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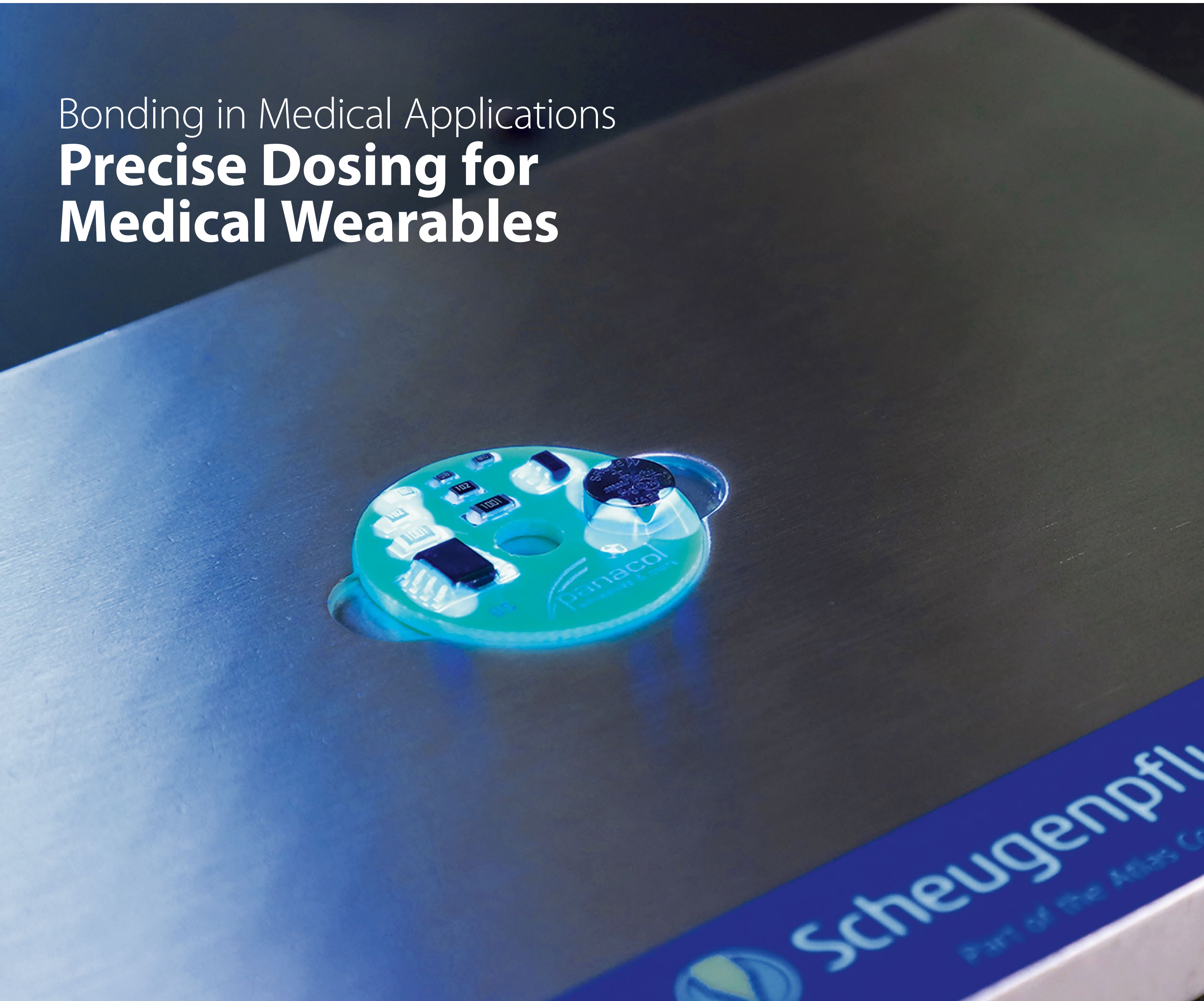

Battery Bonding in Short Cycle Times

The demand for electric drive systems will grow substantially over the next few years. A high degree of automation and streamlining of the manufacturing process should make it possible to produce higher volumes and more powerful batteries at lower prices. The production of a vehicle battery is tailor-made for bonding using polyurea.

