thermal conductivity
- Low viscosity, good impregnation properties
- High crack resistance

Solutions:

WEVOPOX 2513, WEVOPOX 36001 FL, WEVOSIL 27015, WEVOSIL 22002 FL

DC/DC CONVERTER AND ON-BOARD CHARGERS

Source: Brusa

Application:

Basically, fuel cells have a lower output voltage than battery blocks and a volatile voltage level. For this reason, a DC/DC converter is required to compensate for these differences. The 400 V DC/400 V DC converter is also known as a buck-boost converter. The on-board charger is used to charge the battery.

Thermally conductive potting compounds for the potting of the inductive components and gap fillers are used to ensure heat dissipation and control the thermo-management.

Properties:

- High thermal conductivity (up to 1.6 W/m·K), good heat dissipation
- Self-extinguishing properties according to UL 94 V-0 possible
- High heat resistance (up to 160 °C)

Solutions:

WEVOPUR 60416 FL, WEVOPOX 36001 FL, WEVOSIL 22006 FL, WEVOSIL gap fillers

ELECTRONIC CONTROL UNIT

Application:

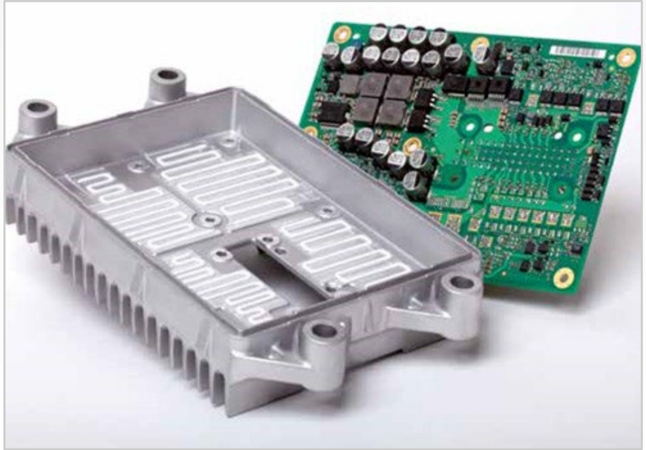
Thermal interface materials, gap fillers and thermally conductive potting compounds to ensure heat dissipation of power electronics to heat sink

Requirements:

- Good heat removal
- High thermal conductivity
- Resistance to temperature changes
- Resistance to hot, humid conditions (85 °C, 85 % r.H.)
- Good adhesion on casted metals and plastics
- UL 94 V-0 is of advantage
- Low CTE

Solutions:

Different thermally conductive WEVOSIL types, WEVOPUR 63515 FL, WEVOPUR PD 64515 FL



ADHESIVES FOR FLUID FILTERS (COOLANTS, HYDRAULIC LIQUIDS)

Application:

Adhesives and potting for fixing the filter media on endplates and filter housings

Requirements:

- High hardness: Shore D 75–90
- Good chemical resistance to coolants (water/glycol, e.g. Glysantin FC G20, hydraulic fluids such as mineral oils and esters)
- Temperature resistance: –40–100 °C (short term 140 °C)
- Good wettability on filter media
- Good adhesion on various end cap materials such as galvanised or tin-plated steel and plastics such as PA

Solutions:

