

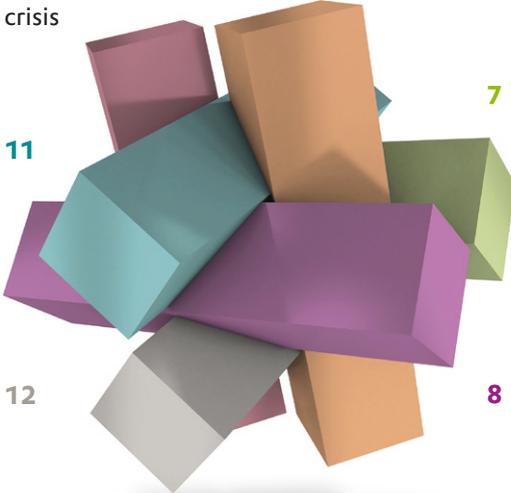
ADHE SIVES!

The Adhesives Journal
of Evonik Industries

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IMPRINT

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helfferich | gestaltung

EDITORIAL



Dear readers,

New market trends, the shift to digital technologies, and increasing demands on products and applications – the adhesive market constantly confronts us with formidable new challenges, and at Evonik we gladly accept those challenges.

As a front runner in innovation, we know that the hunt for truly innovative solutions is something like a brain teaser. Lateral thinking and persistence help solve even the most daunting tasks. But thanks to our broad knowledge of the market and close cooperation with our customers, we can help adhesive manufacturers enhance their formulations to improve performance and effectiveness.

Improved performance of water-based adhesives, resource preservation through the use of foamed hot melts, and new environmentally friendly, low-VOC adhesives are just a few issues that we are exploring.

We are constantly expanding our product portfolio for benign and label-free adhesives, adding products such as new types of functionalized silane co-oligomers with excellent mechanical properties. At the same time, we work closely with our customers in an effort to expand the application areas of our tried and tested silane-modified polymers. In this issue you will learn more about these and many other exciting topics for the global challenges of our time.

We hope you enjoy reading the new journal and look forward to discussing our new product highlights with you!

Yours,
Dr. Claus Rettig



Evonik's polyesters committed to sustainability

DYNACOLL® TERRA



DYNACOLL® Terra grades are not just a "green" version of the petrochemical polyols but also expand the range of properties of the existing product range.

Driven by the growing reactive hotmelt market and the raising concerns on climate change and environmental protection, the need to use renewable raw materials and offer sustainable solutions started. Anticipating this trend, Evonik developed its DYNACOLL® Terra product portfolio, being the first company to launch a catalogue of bio-based polyesters.

Evonik is committed in pursuing this trend and supports it with the continuously development of DYNACOLL® Terra polyesters that provide several benefits to the industry. Firstly, they offer flexibility to formulate reactive hotmelts (RHM), which could have comparable properties to the ones developed with DYNACOLL® 7000. In addition, DYNACOLL® Terra expands and complements the current polyester product portfolio. Thanks to an alternative identified bio-based monomer, scientists have developed bio-amorphous polyesters that improve the

compatibility and lower the viscosities at high glass transition temperatures, in comparison with petrochemical-based polyesters. Finally, polyesters produced with renewable raw materials enable the reduction of the carbon footprint by up to 60%. The road to sustainability has just started and challenges will continue to arise (e.g. limited availability of raw materials, higher performance requirements and many more). Evonik is devoted to accompany the industry aiming at overcoming together current and future challenges, as well as to find sustainable solutions with tailored products.

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The label makes a difference

DYNACOLL® EP 413.10 and EP 415.10



Reactive hotmelts (RHM) typically contain unreacted monomeric Methylene diphenyl diisocyanate (MDI), which can limit their application. Therefore, one of the major challenges is to reduce the monomer content while, at the same time, maintaining the performance of polyurethane (PUR) formulations when using standard polyesters. Lowering the OH number of existing polyesters increases the viscosity significantly, thus leading to poor RHM storage stability. Evonik has developed two amorphous polyesters that enable RHM producers to reduce the monomeric MDI content to weight values lower than 1% (R40 / H351 free labelling) and balance it with the performance of the PUR formulation. The new amorphous polyesters have a higher molecular weight and lower OH number, but similar viscosity levels when compared to standard amorphous grades.

Low emission polyesters

DYNACOLL® 7310

Reactive hotmelts (RHM) formulations are based on a modular system composed of amorphous, liquid and crystalline polyesters that enables to tailor the adhesive to different performance specifications.

The automotive industry, as a main application area, has specific requirements that need to be considered. Automobiles are often exposed to sunlight increasing significantly the temperatures inside the car. Consequently, the adhesives have to be resistant to high temperatures. However, at high temperatures volatile and semi-volatile compounds (VOC/FOG) are emitted and accumulated in the car interior. These compounds have an adverse effect on the air quality, as well as, in the comfort and health of the drivers and passengers.

For these and other reasons, the



demands of the automotive industry are increasing. Although RHM continue to be the preferred option for applications like door panel lamination, headliner production, mirror bonding and others, the requirements are becoming stricter. The limit values apply, not only to the complete system but also, to the individual components and the adhesive. The VDA 278 is the analytic method used to determine

emissions from non-metallic materials; the limit values for the VOC and FOG are, respectively, 100 µg/g and 250 µg/g.

The analysis of the VOC and FOG values on the cured PUR hotmelts, based on conventional polyesters polyols, shows that amorphous and liquid polyesters can fulfill the limit values in certain combinations. Whereas, crystalline polyesters cannot because the emissions are very

high. As crystalline polyesters are important building blocks for the formulation of reactive hotmelts, Evonik have researched and successfully found low VOC/FOG crystalline polyesters. DYNACOLL® 7310 is a commercial example of an alternative solution to reduce the emissions of RHM in automotive applications.

Does it sound interesting?
Contact us to know more.

