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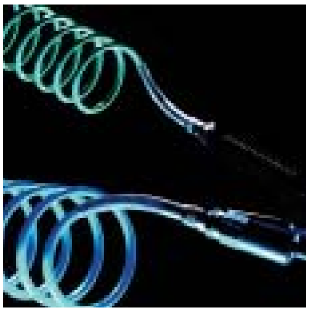
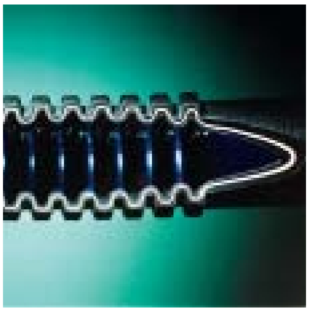
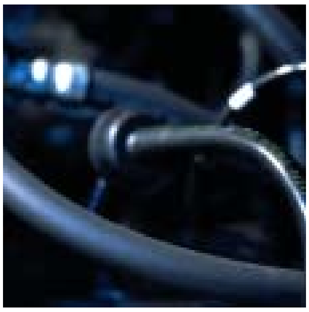
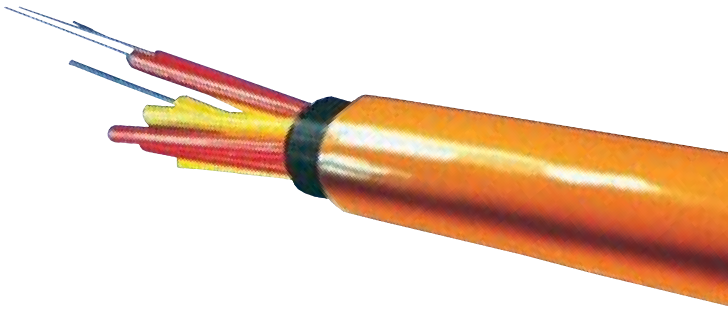
High Performance Polymers

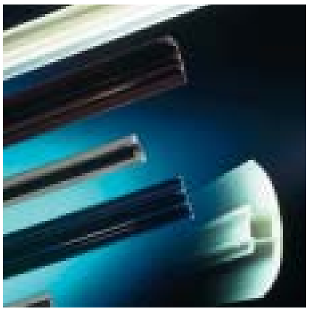
VESTAMID®











- Polyamide 12
  1. Synopsis of Polyamide 12 Grades and Properties
  2. Comparative Tables of Grades
- **Polyamide 12 Elastomers**
- Polyamide 612
- Handling and Processing of VESTAMID

Contents

VESTAMID Polyamide 12 Elastomers

Introduction

The High Performance Polymers Business Unit of the Degussa AG manufactures several polyamide 12 (PA 12), polyamide 612 (PA 612) and polyamide elastomer compounds (PEBA[1]), which it sells under the trade name VESTAMID®.

This brochure describes PA 12 elastomers. The other two product families are described in the separate parts of the VESTAMID brochure series "Polyamide 12" and "Polyamide 612." The brochure "Handling and Processing of VESTAMID" describes the processing of VESTAMID.

PA 12 elastomers, the most important subgroup of polyamide elastomers, belong to the increasingly important material class of thermoplastic elastomers (TPE). Because of their excellent properties, they are indispensable in many applications.

PA 12 elastomers are block copolymers consisting of PA 12 segments and polyether segments. PA 12-rich products have the major properties of PA 12, while the elastomer characteristics become more apparent with increasing polyether content. That is, the polymers become more flexible, with higher impact strength at cold temperatures.

Compared to other contending thermoplastic elastomers, PA 12 elastomers are distinguished by the following properties:

- They have low density.
- They are highly resistant to chemicals and solvents.
- They are easy to process and color and are easy to overmold.
- They can be decorated easily by means of heat transfer printing.
- They have excellent impact strength at low temperatures.
- Their hardness and flexibility can be varied over a wide range.
- They have high elasticity and good recovery.
- Their mechanical properties are only slightly temperature-dependent.
- They are free of volatile or migrating plasticizers.

The PA 12 elastomer compounds we sell are suitable both for precision injection molding and for high-performance extrusion processing, for example, for making tubing and films. We deliver unstabilized or heat- and light-stabilized products, according to the customer's needs.

Like all high-performance plastics of the High Performance Polymers Business Unit, VESTAMID compounds satisfy the highest quality standards. Our system for quality assurance is certified according to ISO 9001 and QS 9000. In several audits conducted by our customers, our compounds received excellent ratings.

[1] PEBA = Polyether block amide according to ISO 1043 or DIN 7728, both Parts 1.

1 Overview of PA 12 Elastomer Compounds, Their Properties and Uses

1.1 Nomenclature

Within the VESTAMID product group, PA 12 elastomers have their own designations, which distinguish commercial products and developmental products from each other. In the case of commercial products, the formulation and manufacturing processes are firmly established on the basis of comprehensive experiences. For developmental products, the testing phase continues on the market. Their compositions and manufacture can still be modified, and in this point we greatly value our customers' cooperation.

The names of the PA 12 elastomer commercial products begin with the trade name VESTAMID, followed by a capital "E" for elastomers and a two-digit number indicating the Shore hardness D of the product. Example: VESTAMID E47.

Other formulation components and properties are indicated by capital letters and numbers preceded by a hyphen:

- S1 Compound is heat-stabilized.
- S3 Compound is heat- and light (UV)-stabilized.
- R2 Compound features permanent antistatic properties. The number indicates the power of 10 of the specific surface resistance in ohms (minimum value).

Developmental products are designated by the trade name VESTAMID and an "X" or "EX" followed by a four-digit number. This number is arbitrary, however, and provides no information on the modification of the compound. Example: VESTAMID EX9200.

1.2 Approvals

S1-stabilized VESTAMID E compounds can be used in contact with foodstuffs if migration limit values are heeded. They satisfy the requirements of 90/128/EEC, the EC directive regarding plastics. Processors of S1-stabilized VESTAMID E compounds have licenses for applications in medical technology, for example, in the manufacture of catheters. Further information on the physiological and toxicological evaluations is found in the brochure "VESTAMID Polyamide 12."
Our Technical Marketing and Environment, Health and Safety Departments will answer your specific questions.

Other properties of VESTAMID elastomers and material information on the other products of the High Performance Polymers Business Unit are contained in the plastics database Campus®[2], which is updated regularly.
You will find Campus on the Internet at www.degussa-hpp.com.

[2] Campus® is the registered trademark of CWF GmbH/Frankfurt (Main).

