Warm Reactive Bonding

Headlamp Bonding. Individual parts of an automobile headlamp, which consists of different plastics, can be bonded economically with a reactive warm melt or warm fusion adhesive and a specially developed technology. The adhesive hardens quickly with environmental moisture and bonds well to plasma pre-treated plastics.

JÜRGEN HORSTMANN
PETER W. MERZ

Automobile headlamps made by the system supplier Hella KG Hueck & Co., Lippstadt/Germany, consist in principle of two parts: a transparent cover shield and a body (Fig. 1). The cover shield is usually a polycarbonate (PC), which is protected from scratches by a hard layer, e. g. by a UV hardening system. The body is generally polypropylene (PP), which modified with fillers such as talcum powder can have a high scratch resistance. Also polybutylene terephthalate (PBT) or PC are used for production of headlamps.

Current Status of the Technology

Sealing materials or adhesives have been used for a long time in the production of headlamps. So far two technologies have been established: reactive and non-reactive adhesive systems. To the reactive systems belong

- single-component adhesives based on silicone,
- two-component adhesives based on polyurethane (PU) or silicone,
- humidity-reactive fusion adhesives or hot melts (RHM) and
- humidity-reactive fusion adhesives or warm melts (RWM).

Hot melt sealants based on butyl rubber are used as non-reactive systems.

For rational manufacture of automobile headlamps it is necessary to achieve a durable connection without mechanical fixation, e.g. clips. At the same time a leakage test must be made as quality control after bonding. Single-component adhesives based on silicone do not fulfil all the wishes of the goal market. These pasty adhesives are sticky and in the uncured state are inclined to contamination, which leads to difficulties with the bonding. Thus additional costs and delay in the leakage test result. In addition adjustments are necessary.

Two-component adhesives likewise need clips to hold both parts together. The low initial viscosity after mixing excludes an immediate leakage test. Also the danger of contamination is clear. For too slow reaction of the two component systems cross-linking time can be shortened in a furnace, e.g. in a paternoster. Such two component systems therefore require a reaction time of 50 minutes before the leakage test. Thus in the case of a mixture error up to 150 incorrect headlamps can be manufactured with a cycle time of two to three headlamps per minute.

Two component systems require complex delivery plants with pumps, dosing equipment and expensive static mixers. The static mixers must be cleaned, which means waste and increased maintenance costs. On the positive side there is the build up of a firm elastomer bond after the cross-linking of the two component adhesive. At the same time this cross-linking guarantees a higher resistance to heat generated by the headlamp or the vehicle engine.

Reactive hot melts are processed at temperatures above 100 °C and are often brittle due to their poor adhesion because of their quick structure formation ("quick-fix"). Because of the rapid crystallisation the " quick-fix" characteristic sometimes leads to poorer wetting of the substrate. At the same time short furnace times and decreased stability limit processing flexibility.

Reactive warm melts are applied below 100 °C and are described in detail later. Reactive sealing materials are not rubber-like hot melts, which are applied at high temperature (>160 °C). Since they do not cross-link hot melts, they remain thermoplastic. In order to prevent resultant creep, mechanical adjustments must be made at higher temperature. A great advantage is that a leakage test can be implemented immediately after application thus achieving 100 % quality control.

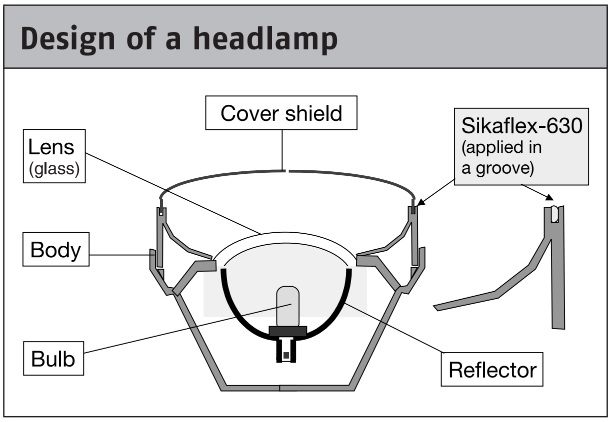

Fig. 1. Automobile headlamps consist of a transparent cover shield and a body

Market Requirements and Wishes

Series production of automobile headlamps is a very fast process. From it important requirements on an adhesive plastic compound system result:

- no displacement of the body and the cover shield with respect to each other;
- touchable, so that there is no danger of contamination;
- the leakage test must be integrated in the process;
- no use of clips or other mechanical adjustments.

