

work.info

Gluings

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1 General

1.1 Definition of terms

Gluing is a method of joining which has become increasingly important recently and has been extended to include more fields of application where other methods of joining cannot or should not be used, e.g. for practical or visual reasons. These include a combination of various materials (e.g. metal and plastic), the integration of additional functions (e.g. watertightness, damping, thermal conductivity or separation), retention of material properties (e.g. prevention of distortion), improvement in component properties (e.g. lightweight construction, attachment of reinforcements) and surface treatment (e.g. design by veneer adaptations).

DIN EN 923 defines the term "adhesive" as a "non-metal substance that can join items by surface bonding (adhesion) and intrinsic strength (cohesion)".

Other standards and guidelines include:

- DVS 2204: Gluing thermoplastics
- VDI 3821: Gluing plastics
- DIN EN 13887: Structural adhesives – Guidelines for the surface preparation of metals and plastics prior to adhesive bonding
- ISO 17212: Structural adhesives – Guidelines for the surface preparation of metals and plastics prior to adhesive bonding
- DIN 8593-8 Production processes for joining – Part 8: Gluing; classification, subdivision, terms

You will find a list of all the standards concerning adhesives in a publication by Industrieverband Klebstoffe e.V..

Adhesive bonding as a physical/chemical process is classified, like welding and soldering, as one of the integral, usually permanent joining techniques. The type of materials being joined, the amount of load and the level of cost-effectiveness are crucial when it comes to selecting the most appropriate method of joining. Weather resistance and chemical resistance also have to be taken into account, especially if there is direct exposure to corrosive media. In such cases welding is preferable, provided it is possible.

The quality of an adhesive bond depends not only on the adhesive itself (selection, storage, metering, application) but also on the parts being joined (tolerances of the surfaces, pretreatment, storage) and production (joining and curing processes, downstream production steps).

General properties of adhesives and the possible adhesive bonds include:

- Setting time is largely adjustable
- Strength and elasticity of the adhesive layer can be adjusted within broad limits. It is possible to achieve tensile shear strengths of < 1 MPa to > 40 MPa and tensile strengths at break of up to 800 %.
- In some cases, thermal resistance is only limited
- Transparency possible
- Uniform distribution of forces
- Gap filling

1.2 Basics

In simplified terms, with regard to adhesion it is possible to distinguish between plastics that are easy to glue (e.g. ABS, PET, PC, PS, PVC), ones that can be glued but only with limitations (e.g. POM, PA) and ones that are difficult to glue (e.g. PE, PP, PVDF, PTFE). One of the reasons for this is the different chemical structure of the plastics. Good adhesive bonding can be expected of plastics that, for example, are readily soluble or have a high level of surface energy or high wettability (polarity). Generally speaking, an adhesive can only wet the surface of a material properly if it has lower surface tension than the material.

Table 1: Surface energy of some plastics

Selection of plastics	Free surface energy [mN/m] (method-dependent)	Glueability ^①
SIMONA® PE 100 / PE-HD	32	0
SIMONA® PP-C grey / natural	28	0
SIMONA® PP-H AlphaPlus®	28	0
SIMONA® PP-H natural	<28	0
SIMONA® PPs	28	0
SIMONA® PVC-CAW	35	++
SIMONA® PVC-MZ COLOR	32	++
SIMONA® PVC-GLAS	35	++
SIMONA® COPLAST-AS-X	35	++
SIMOPOR-LIGHT	35	++
SIMOPOR-LIGHT BRILLIANT	36	++
SIMOWOOD made of Resysta®	28	++
SIMOWOOD IMO	28	++
SIMOLUX (PETG)	35	++
SIMONA® CPVC CORZAN Industrial Grade	32	+
SIMONA® PVDF	38	0
SIMONA® ECTFE	28	0
SIMONA® PFA	<28	0

① 0 = cannot be glued, or difficult to glue and only after pretreatment, + = glueable, ++ = easy to glue

