High-Temperature Resistant Adhesives and Coatings

Heares, a Nolax start-up company, offers newly developed water-based adhesives and coatings that are resistant to extreme temperatures up to 900 °C. The products show good adhesion to fiberglass fabrics, metal or aluminum foil and are easy to apply.

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For bonding in the high-temperature range special adhesives are required, since the organic substances of conventional formulations are broken down and escape when the temperature is increased. In the process, the adhesive strength continues to decrease until the bonded joint finally fails completely. The newly developed adhesives and coatings from Nolax/Heares are suitable for highly heat-resistant and flexible composites, as well as for rigid heat protection components. In addition to the high heat resistance of the composites, the heat barrier and heat shield function of the substrates were also significantly improved. Thus, the heat insulation function of a substrate is increased by 200 °C (IR method) by the coatings. The new adhesives and coatings are easy to apply (blade, roller, nozzle or spray systems) and are resistant to all vehicle fluids. There are already tested and certified products on the market that are finding their first applications in the automotive industry, especially in the exhaust tract.

Heat protection in the engine and battery

High temperatures in the engine are desirable from an ecological point of view but lead to enormous problems for components such as cables and hoses. Heat protection sleeves are available to protect these components. These are already presently exposed to increased heat stress, but will continue to do so in the future, and age faster than desired. Typically, heat protection sleeves consist out of a composite of fiberglass fabric and aluminium foil bonded with silicone or one-component (1C) polyurethane (PU) systems. These conventional adhesives reach their limits at temperatures above 180 °C, while the adhesive developed by Nolax and Heares withstands temperatures of 400 °C over the long term (*Table 1*).

Silicone resin emulsion

- **Chemistry and principle**

Based on the silicone technology, a silicone resin emulsion was developed that was previously unknown in the field of adhesives. The patent application for Heares is already filed (WO2018158407A1 water-based adhesive).

Adhesive	Long-term temperature resistance	Application
Nolax/Heares silicone resins	400 °C	Aqueous system via blade, roller, nozzle, spray systems
Standard 2C silicone	280 °C	Solvent based system via blade, roller systems (complex solvent recovery/combustion)
Standard PU dispersion (not cross-linked)	180 °C	Aqueous system via blade, roller, nozzle, spray systems

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Table 1 > Comparison of high heat-resistant adhesives

Silicone resins are highly branched polysiloxanes in a 3D network with remaining functional groups as shown in *Figure 1*. After application of the aqueous formulation, the coated substrate or laminate is subjected to physical drying in order to evaporate the water and solvent residues (< 5 %). Final curing is achieved by the application of heat, which leads to a condensation reaction of the remaining reactive groups. In summary, the Nolax/Heares adhesives and coatings offer the following key benefits:

- high solids content (approx. 60 %)
- easy application (blade, roller, spray systems, robotics also possible),
- good and fast adhesion to the substrate (fiberglass and metal surfaces),
- high thermal resistance over long term (400 °C), short term (950 °C),
- low flammability (e.g., UL 94),
- low smoke emissions
- good mechanical resistance to, e.g., abrasion (increases the service life of the component),
- resistant to acids, alkalis, solvents, oils and other common liquids,
- non-electrically conductive coating (no stray currents).