Translated from Kunststoffe 8/2003, pp. 94–98

Of the adhesives and sealing materials used so far the reactive warm melts (RWM) best fulfil headlamp manufacturers' requirements.

Just in Time Production Possible

In particular with adhesion-weak plastics the pre-operative method plays a role. It must be simple to apply and provide good resistance to ageing of the bond. The PlasmaTreat system fulfils these requirements. The basis of the plasma pre-treatment is shown in Fig. 2 [1] where different excitation states are represented schematically. The PlasmaTreat process introduces active carboxylates, ether, ketones or other oxygen-containing groups at the plastic surface without the use of a primer. The resulting surface tension is increased to over 60 mN/m (Fig. 3) [1].

i Manufacturer

Sika Technology AG
Branch Zurich
Tüffenwies 16
CH-8048 Zurich
Switzerland
Phone +41 (1) 4 36-4040
Fax +41 (1) 4 36-4444
www.sika.com

In this method the substrate is treated briefly with a potential free flame (Fig. 4 and 5). Thus good wettability is obtained and direct application of the adhesive can take place. The substrate keeps its optimal adhesion quality over more than seven days. Even with metal containing materials short-circuits that can damage the substrates cannot develop, since the ionic parts of the plasma are separated out in the plasma jet nozzle.

A newly developed reactive warm melt (RWM) with the designation Sikaflex-630 (manufacturer: Sika Technology, Zurich) combines the advantages of well-known technologies. Table 1 shows some technical characteristics of this warm hardening adhesive, which makes "instant-fix" handling strength possible. Sikaflex-630 hardens with environment moisture to an elastomer and develops good adhesion with plasma pre-treated polypropylene, non-pre-treated polycarbonate and hard-coated polycarbonate.

The advantages of this warm melt adhesive are

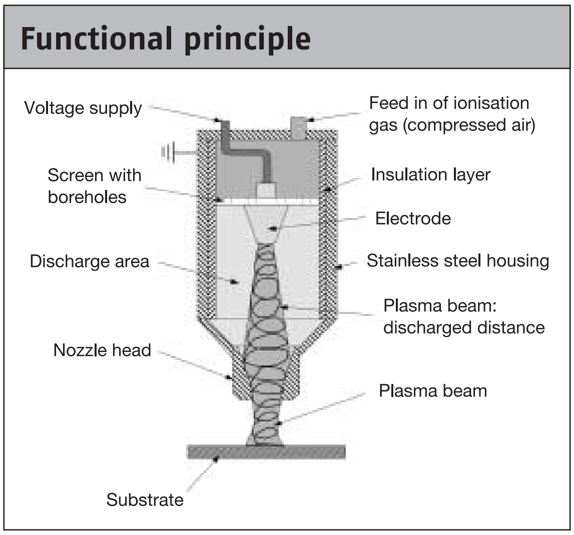

Fig. 4. Technology of an atmospheric pressure plasma

- single component, i.e. no mixing,
- "instant" handling strength for the headlamp adhesion,
- touchable and non-sticking shortly after application,
- directly following leakage test under pressure load possible (owing to the rubber-like rheological behaviour of the adhesive) and
- only temporary mechanical fixation (clip) during the leakage test.

The "instant" solidification of the Sikaflex-630 adhesive permits "just in time" production and packing of the headlamps. The final cross-linking of the adhesive takes place during storage and transport. Further advantages result through

- increasing the productivity (more headlamps per minute),
- in comparison with two component adhesives considerably higher throughput (fewer cleaning interruptions, short maintenance time and lower costs),
- lower initial cost (e. g. no furnace or paternoster) as well as
- smaller number of rejected parts.

