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Raw Materials for Flexible Packaging: Fulfilling Your Specific Needs

Bayhydur® Desmodur® Desmophen® Dispercoll®





Contents

04 - 05	Our Mission: INVENTING FOR YOU
06 - 07	Where the market for flexible packaging is heading
08 - 09	Building blocks for sustainable packaging and process efficiency
10 - 11	Our technology – the right answer to your needs
12 - 15	An overview – polyurethane adhesives by technology
16 - 17	Our mission – safe raw materials for safe packaging laminates
18 - 25	A broad portfolio to suit your needs
26 - 27	Fast-lane access to polyurethane innovations



INVENTING VISIONS FOR YOU

As your leading partner for polyurethane chemistry, we know you are competing in increasingly challenging environments: Your customers are becoming more and more demanding in their expectations for quality, durability, sustainability and aesthetics of products. And they have more choices. For you this means that cost pressure is rising – while innovation cycles are becoming faster and faster.

Helping you to turn this challenge into your competitive advantage is the goal that drives our daily work. We call it: INVENTING FOR YOU. But what exactly are the basic values underlying this promise? What principles enable us to improve your productivity, drive sustainability, ensure reliability and co-create future-proof businesses? First and foremost, we are curious. Because only if we listen closely to you and ask the right questions, we can respond to your individual needs with new, creative and unexpected solutions that make a real difference to you. That's why inventing for us always starts with thinking about your unmet business challenges. It requires an in-depth understanding of your needs along the whole value chain. To make sure: What we invent stands the test of time. Living up to this aspiration requires more than competencies – it calls for a corporate culture of being courageous. A culture that is defined and lived by dedicated people who cooperate to push the boundaries of invention founded on knowledge and experience. Our courage permeates our entire business – from partnerships to business models. This is also reflected in our colorful business philosophy. We appreciate partnerships that go beyond traditional black-and-white ways of acting and thinking. An attitude of openness that invites you to co-create new things – rather enabling you than just providing. We are optimistic and resourceful in finding solutions that inspire our customers and partners.

This set of fundamental values adds up to an unrivaled performance orientation to constantly strive for the better, be it through big or small changes. A true sense of business regardless of function. And a deep commitment to delivering our promise everyday. Anywhere. Again and again.

INVENTING FOR YOU.

Where the market for flexible packaging is heading

Social trends

Flexible packaging is growing as a result of several lifestyle and other social trends. One of them is the trend towards more convenience. People like to buy products that are easy-to-open and reclosable for use on the go. This situation-based convenience trend underlines the growing importance of functional integration and new solutions such as reclosing, lightweight, and easy-opening packaging.

Other lifestyle changes impacting on the industry include the increasing number of single households in developed countries, which is boosting the demand for more and smaller packaging sizes; the fast-growing market for pre-cooked meals in several regions of the world; and the need for flexible packaging to prolong shelf life and thus tackle the serious issue of food waste.

Demand for greater sustainability

The growth in flexible packaging is partly due to the fact that it is lighter than other packaging solutions like glass or metal, which makes it the more sustainable choice. This saves energy during transportation, which also makes it more cost-efficient. At the same time, the flexible packaging industry is constantly looking for solutions to make its packaging even more sustainable, i.e. through bio-based raw materials, even thinner materials, or recyclable solutions.

Stricter food safety regulations

Packaged food regulations are becoming stricter, with new regulations frequently issued. As a result, every member of the value chain from the raw material provider to the brand owner has to be extremely careful about ensuring the safety of their products. The question of which raw materials are used for which individual packed product has to be considered throughout the value chain. And that is why the industry is looking for economical products that simultaneously deliver a high degree of safety and avoid risk.

Maximizing efficiency

In a competitive environment it is crucial for converters to operate at the highest possible level of efficiency. That means high lamination speeds as well as the shortest possible production-to-customer times. Since ever-faster changes in packaging design are leading to smaller order sizes, converters need to adapt their production to this changing environment with a high degree of flexibility, while at the same time maintaining a high level of efficiency.

Covestro is working on new product developments that will enable the flexible packaging industry to respond to these trends.



Building blocks for sustainable packaging and process efficiency

Solutions to enhance process efficiency

Nowadays, the quality demands made on industry processes are very high. But at the same time, there is a clear need to cut costs. Both goals can be achieved by increasing process efficiency. The sheer complexity of the processes involved in manufacturing flexible packaging offers us various opportunities to enhance process efficiency. Significant process-optimizing and cost-cutting gains are possible, for example through faster curing and shorter process times. At Covestro we have a wide range of solutions designed to enhance your process efficiency. Why not take advantage of our know-how? These solutions will be beneficial for your bottom line.