Philipp Hug, Heiko Jung

One in eight newly registered cars in 2021 was purely electric. With growth rates of 30-40 % per year and the planned restrictions on combustion engines for new cars in the EU by 2035, the demand for electric drive systems and their components will increase massively in the coming years. The key to meeting this growing demand depends, to a large extent, on the production of the battery. Not only is their performance expected to grow more and more, but the sheer number of batteries requires new solutions in the production process. According to a study by the Fraunhofer Institute [1], lithium-ion batteries with a total capacity of 295 GWh were installed in electric vehicles in 2021. This value is expected to rise to over 2000 GWh by 2030. At the same time, prices are expected to drop from around 100 euros/kWh today to 50-80 euros/kWh. This will be made possible by a high degree of automation and by streamlining the battery manufacturing process.

Polyurea for temperature sensitive batteries

Special attention must be paid to the individual cells and their installation in the battery. The temperature sensitivity of the battery cells means that heat input (> 50 °C) must be avoided as much as possible during installation. Curing should therefore preferably take place at room temperature.
Adhesives and sealants widely used in vehicle construction include reactive 1K and 2K polyurethanes. These are used when bonding large areas or when the bonded joint is subject to large deformations due to different coefficients of thermal expansion of the various substrates.
The elasticity of slow-curing polyurethanes also has a vibration-dampening effect, yet high strengths are still achieved. All these properties make polyurethanes the ideal material for the adhesive encapsulation of the battery cells in the housing. However, the need to cure the polyurethane after application with curing times in the range of several minutes, form a significant bottleneck in an automated production process. This is especially true since the possibility of accelerated curing at a high temperature is not possible due to the temperature sensitivity of the battery.

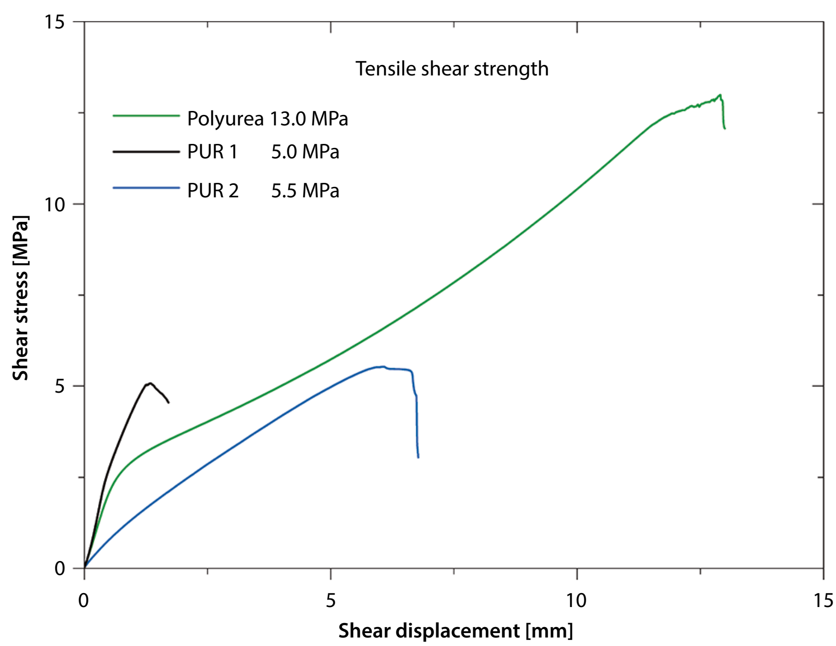

Figure 1 Shear stress-shear displacement diagram of polyurea and polyurethane on CDC coated aluminum with 3 mm joint. PUR 1 = fast-curing system, PUR 2 = slow-curing system.

