# CHARACTERIZATION OF POLYURETHANE, EPOXY AND SILICONE BASED SEALANTS AND ADHESIVES FOR THEIR POTENTIAL USE IN VANADIUM REDOX FLOW BATTERIES

## 01 Introduction

Different 2-component polyurethane, epoxy and silicone sealants and adhesives have been characterized for the potential use in vanadium redox flow batteries by testing their chemical resistance in vanadium containing sulfuric acid based electrolyte in different oxidation levels of vanadium ($V^{2+}$, $V^{3,5+}$ and $V^{5+}$) at different temperatures from 22 to 40 °C for a period of 135 days.

Circular test specimen of cured polymers with a diameter of 55 mm and 70 mm and a thickness of 10 mm have been immersed in the $V^{2+}$, $V^{3,5+}$ electrolyte at 40 °C and the $V^{5+}$ electrolyte at room-temperature (22 °C), representing the different charging levels of the electrolyte present during the operation of the flow battery. After immersion the test specimen have been optically inspected by means of a light-microscope at 50 and 175 magnification for surface changes and possible dimensional changes.

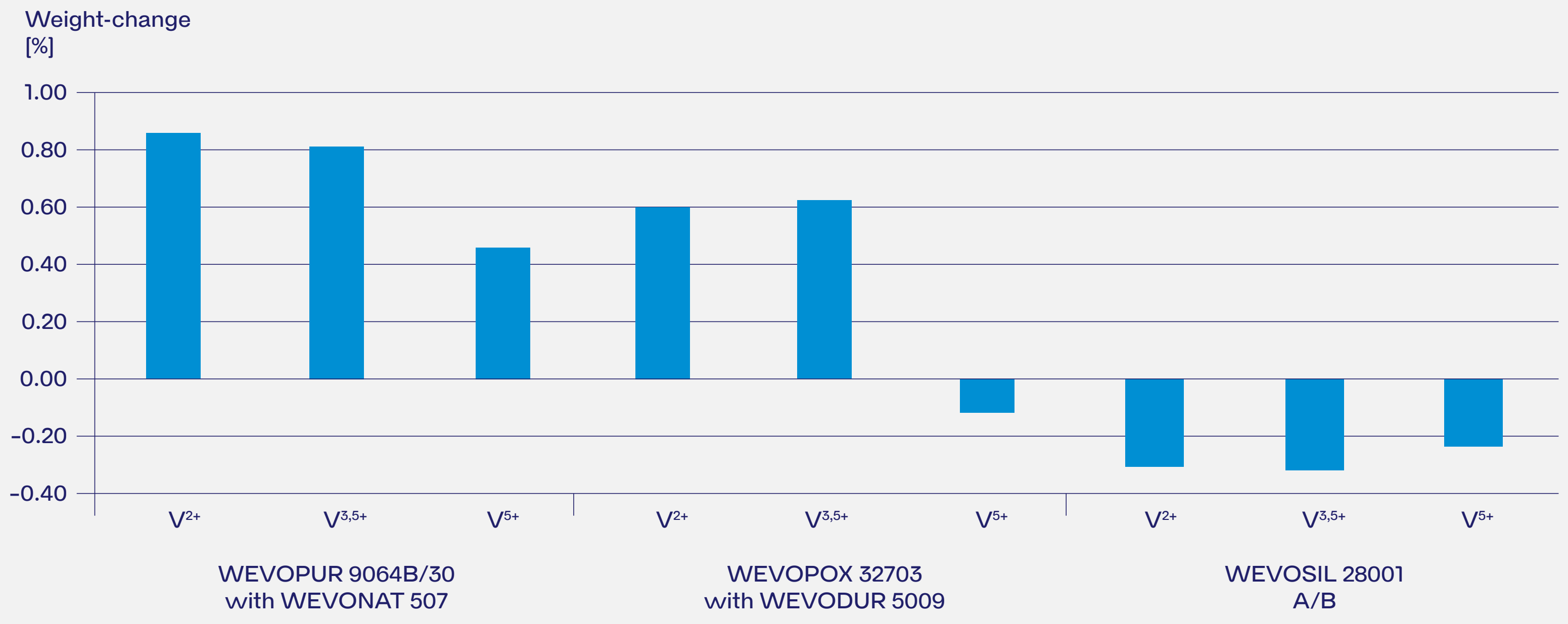
Additionally the change of the shore-hardness and the weight-change of the test specimen as well as the color change and the transparency of the electrolyte before and after the immersion have been determined. A significant change of the weight and dimension is either a result of swelling and or undesired oxidation processes and therefore a weak chemical resistance. An optical change of the polymer and the electrolyte is an indication for undesired interaction with the electrolyte and oxidative or reductive stresses.

