Title

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UV-Curable CIPG for Electronic Enclosures

The miniaturization of electronic systems is placing greater demands on sealing processes. At the same time, aspects such as energy efficiency, design freedom, and repairability are becoming increasingly important. Using the example of a UV-curable Cured-in-Place Gasket (CIPG) sealant and a dispensing and inspection solution, this article demonstrates how short cycle times, precision, and quality assurance can be achieved in the mass production of electronic assemblies and enclosures.

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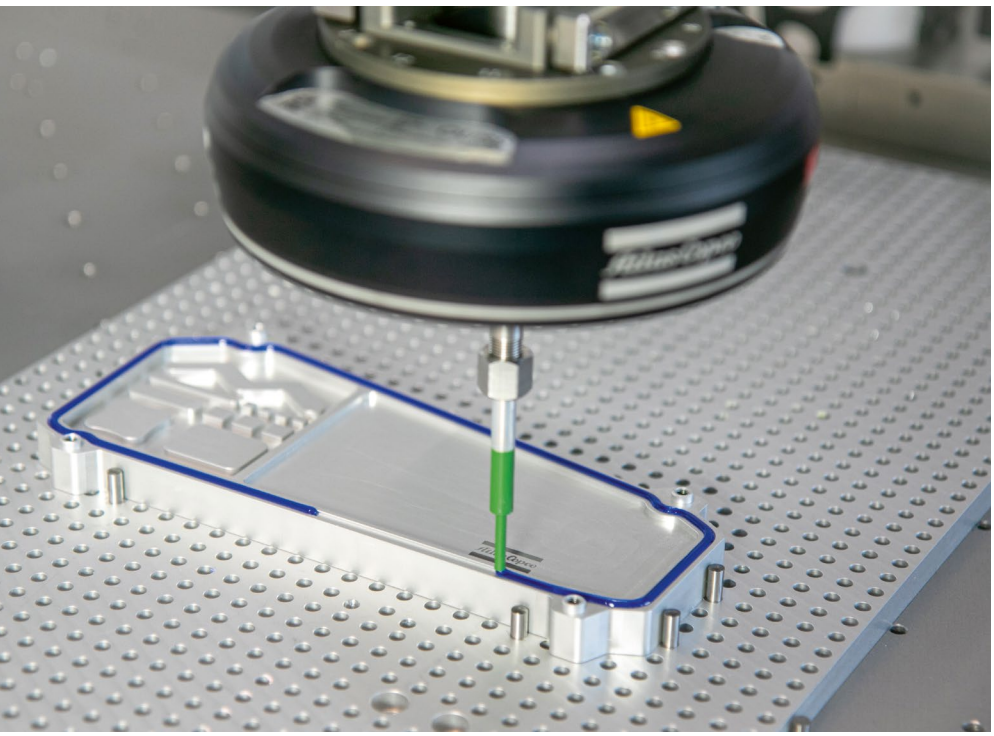
Electronic enclosures are getting smaller, while the demands placed on their protection are increasing. Control units, power electronics, sensors, displays, and battery management systems are becoming more compact, more powerful, and more highly integrated. With the increasing electrification of vehicles and industrial plants, the demands on enclosure sealing are rising. In addition to providing a reliably reproducible sealing function, sealing systems today must meet the demands of highly automated manufacturing processes while also supporting energy efficiency, design flexibility, and repair-friendly product concepts.
UV-curable CIPGs offer a solution for this. Using a newly developed polyacrylate sealant from Hoenle Adhesives as an example, this article demonstrates the potential this technology offers for modern electronic enclosures.

Increased demands on sealing systems

Sealing systems must permanently protect sensitive electronics from moisture, dust, splashing water, chemicals, and thermal stress – while also being cost-effective, automatable, and reproducible to apply. Even the slightest deviations in bead geometry or material application can compromise the protective function and lead to rework, scrap, or functional failures. As miniaturization advances, the demands on the material, dispensing process, and quality control are therefore increasing accordingly.

Automated dispensing processes enable short cycle times while ensuring high-precision application of the sealing bead – even on tight flange radii. Inconsistent beads and an inadequate process monitoring can lead to leaks. Inherently in the au-

As the electrification of vehicles and industrial plants increases, so do the demands placed on sealing systems for enclosure sealing.



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Dispensing a sealant using a high-speed piston dispenser.

tomotive, consumer electronic, and electrical technology sectors, a seal must not only function but also be applied in a verifiably reproducible manner.

Conventional stamped or solid seals reach their limits in this context. Complex housing contours, varying flange geometries, and short product lifecycles drive the diversity of variants: Each geometry requires its own tools and corresponding logistics, which increases development and production costs. At the same time, the risk of assembly errors due to misaligned or damaged seals rises.