1.3 Classification of adhesives

Adhesives can be classified according to various criteria:

- Setting mechanism
 - Physical
 - Chemical
- Raw material basis
 - Epoxy
 - Silicone
 - Polyurethane
- Level of strength
 - Structural adhesive
- Processing
 - Spray adhesive
 - Contact adhesive
 - Adhesive tapes
- Field of application
 - Packaging adhesive
 - Automotive adhesive

Selection of adhesives

Every material, including adhesives, has an optimal field of application. For this reason it is absolutely essential to be aware of the requirements and the adhesive properties. These include the nature of the materials/substrates, the size of the surface being glued and the short- and long-term loads. Not to mention the processing conditions such as viscosity and pot life. In addition, it is important to ask whether, on account of the parameters applicable, the substrates have to be subjected to pretreatment.

Adhesives can have very different properties and they are used in different areas depending on those properties. Properties of adhesives range from very elastic (high elongation at break) to extremely stable (high tensile strength). In this classification the large range of polyurethanes can be subdivided into 1-component and 2-component PU adhesives, which differ in terms of elongation at break.

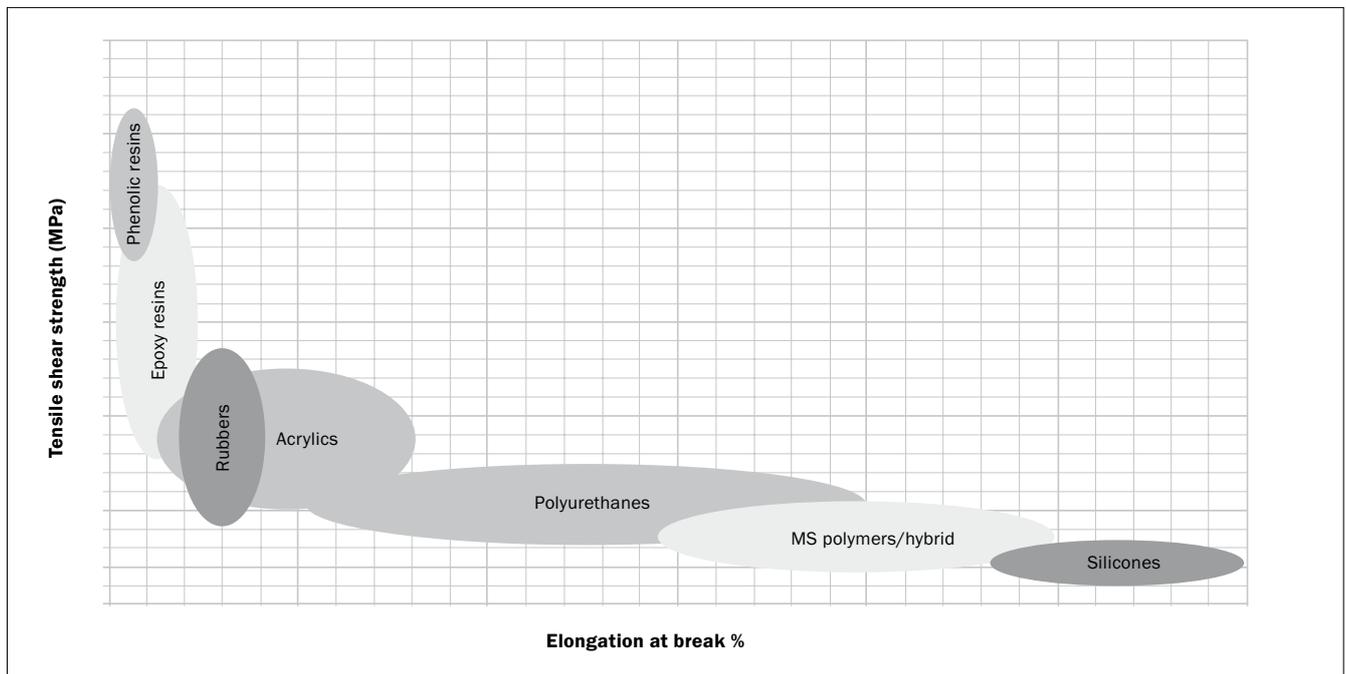


Figure 1: Relative classification of material properties of adhesives from the category of chemically setting adhesives