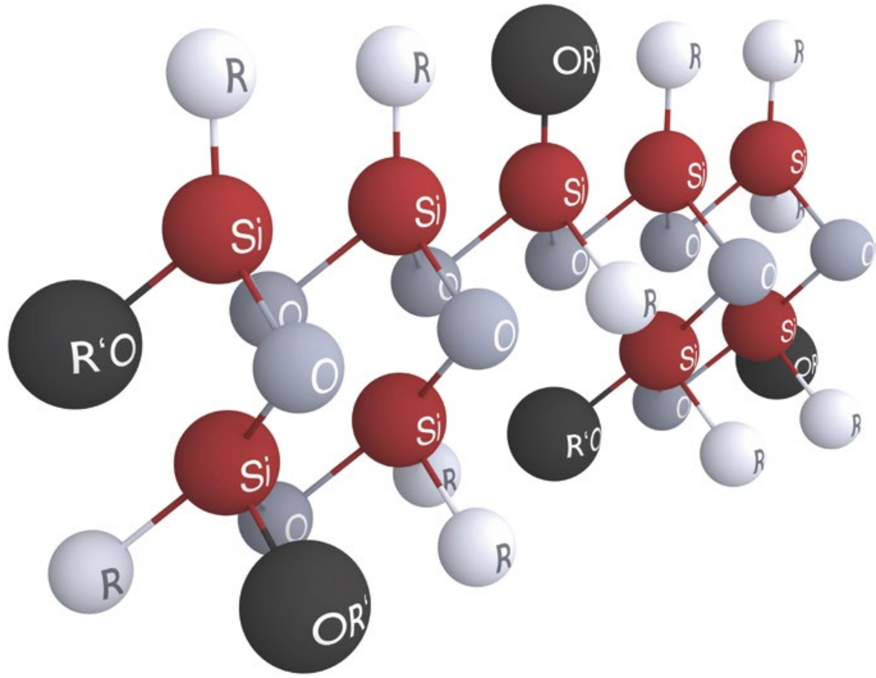

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Figure 1 > Cross-linked silicone resin

● **Simple processing**

The novel silicone resin emulsions are formulated to achieve the desired adhesive properties. They are ready for use and do not need to be diluted, mixed or thickened. Tailor-made formulations are possible, for example by altering the viscosity or by adapting the additives.

Test method	Norm	Values	Results
Short-term ageing, heat resistance IR	Nolax PM 1043, ageing: IR	740 °C, 2 h	No self-delamination
Long-term ageing, thermo furnace	Nolax PM 1065, ageing: thermo furnace	400 °C, 1000 h	No self-delamination

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Table 2 > Results of the heat protection sleeve tests according to the Nolax method

Gomastit®
2060

Outstanding UV resistance
Full elastic
Compatible with paints
Free of hazard substances

2060 TDS

merz+benteli ag

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Figure 2 > Flexible material composite for heat protection sleeves for exhaust gas control flap in a truck. Here, temperatures of up to 400 °C must be withstood over the long term.

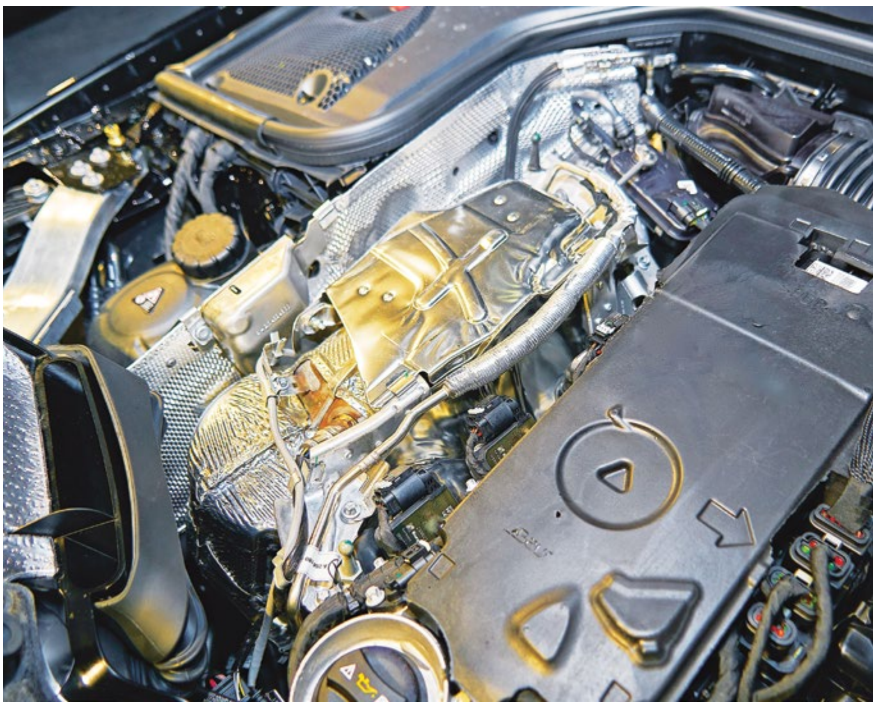

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Figure 3 > Turbocharger cover in a combustion engine

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Figure 4 > Battery cell carrier cover in a challenging impact test: Impact/explosion of a 4.2 V Li-OH battery, performed at the Center for Solar Energy and Hydrogen Research in Ulm (Germany)

The substrates are bonded at the user's site by wet lamination, and depending on the application, drying takes place in an oven or textile dryer (stenter frame). In the stenter frame, the temperatures of the fields are controlled via a ramp-up to 200 °C. When bonding metal half-shells, the bonded part is air dried and the final cross-linking reaction takes place during the initial deployment of the component.