Liquid seals provide design flexibility

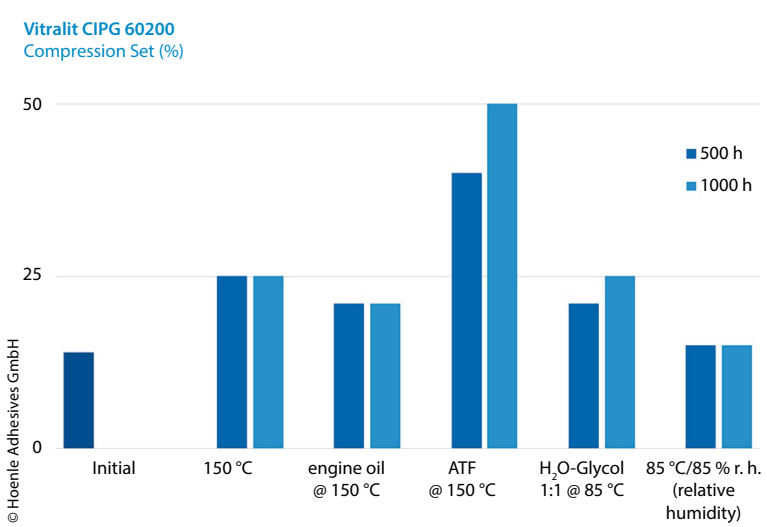
One alternative is liquid-applied CIPG seals: The sealant is dispensed directly onto the housing flange and then cured. This creates a seal that precisely follows the required contour and can be adapted to different geometries using software. There is no need for tooling modifications, development times can be shortened, and variants can be implemented more easily. Since the sealant is applied only where it is needed, material usage can also be reduced. At the same time, the dispensing process can be fully automated and integrated into existing production lines.

UV-curable polyacrylate for demanding electronics applications

To meet these requirements, Hoenle Adhesives has developed a UV-curable polyacrylate CIPG that is specifically tailored for use in electronics enclosures. The sealant combines high resistance to various media with thermal and mechanical stability, as well as short cure times.

The continuous operating temperature is 150 °C; short-term exposure to temperatures of up to 200 °C is possible without significantly altering the seal's mechanical properties, according to the manufacturer – making the material suitable for applications near thermally stressed assemblies. In addition, it offers high resistance to motor oil, automatic transmission fluid, and water-glycol mixtures, as required in automotive and industrial electronics. According to the manufacturer, the material passed the so-called 85/85 test – in which the sealant is exposed to 85 % relative humidity and 85 °C in a climate chamber for 1,000 h – without any significant changes to its mechanical properties.

Another relevant material property is the compression set: It describes a seal's abil-



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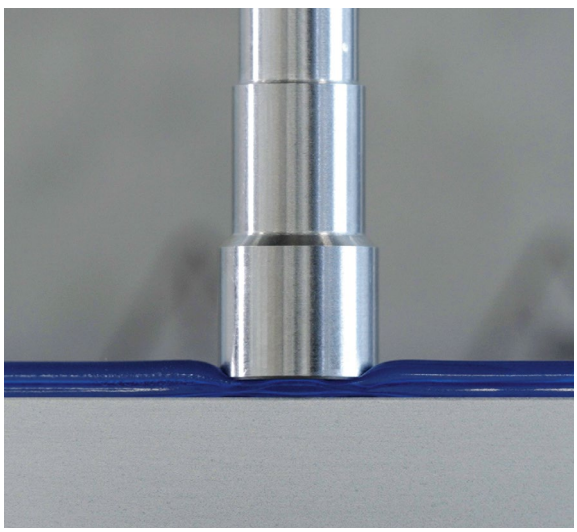
Material testing / reference measurement (The compression set remains largely stable even after aging at 150 °C in aggressive automotive media).