Overview

Table 1: PA 12 elastomer compounds and their typical applications.

VESTAMID	Stabilized against	Shore hardness D*)	Typical applications
E40-S3	heat and light	40	noiseless gears, seals, functional elements of sports shoes, process aids in the extrusion of thermoplastic polyurethanes, films
E47-S1 E47-S3	heat heat and light	47	sports shoe soles, packaging films, non-skid surfaces, sports glasses, protective goggles
E55-S1 E55-S3	heat heat and light	55	alpine ski boots components, sports shoe soles, pneumatic lines, rolls, technical films
E62-S3	heat heat and light	62	alpine ski boots, noiseless gears, conveyor belts
EX9200	heat and light	68	decorative and protective films for sports articles and interior/exterior designs on automobiles
E50-R2	heat (also light from conductive carbon black)	50	permanently antistatic articles ($R_{OE} = 10^2 - 10^5 \Omega$), e.g., conveyor belts, housings, paint spray hoses

*) according to ISO 868

Table 2: Major properties of PA 12 elastomers of different hardnesses compared with PA 12.

Properties	Test-method	Unit	VESTAMID E with Shore hardness D (ISO 868)						PA 12
			30*)	40	47	55	62	68 *)	72
Density at 23 °C	ISO 1183	g/cm³	1.01	1.01	1.02	1.03	1.03	1.03	1.01
Tensile modulus	ISO 527 -1/-2	MPa	45	85	115	240	360	500	1500
IZOD notched impact strength at -30 °C	ISO 180/1A	kJ/mm²	N	N	N	N	N	N	N
Vicat softening temperature method A/10 N	ISO 306	°C	90	125	140	160	165	170	174

N = no break; *) not commercially available

1.3 Supply and coloring

VESTAMID E compounds are delivered as a dry, ready-to-process granulate in moisture-proof bags with a net weight of 25 kg. By mutual agreement we also deliver VESTAMID E in 1,000 kg octabins. The compounds can be processed immediately after the packaging has been opened, without any further pre-drying. The storage time of unopened packaging is almost unlimited under ordinary storage conditions, unless the packaging is damaged.

Like all partially crystalline polyamides, VESTAMID is colorless when molten and whitish-opaque in the solid state (natural color). The same applies to PA 12 elastomers. Films up to several hundred micrometers in thickness, however, are still transparent enough that they can be used, for example, as decorative films with printing on the bottom side.

Most compounds are delivered either naturally colored or black. Others exhibit a specific color produced by the additives used. In appropriate lot sizes, specially colored molding materials can be delivered. Colorants containing lead and cadmium are essentially not used.

VESTAMID E resins can also be colored during processing. In this case, master batches based on PA 12 are the choice here. Dry coloring with fine-powdered colorants is also possible but inconvenient, thus precluding pneumatic conveying of the granulate. Colorant pastes with a "neutral" base (e.g., polyethylene) may be incompatible with VESTAMID E compounds, thus resulting in flaws and inhomogeneity. Therefore, the compatibility of the colorant paste must definitely be pre-tested.

1.4 Processing PA 12 elastomers[3)]

VESTAMID E compounds can be used in all injection molding and extrusion machines suitable for polyamides. With proper processing, no noxious by-products are produced. As a general practice in the processing of thermoplastics, we recommend that the production room be sufficiently ventilated.
In the processing of VESTAMID E compounds, the moisture content must be less than 0.1% by weight. The granulate must be dried only if the package has been damaged or was

Table 3: Recommendations for processing and mold temperatures.

VESTAMID	Melt temperature [°C]	Mold temperature [°C]
E40-S3	170–210	
E47-S1, S3	180–220	
E55-S1, S3		
E62-S3	190–230	20–40
E50-R2		
EX9200	200–240	

opened for an extended duration (more than two hours). In these cases, the compounds must be dried for 4 to 12 hours at 80–100°C, preferably in a dehumidified air drying oven. The bags should be stored for about one day at the ambient temperature of the machine before processing to avoid condensation of moisture on the granulate.

Like most polymers, VESTAMID E is miscible with very few other plastics. Therefore, all machines must essentially be cleaned before processing. HDPE or PP is recommended for cleaning. Talcum-filled PP is particularly suitable.

[3)] You will find detailed instructions on processing in the brochure "Handling and Processing of VESTAMID."

2 Structure-Property Relationships of PA 12 Elastomers

In the manufacture of PA 12 elastomers, laurolactam, the monomer of PA 12, is polycondensated in the presence of a polyether diol and a dicarboxylic acid as a regulator. The result is a multiblock copolymer consisting of polyether and PA 12 blocks:

$$[\ (\text{ polyether })_x\ \text{-ester bond-}\ (\text{ PA 12 })_y\ ]_n$$

<u>p</u>olyeth<u>e</u>r <u>b</u>lock <u>a</u>mide = PEBA

Because of their very low glass transition temperature, polyether sequences are frequently referred to as soft blocks while the crystallizable PA 12 sequences are called hard blocks. The two blocks are actually completely incompatible. However, the chemical linkage of the blocks by the ester bond prevents segregation.

The block composition and block lengths can be varied widely to produce vastly different products.

Figure 1 shows stress-strain diagrams from tensile tests of PA 12 elastomers of different compositions. PA 12-rich elastomers show the typical behavior of a partially crystalline thermoplastic with a pronounced yield point. A transition to purely elastomeric behavior occurs with increasing polyether content.