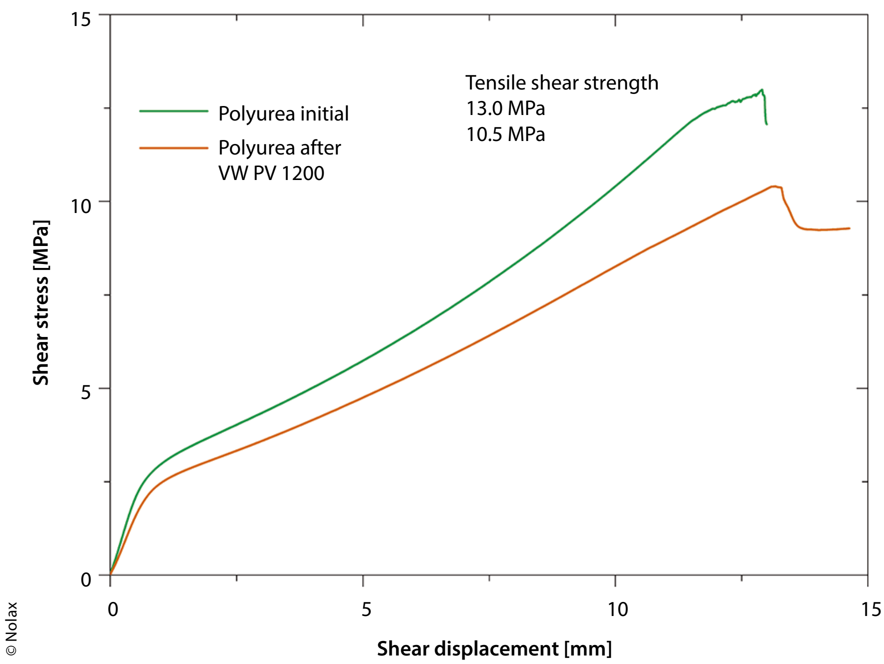

Figure 2 Shear stress-shear displacement diagram of polyurea before and after climate change test (VW, PV 1200).

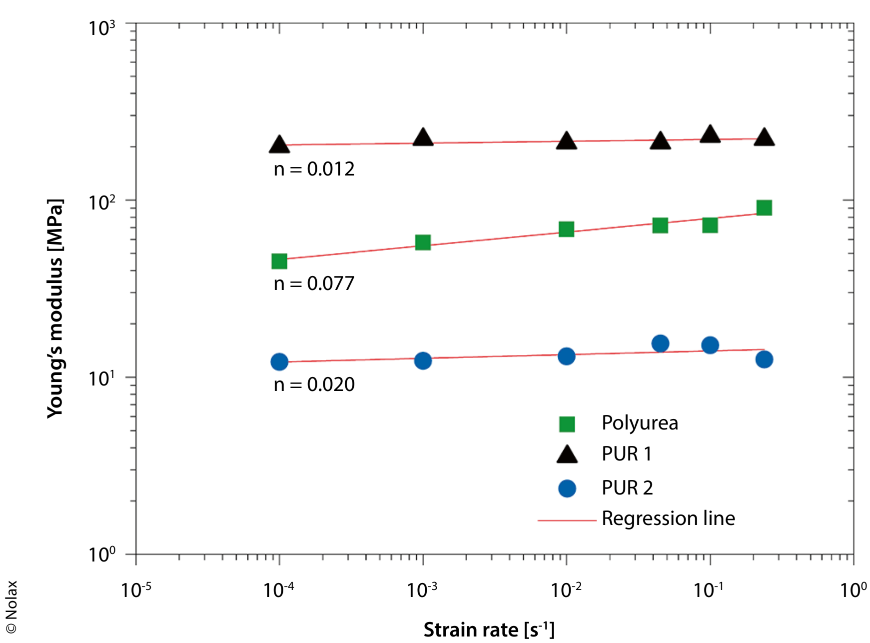

Figure 3 Dependence of stiffness on strain rate. The steeper the regression line, the more the material stiffens during an impact load.

Polyureas are clearly superior to polyurethane adhesives in terms of reaction speed at room temperature. With polyureas, the curing times are in seconds, and they achieve strength that meet the requirements for structural bonds. Due to the fast curing, the application is carried out exclusively via automated application systems. What fast-curing polyureas have lacked up to now in comparison to the slow-reacting polyurethanes was elasticity. This disadvantage has been eliminated by the company Nolax with the development of a new generation of flexible polyureas. These ultra-fast curing, flexible polyureas pass the usual climate change tests of the automotive industry, have a high impact strength, and retain their elasticity over a wide temperature range. In addition, they are characterized by very good adhesion surfaces with E-coat.