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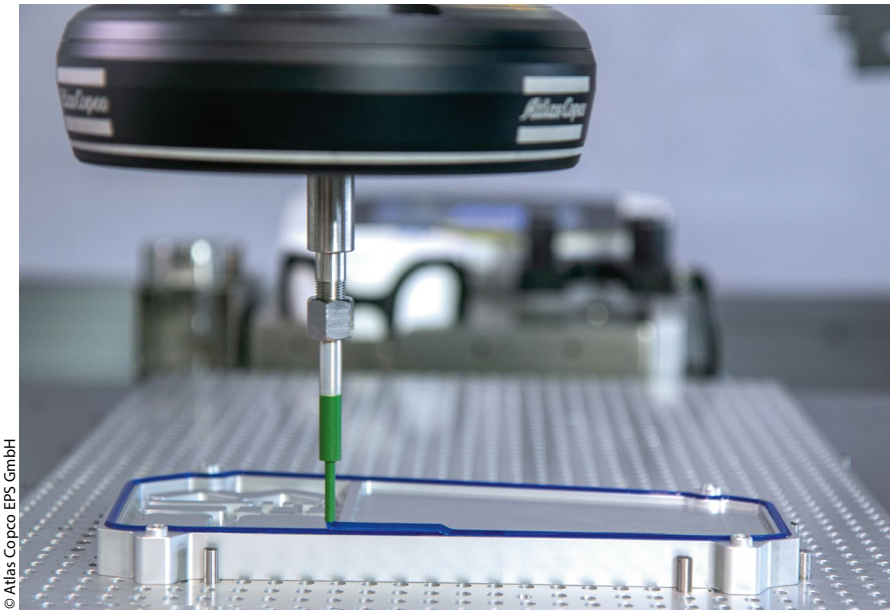
Due to its resilience, the material returns to its original shape completely after compression.



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"Bead-on-Bead" dispensing.

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High-speed dispensing system with a single-component dispenser for serial sealing applications.

ity to recover after prolonged thermal stress and is considered an important indicator of long-term sealing performance. Tests conducted in accordance with ASTM D395-2 and DIN ISO 815 demonstrate stable elastic behavior even after demanding aging tests – the basis for uniform contact pressure throughout the entire service life of the assembly. The material also meets the requirements of IPX5 and IPX7 protection classes as well as the UL 94 HB classification. It is free of CMR substances and contains no cyclic methylsiloxanes of groups D4 through D10, the use of which is increasingly restricted by regulations.

Processability as the key to mass production

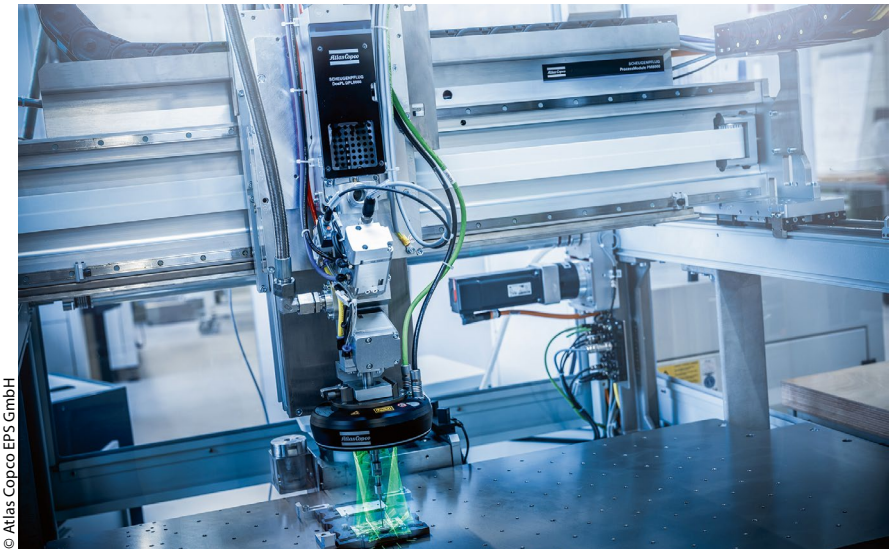
In addition to material properties, processability determines the industrial suitability of a sealing system. The polyacrylate is shear-thinning and can be applied using both needle dispensing and the contactless jetting process – reproducibly ranging from high-volume sealing profiles to fine beads in the range of a few hundred micrometers. Due to its thixotropic properties, "bead-on-bead" dispensing is possible, allowing for larger aspect ratios of bead height to bead width, which expands the design flexibility for miniaturized and highly integrated assemblies.