Helping to solve silicone crisis

POLYMER ST and TEGOPAC®



Silane-modified polymers like POLYMER ST and TEGOPAC® have arrived in a variety of adhesive and sealant applications for many years. Irrespectively, they keep their dynamic growth year after year. Lately, there have mainly been three drivers fueling this development:

1 Liquid membranes for waterproofing applications are one of the most recent applications for silane-modified polymers as they provide an alternative to e.g. isocyanate containing PU roof coatings. Especially with the development of reactive diluents like TEGOPAC® RD which has enabled self-levelling, but still elastic and resistant products to be made. These products can be spray- or roller-coated and can be applied in several layers even with intermissions of many days.

2 Global silicone shortages and dramatic price increases have raised the demand for viable alternatives. There are several applications where a sealant does not need the outstanding temperature and chemical resistance of a silicone and can be replaced by other solutions. E.g. low modulus construction sealants can well be formulated using silane-modified polymers. Specialty products like reactive plasticizers of the TEGOPAC® RD range even allow for migration-free formulations.

3 An increasing consciousness about environmental and health issues is driving the need (and demand) for benign adhesives, especially when it is applied repeatedly or in larger quantities, for example in flooring adhesives. By using TEGOPAC® polymers combined with DYNASYLAN® ethoxy silanes it is now possible to make formulations which do not liberate any methanol upon cure, but only the less harmful ethanol. In these systems, the lower ethoxy silane reactivity is compensated by the polyfunctional design of the base polymer.



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New ultra-fast curing agent for adhesives applications

Ancamine® 2914UF



In response to market demand for increased productivity and environmental friendliness, Evonik designed a new ultra-fast 2K epoxy hardener for structural adhesives applications. Ancamine® 2914UF curing agent not only sets within 10 minutes at ambient temperature but also offers ultra-fast cure speed along with rapid property development. Another key benefit of this product is that it is an odorless non-Mercaptan, 100% solids, BPA-, nonyl phenol- and benzyl alcohol-free curing agent. Additionally, it provides excellent mechanical properties and good thermal resistance. **Figures A and B** demonstrate selected performance properties of Ancamine® 2914UF (since most solvent-free fast cure systems for epoxy resin are Mercaptan, the attached figures use that system as a reference). These properties make Ancamine® 2914UF curing agent an ideal choice for the structural and general-purpose adhesives, where it allows end users to improve production throughput.

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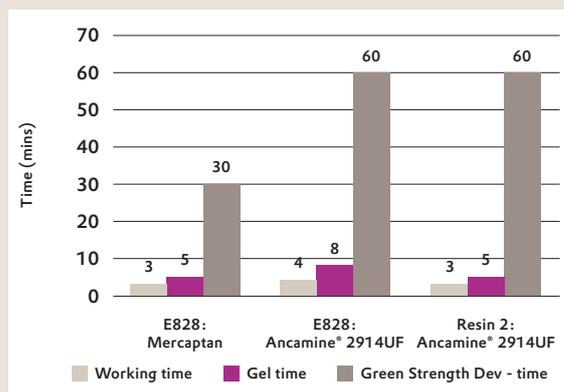


Figure A Cure properties of Ancamine® 2914UF curing agent, Gel time (20g) - Shydu

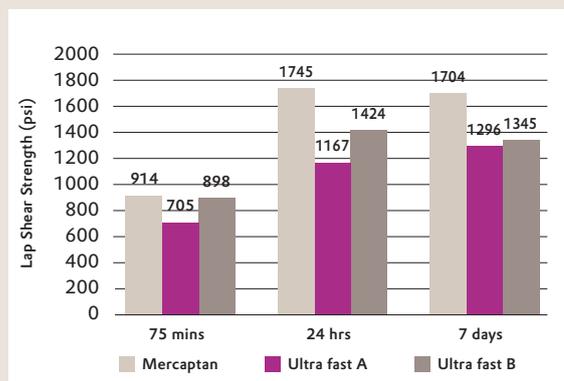


Figure B Lap shear strength development at ambient temperature

Resin	Mercaptan Formulation	Ultra Fast A	Ultra Fast B
Epon 828	100	100	
Resin-2			100
Curing agent			
Capcure 3800	95		
Ancamine® K54	5		
Ancamine® 2914UF curing agent		50	50
Resin:CA Ratio (wt.)	100:100	100:50	100:50
Gel time (25°C, 20g)	280 s	460 s	279 s
Tg after 7 days scan (25°C)	27.8	65	58
	Wt %	Resin-2	
	Epon 828	100.00	88.00
	TMPTA	-	7.00
	Lauryl acrylate	-	5.00
	Subtotal %	100	100
	EEW	190	180.2

Evonik's first amino-/alkylfunctionalized silane co-oligomer for methanol-free adhesives and sealants

VPS SIVO 324-1



As one of the leading manufacturer of organofunctional silanes and as pioneer in the area of silane oligomers, Evonik has developed the first organofunctional silane co-oligomer bearing both amino- and alkyl groups on the siloxane backbone, which is poor in VOC and which releases no methanol upon hydrolysis.

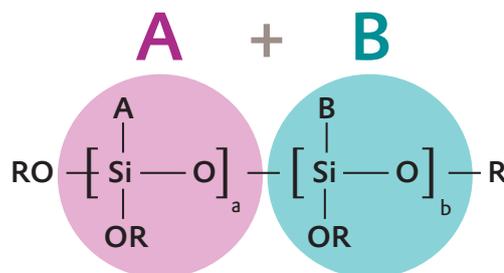
With the new member of our oligomer family, the major (and future) trend towards environmentally friendly adhesives and sealants in automotive, construction, industrial assembly and DIY can be successfully accompanied. This accomplishment comes along without any labelling !

The experimental product VPS SIVO 324-1 has been developed specifically for moisture curable SMP products (SMP = silane modified polymers, STPE/STPU) and RTV silicones while it can also be formulated in 2K polyurethane or 2K epoxy technologies.

As a silane oligomer, VPS SIVO 324-1 offers the following key features and advantages to formulators:

- Pure, ready-to-use product (no solvent)
- Chemical multifunctionality in one product
- One diffusion rate and one reactivity
- Better compatibility to polymers and resins
- Polymer by OECD definition, and consequently NO INDIVIDUAL REGISTRATION necessary

Several functional groups = One product



A, B = organofunctional groups, OR = alkoxy (e.g. MeO, EtO ...)