Influence on Handling Strength

The handling strength, an important factor in the leakage test, depends to a large extent on the reactive, warm-hardening adhesive. RWMs usually contain rubber-like thermoplastic components or a crystallising resin. These are defined in Fig. 6 and 7.

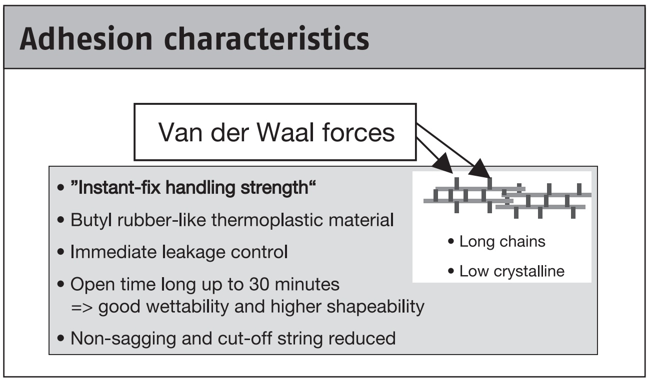

Fig. 6. Characteristic properties of a reactive warm hardening adhesive or warm melt with instant-fix initial strength

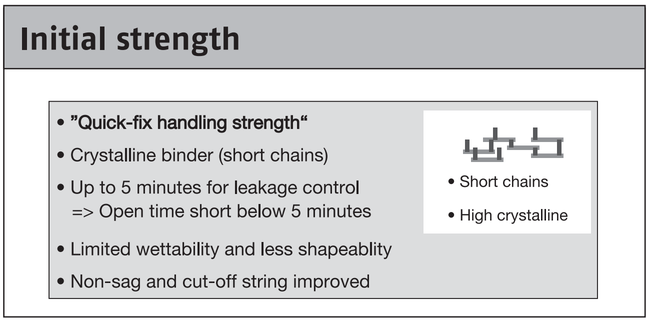

Fig. 7. Characteristic properties of a reactive warm hardening adhesive or warm melt with quick-fix initial strength

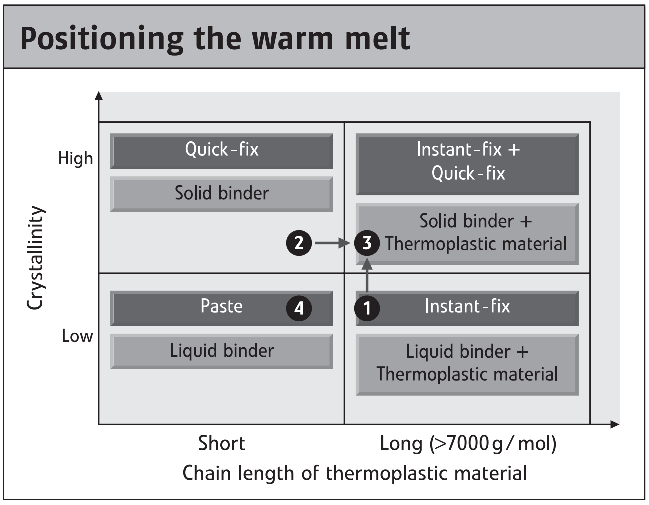

Fig. 8. Dependence on the chain length of the thermoplastic material and the crystallinity of the warm melt

Instant-fix RWM. "Instant-fix" RWM makes possible a handling strength that permits leakage testing immediately after bonding the headlamp construction units. It consists of a rubber-like thermoplastic material where the polymer chain is comparatively long and has a molecular weight of more than 7000 g/mol. Between the chains there are intermolecular forces that permit plastic ductility. Therefore simple assembly without the danger of cracking is feasible. The open time of this RWM is long, and at the same time it shows good wetting. This makes good adhesion possible without the danger of building up stresses in the adhesive.

Quick-fix RWM. "Quick-fix" RWM is semi-crystalline and needs up to five minutes to develop the required handling strength for the leakage test. Since this product does not contain a rubber-like component, it needs time for the crystallisation process of the melted adhesive. This procedure is comparable with a candle wax, which also solidifies slowly. In contrast, the thermoplastic material described above consists of a liquid resin and a liquid chain-extender so that it behaves like chewing gum.