Applications

- **Heat protection sleeve automotive**

During the laminating process, the highly heat-resistant silicone resin adhesive is applied to the aluminium foil by means of a roller coating application, whereby the fiberglass fabric is wet laminated, dried and activated in a textile dryer. *Figure 2* shows ready-made heat protection sleeves. When used in the engine compartment, the heat protection sleeve is permanently exposed to temperatures of up to 400 °C. The following system has already been subjected to several tests:

VW LV 312-3 (Volkswagen purchasing standard for heat protection sleeves)

- media resistance
- PV (test specification) 1200 climate change test: 20 cycles; +80 °C and 80 % relative humidity, -40 °C
- PV (test specification) 1210 corrosion test: 15 cycles; 5 % sodium chloride solution
- FMVSS 302 (horizontal burning test)

No self-delamination was observed. The corresponding test methods and results are listed in *Table 2*.

Figure 5 > Impact test at the ZSW, Ulm: Test specimen consisting out of fiberglass fabric coated with a combination of reflective and insulating Nolax/Heares products thereafter bonded to an aluminium plate; the impact side shows neither a hole nor a burn through.

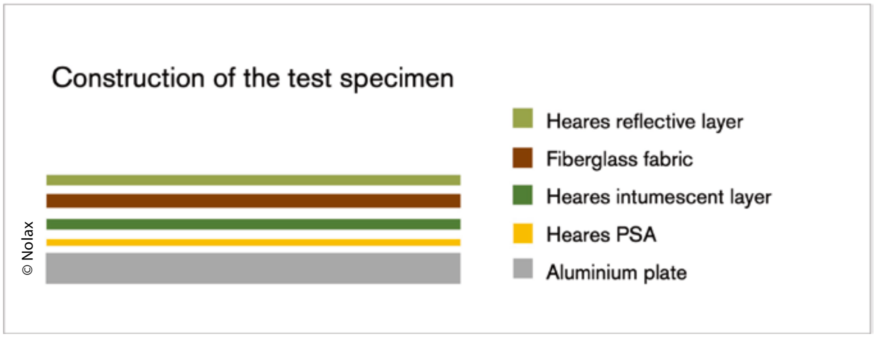

Figure 6 > Construction of the test specimen for the impact test

- **Turbocharger cover**

For turbocharger covers or SCR catalyst housings, a glass mat is bonded into a shaped stainless-steel molding via a high temperature resistant adhesive (*Figure 3*). Here, it is necessary to permanently meet the requirement regarding a temperature load of up to 500 °C. In addition, there is the requirement of "no outgassing" and the resulting odor. The Nolax/Heares adhesive fulfils the VDA 270 odor test and at the same time sets new standards in simplicity of application. Precision application by means of robotics reduces the adhesive consumption. This application can alternatively also be performed by hand followed by air drying which enables a just-in-time production.

- **Heat and fire protection of the battery cell carrier cover**

As *Figure 4* illustrates, in the event of an impact (short circuit of a battery cell), covers of battery cell carriers are exposed to