VPS SIVO 324-1: Characteristics

Appearance	Colorless, transparent liquid
Flash point [°C]	> 90°C
Viscosity [mPas]	Approx. 500
MeOH release [g/100 g silane]	0
VOC [g alcohol/100 g silane]	Approx. 30 (EtOH)
Classification EU 1272/2008	None

The technical benefits of VPS SIVO 324-1 have been displayed in diverse lab studies.

Study

1

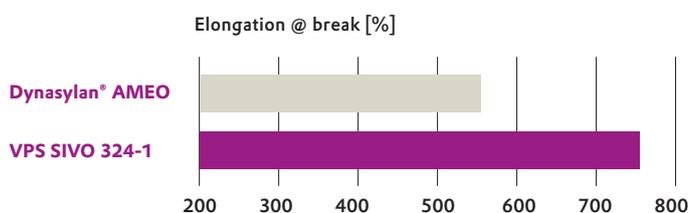
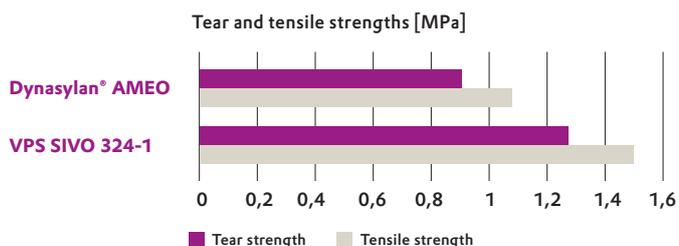
Comparison study of Dynasylan® AMEO vs. VPS SIVO 324-1, in a RTV-1 alkoxy silicone sealant formulation

Components of formulation:

- Alkoxy-terminated silicone polymer
- Silicone oil
- CaCO₃
- Silane adhesion promoter (2 wt.-%)
- Catalyst

Results:

Apart from a positive impact on both sealant strength and elongation, VPS SIVO 324-1 gave better adhesion on aluminum, glass and polycarbonate while PVC and PMMA still stayed critical.

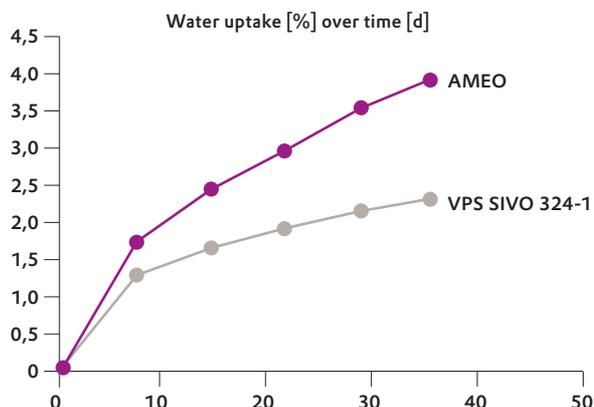


	Viscosity @ 0.1s ⁻¹	SFT [min]	TFT [d]	Cure through [d]	Modulus 100	Alu [N/mm ²]	PC [N/mm ²]
Dynasylan® AMEO	3500	40	1	9	0.32	1.61 K	1.64 K
VPS SIVO 324-1	4600	90	2	5	0.33	1.98 K	1.94 K

Study

2

Comparison study of Dynasylan® AMEO vs. VPS SIVO 324-1, in a STPU sealant formulation (base: Polymer ST 77)



Another big plus of VPS SIVO 324-1 is its intrinsically hydrophobicity which makes it a strongly preferred additive when it comes to reduced water uptake, and thus leads to a (much) higher water resistance of adhesives and sealants. This is illustrated in the graph: the standard polar aminosilane Dynasylan® AMEO led to much higher values (nearly doubled) compared to the more hydrophobic VPS SIVO 324-1.

Study 3

Comparison study of two silane oligomers, Dynasylan® 1146 and VPS SIVO 324-1, in a MS-Polymer adhesive

Formulation:

Parts [wt. %]	Raw material
25.0 – 40.0	MS-Polymer
15.0 – 20.0	Plasticizer
0.5 – 1.0	Dynasylan® VTMO
45.0 – 55.0	CaCO ₃ , coated with stearic acid
≤ 6.0	AEROSIL® R 208
≤ 0.3	Stabilizers
0.5	Dynasylan® VTMO (no vacuum)
1.5	Adhesion promoter (e.g. Dynasylan® 1146)
0.4	Catalyst

All deep purple colored additives are available from Evonik.

In the a.m. formulation VPS SIVO 324-1 led to following improvements compared to Dynasylan® 1146, which is also linked to its unique structure and moderate N-content:

- **Strongly increased elongation at break**
- **Higher tensile strength values**
- **Improved adhesion profile on certain substrates**
- **Faster cure through**

Results:

	Dynasylan® 1146	VPS SIVO 324-1
SFT [min]	10	20
Cure through [d]	10	8
Elongation [%]	310	490
Tensile strength [N/mm ²]	1.35	1.50
Alu [N/mm ²]	2.13	2.30
PC [N/mm ²]	1.90	1.71

Especially expansion sealing joints in the construction industry, floor and connection joints require very broad adhesion spectrum as well as high elongation and resilience, which can be adjusted using the unique synergy of specific Dynasylan® organofunctional silanes and AEROSIL® fumed silica in SMP formulations.

As is known, special hydrophobic AEROSIL® products are of essential importance with regard to reinforcement, rheology and even transparency - both in chalk filled and transparent systems. That's why high-thickening AEROSIL® R 208 (a highly hydrophobized fumed silica) is preferred to be used, e.g. in non-transparent, high-strength applications such as flooring/parquet adhesives (see formulation).

SUMMARY:

VPS SIVO 324-1, Evonik's first amino-/alkylfunctionalized silane co-oligomer, is a novel label-free adhesion promoter to formulate methanol-free adhesives and sealants. Next to excellent flexibilities (improved mechanical properties), VPS SIVO 324-1 imparts outstanding hydrophobicities (low water uptake) in moisture curable technologies.