## 02 Tested material properties

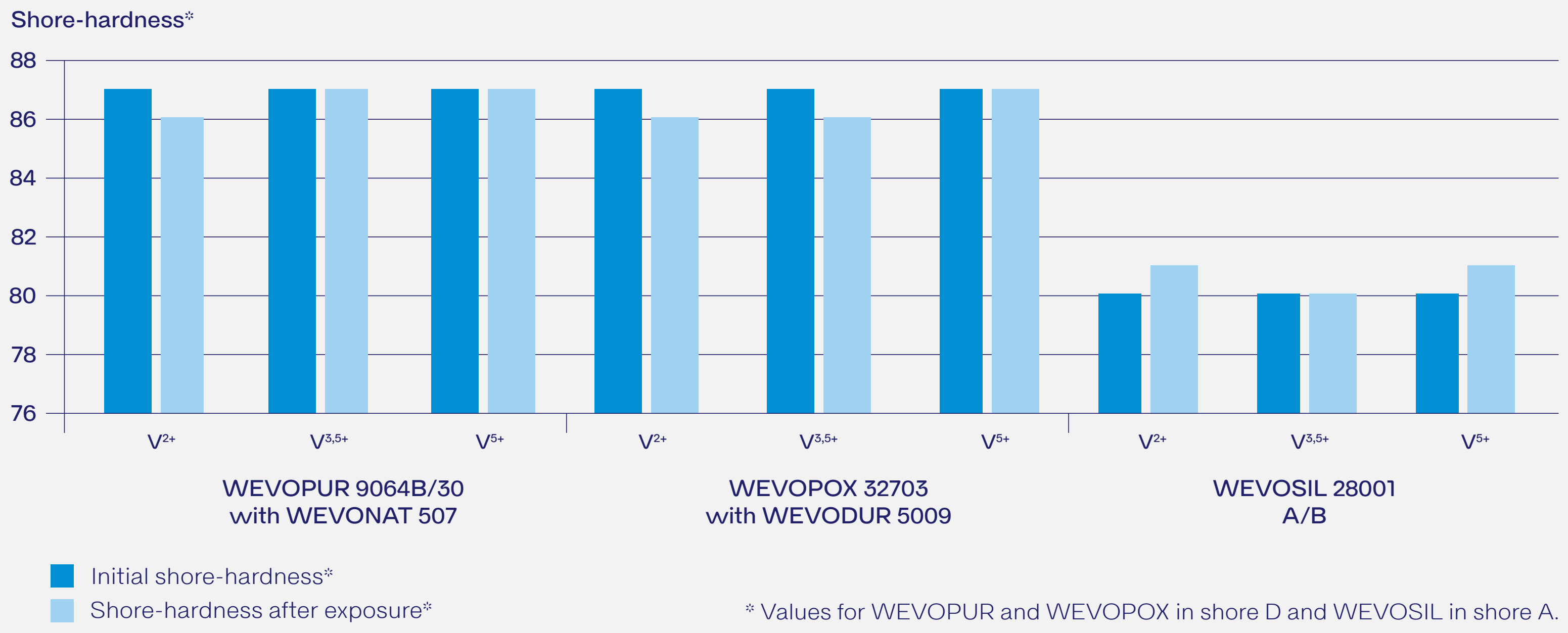
| | Test-standard | WEVOPUR 9064B/30 with WEVONAT 507 | WEVOPOX 32703 with WEVODUR 5009 | WEVOSIL 28001 A/B |
|---|---|---|---|---|
| **Type** | | 2-component room temperature curing polyurethane resin | 2-component hot curing epoxy resin | 2-component room temperature curing silicone sealant |
| **Mixing ratio (part per weight)** | | 100 : 35 | 100 : 12 | 100 : 100 |
| **Mixed viscosity [mPa·s]** | Rotational viscosimeter | 1,200–1,600 | 5,000–8,000 | 30,000–60,000 |
| **Pot life at 22 °C [min.]** | | app. 30 | app. 30 min@120 °C | 60–90 |
| **Density A-component [g/cm³]** | DIN EN ISO 2811-1:2016-08 | 2.02–2.08 | 1.65–1.70 | 1.28–1.32 |
| **Density B-component [g/cm³]** | DIN EN ISO 2811-1:2016-08 | 1.20–1.24 | 1.00–1.04 | 1.28–1.33 |
| **Shore-hardness** | DIN EN ISO 7619-1:2012-02 | 85–92 D | 80–90 D | 60–70 A |
| **Operating temperature [°C]** | | -30 up to +140 | -40 up to +155 | -60 up to +200 |
| **E-Modulus [N/mm²]** | DIN EN ISO 527-2:2012-06 | | 5,000 | 4.5 |