Precise bead application at high speed

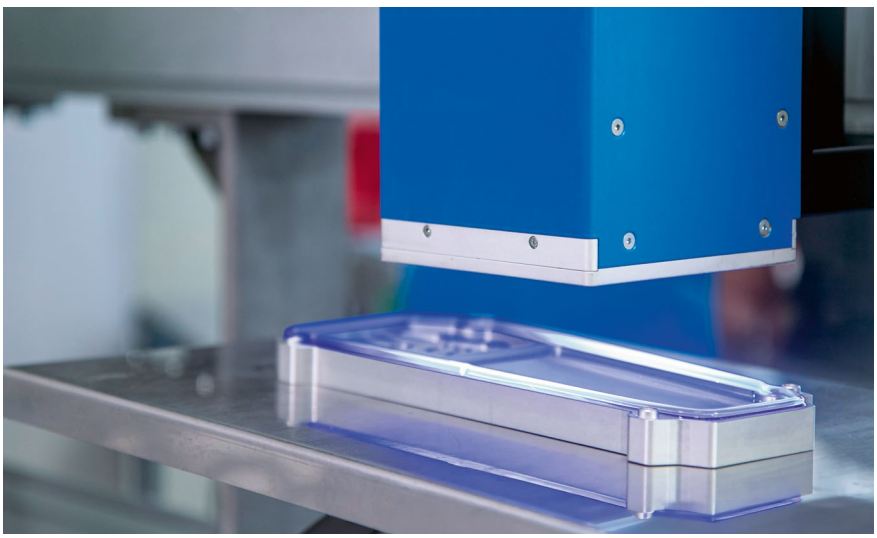
For the application of these CIPG sealants, Atlas Copco has developed the Scheugenpflug 8000 series for high-volume production. The dispensing system applies complex sealing contours with short cycle times. Features such as on-the-fly dispensing and the decoupling of axis and dispensing speeds enable high dispensing quality even with complex geometries.
The dispenser is designed for high dispensing speed, short valve switching times, and fast, guided refill operations. This ensures that the bead geometry remains stable and reproducible even at tight radii.
In combination with an integrated machine vision system and integrated process monitoring, the dispensing system is particularly well-suited for the automated series production of electronic assemblies and housings with high quality requirements. The Secure-by-Design architecture supports secure data processing and user-friendly operation.

Integrated image processing system documents quality

To ensure application quality, the system features integrated inline inspection using the RTVision.3d and RTVision.t machine vision systems. Depending on customer requirements, both systems provide a non-contact OK/NOK evaluation via the human-machine interface (HMI) immediately after application. This enables immediate defect identification and provides statistical data for production overviews. As a result, quality data can be not only verified but also documented. In industries with strict traceability requirements – such as the automotive industry, medical technology, or safety-critical industrial electronics – this traceability is a central component of modern manufacturing processes. After inspection, curing



Quality assurance via 2D or 3D inline inspection of the seal contour.



UV curing of the seal bead.

MRO-compatible: The seal beads can be easily removed without leaving any residue.

takes place using UV light that is integrated with the dispensing system.

Fast UV curing

Conventional room-temperature vulcanizing silicones (RTV silicones) often require several hours to days to reach their final strength. In addition, temperature and humidity affect the cross-linking of these materials. UV-curing systems, on the other hand, cure within a few seconds: Depending on the light source, cure times of between 10 and 25 s can be achieved for sealant beads with a diameter of four millimeters – depending on whether a comparatively dry or tacky surface is to be produced. This allows components to undergo a leak test immediately afterward and be transferred to the next stage of the manufacturing process without any waiting time. Since only the applied sealant itself cures – and the entire assembly does not need to be heated – energy consumption can be reduced compared to thermal oven processes. This also has a positive impact on energy consumption and the CO_2 footprint of production.

Numerous CIPG systems on the market still rely on gas discharge lamps for curing. The newly developed polyacrylate, however, can also be cured using UV-LED technology in the wavelength range of 365 or 405 nm. UV-LEDs require less energy, last longer, and reduce maintenance requirements, as they eliminate the need for lamp replacement and warm-up times. Depending on the production concept, stationary LED panel emitters – with full-surface or contour-following irradiation – or high-performance LED linear emitters for continuous throughput are used. The UV dose required to cure a 4-mm bead of sealant is only 30 to 50 % of that required by comparable systems, according to benchmarking.

Repairability supports sustainable product concepts

With the growing importance of the circular economy, the repairability of electronic systems is also coming into focus: High-quality control units or power electronics should be repaired more often rather than replaced in the future. UV-curing CIPG systems can support this, as the surface properties can be specifically influenced by adjusting the curing process. For serviceable enclosures, this allows for the creation of a

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3D measurement of component and application using the 3D profilometer.

comparatively dry sealing surface. The seal remains on the flange when the enclosure is opened and can be reused once service work is complete. This helps reduce material consumption, the need for replacement parts, and downtime.

Today's electronic enclosures require sealing systems that go beyond mere protection against environmental influences and combine high reliability with cost-effective manufacturing, even for complex assemblies. UV-curable CIPG seals can meet these requirements by combining design flexibility with short cycle times and reproducible dispensing processes. Added to this is the thermal, chemical, and mechanical resistance of both the material and the application.

With the ongoing electrification of vehicles and industrial plants, the importance of this technology is likely to continue to grow. It is particularly relevant in applications where compact designs, high process reliability, and repair-friendly concepts are required. //

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