When the "quick-fix" RWM cools, the open time also ends immediately because of the high injection forces arising then. The cooling leads to material shrinkage through crystallisation, which can lead to stress cracks in the adhesive as well as between adhesive and substrate.

Combined Handling Strength. The interdependence between the chain length of the thermoplastic material and the crystallinity is shown in Fig. 8. Here number 1 stands for an "instant-fix" RWM1, number 2 for a "quick-fix" RWM2, number 3 for an "instant-fix" and "quick-fix" RWM3 and number 4 for a pasty (reactive) adhesive. Fig. 9 makes clear that the handling strength of the RWM3 is higher than that of the RWM1, which is Sikaflex-630. RWM3 has an instant strength and at the same time quick strength build up and the crystalline bonding agent increases the initial strength of the reactive thermoplastic (= RTP) after five minutes. RWM1 and RWM3 permit bonding with directly following leakage testing for headlamps.

In Fig. 10 the viscosities of the thermoplastic RWMs are shown for the relevant temperature range. Different processing temperatures exist as a function of the kind of RWM. According to experience a viscosity range between 800 and 1200 Pa*s is the limit for good pumpability. RWM1 shows a linear viscosity curve and needs 95 °C for processing by extrusion. The rubber-like thermoplastic causes this behaviour and it exhibits outstanding bonding characteristics. Good adhesion is already reached at ambient temperature. RWM2 contains a crystalline solid bonding agent without thermoplastic and needs lower processing temperatures of approximately 50 °C compared with RWM1. The rapid solidification with cooling in five minutes to achieve handling strength is nevertheless too long a time for a leakage test integrated into the production process.

RWM3 is a combination of the rubber-like thermoplastic with the crystalline solid bonding agent. It can be processed at 80 °C. Over 60 °C the viscosity curve is more or less identical to that of RWM1 and lower than that about like to that of the quick-fix warm hardening RWM2. This combination leads to a so-

Reactive warm melt (RWM)

Properties	Values
Application temperature	95 °C
Non sagging	3 mm bead okay
Fast physical hardening	< 2 minutes
Tensile strength	≈ 4,5 MPa
Elongation at break	> 800 %

Table 1. Technical characteristics of the warm curing melt adhesive Sikaflex-630

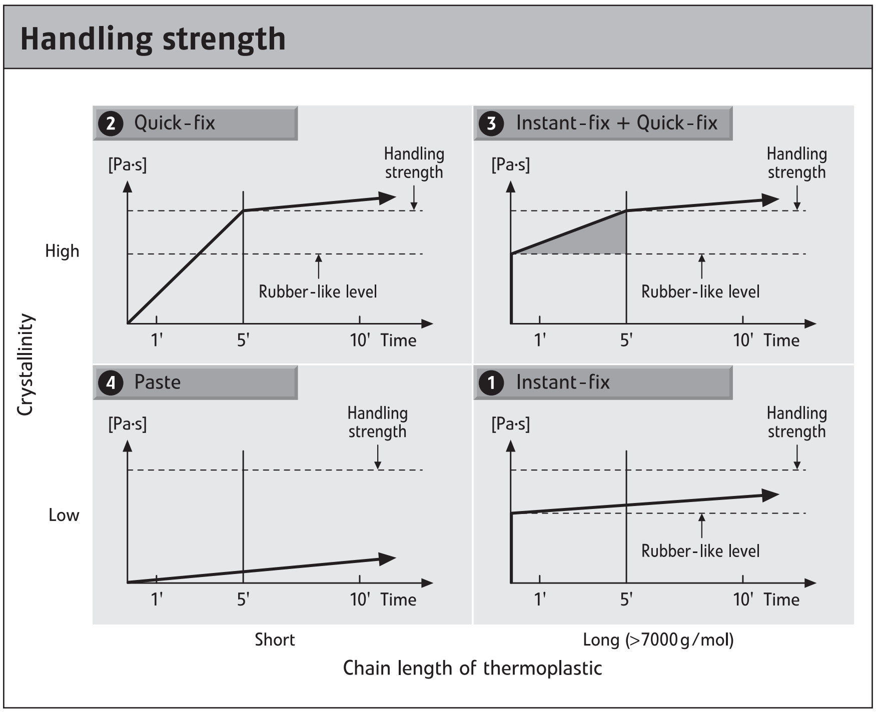

Fig. 9. Comparison of the initial strengths of different warm melts

lidification behaviour between RWM1 and RWM2.