Solvent adhesives (mainly diffusion adhesives)

The parts to be joined are mainly connected by diffusion and evaporation of the solvent. Solvent adhesive systems chiefly consist of the corresponding thermoplastics and suitable solvents. In this method it is sufficient to apply adhesive to just one of the parts being joined. After the joining process only moderate pressure should be applied so that the adhesive is not squeezed out.

Water-based glue

Water-based glue is an adhesive dissolved in water and of vegetable, animal or synthetic origin. The bond strength required is only achieved if, during the setting process, water is withdrawn from the glued joint by at least one of the parts being joined.

Two-component adhesives (2K adhesives)

These are manufactured with or without reaction accelerator and are based on polyester resin, epoxy resin, polyurethane or isocyanate. Instead of the suitable hardeners, it is also possible to use light, oxygen or increased temperature as the second component (also referred to as 2-component reaction adhesive, e. g. so-called superglue). Such adhesives can be applied and adjusted within the so-called pot life.

Hot-melt adhesives

Hot-melt adhesives are mainly thermoplastics. To make them adhere, they are melted and allowed to set by cooling down. If the adhesive is reheated, it melts again.

Adhesive tapes

There are always two types available:

1. Base tapes/films coated with adhesive on one side or both sides
2. Tapes with adhesive continuously integrated

For adhesive tapes various types of adhesive are used.

For further information, please refer to the information brochures and datasheets provided by adhesive tape manufacturers.

2 Setting mechanisms

The setting of adhesives is based either on physical processes or on chemical reactions.

Physical processes:

- Evaporation of solvents (in the case of solvent adhesives and contact adhesives)
- Release of water (in the case of water-based glues)
- Solidification of a melt (in the case of hot-melt adhesives)

Chemical reactions:

- Polymerisation (in the case of polyester resins, PMMA)
- Polyaddition (in the case of epoxy resins, polyurethanes)
- Polycondensation (in the case of phenolic resins, urea resins and formaldehyde resins)

2.1 Adhesion bonding

The mode of action of an adhesive and the strength of the bond are dependent on the boundary surface forces of the two parts being bonded (adhesion), in conjunction with the intrinsic strength of the adhesive (cohesion). Neither solvents nor adhesive constituents interact with the plastics. Stress cracking is not to be expected. The method is used for bonding plastics to different materials and for bonding solvent-insensitive plastics to one another.