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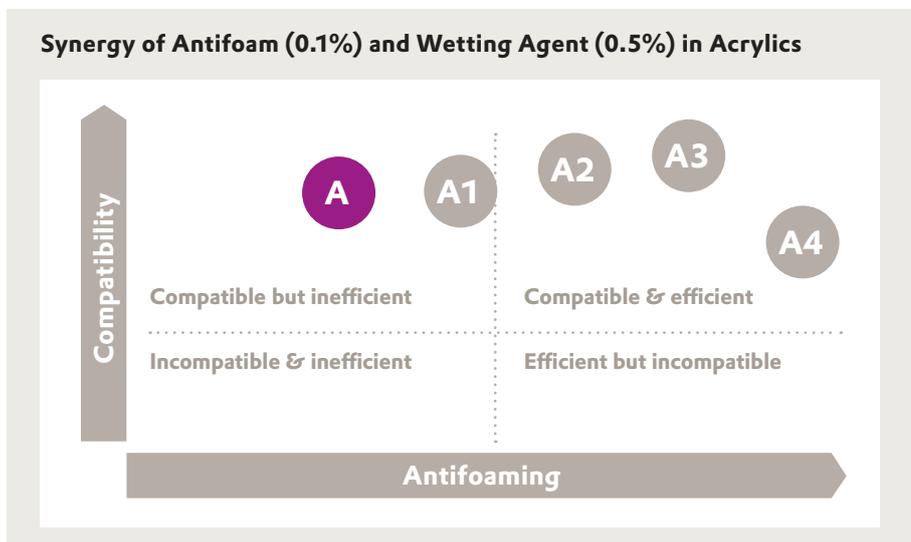
Welcome to the family: SURFYNOL® AS joins together with TEGOPREN® and TEGO® Antifoam to build even stronger team

SURFYNOL® AS

CUSTOMERS CAN NOW BENEFIT FROM SYNERGIES ALL FROM ONE HAND.

The recently incorporated SURFYNOL® AS products add to the already strong portfolio of Evonik Nutrition & Care and offers customers a greater variety of solutions to improve the performance in water based adhesives. Additionally, Evonik expanded its portfolio of defoamers and wetting agents with food contact compliance to support manufacturers of polymer dispersions and adhesive formulations who have special requirements with such legislations. It should be emphasized that the mentioned product groups can reinforce each other in the effect. The attached figure shows that the use of SURFYNOL® AS and TEGOPREN® wetting agents, not only improves the expected wetting pattern but also enhances the

effect of the TEGO® Antifoam products which can lead to potential cost savings. In a wider range of acrylate-based adhesives SURFYNOL® AS 5120, SURFYNOL® AS 5140, SURFYNOL® AS 5160 and TEGOPREN® 5890 showed the best interaction. In addition to the synergistic effect that they have with the TEGO® Antifoam products, the aforementioned wetting agents can be used in indirect food contact applications. They comply with the requirements of FDA 175.105 (adhesives), EU Regulation 10/2011 (on plastic materials and articles intended to come into contact with food) and the XIV Recommendation of the BfR (Polymer Dispersions).



A: TEGO® Antifoam KE 600 EC

A1: A + SURFYNOL® AS 5160

A2: A + SURFYNOL® AS 5140

A3: A + SURFYNOL® AS 5120

A4: A + TEGOPREN® 5890

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Enhanced heat seal binders for versatile applications

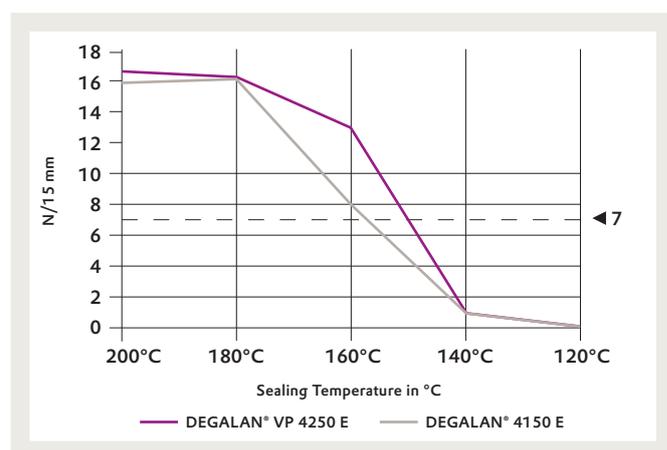
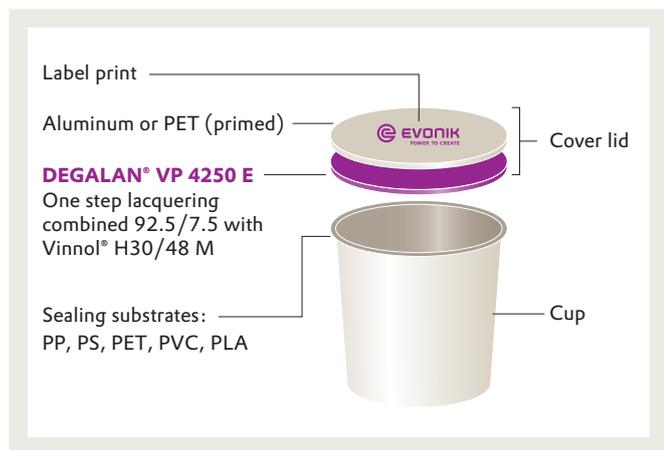
DEGALAN® 42 series