High performance – enabled by nature

Sustainability drives innovation at Covestro. We are committed to optimizing our manufacturing processes, reducing the impact of logistics, and enabling sustainability along the value chains. Renewable feedstocks offer opportunities for developing more sustainable building blocks for flexible packaging – with significant potential for reducing the carbon footprint of end products while also reducing our overall dependence on fossil-based resources. But to make more sustainable solutions not just possible but also economically feasible, the performance of polyurethane adhesives, as the main

technology for flexible packaging, needs to satisfy high industry standards. To this end, we are evaluating the use of renewable raw materials and will enlarge our product portfolio with new bio-based and mid- to long-term cost-competitive products, provided the raw materials become commercially available. In all these efforts we are committed to focusing on products that perform at least as well as established products but are at the same time more sustainable.

Outstanding reliability, quality and supply security – worldwide

Covestro, the world's leading manufacturer of aliphatic and aromatic isocyanates, offers an extensive range of raw materials and services for manufacturers of flexible packaging. This allows the very latest technology to be used extremely effectively for a variety of applications. Thanks to its unique setup and worldwide network of state-of-the-art production sites, R&D facilities and customer technical centers, industry-leading supply chain setup, global orientation and local stocks, large and diversified product portfolio, highest health, safety and environmental (HSE) standards, as well as tailored supply chain flexibility with short lead times, Covestro offers the flexible packaging industry unrivaled supply security and assured quality.



Our technology – the right answer to your needs

Polyurethane adhesives – the main technology for flexible packaging

Polyurethane (PU) adhesive polymers can be produced from a wide range of raw materials. The enormous adaptability of PU polymers allows adhesive manufacturers to provide tailor-made adhesive polymers for flexible packaging applications. PU adhesives are therefore the number one choice for producing film/film or film/foil laminates. PU adhesives are in use for all classes of laminates from general-purpose laminates for dry food up to high-performance laminates for steam sterilization processes at temperatures of up to 134 °C and/or aggressive products. At Covestro we offer a broad range of raw materials for PU adhesives used for flexible packaging applications. Our product range comprises

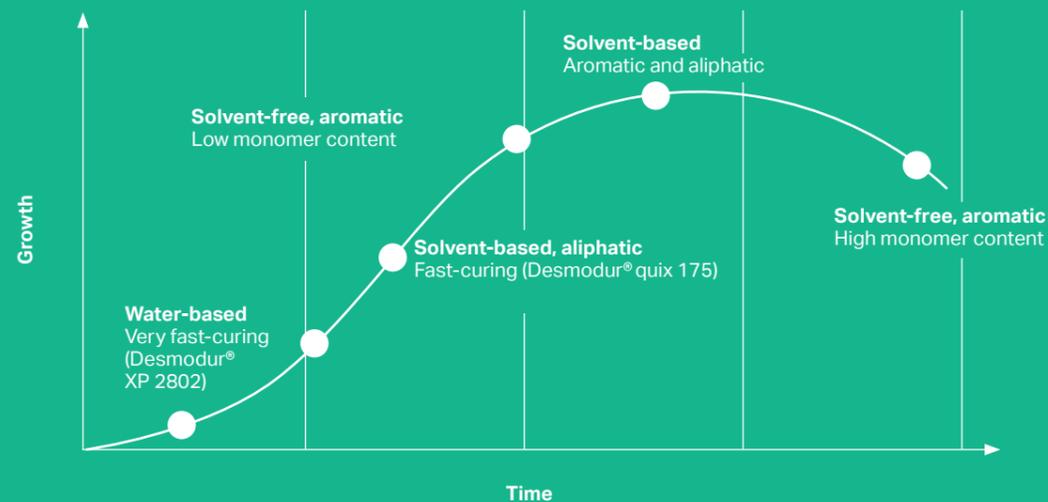
aromatic and aliphatic diisocyanates, pre-polymers, aliphatic and aromatic crosslinkers for solvent-based adhesives, as well as difunctional or polyfunctional polyether and polyester polyols. The raw materials we provide are manufactured in compliance with good manufacturing practice and fulfill the requirements of Regulation (EC) 1935/2004.

The requirements for adhesives differ from market segment to market segment. Laminated film/film or film/foil composites are generally divided into three quality clusters: general-purpose, medium-performance, and high-performance laminates. The filling, the filling process, and the final use of the product determine the type of raw material to be used.