| **Elongation [%]** | DIN EN ISO 527-2:2012-06 | | 1 | 100 |
| **Glass transisition temperature [°C]** | TMA ISO 11359-2:1999-10 | 88 | 117 | -55 |
| **Coefficient of thermal expansion [ppm/K]** | TMA ISO 11359-2:1999-10 | 63 (< 85 °C)<br>195 (> 90 °C) | 53 (< 110 °C)<br>157 (> 120 °C) | 145 (< -55 °C)<br>210 (> -55 °C) |
| **Water absorption [%]** | 30 days at 22 °C | 0.3 | 0.2 | < 0.2 |
| **Dielectric strength [kV/mm]** | DIN EN 60243-1:2014-01 | 31 | | > 30 |
| **Dilectric constant at 50 Hz, 22 °C** | DIN EN IEC 62631-2-1:2018-12 | 4.9 | 5.1 | 3.1 |
| **Dissipation factor at 50 Hz, 22 °C** | DIN EN IEC 62631-2-1:2018-12 | 0.05 | 0.02 | 0.013 |
| **Volume resistance at 23 °C/50 % r. h. [Ω·cm]** | DIN EN 62631-3-1:2017-01 | $10^{15}$ | $10^{15}$ | $10^{14}$ |
| **Surface resistance at 23 °C/50 % r. h. [Ω]** | DIN EN 62631-3-2:2017-01 | $10^{15}$ | $10^{14}$ | $10^{14}$ |
| **Target application** | | anti-corrosive coating, encpasulation, potting | anti-corrosive coating, encpasulation, potting | sealing, encpasulation, potting |