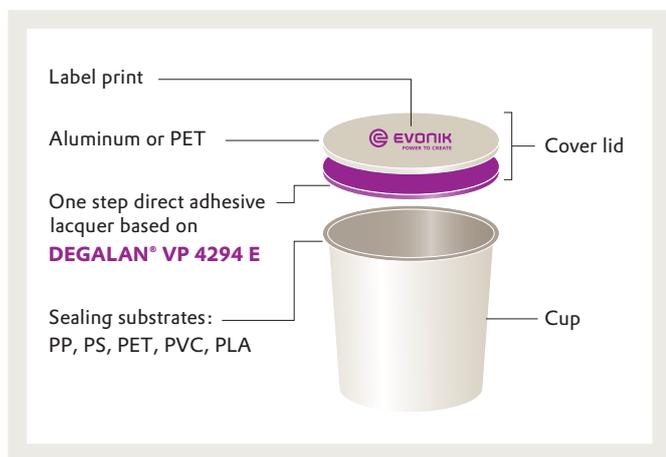
During the last European Coatings Show in 2017, the Product Group Specialty Acrylics of Evonik Resource GmbH introduced new binders for heat sealing applications which are mainly applied for food and beverage packaging. Major advantages of DEGALAN® binders are a smooth and easy opening behavior and at the same time a secured sealability. Dairy goods such as yoghurts or single served coffee creamers require such properties to avoid leakage or cracks. The DEGALAN® 42 series is characterized by improved properties such as causing less rub-off when applying the formulated lacquer or by increasing customer's output due to higher solid content of our binders. The upcoming discussions with existing and prospective customers – usually converters within the flexible packaging industry or formulators – were very promising. Almost all of them expressed their interests in testing our new products in order to further improve the properties of their heat seal lacquer. This process is finished now and the promised benefits were confirmed.

DEGALAN® VP 4250 E is one of the new products which was successfully tested and specified by several industry leaders. The high sealing strength of more than 10 N/15mm and the increased solid content of 45% - compared to 43% of its predecessor DEGALAN® 4150 E – contribute to its success.



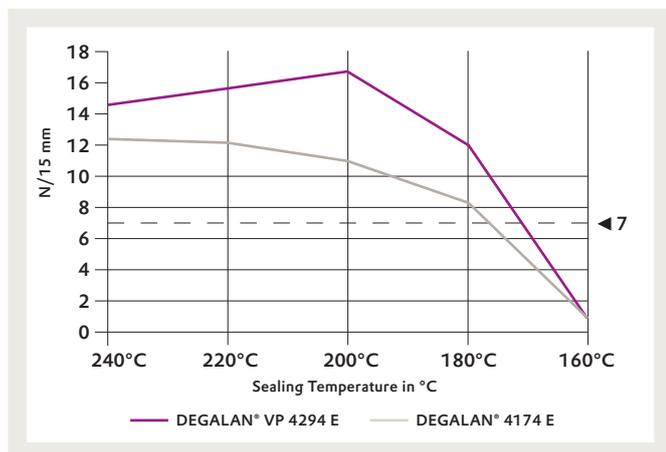
The most important factor reported by customers was a significant reduction of cleaning cycles and consequently longer production runs which resulted in more output and higher yield. This proven effect is achieved by a narrower molecular weight distribution of new olefin copolymers which significantly reduce the causing of rub-off deposits on rollers during printing or sealing. Other properties like sealability against all common substrates such as PP, PS, PVC, PET or PLA remain unchanged. A typical sealing curve of DEGALAN® VP 4250 E is shown below.





DEGALAN® VP 4294 E is another newly developed product which is already utilized by many customers. It has direct adhesion to aluminum or PET as major lidding materials and is sealable to common substrates like PP, PS, PVC, PLA or PET. Applied in single step coating process, DEGALAN® VP 4294 E does not require any adhesion promotor and therefore contributes to a faster production run.

Customers also appreciate the enhanced sealing strength of DEGALAN® VP 4294 E. At 180 °C temperature, a sealing strength of more than 12N/15mm can be achieved. Below graph shows a comparison of sealing strength values with the equivalent product DEGALAN® 4174 E. Besides technical properties, DEGALAN® VP 4294 E is also business wise rather attractive. A solid content of 52% is by far the highest within the DEGALAN® portfolio and is directly linked to an increased quantity of final lacquer.



DEGALAN® VP 4322 E was also launched successfully and is well established in the flexible packaging market. The product was developed as a binder for transparent packaging applications. It has direct adhesion to PET without the additional process step of using a primer. Therefore DEGALAN® VP 4322 E is suitable for mono PET packaging like PET film sealed against PET trays. This mono packaging is fully recyclable and contributes to less waste and a cleaner environment and which represents a true and cost-effective alternative to existing PET-PE composites which are currently used. A low haze value of less than 6 (delta haze, comparing pure PET film against coated PET film with heat seal lacquer) ensures an unbiased view on the packaged products.



PET-film, 36µm, 5.0 gsm coated with heat seal lacquer based of **DEGALAN® VP 4322 E**



PET-film, 36µm, 5.0 gsm coated with standard heat seal lacquer

DEGALAN® VP 4322 E is a versatile binder for heat seal applications. Besides transparent packaging, it is also applicable for sealing Paper/PET laminates against substrates made of PS, PET, PVC, PVdC, PLA and PBT. All DEGALAN® heat seal binders fulfill the International requirements for direct food contact applications.

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Where quality matters the most.

Shell GTL Sarawax SX 80

for hygiene applications

Shell GTL Sarawax SX 80 is a low melting Fischer-Tropsch paraffin wax with a relatively low molecular weight and an extremely narrow molecular weight distribution. Additionally, it provides a low drop point along with a reduced melt viscosity, resulting in a strongly pronounced crystallinity which allows for precise control of industrial processes. Further technical details can be found in the **Figure 1**.

Figure 1

Property	Method	Typical Values	Specification	Remarks
Congealing point	ASTM D 938	84°C	81 - 86 °C	
Penetration number	ASTM D 1321	4 mm * 10 ⁻¹	3 - 6 mm * 10 ⁻¹	
Viscosity	Cone & Plate (30,5 s ⁻¹)	12 mPa s 6 mPa s	<10 mPas	at 100°C at 120°C
Molecular weight distribution	HT-GPC	550g/mol 600g/mol 1.09		M _n M _w Polydispersibility
Melting enthalpy	DSC	237 J/g		

In formulations Shell GTL Sarawax SX 80 out performs alternative low melting waxes significantly in setting time while having a higher shear adhesion failure temperature. Compared to standard Fischer-Tropsch waxes, Shell GTL Sarawax SX 80 provides a lower viscosity leading to a much better wetting of substrates.