- WEVOPUR 801 GV/3, WEVOPUR 801 T 2.5, WEVOPUR 80814 N/2, WEVOPUR 87210 G/3
- WEVOPOX 399, WEVOPOX 30010

02—4

PROCESSING

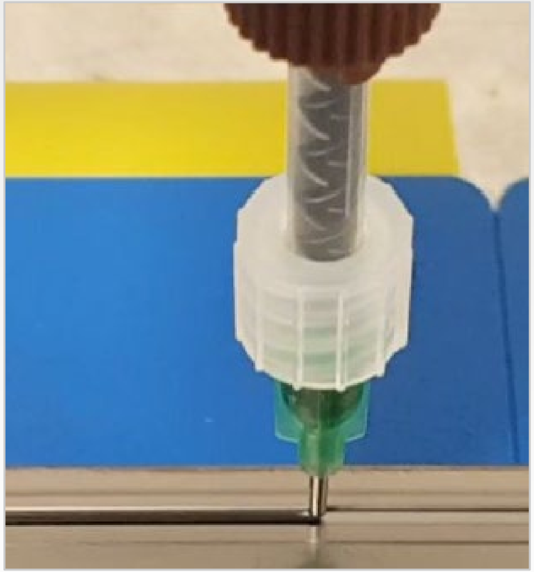
PROCESSING/APPLICATION

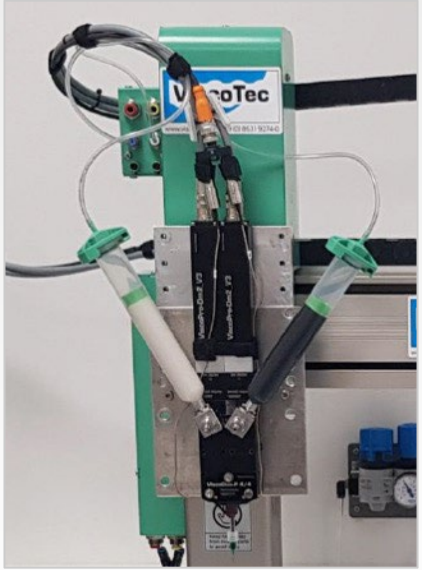
The above-mentioned materials can be processed with 2-component mixing and dosing machines and then be applied by the following methods:

- Dispensing
- Screen printing

Dispensing is an established method and partner companies can be involved accordingly.

The materials are room temperature curing, but curing can be significantly accelerated by heat (convection ovens) and/or by IR heaters





Source: Viscotec / FCI / Fraunhofer IPT

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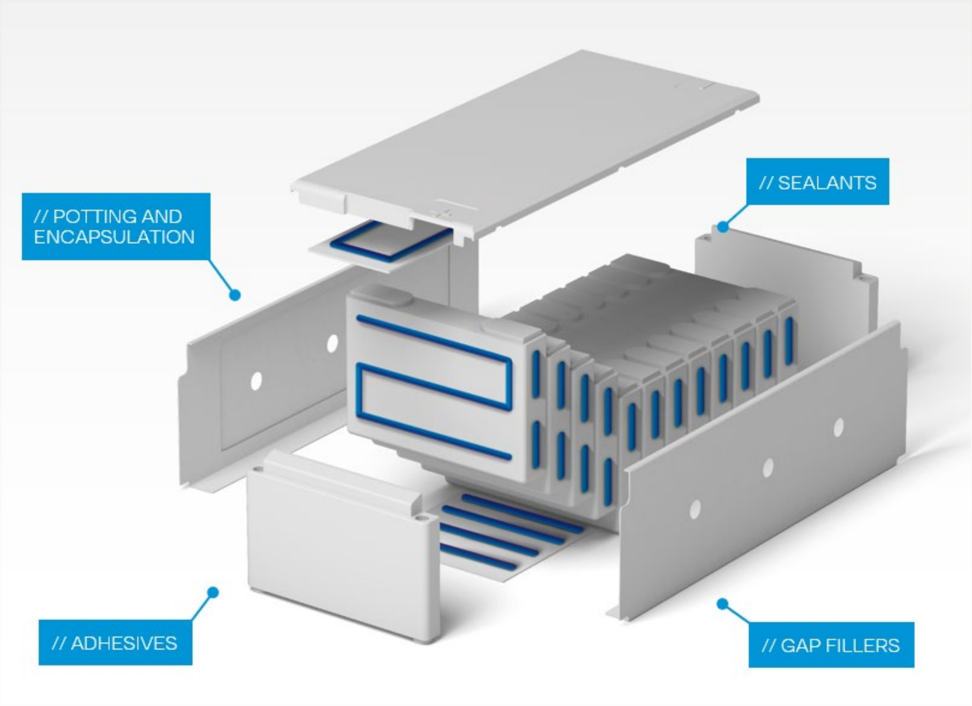
03

SOLUTIONS FOR BATTERIES AND SUPERCAPS

BATTERY PACK AND MODULE ASSEMBLY

For e-mobility and stationary energy storage:

The exponential growth of e-mobility and stationary energy storage is giving rise to demand for economic and fully automated production lines for the assembly of battery packs and modules. Wevo's high-performance adhesives, potting compounds, encapsulants and thermal interface materials are used in these applications, e.g.:



WEVOPUR 60910 FL with WEVONAT 900

- Tough-elastic thermally conductive polyurethane adhesive
- Thermal conductivity: 1.0 W/m·K
- Shore D 35–45
- Flame retardant: UL 94 V-0 (3 mm), all colour
- HAI, HWI, CTI: PLC 0

SUPERCAPACITOR PACK ASSEMBLY

Supercapacitors or power caps can withstand more charge and discharge cycles than rechargeable batteries. They are typically used in energy storage applications where fast delivery of high power is needed, as for example in hybrid vehicles such as diesel locomotives or heavy-duty vehicles.