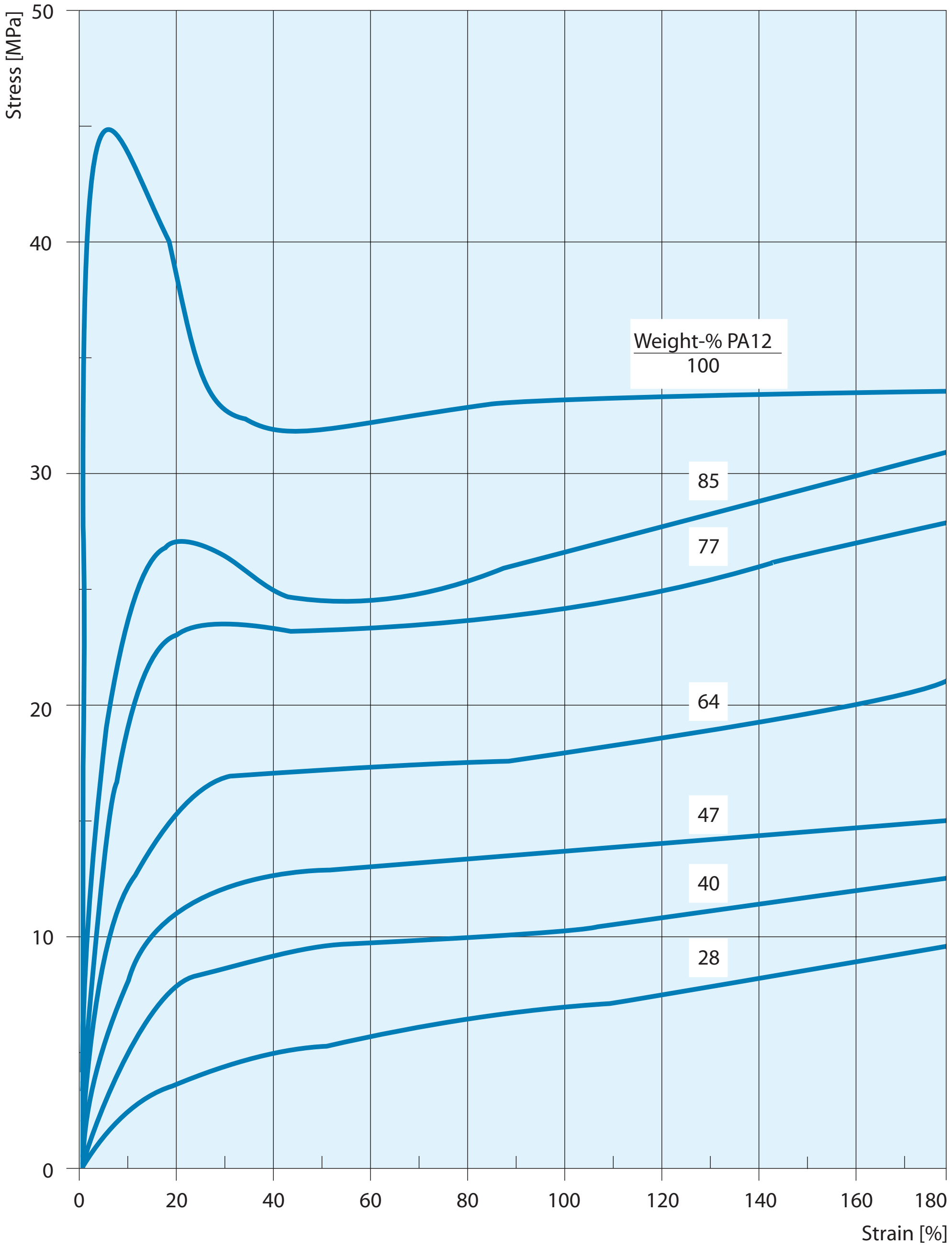


Figure 1: Stress-strain diagrams from tensile tests according to ISO 527 on PA 12 elastomers with polytetrahydrofuran soft blocks.

A detailed investigation of the phase morphology shows that, with all compositions, the matrix of the PA 12 elastomer consists of a hard block-rich mixed phase of PA 12 and polyether blocks. In PA 12-rich products, the hard blocks crystallize as they do in pure PA 12, in the form of lamellae with a spherulitic superstructure, and form a second continuous phase (Figure 2). This crystalline superstructure is lost in products with low PA 12 fractions. In this case, only formulations of spherulites or single lamellae are produced (Figure 3).

The crystalline superstructures are responsible for the particular difference from other partially crystalline thermoplastic elastomers and for some outstanding mechanical properties—including low temperature-dependence, high elasticity and good recovery.

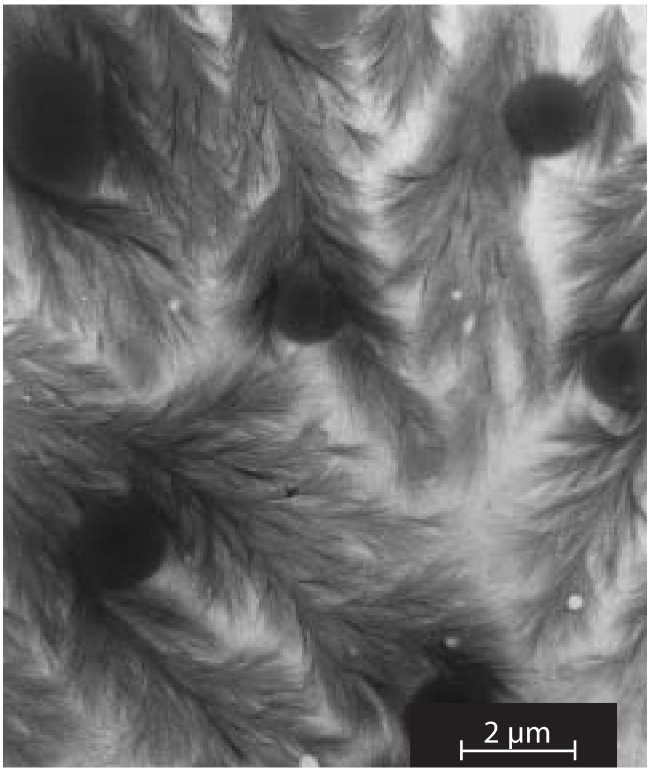


Figure 2: Photo of a PA 12-rich elastomer taken under a transmission electron microscope.

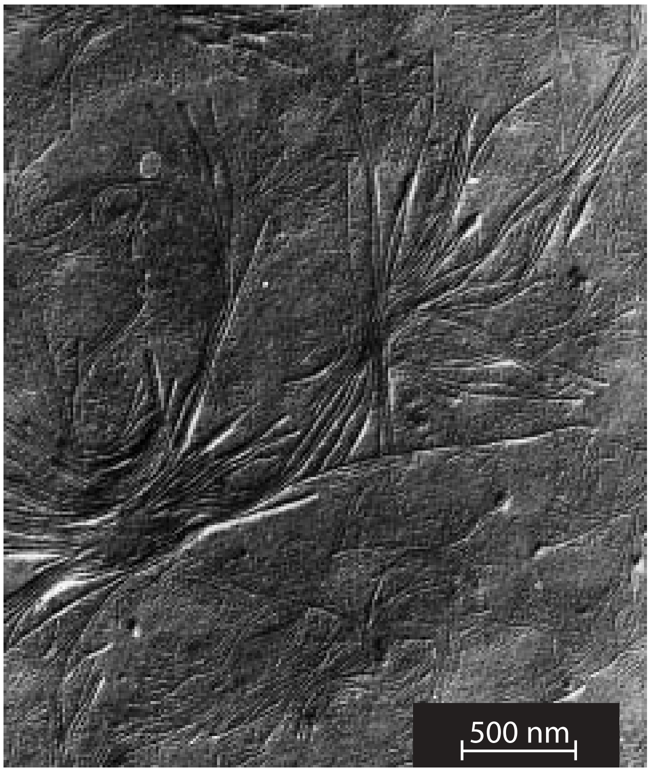


Figure 3: Photo of a polytetrahydrofuran-rich PA 12 elastomer taken under a transmission electron microscope.