The low melting point and the low viscosity make Shell GTL Sarawax SX 80 an excellent additive for hygiene formulations. The new generation of hot melt adhesives for the hygiene industry especially for the construction part of diapers are amongst others low in odor, have a white color and no surface tackiness. Therefore high quality raw materials are needed to achieve those properties. Formulations with polyolefins such as Evonik's amorphous poly-alpha-olefin VESTOPLAST® provide exactly the needed quality and performance. Combined with Shell GTL Sarawax SX 80, an excellent package for hot melt adhesives is formed which provides a solid basis for hot melt formulations for hygiene applications.


 Quality & Performance

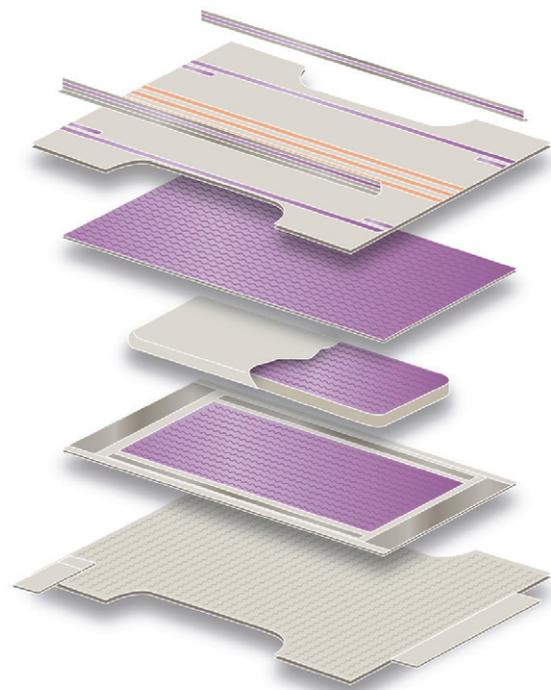
Common rubber based hygiene formulations (e.g. SBS) often contain oil in order to decrease the viscosity. However it also affects physical properties, especially the adhesion and the quality of the final adhesive. By adding Shell GTL Sarawax SX 80 instead, the viscosity can be reduced as well. The low melting temperature of the wax improves the flow behavior of the adhesive inside the production machine as well as during application through the nozzle. Once the adhesive is on the substrate, the crystalline parts built up very fast for a short setting time and a good bonding strength supporting production efficiency and speed. An exemplary formulation with and without the addition of Shell GTL Sarawax SX 80 is shown in **Figure 2**.

The product also supports the trend towards low application temperature. By combining it with a low softening point VESTOPLAST® grade, application temperatures down to 130°C are possible even with spray application.

Figure 2

Exemplary formulation		A	B
VESTOPLAST® EP V2094	%	70	65
Escorez 5300	%	30	-
Escorez 5380	%	-	30
Sarawax SX 80	%	-	5
Irganox 1010	%	0,2	0,2
Melt viscosity @190°C	[mPa*s]	1,800	800
Needle penetration	[0,1mm]	24	24
Softening point (R&B)	[°C]	82	81

Different layers of a diaper:
The deep purple areas show possible applications for hot melt adhesives

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It's all about the bubbles! Better foaming with **VESTOPLAST®**

Foaming technologies have been known by the market for years. Foamed hot melt formulations however have gained more and more interest just recently as the industry strives towards more resource and cost efficient solutions while maintaining or even improving the performance. By increasing the volume of the hot melt adhesive and thus reducing the material usage, foaming has become an attractive alternative in various applications.

The experts for amorphous-poly-alpha-olefins (APO) have picked up this trend and started an extensive research on the foaming process as such as well as the foaming behavior of different polymers in order to provide customers with the best solution for their individual request.

A detailed evaluation regarding performance, application and machine parameters was conducted to get a better understanding of the conditions for foaming applications. The team also looked into old and new applications to gather more detailed insights and develop new markets and possibilities for foamed hot melts.



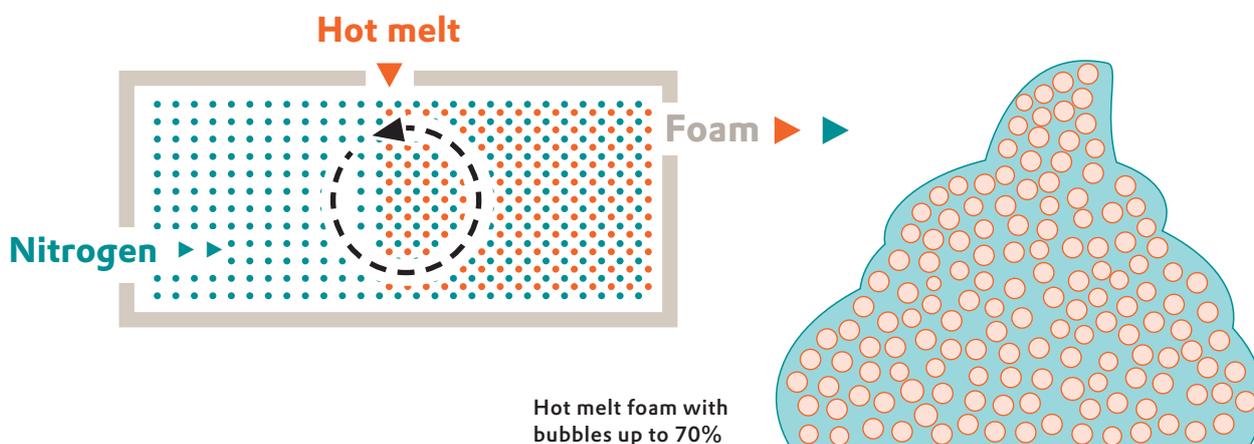
FOAMING PROCESS

For the foaming process a standard hot melt unit can be utilized, which is roughly sketched in **Figure 1**. It consists of a tank where the hot melt is melted. The temperature of the tank can be adjusted according to the viscosity of the adhesive and the characteristics of the substrate, on which the foam line will be applied. Common temperatures are in the range of 150°C to 170°C.