Wevo's tailor-made and highly engineered WEVOPUR, WEVOPOX and WEVOSIL potting compounds and adhesives are used to assemble the supercap cells in packs and modules, for example:

WEVOPUR 512 FL with WEVONAT 900

- Polyurethane potting compound
- Low viscosity (500 m·Pas @ room temperature)
- Elastic (Shore D 30–40) and therefore shock and vibration resistant
- Thermal conductivity: 0.8 W/m·K
- Self extinguishing acc. to UL 94 V-0 (4 mm), all colour, RTI elec and Str 130 °C
- HWI, HAI, CTI: PLC 0
- Railway fire standard EN 45545-2 HL 2 rating (R 22/R23)
- Versions WEVOPUR 512 FLE with WEVONAT 900 E: HL 3 rating

Source: WIMA GmbH & Co. KG

THERMAL MITIGATION

Identified challenges:

Thermal runaway of cells as the worst-case scenario, spot fires, heat spreading, (toxic) hot burning gases/particles, carbon production (risk of short circuits)

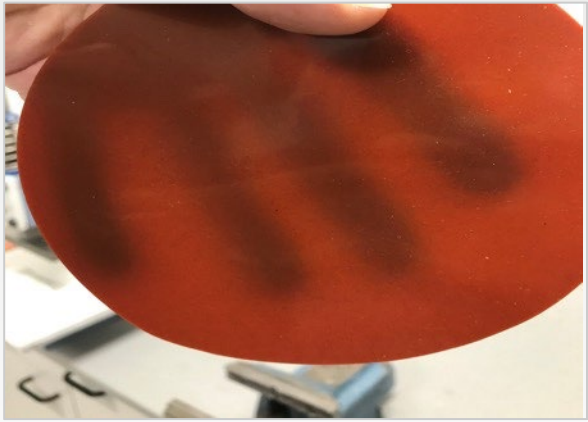
Silicone solution:

- Reducing potential ignition by possible means of flame suppression
- Inorganic with no (conductive) carbon build-up after thermal incident
- Controlled exhaust of venting cells

> 1,000 °C flame on a 1 mm silicone coated steel plate

THERMAL MITIGATION

Potting of the whole battery pack with the low-viscous version:



WEVOSIL 22027 FL A/B

- Creates a silica protective layer
- Endothermic reaction (boosted by special additives inside)
- Release of water and CO_2, to dilute and cool down the gases
- Easily repairable and refillable
- Sticky for self-adhesion properties and to compensate for swelling of cells without delamination
- Does not produce carbon
- Not corrosive

THERMAL MITIGATION

Protective coating on cells, connectors and busbars:

WEVOSIL 27001 FL A/B

- Creates a silica protective layer
- Can be applied as a coating or encapsulant and in cured form as thin pads on battery cells/assemblies and cell heads or busbars
- Low thermal conductivity (0.2 W/m·K), therefore acts as a thermal barrier and allows single fracture/opening to guide venting gases away from adjacent battery cells
- Sticky and soft for self-adhesion properties and to compensate for swelling of cells without delamination
- Easily repairable and refillable
- Does not produce carbon
- Electrically isolating, not corrosive

WEVOSIL 27001 FL after 5 min burning @ app. 1000 °C

WEVOSIL 27001 FL / 22027 FL

	WEVOSIL 27001 FL A/B Coating	WEVOSIL 22027 FL A/B Potting
Type	2-component addition curing silicone	2-component addition curing silicone
Operating temperature [°C]	−60 to +250	−60 to +180
Mixed viscosity @ 23 °C [mPa·s]	4,000–8,000	700–1,300
Pot life @ 23 °C [min.]	50–70 (adjustable)	50–70 (adjustable)
Curing	Room temperature, can be accelerated by heat or IR	Room temperature, can be accelerated by heat or IR
Shore hardness A	25–35	25–35
Elongation at break [%]	100	100
Melting point [°C]	< −45	< −45
Water absorption 30 d @ 23 °C [%]	< 0.2	< 0.5

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SEALANTS, COATINGS AND ADHESIVES FOR FLOW BATTERY MANUFACTURING

REDOX FLOW BATTERIES

Redox flow batteries (RFB) are elaborately constructed electrochemical devices.