PU adhesives are in use for steam sterilization processes at temperatures of up to

134 °C

Technology lifecycle in flexible packaging Polyurethane adhesives



General-purpose laminates

comprise film/film- or film/paper composites and are typically used to pack dry food in room-temperature storage conditions.



Medium-performance laminates

are used in fatty or acid food packaging, temperature treatment up to pasteurization temperatures, and foil laminates.



High-performance laminates

are used for boil-in bag applications, hot fillings, sterilization processes up to 134 °C, pharmaceuticals, etc.

The more demanding the application, the higher the degree of resistance required against chemical degradation and heat in the adhesive polymer, and the more food safety aspects that have to be taken into account. The resistance of a polyurethane adhesive polymer can be significantly influenced by means of the polyurethane polymer building blocks, i.e. polyether or polyester polyol, the crosslinking density, and the molecular weight of the adhesive polymer. Our raw materials for polyurethane adhesives can be used to produce single- and two-component solvent-based, solvent-free and water-based adhesives.

Safe adhesives for safe food

Laminated films and foils for flexible packaging need to meet demanding and very specific requirements. This is particularly true when they are being used for food or in medical applications. A polymer used in food packaging applications – in either direct or indirect food contact – has to comply with various regulations depending on the region the flexible packaging laminate is used in, for example:

- Commission Regulation (EU) No. 10/2011
- BfR Recommendation XXVIII (Cross-linked polyurethanes as adhesive layers for food packaging materials)
- FDA Regulations in 21 CFR 175.105 (Adhesives) and 21 CFR 177.1390 (Laminate structures for use at temperatures of 250 °F and above)
- Chinese Hygienic Standard GB 9685-2008

Upon request, we can provide you with a food contact use statement for suitable adhesive raw materials. Nevertheless, every adhesive manufacturer needs to make their own assessment of compliance for each particular adhesive formulation and provide a declaration of compliance to downstream users, i.e. converters and food manufacturers.

An overview – polyurethane adhesives by technology

Solvent-based polyurethane

Solvent-based polyurethane adhesives can be used as single-component NCO-terminated pre-polymers or as a combination of an OH-terminated polyurethane pre-polymer processed in combination with an isocyanate crosslinker (two-component solution). Since NCO-terminated pre-polymers require moisture to cure, they can only be used for laminates containing at least one moisture permeable substrate (e.g. paper). NCO-terminated pre-polymers are based on polyester and/or polyether polyols, which are chain-extended by monomeric diisocyanates. Typically we supply Desmodur® 44M for this. The chain extension can be adjusted to the specific requirements with regard to the solid content, viscosity and adhesion properties of the adhesive polymer.

Two-component solvent-based adhesives typically consist of an OH component and a solvent-based crosslinker. The OH component itself usually is a pre-polymer based on polyester and/or polyether polyols that are chain-extended with monomeric diisocyanates. The chain extension can be adjusted to the requirements with regard to the solid content, viscosity and adhesion properties of the adhesive polymer. Suitable solvent-based crosslinkers include Desmodur® L 75, Desmodur® UL-75 XP and Desmodur® quix 175. The dosage of crosslinker depends on the OH content of the OH component. Typically the mol ratio of mol NCO : mol OH is in the range of 1.2–1.4.

Solvent-free polyurethane

Solvent-free polyurethane adhesives can be used as one-component NCO-terminated pre-polymers or as two-component adhesives consisting of an OH component and an isocyanate component. Since one-component adhesives

are NCO-terminated pre-polymers that need moisture to cure, the NCO pre-polymers can only be used for laminates containing at least one moisture permeable substrate (e.g. paper). NCO-terminated pre-polymers are usually based on polyester and/or polyether polyols that are chain-extended by monomeric diisocyanates (typically Desmodur® 44M). The chain extension can be adjusted to suit the requirements with regard to viscosity and adhesion properties of the adhesive polymer.

Two-component solvent-free adhesives typically consist of:

- An OH component ranging from low molecular weight polyfunctional polyols to chain-extended polyether / polyester polyols; the chain extension reaction is carried out with difunctional monomeric isocyanates.
- Plus an isocyanate component, comprising one or more NCO-terminated pre-polymers which are based on polyether / polyester polyols and monomeric isocyanate (e.g. Desmodur® 44M); a low monomeric isocyanate content is an important aspect for product safety.