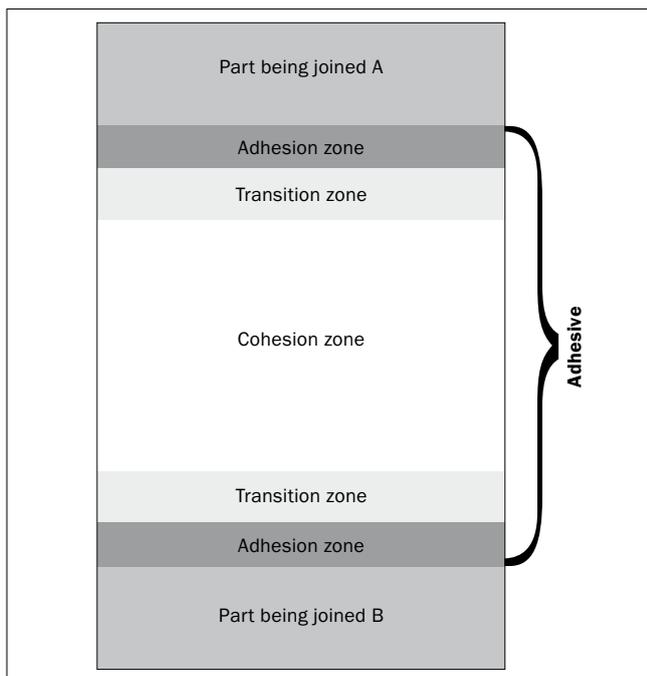


Figure 2: Diagram of an adhesive bond

2.2 Diffusion bonding

In diffusion bonding, solvent molecules migrate into the plastic and by means of swelling and dissolving effects they cause molecular movements that bring about connections similar to welded joints. Owing to the modification of molecular structure, the mechanical properties may change, possibly accompanied by stress cracking. The adhesive zone, i. e. the glued part, can only be subjected to mechanical loads when the solvents have completely evaporated from it.

3 Pretreatment

Surface pretreatment is designed to remove soiling, roughen the surface (surface area enlargement → more surface area being bonded → higher adhesion) or increase the surface energy (increase in wettability). Pretreatment of the surfaces being bonded can be performed as follows:

Cleaning and degreasing

The aim here in particular is to remove oily and greasy residues from the surfaces being joined. Wettability by the adhesive is also improved. Good results have been achieved with methylated spirits (refer to the instructions provided by the adhesive manufacturers where necessary). To remove dust and sand, it is also possible to use microfibre cloths or water.

Mechanical methods

Sandblasting, grinding and brushing increase the surface area and thus bring about an increase in adhesive strength.

Thermal method

Burning off the surface with a gas flame in conjunction with atmospheric oxygen (oxidisation of the surface) is a method that is ideal for PE-HD, for example.

Chemical method

By pickling with chromosulphuric acid, also using primers, the adhesion properties of polyolefin surfaces can be improved for adhesives.

Physicochemical method

In atmospheric plasma treatment a potential of up to 20 kV is applied in a firing chamber and a discharge reaction is triggered in a gas flow. This reaction generates a plasma that emerges from the firing chamber and influences the surface energy on impact with the surface of the substrate.

Electrical pretreatment

By means of a corona discharge (using high voltage or high-frequency currents) polyolefin surfaces are also enhanced for adhesion.

4 Adhesive processing and adhesive application

Depending on the type and properties of the adhesive (e.g. viscosity, substrate-bound), there are various processing options available. These include:

- Bead application, i.e. linear application with variable bead diameter and cross-section
- Fluid bed application, i.e. quasi-flat area application without any spray mist
- Flat-area application, i.e. adhesive application using a roller or flat-sheet die
- Spray application, i.e. flat-area application with spray mist, possibly irregular
- Screen printing, i.e. application of defined adhesive patterns
- Application of adhesive tapes

5 Special aspects of gluing plastics

Adhesives and their constituents exert an influence on the plastic surface. This influence is necessary to create an adhesive bond but some constituents also have a detrimental effect on the plastic. Adhesives may contain the following critical constituents, among others:

- Solvents
- Low-molecular-weight constituents (e. g. (residual) monomers)
- Surface-active substances (e. g. emulsifiers, surfactants, wetting agents)
- Plasticizers

The surface of PVC-based plastics can be dissolved by solvent adhesives. Low-molecular-weight constituents can penetrate the surface of plastics and thus interfere with the bonds between the polymers. On account of this, stresses and strains in the material can relax and result in stress cracking. This also applies to the long-term storage of adhesives and adhesive constituents in plastic containers. In the case of adhesive bonded chemicals of leading plastic systems, e. g. PVC piping systems, it is not only the plastics that have to be tested for chemical resistance and general suitability for the operating conditions (e. g. temperature) but also the adhesives.

Depending on the manufacturing process and type of use, it may happen that certain plastic products contain adhesive-retardant substances. Furthermore, certain manufacturing processes use additives which, in injection moulding for example, facilitate removal from a mould but may reduce adhesive strength. Residues from labels and lettering can also have a detrimental effect on an adhesive bond. For this reason, it is always advisable to clean the plastic parts in an appropriate manner, remove all residues and conduct an adhesive bond test.