Accordingly, the morphology of the PA 12 elastomers is characterized by three major phases: a crystalline phase of lamellarly crystallized PA 12 whose melt transition temperature is shifted to lower temperatures as compared to PA 12 (Figure 4). Between the lamellae of crystallized PA 12 blocks, we find the amorphous mixed phase of hard and soft blocks, whose glass transition temperature depends greatly on the block composition (Figure 5). A dispersely amorphous soft-block-rich phase with a low glass transition temperature can be detected as a third phase with mechanical-dynamic measurements. This phase apparently arises through segregation of soft-block-rich block copolymer molecules and behaves like a rubber that has been added as an impact modifier[4]. Free polyether blocks are not detectable.

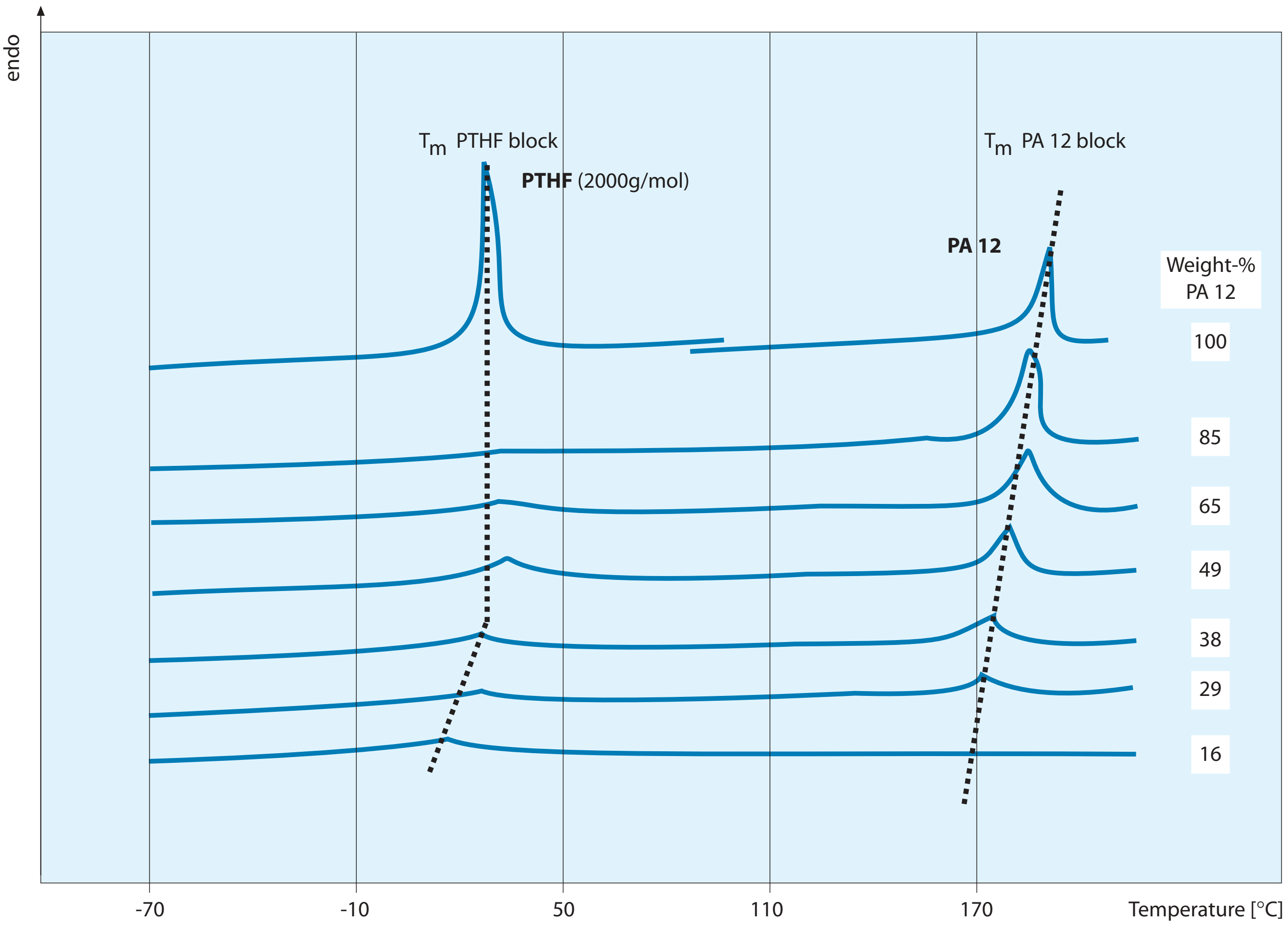


Figure 4: Melting point diagrams (DSC) of PA 12 elastomers with polytetrahydrofuran soft blocks (PTHF) ;
T_m = melting temperature

[4] In PEBA with very long polytetrahydrofuran blocks, polytetrahydrofuran crystallized as a 4th phase can be detected in this disperse soft-block-rich phase. However, this phase has no significance in terms of application technology.