The molten adhesive is fed through a heated hose to the pumping unit which forces inert gas into solution with the adhesive under pressure. A high pumping speed results in high pressures within the unit, therefore experienced and trained handling of the machine is necessary. Within the pumping unit the molten adhesive is in constant circulation, the inert gas, usually nitrogen can be added step by step over a needle valve. The ability of the hot melt to take up a certain amount of nitrogen defines its so called foamability, depending on the used material this can be up to 70%. During application the hot melt is released out of a heated dispense head and exposed to atmospheric pressure leading the dissolved gas to come out of solution and to create a hot melt filled with small gas bubbles.

The foaming process at a glance: Nitrogen is being forced into solution with the molten hot melt under pressure. Once the hot melt is released out of the dispense head, a hot melt foam fill led with evenly distributed small gas bubbles is created.

Figure 1: High pressure foaming process



PROPERTIES OF THE ADHESIVE

In order to achieve excellent foaming results specific product properties are required. The Evonik VESTOPLAST® portfolio provides exactly those needed properties, which are necessary for a perfectly foamed adhesive. First of all the relation between flexibility and cohesion has to be balanced. A good flexibility of the adhesive allows the nitrogen bubbles to expand once it is released out of the dispense head while the cohesion keeps them inside the adhesive to create an excellent foam. Only a perfect balance between those two properties allows the combination of nitrogen and adhesive to form a foam.

Figure 2

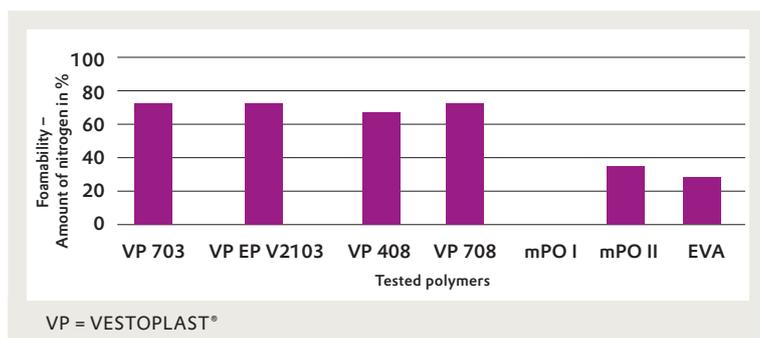
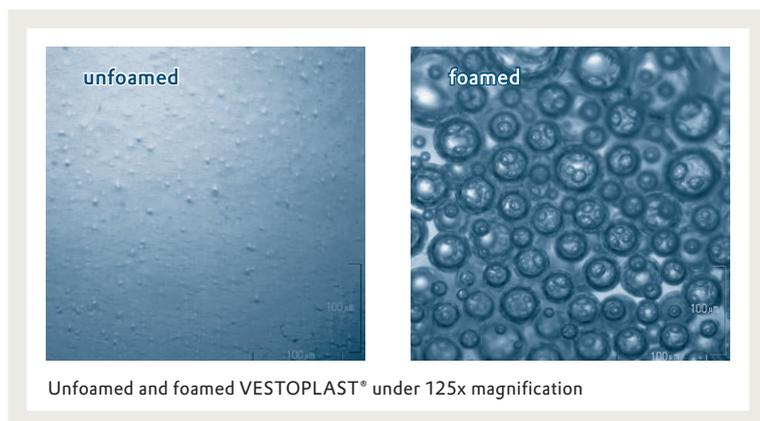


Figure 3, Foamability of different polymers

This balance comes from the crystalline and amorphous parts of Evonik's VESTOPLAST®, an amorphous poly-alpha-olefin used as a raw material for hot melt adhesives. It is based on ethene, propene and 1-butene and provides a unique molecular weight distribution with crystalline and amorphous parts.

The amorphous parts are important for the flexibility and adhesion to different sub-

strates. The crystalline parts are responsible for the inner strength as well as the good cohesion, which keeps the nitrogen bubbles inside the hot melt when it comes to the cool down of the foamed material to room temperature.

This effect can be seen in the evenly dispersed nitrogen bubble under the microscope as shown in **Figure 2**. The first picture shows pure VESTOPLAST® without any nitrogen, the second one contains 65% nitrogen. As the picture shows the bubbles are evenly distributed in the pure polymer.

Further detailed analysis were done with different polymers. The foaming behavior of each material was evaluated step by step with a design of experiment. Every material has its own foaming behavior, some start to take up the nitrogen already at a very early stage, others need more nitrogen and pressure inflow until the mixing starts. Therefore a deep understanding of the polymer as well as the machine is very important.

The extensive tests have shown that not only the physical properties of the polymer influences the foaming behavior but also the polymer structure as such. Most of the tested polymers are foamable but the maximum ratio varies. It is a huge difference if a hot melt is able to take in 40% or 70% of nitrogen. The results are shown in **Figure 3**. The team has tested two butene-rich and two propene-rich VESTOPLAST® grades with different viscosities, softening points and crystallinities. As the results show all four grades can be foamed with up to ~70% of nitrogen resulting in a reduction of the actual polymer down to ~30%. The three alternative polymers show significant less intake of nitrogen, with a maximum of ~35%, which only results in a reduction of the polymer down to ~65%. All polymers were tested purely with the same foaming unit.

VESTOPLAST® FOR FOAMING

As VESTOPLAST® has shown excellent foamability results two grades were chosen from the portfolio for more detailed analysis. Depending on the properties which are required for the application, generally all VESTOPLAST® grades could be considered. However the viscosity can be a limitation, as high viscous grades are more difficult to feed through the hose as well as the dispenser. VESTOPLAST® 703 is a low viscous propene-rich grade with high flexibility and a fast setting time. VESTOPLAST® 408 on the other hand is a butene-rich grade with a slightly higher viscosity and more crystalline parts, thus providing great cohesion properties. Technical details of both grades can be found in **Figure 4**.