This clears the field for highly automated and thus economical adhesive potting to permanently fix the battery cells in their final position in the housing. Rivets and screws for positioning can be eliminated. In addition, weight is massively reduced by the light adhesive bonding.

Curing takes place at room temperature. The necessary handling strength is achieved within seconds. This means that the bonded part can be immediately moved to the next station for further processing. Subsequent process steps such as tilting the battery housing to mount high-voltage connections, which can strain the bondline, can be implemented directly without a curing time. Since the potting and curing take place at room temperature with polyureas, a stress-free bonding of the joined parts is achieved, and at the same time, the process reliability is increased. This is a major advantage of the polyureas in comparison to polyurethanes because no heating and subsequent cooling of complex components is necessary. Polyureas shorten the cycle time and create a more stable production process.

When repairing a defective battery cell is required, the housing can be removed with a simple cutting wire. Fixing the replacement cell is again done by potting a polyurea for a quick and mechanically stress-free connection with the same properties of the original bonding.

Polyurea – the better polyurethane

The unique performance of flexible polyurea can be demonstrated by some characteristic data. Compared to two commercially available polyurethane systems, the polyurea shows a significantly higher tensile shear strength of >12 MPa with a significantly higher elongation at break on CDC-coated aluminum. In comparison, commercially available polyurethane systems have a tensile shear strength of approximately 5 MPa. The polyurea thus absorbs significantly more energy under load before the joint fails (*Figure 1*).

These excellent properties are retained even after ageing in a climate change test (VW PV 1200) [2] between +80 °C and -40 °C with varying relative humidity (0 to 80 %). The elongation at break

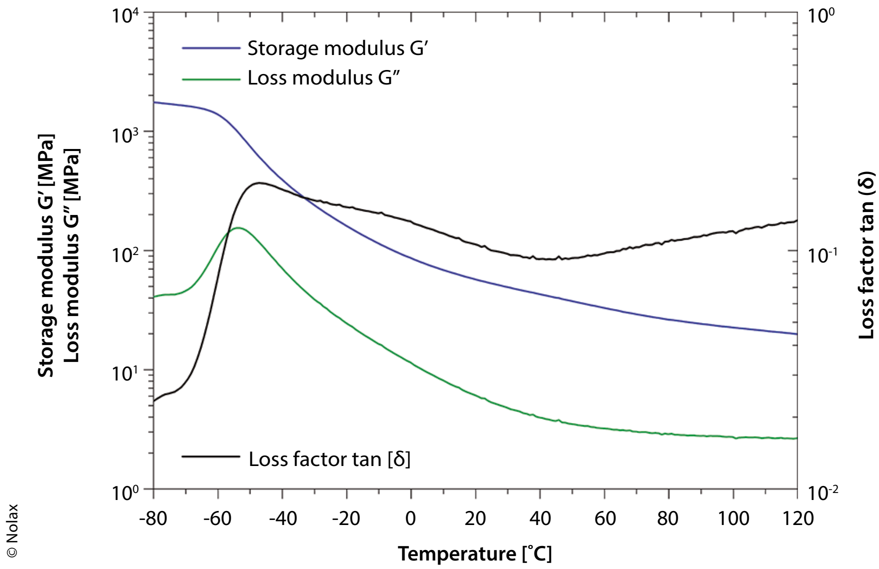

Figure 4 DMTA curve of the flexible polyurea. The maximum peak value of tan(δ) is at -47 °C, outside the application temperature.