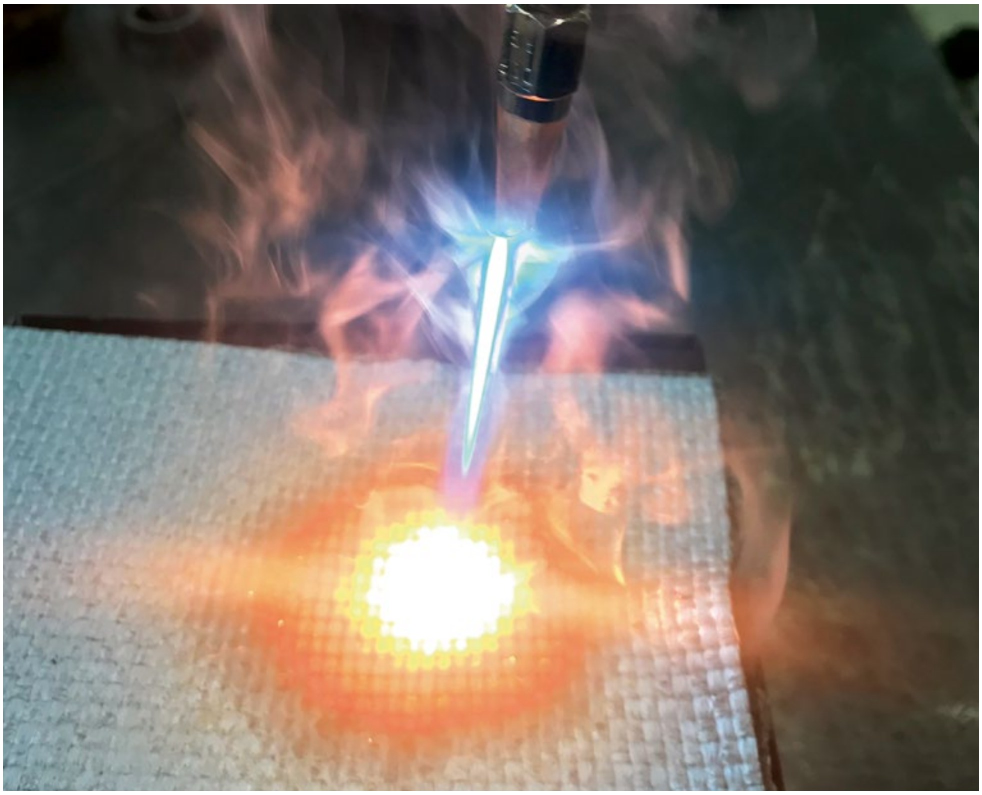

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Figure 7 > Testing of the specimen via the welding torch method (acetylene/oxygen gas mixture, torch nozzle type: 0.5 mm)

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Figure 8 > Fire test according to EN 1634-2019 at the IBS, Linz

gases and particles at temperatures of up to 1000 °C on the inside for a short time. This releases extremely high energies in very short cycles. The high-temperature resistant, reflective and intumescent Nolax/Heares coatings ensure high safety and heat reduction on the battery cell carrier.

During an impact test at the Center for Solar Energy and Hydrogen Research (ZSW) in Ulm, a short circuit was created in a battery cell when fully charged with a nail (*Figure 5*). The battery cell became extremely hot, and gases with a temperature of up to 900 °C (accompanied sporadically by flames) were released immediately and violently. Hot metal (aluminium and copper) particles are also ejected out as glowing particles. This results in high mechanical loads for the heat protection system. The construction of the heat shield tested here is shown schematically in *Figure 6*.

For the corresponding products, Nolax has also developed its own test with a welding torch to simulate this brief release of high-energy hot gas (*Figure 7*). A specimen was subjected to a 1300 °C hot flame originating from the welding torch held vertically above via a test stand. The specimen resisted the flame for 20 minutes until a hole was formed. After 10 minutes, the surface temperature of the aluminium plate located under this construction was only approx. 200 °C (ΔT = 1100 °C to the temperature on the upper side). The reflective properties of the silicone resin coating increase the heat resistance of the fiberglass fabric. In addition, the intumescent coating applied to the rear of the fiberglass fabric significantly reduces the heat transfer coefficient of this construction.

The coating is applied using conventional textile coating machines and dryers. With the system described here, the following results were obtained in the respective tests:

- flammability test according to DIN EN ISO 60959-11-10 (horizontal, 10 min; 950 °C): ΔT 800 °C
- standard UL 94: class V-0 (low flammability)
- Nolax method (welding torch, >20 s, approx. 1300 °C): no burn through

- **Structural fire protection – flexible fire and smoke barriers**

The novel adhesives and coatings are also suitable for smoke protection or fire protection doors and slats, as the reflective, highly heat-resistant coatings can be used for surfaces such as fiberglass fabrics, while the adhesives are suitable for wet bonding of aluminum foils with fiberglass fabric. Both applications have already been successfully subjected to the following tests and classifications:

- fire box test according to EN 1634-2019 at IBS, Linz *(Figure 8)*
- fire behavior test according to DIN EN ISO 11925-2 at ift – Institute for Window Technology, Rosenheim,
- classification of fire behavior according to DIN EN 13501-1 (ift, Rosenheim)
- standard UL 94

The fire test at IBS – Institute for Technical Fire Protection and Safety Research in Linz (Austria) demonstrated that the fiberglass fabric laminated with a 25 µm standard aluminium foil showed no delamination after 60 minutes.

Conclusions

The new adhesives and coatings based on aqueous silicone resin dispersions are characterized by high heat resistance and a reduction of the heat transfer coefficient. They are suitable for a wide range of applications, while handling is simple. In addition, they open up new design and material freedoms in various fire protection applications. //

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