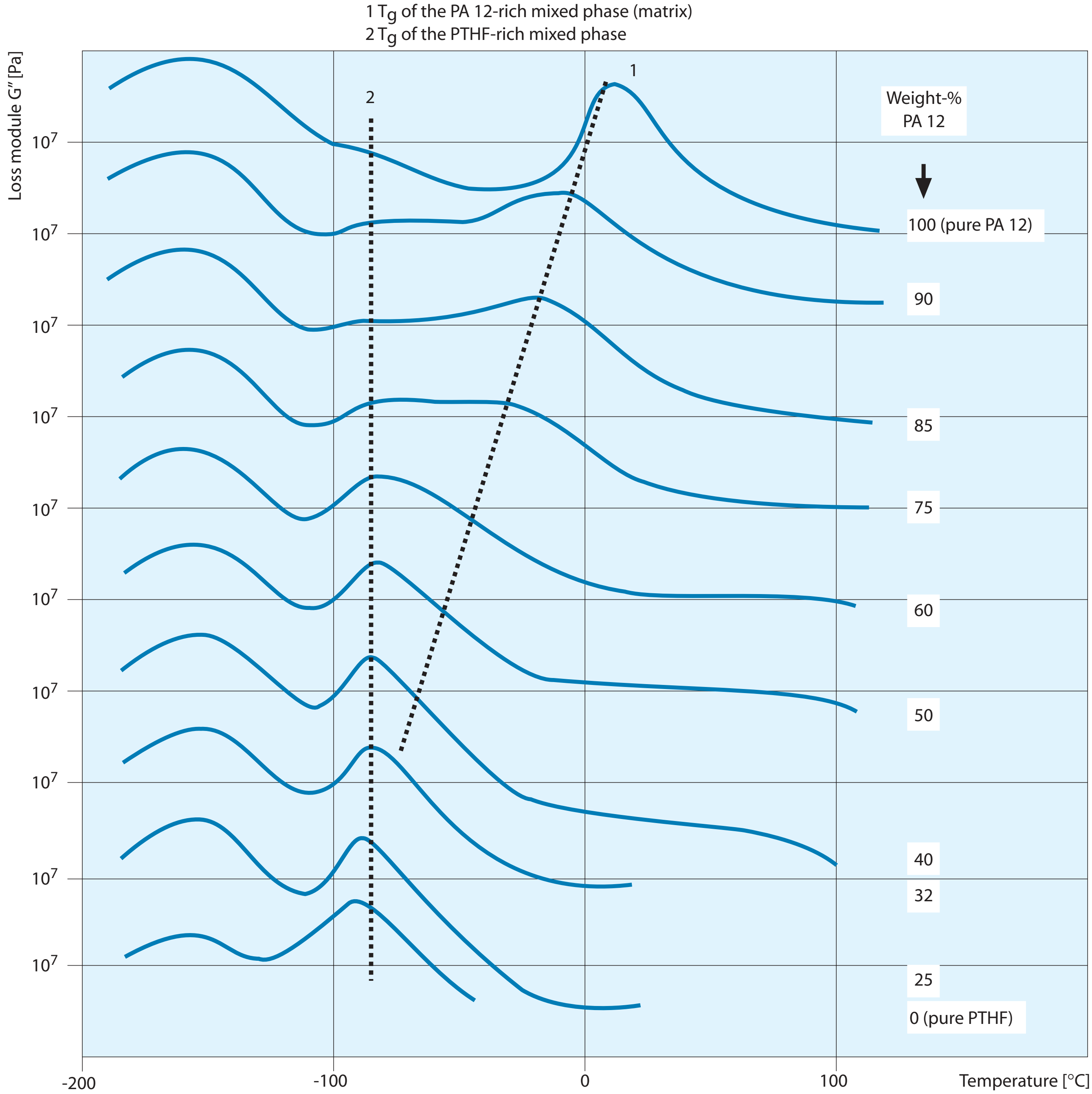


Figure 5: Loss module curves from torsional vibration analyses of PA 12 elastomers with polytetrahydrofuran soft blocks (PTHF); T_g = glass transition temperature

3 Mechanical Properties

Among the polyamides, PA 12 has the lowest water absorption and therefore features particularly high dimensional stability and little influence of moisture on the mechanical properties. These advantages are transferred to the PA 12 elastomers. Therefore, mechanical data on as-injection-molded and conditioned products differ only slightly.

3.1 Hardness and strengths

In the case of rubbers, the products are commonly classified according to Shore hardness. For a direct comparison, thermoplastic elastomers are categorized similarly. Shore hardness D is used for the harder types while Shore hardness A is used for the softer ones. Essentially, the range from hard thermoplastics with a Shore hardness of D 72 to soft rubbers with a Shore hardness of A 70 can be covered with polyamide elastomers by varying the block composition. No other thermoplastic elastomer covers such a large range. The High Performance Polymers Business Unit is currently selling VESTAMID E products with Shore hardnesses from D 68 to D 40.

For the plastics designer, however, module values are more important. Figure 6 shows the tensile moduli of VESTAMID E commercial products plotted against Shore hardness D.

3.2 Temperature dependence

In numerous applications for PA 12 elastomers, the relatively low temperature-dependence of the mechanical properties is of crucial importance. Figures 7 through 9 demonstrate this using the parameters of Shore hardness, storage modulus G‘ and loss factor tan δ.

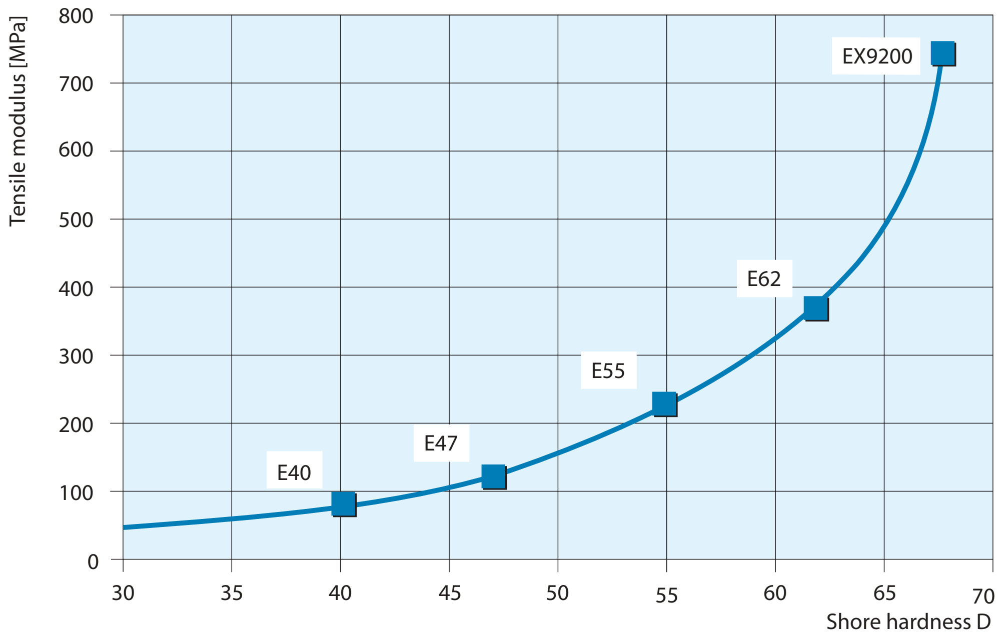


Figure 6: Relationship between tensile modulus and Shore hardness of VESTAMID elastomers.