Pump and Delivery System for Production

A discharge performance of at least 350 g/min is needed for production of headlamps. Conventional pumping equipment is too weak for such discharge quantities, as the rubber-like behaviour of the Sikaflex-630 (RWM1) requires high processing pressures. New pumps had to be developed in order to achieve the required performance. This new pump, RT Warm Melt 800, has up to 800 g/min discharge capacity depending on the material viscosity [2]. The adhesive is in a composite foil bag in a hobbock 280 mm in diameter and 380 mm high. After putting the foil bag into the press out pipe a hydraulic cylinder presses the adhesive into the heating chamber and then into the supply pump.

The adhesive arrives at the delivery nozzle through heated hoses, where also a volume dosing unit can be inserted. Change of material can be carried out very easily. Almost 100 % of the material is pressed out and the empty foil bags can be removed (Fig. 11). Because of thermal stability no 200 litre barrels can be filled. This is because the filling up temperature of the warm melts corresponds to the temperature during production and application and a heat build-up develops in the centre of the barrel, which leads to uncontrolled hardening.

Use in Series Production

The new system for the assembly of the headlamps is presently used in series production of automobile headlamps (Fig. 12). This kind of bonding of headlamps is unique due to the special characteristics of its components:

- reactive warm melt,
- plasma pre-treatment and
- pump and delivery system.

The procedure is not limited only to the assembly of headlamp bodies, but it can be used favourably whenever there are high requirements on the quality of the bond simultaneously with short cycle times. ■

i User

Hella KG Hueck & Co.
Rixbecker Str. 75
D-59552 Lippstadt
Germany
Phone +49 (0) 2 94/1 38-0
Fax +49 (0) 2 94/1 38-7133
www.hella.com

THE AUTHORS

JÜRGEN HORSTMANN, born in 1963, has been responsible for adhesives and adhesion processes at Hella KG Hueck & Co., Lippstadt, since 1999.

DR. PETER W. MERZ, born in 1953, has been technical editor at Sika Technology AG, Zurich, since 2002; merz.peter@ch.sika.com

Title photo. Automobile headlamp system made of different plastics by the manufacturer Hella KG Hueck & Co. for the BMW 5 series

Fig. 2. Plasma pretreatment: Composition of the plasma
Energie = Energy; Temperatur = Temperature; Gasmolekül (aktiviert) = Gas molecule (activated); Ionische Teile = Ionic parts; Freie Elektronen = Free electrons; Molekülfragment (hochenergetisch) = Molecule fragments (high-energetic)

Fig. 3. Surface pretreatment: XPS analysis of a PP foil
Nicht vorbehandelt = Not pretreated; Oberflächenspannung = Surface tension

Fig. 5. Plasma generator
Rotierend: Durchmesser der Plasma-Flamme bei ≈ 44 mm = Rotating: diameter of the plasma flame at ≈ 44 mm

Fig. 10. Viscosity comparison: The different viscosities influence the processing properties of the current warm melt
Viskosität = Viscosity; Temperatur = Temperature; Kristallines festes Bindemittel (bei RT plastisch nicht verformbar) = Cristalline solid binder (at RT plastically not deformable); Festes Bindemittel = Solid binder; Flüssiges Bindemittel = Liquid binder

Fig. 11. The adhesive is fed to the production unit in the headlamp production part of the tandem equipment
Zusammenführung der beheizten Schläuche = Joining the heated up strings; Presse = Press; Schöpfkolbenpumpen = Cup piston pumps

Fig. 12. Assembly of front headlamps in a production line