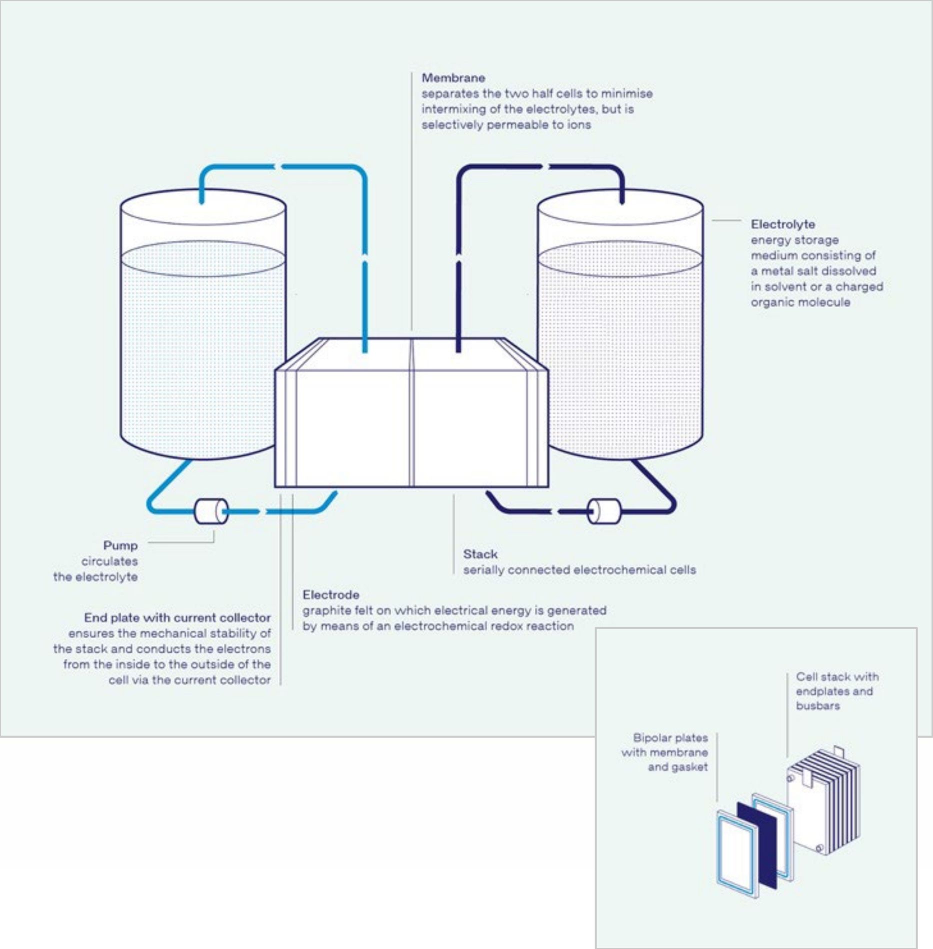
In RFBs the energy is stored in an electrolyte, often based on vanadium.

The electrolytes are circulated in two separate circuits by means of pumps. Energy conversion takes place in an electrochemical cell that is separated into two halves by a membrane.

Comparable to fuel cells, the individual cells can be connected in series to form a stack.

The aggressive V-electrolyte places very high demands on the materials used, making design of the battery complex.

Specially developed, highly chemical-resistant potting compounds, adhesives and sealants from Wevo are suitable for use in this aggressive environment – and they also provide multiple other benefits for this battery technology.



STACK ASSEMBLY IN RFB

New production technologies for the stack assembly play an essential role in the industrialisation and scaling up of redox flow batteries.

Instead of using preformed gaskets and manual assembly of the stack by means of threaded rods or clamping rings, the use of adhesive joining technologies and liquid formed-in-place gaskets (FIPGS) offers new possibilities, design freedom and simplified and faster automated production technologies.