Figure 4 VP = VESTOPLAST®

Properties	Unit	VP 703	VP 408
		Propene-rich	Butene-rich
Softening point	[°C]	124 (+/- 6)	118 (+/- 4)
Needle penetration	[0,1mm]	12 (+/- 3)	5 (+/- 2)
Melt viscosity @ 190 °C	[mPa*s]	2,700 (+/- 700)	8,000 (+/- 2,000)
S.A.F.T. acc. to WPS 68	[°C]	75-80	85-90
Open time	[s]	15	65
Tensile strength	[MPa]	2,1	6,8
Elongation@break	[%]	43	80
Tg (acc. to DSC method)	[°C]	-28	-27

Both grades were tested at application temperatures of 130°C and 150°C with outstanding results. Currently the application temperature is still in the range of 150°C to 170°C. However a reduction down to 130°C can save melting time and energy. Additionally, a low application temperature protects the product while reducing the thermal load and reduces the need for maintenance of the machine. Further it is suitable for application on temperature sensitive substrates. **Figure 5** shows the foaming behavior of VESTOPLAST® 703 and 408 at 130°C and 150°C. Generally it can be observed that VESTOPLAST® 408 needs more nitrogen inflow until it starts to take in the gas. However once this point is reached the polymer volume is immediately decreasing to a very low level of ~30% at temperatures of 150°C, which means in reverse that the polymer has taken in ~70%

of the nitrogen. With VESTOPLAST® 703 this process already starts at an earlier stage at a slightly higher level with ~40% of nitrogen and ~60% of polymer at 150°C, but a gradual decrease takes place until the polymer has reached its final point at ~30% polymer and ~70% nitrogen.

At temperatures of 130°C, the starting point is postponed and both grades start the intake process at a later stage. The lagging effect between the both grades as well as between the different temperatures can be explained by the viscosities. As **Figure 6** shows, a huge difference exists between the viscosities of the two grades and between the two different application temperatures. A low viscosity amongst others can support the intake of gas as well as an easy application out of the dispense head. With higher viscosities the pressure increases and more inflow of nitrogen to start the intake process is needed. Depending on the application and the individual needs of the applicator, different combinations of polymer and nitrogen content can be achieved with VESTOPLAST®, thus making it a suitable polymer for a wide range of applications.

Figure 5 VP = VESTOPLAST®

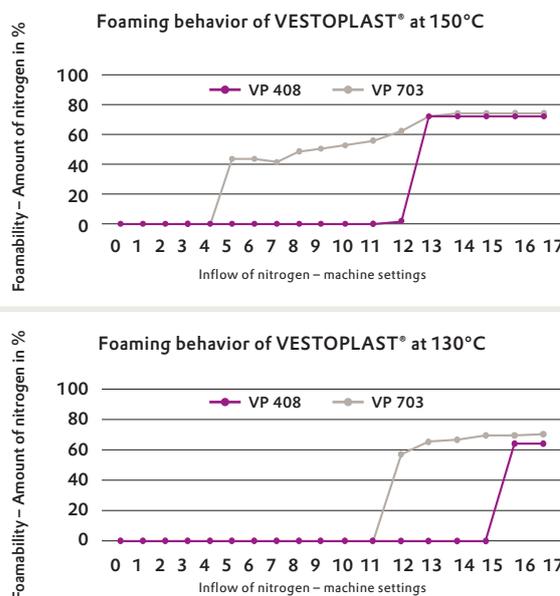


Figure 6

Viscosity	@150°C	@130°C
VESTOPLAST® 703	7800 mPa*s	14600 mPa*s
VESTOPLAST® 408	22400 mPa*s	41500 mPa*s

APPLICATION EXAMPLES FOR FOAMED ADHESIVES

Some well-known applications for foamed adhesives can be found in the filter market. Air filters used in passenger cars or big filter sheets for ventilation systems or air conditioning systems are using foamed hot melts for e.g. pleat stabilization. The folded filter pleats are fixated with a line of hot melt to keep the pleats together for the next production step or to build up the different filter layers. By using foamed hot melts instead of common hot melts, filter producers can save a significant amount of material and lower the heat density, as the foamed hot melt contains less mass of the adhesive compared to an unfoamed one, the heat will dissipate faster and prevent the thermal distortion of the substrate. Further the foamed VESTOPLAST® line has a white and clean color and no odor.



Another application can be gap filling for white goods. The gaps between the metal sheets of a refrigerator or a washing machine can be filled with the foamed material. The ability to add up to 70% nitrogen saves cost but fulfill the demand of a good adhesion to coated metal plates and a white appearance. It also provides a good heat and cold resistance and water and moisture resistance. The above mentioned applications are only two possibilities for foamed adhesives. More industries and applications can be suitable. Especially applications where the following properties are required:

- High bond strength
- Prolonged open time compared to the unfoamed product
- Faster set times
- Low application temperature for temperature sensitive materials
- Bond to porous or irregular surfaces
- Reduced adhesive consumption
- White color



BENEFITS OF FOAMED ADHESIVES

Using a foamed hot melt instead of a regular hot melt can provide several advantages for the applicator. One of the main benefits are cost savings, which can be achieved on the one hand by the usage of less adhesive while keeping the same or even better performance and on the other hand by reducing energy consumption when using low application temperatures as shown with VESTOPLAST®.

In addition, a low application temperature can also broaden the application window as it enables a greater variety of substrates such as heat sensitive or very thin substrates. As the foamed adhesive also contains less mass of adhesive, quicker cooling takes place as the heat dissipates faster supporting the use of more demanding substrates.

On the technical side, foaming an adhesive can provide several benefits as well. The set time is reduced significantly with foamed adhesives, enabling for an improved production rate. The open time is prolonged at the same time, as the nitrogen bubbles insulate the material and increase the time the applicator can still adjust the to be bonded substrates (e.g. as in mattress bonding) and thus offers a greater flexibility. Further an increased surface penetration can be achieved. Once the adhesive is dispensed and the nitrogen starts to form the bubbles, the material expands, providing more volume and therefore can fill up even small gaps on an uneven or porous substrate.

Overall foamed adhesives provide an attractive alternative to the common hot melt in various applications allowing for greater flexibility and efficiency during the process and the used materials. VESTOPLAST® built up a great basis for your final foaming formulation.

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