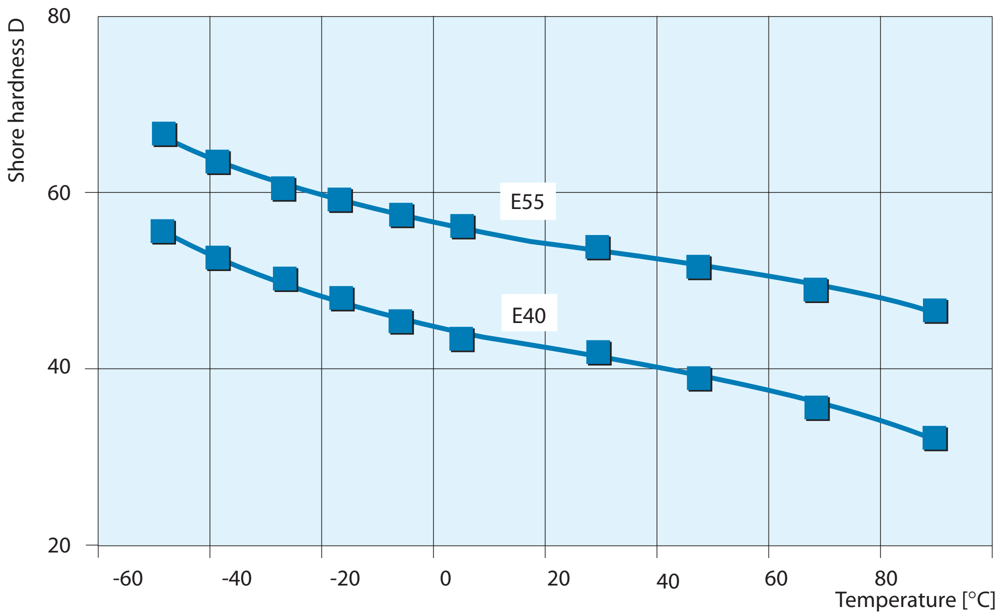


Figure 7: Temperature-dependence of Shore hardness using VESTAMID E 40 and VESTAMID E55 as examples.

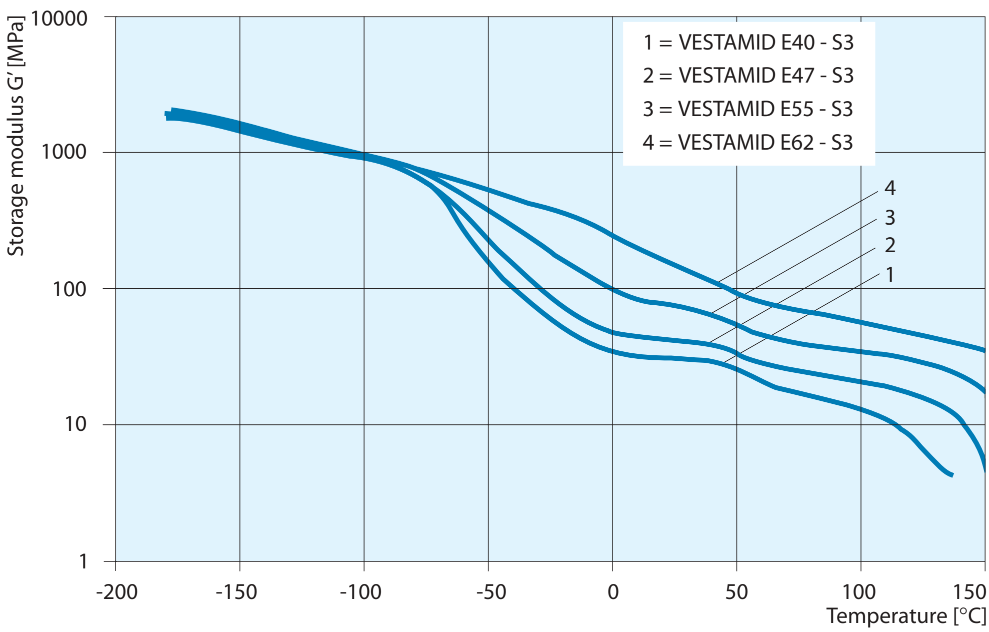


Figure 8: Temperature-dependence of the storage modulus of VESTAMID elastomers determined with torsional vibration analyses according to ISO 6721-2.

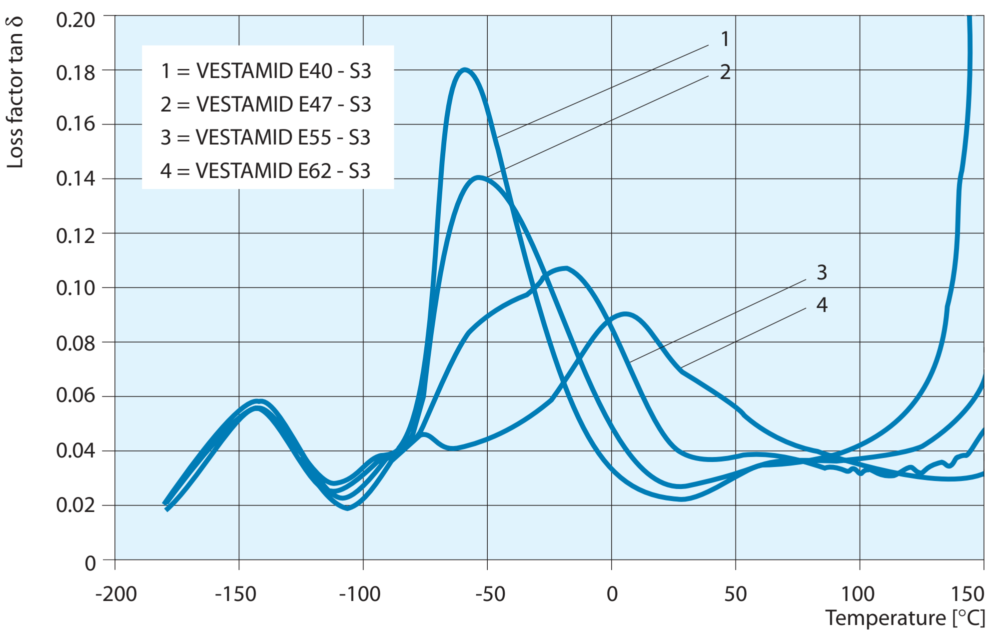


Figure 9: Temperature-dependence of the loss factor tan δ of VESTAMID elastomers determined with torsional vibration analyses according to ISO 6721-2.