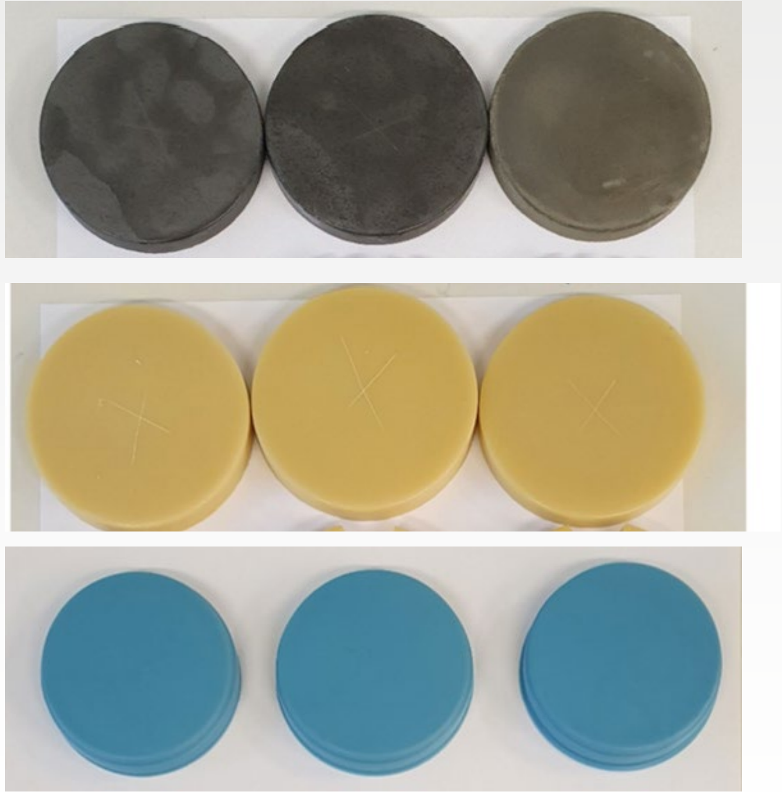
Chemically resistant sealants and adhesives were developed and their chemical resistance in vanadium electrolytes at different oxidation levels of vanadium (V^{2+}, $V^{3.5+}$ and V^{5+}) was examined.

This work was done in collaboration with Fraunhofer ICT, the DECHEMA Research Institute and the University of Applied Sciences (HAW) Hamburg.

TEST PROCEDURE AND EXAMPLES OF USE

Chemical stability tests of cured polymers and electrolyte alteration after chemical exposure in the vanadium electrolytes:

- Change of shore hardness and weight of the polymers (Fraunhofer ICT and DECHEMA Research Institute)
- Alteration of the polymer surface by optical inspection with a light microscope (Fraunhofer ICT)
- Optical and quantitative inspection of the electrolytes including titration, UV-VIS spectroscopy, colour change and transparency (DECHEMA Research Institute)



V^{2+} solution $V^{3.5+}$solution V^{5+} solution

OVERVIEW OF TESTED MATERIALS

	WEVOPUR 9064 B/30 WEVONAT 507	WEVOPOX 32702 WEVODUR 5008	WEVOPOX 32703 WEVODUR 5009	WEVOSIL 28001 A/B
Type	2-component room temperature curing polyurethane resin	2-component room temperature curing epoxy resin	2-component hot curing epoxy resin	2-component room temperature curing silicone sealant
Mixing ratio (part per weight)	100 : 35	100 : 10	100 : 12	100 : 100
Mixed viscosity [mPa·s]	1,200–1,600	2,000–3,500	5,000–8,000	30,000–60,000
Pot life at 22 °C [min]	app. 30	60–80	app. 30 min @ 120 °C	60–90
Density A-component [g/cm³]	2.02–2.08	1.78–1.84	1.65–1.70	1.28–1.32
Density B-component [g/cm³]	1.20–1.24	0.95–0.99	1.00–1.04	1.28–1.33
Shore hardness	85–92 D	80–90 D	80–90 D	60–70 A
Operating temperature [°C]	–30 to +140	–40 to +130	–40 to +155	–60 to + 200
E-module [N/mm²]		6,200	5,000	4.5
Elongation [%]		1,4	1	100
Glass transition temperature [°C]	88	76	117	–55
Water absorption [%]	0.3	0.3	0.2	< 0.2
Dielectric strength [kV/mm]	31			> 30
Dielectric constant at 50 Hz, 22 °C	4.9	4.7	5.1	3.1
Dissipation factor at 50 Hz, 22 °C	0.05	0.011	0.02	0.013
Volume resistance at 23 °C/50 % r.h. [Ω.cm]	10^{15}	10^{15}	10^{15}	10^{14}
Surface resistance at 23 °C/50% r.h. [Ω]	10^{15}	10^{14}	10^{14}	10^{14}
Target application	anti-corrosive coating, encapsulation, adhesive	anti-corrosive coating, encapsulation, adhesive	anti-corrosive coating, encapsulation, potting	sealing, adhesive, encapsulation