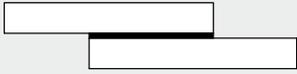
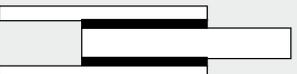
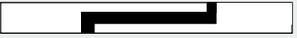
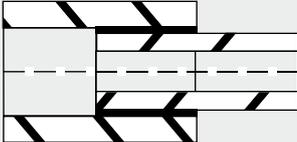
6 Safety measures

Solvent-containing adhesives, solvents, diluents, detergents and degreasing agents rank among the most hazardous industrial substances, in the presence of which fire hazards, explosion hazards and damage to health can occur. In addition to complying with the maximum workplace concentration limits, the following protective measures are recommended:

- Ventilation of the working areas
- Extraction of solvent vapours by suction
- Use of face masks, safety goggles, protective gloves, protective clothing
- Prohibition of smoking and eating

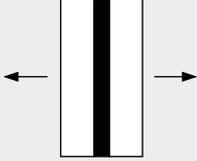
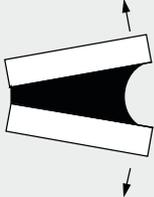
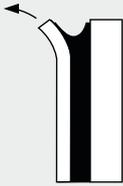
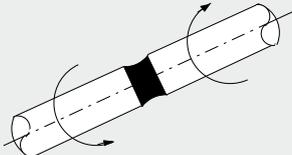
7 Configuration of adhesive bonds

To create an adhesive-friendly design, the processing company must choose an area of surface that is adequate for adhesive bonding. Also, the thickness of the adhesive must be adjusted for the particular adhesive, whilst stresses and strains inside the adhesive bond and the substrate must be avoided.

	<p>Single overlaps are chiefly used where walls are thin. The advantages are that the procedure is easy and strength is good.</p>
	<p>Double overlaps produce firm bonds at low cost. The target should be wall thickness ratios of 1:2:1 for reasons of cost-effectiveness.</p>
	<p>A single butt strap joint is used to achieve a smooth surface.</p>
	<p>A double-overlap butt adhesive bond produces high levels of strength. Its drawback is that neither side has a smooth surface.</p>
	<p>Finger-jointing only allows reasonable levels of strength if walls are thick.</p>
	<p>In the case of a straight flush (stepped) overlap the levels of seam strength are inadequate and the cost of preparation is high.</p>
	<p>A straight flush double butt strap joint requires considerable effort whilst seam preparation has to be precise.</p>
	<p>The butt joint can scarcely transfer forces because the area to be glued is small. Only suitable in exceptional cases.</p>
	<p>With parts subject to torsion (pipe connections), adhesive bonds with large areas are exposed to loads uniformly. High levels of strength can be expected.</p>

8 Main types of load on glued structures

Adhesive bonds should preferably be designed in such a way that the load is absorbed by the entire surface glued. When designing the joint, importance should always be attached to tensile force, shear force or also torsional force, which in turn means that splitting forces and peeling forces have to be reduced to a minimum. The areas to be glued should always be as large as possible in order to ensure optimal transfer of force.

	<p>Influence of tensile forces Uniform loading of the glued surface</p> <p>Connection to be recommended</p>
	<p>Influence of splitting forces Uneven loading of the glued surface, i. e. one part is subject to heavy loading whilst the other is not.</p> <p>Not to be recommended</p>
	<p>Influence of shear forces Uniform loading of the glued surface</p> <p>Connection to be recommended</p>
	<p>Influence of peeling forces Uneven loading of the glued surface</p> <p>Not to be recommended</p>
	<p>Influence of torsional forces Uniform loading of the glued surface</p> <p>Connection to be recommended</p>

9 Testing adhesives and glued joints

The quality of an adhesive bond can be checked by conducting either non-destructive tests or ones that destroy the joint.