Modern two-component solvent-free polyurethane adhesives therefore work with isocyanate components featuring low or ultra-low free monomeric isocyanate content. This improves food safety as well as making the converting process more economical. In addition, NCO-terminated pre-polymers with a low or ultra-low monomeric MDI content can be processed in combination with polyfunctional aliphatic isocyanates such as Desmodur® N 3600. The co-use of Desmodur® N 3600 helps to increase the functionality and the isocyanate content, reduce the viscosity of the two-component adhesive, and improve product safety.





The polymer content of a polyurethane dispersion is typically in the range of

40–50 %

Water-based polyurethane

Water-based polyurethane adhesives contain discrete droplets of polyurethane polymer. This is why even adhesive polymers of very high molecular weight can be applied as low-viscous adhesives. The polymer content is limited by the volume of polymer droplets in the dispersion. The polymer content of a polyurethane dispersion is typically in the 40–50 % range.

For two-component solvent-based and in particular solvent-free polyurethane adhesives, in contrast, the processing viscosity depends to a high degree on the molecular weight of the adhesive polymers. The higher the molecular weight, the higher the processing viscosity or, in the case of solvent-free adhesives, the higher the required application temperature has to be. Due to the lower molecular weight of their adhesive polymers, the initial bond strength of these adhesives is limited.

Water-based adhesives overcome this barrier. Polyurethane dispersion adhesives permit the application of adhesive polymers with higher initial bond strength and thus allow a fast further processing of the laminate (slitting). Another important aspect is the fact that polyurethane adhesive dispersion polymers contain a much lower amount of low molecular weight constituents, which improves food safety even further by reducing the maximum migration from the adhesive polymer.

Polyurethane dispersion adhesives can be used individually or in conjunction with a crosslinker. Two crosslinking technologies are available:

- Hydrophilic-modified aliphatic isocyanate (e.g. Bayhydur® 3100)
- Polycarbodiimide dispersion (e.g. Desmodur® XP 2802)

The hydrophilic-modified aliphatic isocyanate is added to the polyurethane dispersion prior to use. The pot life of the two-component adhesive dispersion ranges from 3 to 6 hours depending on the type and amount of crosslinker used.

A new and innovative crosslinking technology offered by Covestro is polycarbodiimide crosslinking (Desmodur® XP 2802) for polyurethane dispersions. Desmodur® XP 2802 enables the preparation of reactive one-component polyurethane dispersions that are storage-stable for up to six months, which makes processing very easy. Crosslinking is blocked as long as the system is still in dispersion state; the reaction of the adhesive polymer starts with the film formation of the adhesive layer, but, once it has started, it proceeds at very high speed.

Our mission – safe raw materials for safe packaging laminates



Innovations for safe packaging and more efficient processes

Modern PU adhesives for flexible packaging applications ideally combine three aspects: good processability, fast curing, and safety in both use and for consumers at the end of the value chain. The high reactivity of the adhesives enables converters to further process the laminate within a short period of time, which in turns allows laminates to be produced more economically.

By using our PU raw materials adhesive manufacturers can offer their customers convincing answers to industry trends.

PU ADHESIVE	RAW MATERIAL	CHARACTERISTIC FEATURE	OPPORTUNITIES
2K solvent-based PU adhesive	Desmodur® quix 175	Highly reactive crosslinker with aliphatic bound NCO groups	Crosslinker for solvent-based adhesives for high-performance laminates; fast curing at room temperature with no risk of aromatic amine formation Desmodur® quix 175 complies with FDA § 177.1390: Laminate structures for use at temperatures of 250 °F and above
1K reactive PU dispersion	Desmodur® XP 2802	Highly reactive polycarbodiimide crosslinker dispersion	Crosslinker for water-based adhesives containing carboxyl groups in the polymer chain; fast curing after drying
2K solvent-based PU adhesive	Desmodur® UL 75 XP	Aromatic crosslinker with ultra-low monomeric diisocyanate	Crosslinker for solvent-based adhesives; low monomeric TDI content (< 0.1%) allows fast migrate-free laminates



A broad portfolio to suit your needs

Diisocyanates as building blocks for pre-polymers

Diisocyanates, and in particular the MDI-grades, are used in combination with polyether or/and polyester polyols for manufacturing NCO-terminated pre-polymers.

Desmodur® T, Desmodur® I and Desmodur® H are usually used to extend the molecular weight of polyether or polyester diols in order to adjust the processing window and adhesion properties of the adhesive polymer.