MICROSCOPIC PICTURES AFTER CHEMICAL EXPOSURE

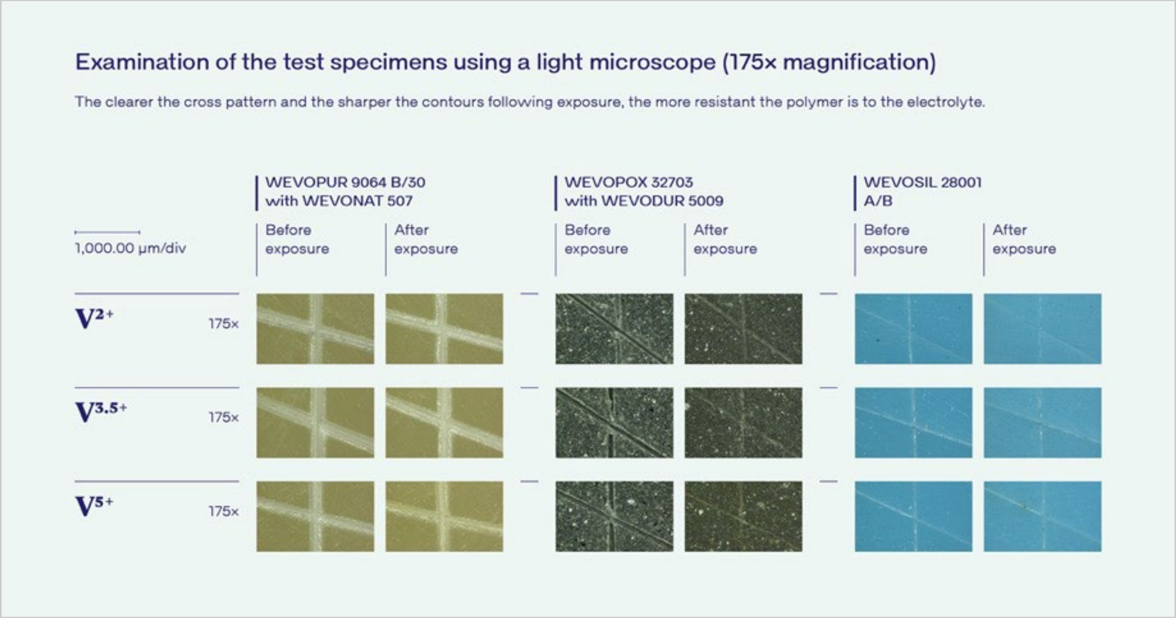
Optical analysis of test specimens with a light microscope before and after exposure to the different electrolytes (135 days at 40 °C for V^{2+} and $V^{3.5+}$ and room-temperature V^{5+}).

The test specimens were scratched with a cutter knife to form a cross-shaped pattern.

The more visible the cross pattern is and the sharper the lines after electrolyte exposure are, the more stable the polymer is against the electrolyte.

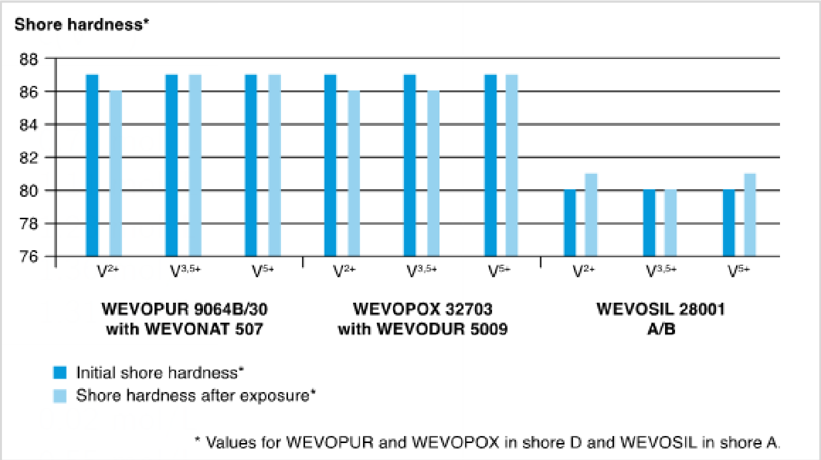
The pattern is still visible and especially for WEVOPUR and WEVOSIL nearly unchanged.