Non-destructive tests include:

- Visual assessment (e. g. detection of air inclusions, complete application of adhesive, where possible)
- Leak tests

Destructive tests can provide information about the strength of the glued joint. Destructive test procedures can be divided up into static, cyclic and impact tests:

Static	Static	Impact
Shear tests (tensile tests, pressure tests, torsion tests, roll tests, climbing drum tests, bending tests)	Vibration resistance test	Impact tests (e. g. falling dart, hammer blow)
Cross-peel test, creep strength		
3-point bending test		

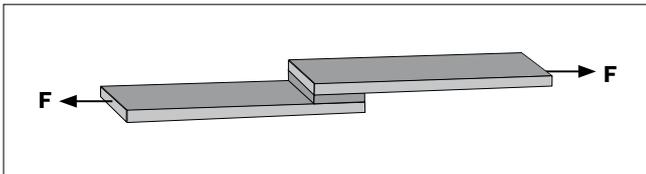


Figure 3: Diagram of a tensile shear test conforming to DIN EN 1465

10 Gluing SIMONA plastics

The following information is intentionally of a general nature and is based on basic information from adhesive manufacturers and our own experiments. This list is not exhaustive and does not provide any guarantee of successful adhesive bonding in a particular application. In all cases, the information and instructions for use provided by the adhesive manufacturers must be complied with.

10.1 SIMONA® PE and PP

Without any backing it is difficult to make a non-positive connection between these two groups of materials. To accomplish adhesive bonding between materials or with other materials, it is essential to conduct thorough preparation by means of long-pile roughening or thermal, chemical or electrical pretreatment. However, there are also adhesives available that have been specially developed for low-energy surfaces.

Examples:

Acrylic-based 2-component structural adhesive, e.g. 3M™ Scotch-Weld™ DP 8005 or WEICON Easy-Mix PE-PP 45.

Far better results can be achieved with surfaces that have one-sided backing where, for example, the stretch fabric is pressed into the plastic (SIMONA® PP-H AlphaPlus®-SK). Composite structures are particularly important. They exploit the high chemical and thermal resistance of thermoplastics, combine it with the strength of other materials and make a major contribution towards improving cost-effectiveness. The main fields of application involved are laboratory construction, composite tank construction and interior linings.

From the range of 2-component adhesives the following are available for these uses:

- PUR-forming adhesives, e.g. Icema R 101 with hardener 7 (H.B. Fuller GmbH, Munich)
- Epoxy resin adhesives, e.g. Araldite (Huntsman, Salt Lake City (USA)), or WEVOPOX (Wevo-Chemie, Ostfildern-Kemnat)
- Polyester resins, e.g. Palatal (DSM Coating Resins, Augusta (USA))

10.2 SIMONA® PVC (rigid and foamed PVC)

PVCs can be joined to one another by means of diffusion bonding with solvent adhesives. Prior cleaning should be performed with special cleaning agents or methylene chloride.

Examples:

- Tangit PVC-U (Henkel, Düsseldorf)
- The PVC-based adhesive with tetrahydrofuran as solvent is particularly suitable for non-positive connection of pressure pipes. According to information from the adhesive manufacturer, this adhesive should not be used for adhesive bonds between pipes that convey the following acids:

Sulphuric acid	above 70 %
Hydrochloric acid	above 25 %
Nitric acid	above 20 %
Hydrofluoric acid	any concentration
- Tangit Dytex (Henkel, Düsseldorf)
Its basis is post-chlorinated PVC, dissolved in methylene chloride (under certain conditions also suitable for bonding PVC to other materials such as wood and concrete). However, for bonding PVC to other materials 2-component systems or contact adhesives should always be used.
- COSMOFEN PLUS white (Weiss, Haiger)
This solvent adhesive is dyed white. Among other things, it can be used as an adhesive for SIMONA® COPLAST-AS and as an edge sealant.

10.3 SIMONA® CPVC

CPVCs can also be joined to one another by diffusion bonding with solvent adhesives. Prior cleaning should be performed with special cleaning agents or methylene chloride. As opposed to rigid PVC adhesives, a different solvent mixture is normally used in which CPVC is dissolved instead of PVC-U.