3.3 Tensile creep strength

In the tensile creep test according to ISO 899, the strain and strength behavior can be determined under static tensile stress. Figures 10 through 12 and 13 through 15 show the creep curves of different tensile stresses and temperatures for VESTAMID E47 and E40. The creeps observed in the curves are the sum of the elastic, viscoelastic and permanent deformations of a sample under stress. When the load is relieved, the elastic deformation is restored almost immediately and the viscoelastic deformation is restored more or less completely, depending on the time. Approximately linear creep strength curves for mean stresses and strains can generally be extrapolated rectilinearly up to 10 times the test time without risk if the resins are sufficiently stable at the test temperature under ambient conditions.

VESTAMID E47-S3

Tensile creep curves according to ISO 899-1

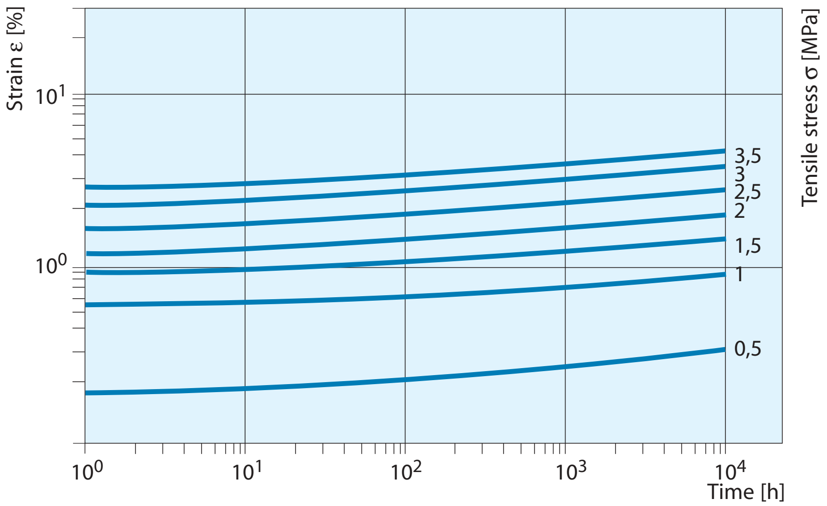


Figure 10: Test conditions 23°C/50% RH

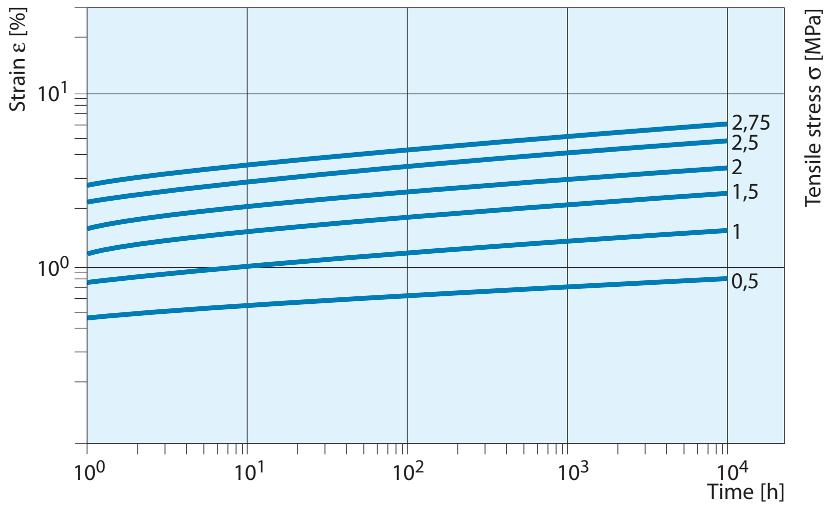


Figure 11: Test condition 60°C

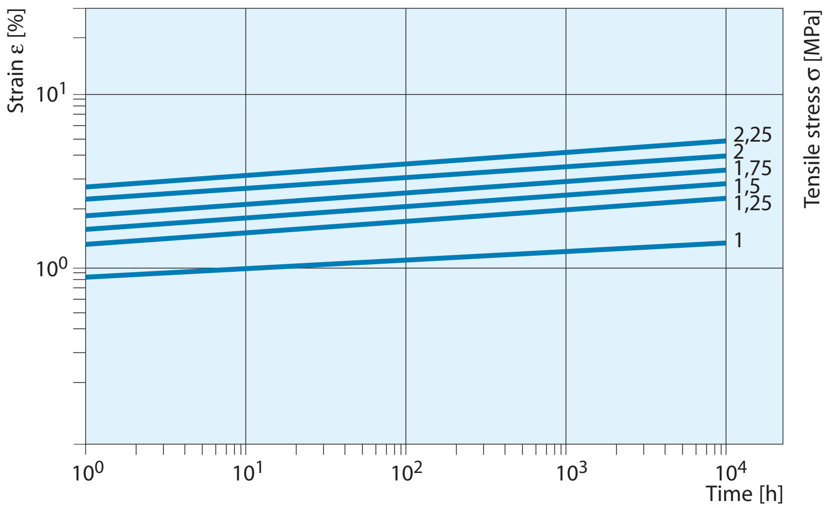


Figure 12: Test condition 80°C

VESTAMID E40-S3

Tensile creep curves according to ISO 899-1

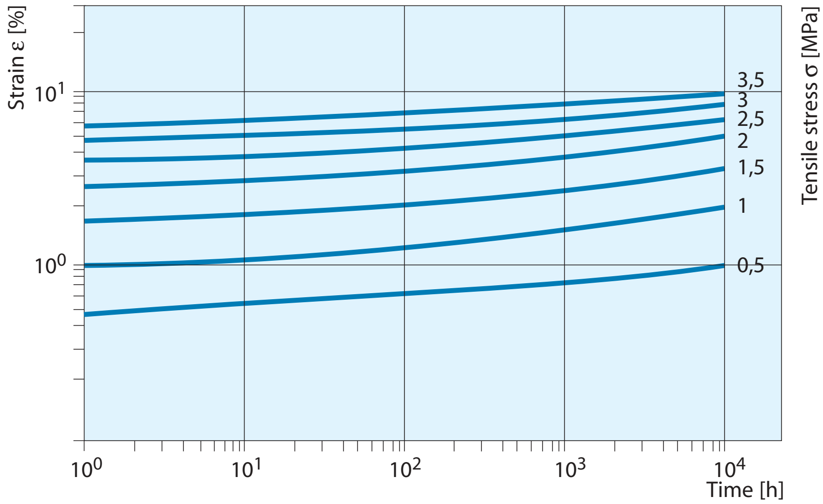


Figure 13: Test conditions 23°C/50% RH

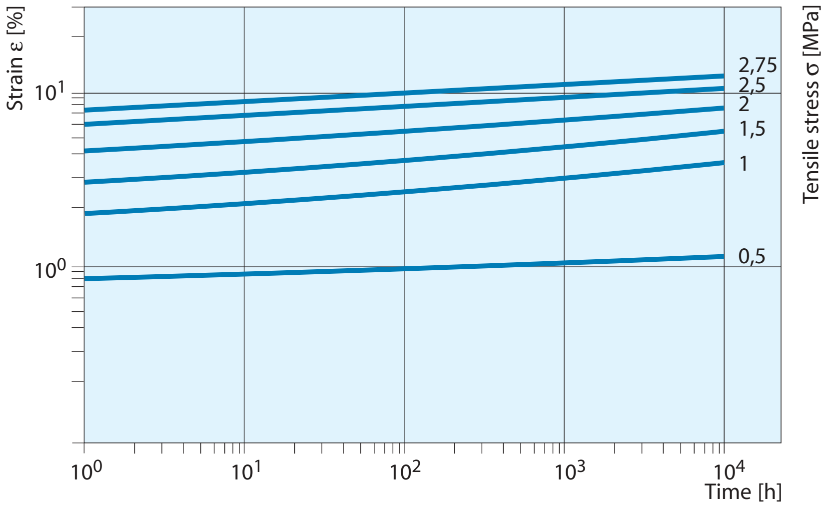


Figure 14: Test condition 60°C

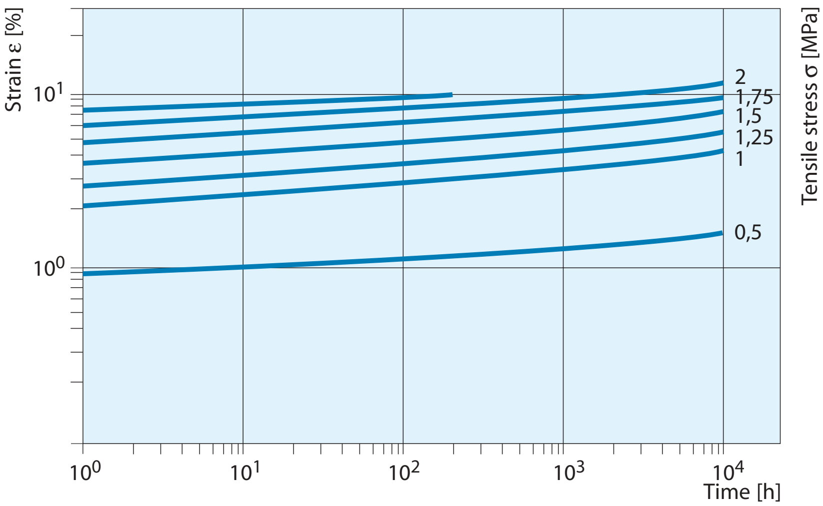


Figure 15: Test condition 80°C

3.4 Permanent set

Among the thermoplastic elastomers, PA 12 elastomers feature high recovery following deformation. For the permanent set according to ISO 815, for example, the following data were found:

VESTAMID	23 °C	70 °C	100 °C
E40-S3	32%	47%	84%
E62-S3	34%	48%	85%

Table 4: Permanent set of VESTAMID elastomers according to ISO 815.

4 Abrasion Behavior

Even with very abrasive friction pairs, VESTAMID elastomers exhibit favorable abrasion behavior. This property is prized for many heavy-duty applications, such as in sports articles. Thanks to the high elasticity of VESTAMID elastomers, surfaces can recover from distortions if they have not been severely damaged. This is referred to as the "self-healing" effect.