PAA migration

Please note:

When using MDI-based pre-polymers it is the converters'/packagers' responsibility to make sure that only laminates that display no monomeric MDI migration are used. The absence of MDI migration can be controlled by testing the primary aromatic amine (PAA). In conducting such tests, converters and packagers have to take into account the storage length and conditions of the packaged food for which the laminate is used (see Commission Regulation EU 10/2011).

PRODUCT	NCO CONTENT [%]		PROPERTIES/ APPLICATIONS
	TYPE	VISCOSITY [mPa · s]	
Desmodur® 44M, liquid	4,4' MDI	33.6 4 @ 40 °C	Chain extender; pre-polymers for solvent-free adhesives
Desmodur® LS 2424	MDI with high 2,4'-MDI isomer	33.6 12 @ 25 °C	Chain extender; pre-polymers for solvent-free adhesives with reduced viscosity or/and reduced monomer content
Desmodur® 2460 M	MDI with high 2,4'-MDI isomer; color-stabilized	33.6 12 @ 25 °C	Chain extender; pre-polymers for solvent-free adhesives with reduced viscosity or/and reduced monomer content
Desmodur® T 100	TDI with > 99.0 % 2,4-TDI	48 3 @ 25 °C	Chain extender
Desmodur® T 80	TDI with 80.5 % 2,4-TDI	48 3 @ 25 °C	Chain extender
Desmodur® I	IPDI	37.5 10 @ 25 °C	Chain extender
Desmodur® H	HDI	49.7 3 @ 25 °C	Chain extender

A broad portfolio to suit your needs



NCO-terminated pre-polymers and polyfunctional isocyanates for solvent-free adhesives

NCO-terminated pre-polymers are reaction products of aromatic or aliphatic isocyanates and polyols, such as polyethers or polyesters. Thanks to the wide variability of the isocyanate content and functionality, the viscosity of the pre-polymers and the mechanical properties of the finished products can be precisely adjusted. NCO-terminated pre-polymers can be used as the isocyanate components of 2K solvent-free adhesive. The pre-polymers can be used individually or in combination with other pre-polymers, e.g. to adjust the processing viscosity or crosslinking density of the adhesive polymer.

PRODUCT	TYPE	NCO CONTENT [%]		VISCOSITY @ 23 °C [mPa · s]	PROPERTIES/ APPLICATIONS
			MONOMERIC DIISOCYANATE		
Desmodur® E XP 2726	MDI pre-polymer	6.0	ca. 15 %	4,500	Pre-polymers for solvent-free adhesives
Desmodur® E 23	MDI pre-polymer	15.4	ca. 40 %	1,800	Pre-polymers for solvent-free adhesives
Desmodur® XP 2617	HDI pre-polymer	12.5	≤ 0.5 %	4,250	Pre-polymers for solvent-free adhesives
Desmodur® N 3600	HDI trimer	23.0	≤ 0.25 %	1,200	HDI isocyanurate
Desmodur® N 3300	HDI trimer	21.8	≤ 0.15 %	3,000	HDI isocyanurate



A broad portfolio to suit your needs



Isocyanate crosslinkers for solvent-based adhesives

Crosslinkers are used to crosslink solvent-based OH-terminated pre-polymers manufactured from polyether and/or polyester diols. The dosage of isocyanate crosslinker is usually in the range of isocyanate index 1.2–1.4. All isocyanate crosslinkers except Desmodur N 3300 are dissolved in ethyl acetate. As an innovative product for flexible packaging, Desmodur® quix 175 provides both aliphatic-bound isocyanate groups and high reactivity, which means a high degree of safety and efficiency for the converter.

PRODUCT	NCO CONTENT [%]		PROPERTIES/ APPLICATIONS	
	TYPE	VISCOSITY @ 23 °C [mPa · s]		
Desmodur® L 75	Adduct of TDI/TMP	13	1,600	Standard crosslinker for solvent-based adhesives
Desmodur® UL-75 XP	Adduct of TDI/TMP	13.3	1,600	Crosslinker for solvent-based adhesives with ultra-low monomeric TDI
Desmodur® quix 175	Adduct of m-XDI/TMP – aliphatic isocyanate with reactivity of aromatic with TMP	11	800	Crosslinker for solvent-based adhesives for high-performance laminates (FDA 177.1390)
Desmodur® IL/EA	TDI isocyanurate	8	700	Highly functional crosslinker for solvent-based adhesives
Desmodur® HL/EA	TDI/HDI isocyanurate	10.5	1,100	Highly functional crosslinker with partly aliphatic NCO groups for solvent-based adhesives
Desmodur® N 3300	HDI isocyanurate	21.8	3,000	Highly functional crosslinker with aliphatic NCO groups for solvent-based adhesives

Solutions for water-borne adhesives

Our water-based raw materials enable adhesive solutions that are both highly efficient and sustainable. Laminates made from water-based adhesives can be immediately processed and thus help to optimize and reduce costs in a converter's production process.