## 03 Chemical stability test

### Weight-change of polymer test specimen after exposure to the V-electrolyte

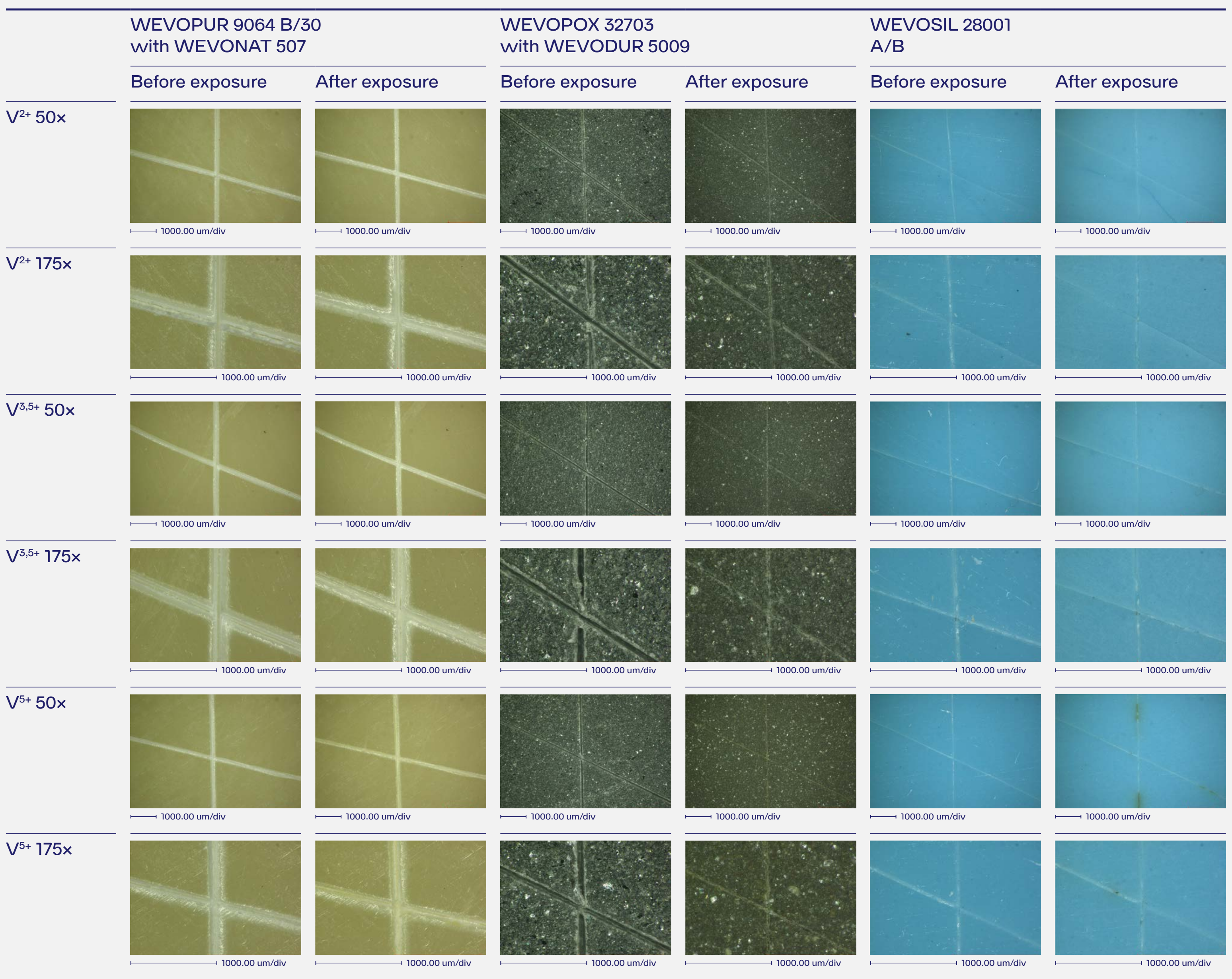


### Change of shore-hardness of polymer test specimen after exposure to the V-electrolyte



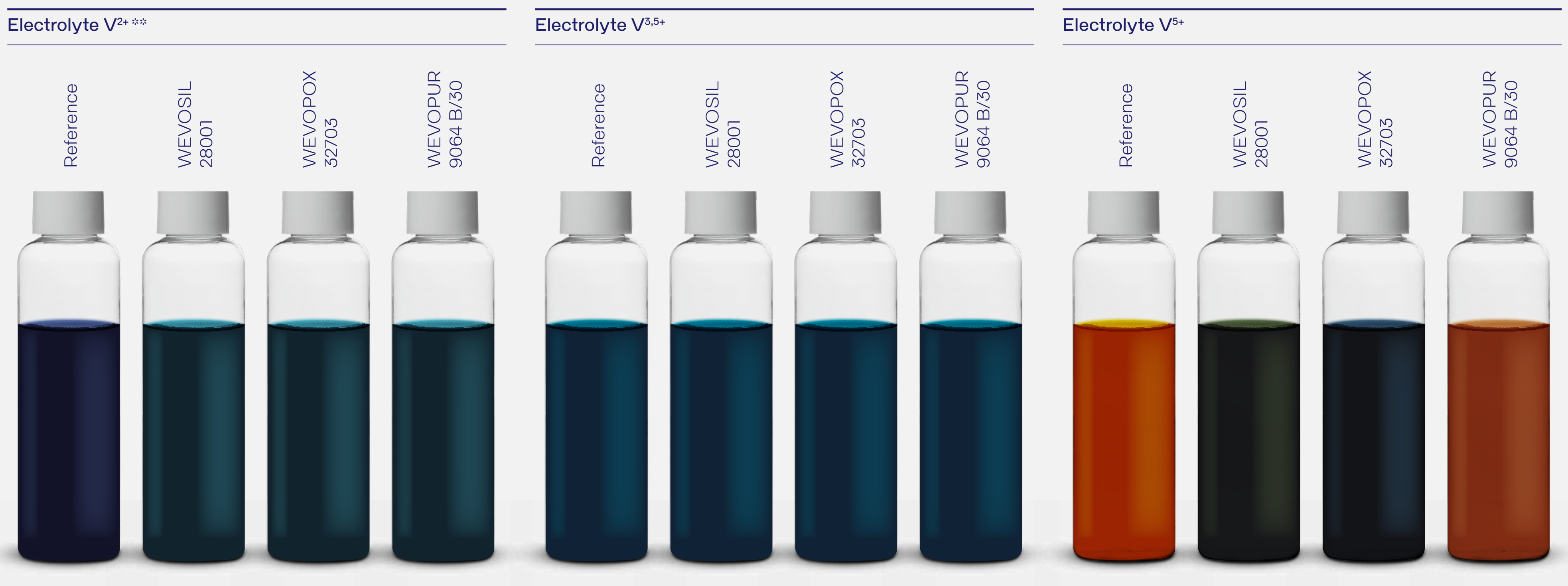
* Values for WEVOPUR and WEVOPOX in shore D and WEVOSIL in shore A.

## 04 Microscoping pictures after chemical exposure



Optical analysis of test specimen with a light microscope at a magnification of 50 and 175 before and after exposure to the different electrolytes. The test specimen have been scratched by means of a cutter knife with a cross-shaped pattern. The better the cross pattern is still visible and the sharper the lines are after electrolyte exposure, the more stable is the polymer against the electrolyte.

## 05 Electrolyte condition after chemical exposure



** The slight green change in the $V^{2+}$ electrolyte might be caused due to oxidation via air-oxygen.

## 06 Conclusions

Due to the minor influence on the color and the transparency of the different electrolytes and the very small changes of the shore-hardness, dimension, weight and its minor surface alteration the silicone sealant WEVOSIL 28001 and the polyurethane resin WEVOPUR 9064 B/30 can be regarded as very resistant against the aggressive V electrolyte at all oxidation levels making it suitable as adhesives, encapsulation materials and sealants for the assembly of flow battery stacks. The polyurethane resin could also be used as potting compound for full stack encapsulation and anti-corrosive coating for protection of the bus-bars of the stack. The epoxy resin WEVOPOX 32703 showed no influence on the color of the $V^{2+}$ and $V^{3,5+}$ electrolyte, and a slight influence on the color of the $V^{5+}$ electrolyte and the test specimen didn't show any significant optical and dimensional changes after exposure. Due to its low weight change and stable shore-hardness it can be regarded as chemical stable and electrolyte resistant, making it suitable as an anticorrosive coating for bipolar plates and bus-bars and as potting compound for full encapsulation of the battery stack.

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