Example:

- Tangit PVC-C (Henkel, Düsseldorf)
PVC-based CPVC adhesive with tetrahydrofuran and butanone as the principal constituents is especially suitable for hot-water applications and for use with corrosive media at high temperatures so it is used for plant construction in the chemical and metal industries (e.g. hot water, waste acids).

10.4 SIMOLUX (PETG)

Solvent mixtures have proved successful for gluing SIMOLUX products, e. g.:

- 42 % methyl ethyl ketone (MEK) + 42 % trichloroethylene + 16 % methylene chloride
- 85 % methylene chloride + 12 % trichloroethylene + 3 % MEK
- 90 % chloromethane + 10 % acetic acid

By dissolving approx. 10 % SIMOLUX shavings in the solvent the evaporation rate of the solvent adhesive can be substantially reduced. In particular this leads to longer fixation times for adhesive bonds over large surfaces. In addition, the risk of white discoloration in the adhesive zone is reduced considerably.

SIMOLUX products can also be joined using most commercially available polyester adhesives and double-sided adhesive tapes.

10.5 SIMONA® PVDF, ECTFE and PFA

Without backing: fluorinated plastics such as PVDF can only be bonded with considerable cost and labour. One option is adhesion bonding with epoxy resin-based or cyanoacrylate-based 2-component reaction adhesives. It is absolutely essential to pretreat the surfaces. For adhesive bonds with partially fluorinated or fully fluorinated plastics it is explicitly advisable to perform a test and consult the adhesive manufacturer.

With backing: The same systems can be used as those specified for SIMONA® PP. If high temperatures occur (approx. 90°C to 120°C), epoxy resins are preferable.

For the other partially or fully fluorinated SIMONA® Semi-Finished Products such as ECTFE or PFA, the behaviour in adhesive bonding can be expected to be similar to that of PVDF.

10.6 SIMOWOOD made of Resysta®

It is possible to glue SIMOWOOD. Owing to the large number of different adhesives and their options for bonding to various material surfaces, we recommend performing tests beforehand. Good results are to be expected with various makes of adhesive that are suitable for rigid plastics (rigid PVC / PVC-U). These include, for example, STPU (Hybrid) and 1K- and 2K-PU/PUR adhesives as well as polyester resins and epoxy resins. For many adhesives it is also advisable to pretreat the substrate using a cleaning agent or primer.

For gluing SIMOWOOD to various substrates we have been able to achieve good short-term results and good adhesion properties on, for example, SIMOWOOD, gypsum, concrete, PVC-U, steel, aluminium, tiles, wood and GRP. For other material combinations, please consult your adhesive manufacturer or contact our Technical Service Centre (tsc@simona.de).

In addition to information in the manufacturers' technical data-sheets, the following points should be observed in adhesive bonding, depending on the field of application:

- Adhesive bonding before assembly
- Application of pressure to the adhesive seam
- Hydrolysis resistance of the adhesive
- Application temperature
- Pot life
- Adhesive layer thickness
- Clean surface devoid of dust and grease
- Priming and substrate pretreatment (e. g. roughening)

We are in close contact with other well-known adhesive manufacturers; this allows us to expand and verify our state of knowledge about the adhesive bonding of SIMOWOOD. For other processing instructions and adhesive suggestions, please refer to the tech.info SIMOWOOD made of Resysta®.

10.7 SIMOLIFE EVA

In the orthopaedic sector it is sometimes desirable to glue components to orthotic devices and prostheses, e. g. foam materials. For this purpose appropriate adhesives have to be used (e. g. Siemapren 1309/60 (SIEMA)).

For gluing SIMONA® materials to various substrates we have been able to achieve good short-term results and good adhesion properties. The adhesive types listed here serve as suggestions for users and do not constitute binding recommendations. The suggestions are based on our own tests and recommendations from adhesive manufacturers. Nor does the list claim to be exhaustive.