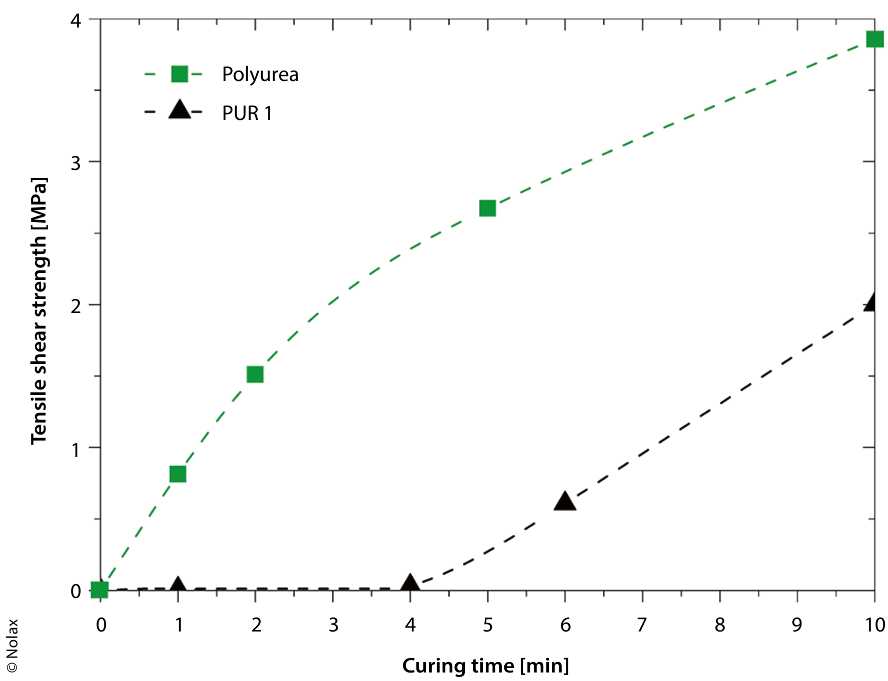

Figure 5 Development of tensile shear strength as a function of curing time (CDC coated aluminum 3 mm joint).

remains constant, and the tensile shear strength drops only slightly from 13.0 to 10.5 MPa, which is still twice the value achieved with non-aged polyurethane (*Figure 2 and Figure 1*).

Toughness

Tensile tests at different loading speeds were carried out to assess the toughness, especially under impact loading. Compared to the two polyurethane systems mentioned above, the polyurea shows a stronger increase in the modulus of elasticity with increasing strain rate. This means that the material becomes stiffer with the increasing strain rate and thus more energy is required to destroy the component. The polyurea therefore absorbs impact loads better, respectively, shows a better dampening profile than the two polyurethanes (*Figure 3*).

Temperature behavior

The elastic properties must be effective at room temperature, as well as at lower temperatures. The DMTA curve of polyurea shows that the glass transition temperature Tg (maximum peak value of the loss factor tan(δ)) is at -47 °C. Embrittlement at service temperatures down to -40 °C therefore does not occur (*Figure 4*).

Speed

For short cycle times, fast curing and rapid achievement of handling strength is crucial. This can be shown by measuring the tensile shear strength as a function of the curing time. A fast-curing polyurethane develops a measurable strength only after 4-5 minutes, whereas the polyurea builds it up immediately. This results in a time gain of several minutes even compared to a fast polyurethane (*Figure 5*).

Polyurea in battery manufacturing

The fast curing not only brings advantages in terms of short cycle times, but also challenges in the processing of the polyurea adhesives, which consist of two components. To prevent the discharge nozzles from sticking, the dwell time of the reactive compound in the applicator must be as short as possible. A proven method for this is processing via a high-pressure impingement mixing system. Here, the two components are injected at high pressure in a very small chamber, thus mixed and immediately discharged. The components to be joined can be positioned and the joints subsequently filled with the potting adhesive under robot control (*Figure 6*). Seconds later, the mounting of the components can be released and directly delivered to the next process step.

The production of a vehicle battery is the ideal application for bonding using polyurea. High quantities and complex geometries in lightweight construction clearly favor robot-assisted adhesive dispensing. The temperature-sensitive cells can be fixed in the battery housing in short cycle times thanks to rapid curing at room temperature. Due to the high adhesive forces and the elasticity of the cured polyurea, the joints achieved are highly resilient and thus also have a force-dissipating effect in the event of a crash, which increas-