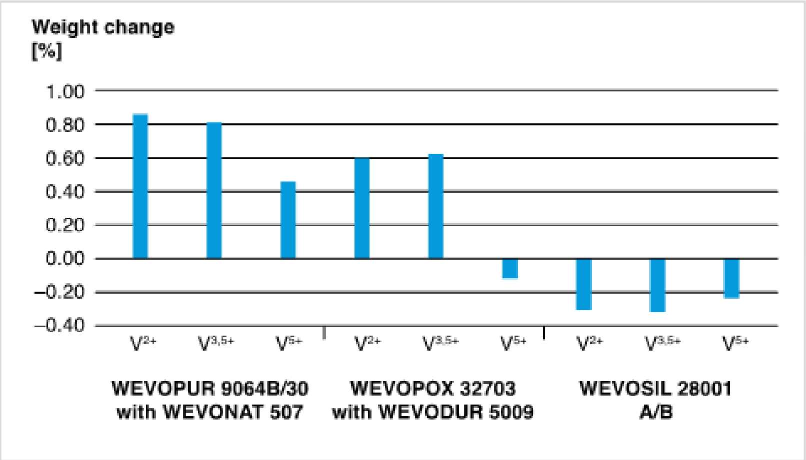
Investigation carried out by Contract Research at Fraunhofer ICT, Pfinztal, Germany.



SHORE HARDNESS AND WEIGHT AFTER ELECTROLYTE EXPOSURE

Hardness and weight change of test specimen after exposure to the different electrolytes (135 days at 40 °C for V^{2+} and $V^{3.5+}$ and room temperature V^{5+}). A significant change in Shore hardness (+–10 units) and weight (+–5 %) is an indication of weak chemical resistance.





The observed change in Shore hardness was minor for all tested polymers and from this point of view it can be stated that the materials are resistant in the electrolytes at different oxidation levels.

Investigation carried out by Contract Research at Fraunhofer ICT, Pfinztal, Germany

USE CASE: ASSEMBLY OF PLANAR RFB STACKS

VANEVO has developed a new assembly approach for the key component of redox flow batteries – the stack. VANEVO stacks need less complex parts compared to state-of-the-art stacks, reducing the overall requirements. The assembly process is optimised for automation, allowing for fast stack manufacturing at low costs.

Vanevo's approach:
Using adhesives instead of compressible sealings.

USE CASES IN RFB

Use cases of the tested materials in redox flow batteries:

- Adhesives, encapsulants and sealants for the stack assembly
- Full stack encapsulation (epoxy and polyurethane)
- Anti-corrosive coating for bipolar plates and busbars
- Potting and encapsulation of sensors
- Potting and encapsulation of flow meters and pumps
- Chemical-resistant coating for the electrolyte tanks (epoxy)

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TAKEAWAYS

CONCLUSIONS AND OUTLOOK

- Adhesives and sealants based on polyurethane, epoxy and silicone have been developed for stack assembly of fuel cells, humidifiers and electrolysers with a focus on low hydrogen permeability.
- Polyurethanes can be used as an adhesive and sealant at the same time and could be an alternative to the silicone sealants typically used for sealing bipolar plates.
- Polyurethanes have much lower hydrogen permeability compared to silicones and can increase the production speed due to their possible high reactivity.
- We also developed a silicone sealant (WEVOSIL 28002) with exceptionally low hydrogen permeability.
- The application of thermally conductive and flame-retardant resins for Battery pack and module assembly has been shown. New silicone-based materials have been developed with the goal of mitigating thermal runaway, thermal propagation of batteries and suppressing fire.
- Different polymer materials based on polyurethane, epoxy resin and silicones have proven their chemical stability in V-electrolytes at different oxidation levels for use as adhesives and sealants in VRFB.
- The materials are the subject of further investigation as potential coatings and encapsulants for current collectors, busbars and sensors in the flow battery systems.
- The tested materials are currently also being evaluated in flow batteries based on organic electrolytes.

THANK YOU FOR YOUR ATTENTION! ANY QUESTIONS?

Andreas Arlt
Business Development Manager
Phone +49 711 167 61-535 · andreas.arlt@wevo-chemie.de

WEVO-CHEMIE GmbH
Schönbergstr. 14 · 73760 Ostfildern-Kemnat · Germany

wevo-chemie.com