Advantages of water-based adhesives in flexible packaging:

- Immediate slitting after lamination
- Very short post-curing time needed
- Quick response to customer requests
- Easy production handling thanks to 1K processing reactive adhesives
- Crosslinkers for water-based adhesives based on purely aliphatic raw materials

Dispersions

PRODUCT	NON-VOLATILE CONTENT [%]		PROPERTIES/ APPLICATIONS	
	TYPE	VISCOSITY @ 23 °C [mPa · s]		
Dispercoll® U XP 2643	Polyether-based PU dispersion	39–41	< 1,000	Dispercoll® polymer containing carboxyl groups in the polymer chain; can be crosslinked with isocyanate and polycarbodiimide
Dispercoll® U 2824 XP	Polyester-based PU dispersion	38–41	50–400	Dispercoll® polymer containing carboxyl groups in the polymer chain; can be crosslinked with isocyanate and polycarbodiimide
Dispercoll® U 42	Polyester-based PU dispersion	48–52	150–800	Dispersion polymer can be crosslinked with isocyanate
Dispercoll® U XP 2682	Polyester-based PU dispersion	49–51	< 1,000	Dispersion polymer can be crosslinked with isocyanate

Crosslinkers

PRODUCT	VISCOSITY [mPa · s]		PROPERTIES/ APPLICATIONS
	ACTIVE INGREDIENTS		
Bayhydur® 3100	17.4 % NCO	Approx. 2,800 @ 23 °C	Isocyanate crosslinker for water-based adhesives
Desmodur® XP 2802	Approx. 1 mmol/g –N=C=N–	Approx. 30	Polycarbodiimide dispersion; crosslinker for carboxyl group containing water-based adhesive polymers

A broad portfolio to suit your needs

Polyether and polyester diols

Polyester and polyester polyols can be used to produce both NCO- and OH-terminated pre-polymers for solvent-based or solvent-free one-component or two-component adhesives. Polyester polyols generally provide better adhesion to many substrates. Polyether polyols are used to reduce the processing viscosity and adjust the reactivity of the 2K polyurethane adhesives.

Covestro offers a broad portfolio of polyester and polyether polyols that are suitable as building blocks for adhesives. The following table shows some selected examples. Please see also our brochure "Resins – Polyols and Aspartics for Reaction with Polyisocyanates" for additional products.

PRODUCT	TYPE	OH NUMBER	VISCOSITY	PROPERTIES/ APPLICATIONS
		[mg KOH/g]		
Baycoll® AD 2047	Polyester diol	Approx. 56	Approx. 7,000 @ 75 °C	Hydrolysis resistance, slip agent compatibility
Baycoll® AD 2055	Polyester diol	Approx. 56	Approx. 630 @ 75 °C	Hydrolysis resistance, slip agent compatibility
Baycoll® CD 2084	Polyester diol	Approx. 84	Approx. 120 @ 75 °C	Compatibility
Desmophen® BD 2060	Polyether diol	Approx. 56	Approx. 310 @ 25 °C	Low viscosity, compatibility
Desmophen® BD 1110	Polyether diol	Approx. 112	Approx. 140 @ 25 °C	Low viscosity, compatibility
Desmophen® 1400 BT	Polyether triol	Approx. 400	Approx. 370 @ 25 °C	Long pot life, short reaction time, compatibility, increase functionality



Fast-lane access to polyurethane innovations

At Covestro innovation is in our DNA. Ever since Otto Bayer discovered polyurethanes in 1937, we have been driving polyurethane innovations in coatings and adhesives as well as in other application areas. As our partner you enjoy fast-lane access to polyurethane innovations, and can help us in developing the next generation of polyurethanes to meet the industry's upcoming challenges and needs. What can we offer you?

- Powerful know-how on both established and new polyisocyanates, as well as on new polyurethane hybrid technologies.
- The prospect of new application technologies to enable efficient processes.
- More sustainable, biomass- or CO₂-based materials that do not sacrifice high performance.

Join us to shape the future!