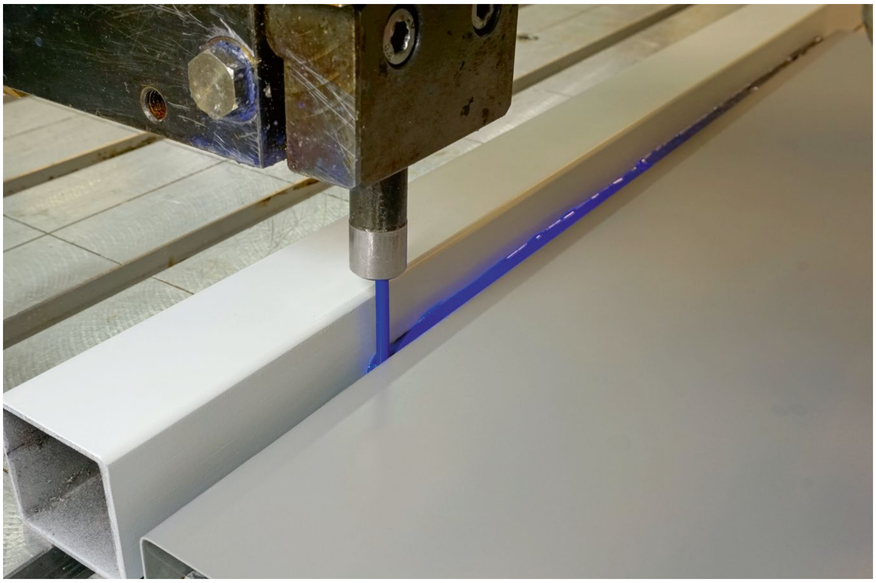
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Figure 6 Thanks to the casting of fast-curing polyurea (fluorescent blue) directly into the joint gap, a quick handling strength is achieved.

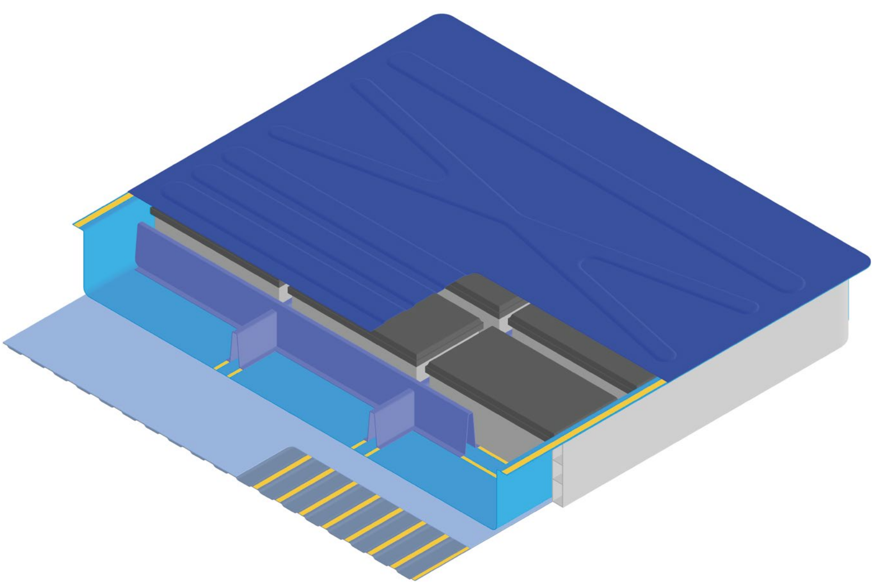
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Figure 7 Use of polyurea (yellow) potting compounds in the vehicle battery.

es the safety of the batteries installed in the vehicle as well as the safety of the passengers. The adhesive bond remains permanently elastic and has good ageing resistance. These are all properties that are necessary for the operation of a vehicle battery designed to be maintenance-free for many years.

In addition to cell fixation, polyurea offers new solutions for other bonding applications in the vehicle battery, such as stiffening the housing, bonding the heat exchanger or the adhesive seal between the housing and the cover (*Figure 7*).

Outlook and Conclusions

The use of polyurea is not limited to the vehicle battery. Other areas of application are, for example, the potting of electronic components, bonding of wood [3] with plastics in furniture construction [4] or in the manufacture of industrial goods [5] – everywhere where automation of the bonding process with fast cycle times and high quantities are required.

The new elastic polyureas make industrial bonding and sealing processes fast and safe. A key driver for high process speed is the immediate handling strength of applied polyurea. Short cycle times of a few seconds and low reject rates lead to economical processes.

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