	SIMONA® PE-HD / SIMONA® PE 100 / SIMONA® PP-H AlphaPlus® / SIMONA® PP-H	SIMONA® PVC- CAW / SIMONA® PVC-MZ COLOR / SIMONA® COPLAST / SIMOPOR	SIMONA® CPVC Corzan Industrial Grade	SIMOWOOD^①	SIMOLUX / SIMOLIFE PETG	SIMOLIFE EVA
3M™ Scotch-Weld™ DP 8005 (3M)	x					
3M™ Scotch-Weld™ DP 8010 (3M)	x					
Easy-Mix PE-PP 45 (WEICON)	x					
Tangit PVC-U (Henkel)		x		x		
Tangit PVC-C (Henkel)			x			
Tangit Dytex (Henkel)		x	x	x		
COSMOFEN PLUS weiß (Weiss)		x		x		
COSMOFEN PLUS HV (Weiss)					x	
MR-AP 35, MR-AP 49 (Lorenz)					x	
Agomet F 347 (Huntsman)		x			x	
ACRIFIX® 2R 1900 (Evonik) (for transparent adhesive bonds)					x	
Dymax MD® 191-M (Dymax) (for the medical sector ^②)					x	
Dymax Ultra Light-Weld® 3094 (Dymax)					x	
VHB™ Tape 4941 (3M)		x			x	
ASX ^{plus} 7078 (tesa)		x			x	
Siemapren 1309/60 (SIEMA)						x

^① For other adhesive suggestions, please refer to the tech.info SIMOWOOD made of Resysta®.

^② Depending on the particular field of application, it is absolutely essential to obtain manufacturers' information and approvals.

Adhesive-specific advice and sales are handled directly by the adhesive manufacturer. Successful performance of an adhesive bond usually calls for interdisciplinary exchange between all those involved, i. e. between substrate manufacturers, adhesive manufacturers, processing companies and users.

11 Legal note and advice

Legal note

Upon publication of a new edition all previous editions shall become void. The authoritative version of this publication can be found on our website at www.simona.de.

All information furnished in this publication reflects our current scope of knowledge on the date of publication and is designed to provide details of our products and potential fields of application (errors and omissions excepted, including typographical mistakes). This shall not be deemed as constituting the provision of legally binding guarantees or warranties as to specific properties of the products or their suitability for specific areas of application.

We provide warranty for the faultless quality of our products solely within the framework of our Standard Terms and Conditions of Business and only within the scope specified therein.

We shall assume no liability for the application, utilisation, processing or other use of this information or of our products. Furthermore, we shall assume no liability for any consequences related thereto. The purchaser is obliged to examine the quality and properties of these products; he shall be responsible in full for selecting, applying, utilising and processing said products as well as applying any information relating thereto, which shall also include all consequences associated with such actions. Third-party property rights shall be observed accordingly.

Advice

Our applied technical advice is given according to our best knowledge and is based on the information you have provided and the state of the art known to us at the time such advice is furnished. The advice shall not constitute a guarantee or warranty of specific characteristics or qualities and shall not establish an independent contractual legal relationship.

We shall only be liable for cases of intent or gross negligence. Under no circumstances shall we be held liable for the correctness or completeness of information you have provided or the advisory/consulting services rendered by us on the basis of such information. Any information provided by us shall not release you from your obligation to conduct your own assessments and evaluations.

We reserve the right to update information without notice as part of our continuous research and development programme.

Our staff at the Technical Service Centre and Customer Service will be pleased to advise you on the processing and use of semi-finished thermoplastic products and the availability of our products.

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12 Further information and literature

- Industrieverband Klebstoffe e.V., www.klebstoffe.com
- M. Rasche: Handbuch Klebtechnik, Carl Hanser Verlag
- G. Habenicht: Kleben – Grundlagen, Technologien, Anwendungen, Springer Verlag
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