VESTAMID	Shore hardness D	Test procedure according to DIN 53754 mg/100 revolutions	Test procedure according to DIN 53516 mm/40 m rubbing distance
E40-S3	40	20	105
E47-S3	47	-	63
E55-S3	55	8–9	50
E62-S3	62	9–10	47

Table 5: Abrasive behavior of PA 12 elastomers.

5 Overmolding and Bonding

All VESTAMID elastomers can be welded to each other and to VESTAMID L (PA 12). This applies in particular to the overmolding of compounds of different hardness or colorability. This property is taken advantage of quite often in the manufacture of multi-component and multi-colored parts of sports articles such as special sports shoe soles or ski boots.

An elevated mass temperature of up to 300°C, a high injection speed and high dwell pressure are recommended for overmolding. Better layer adhesion can be achieved if the mold temperature is raised to 100°C. However, a lower processing temperature can be helpful for more-transparent overmolding.

VESTAMID elastomers can also be bonded to many other polymers by overmolding. In adhesion tests, the results listed in Table 6 were obtained.

Special polyamide adhesives are used for adhesion bonding.

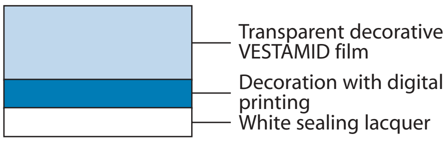
Table 6: Lamination strength during overmolding of VESTAMID E with different polymers.

Polymer	PP	PE	PA 6	PA 66-GF30	PA 12	PA 12-PEBA	PBT	POM	PET/PBT	TPU	PS
Adhesion	-	-	+	+	+	+	+	-	-	+	+/-

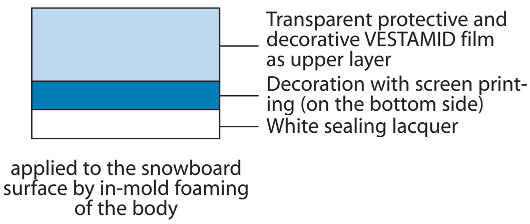
6 Printability

In recent years, creating designs on injection moldings and films has become increasingly important in processing the surfaces of high-quality consumer goods. VESTAMID elastomers lend themselves excellently to decorative application by means of thermodiffusion printing processes. In particular, brilliant decorative films, which have been used as highly attractive protective films in the sports article and automobile construction sectors, can be manufactured by sublimation printing and state-of-the-art digital printing processes.

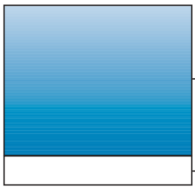
Design of a decorative film for tennis racks



Production of a snowboard with a screen-printed VESTAMID film



Design of skies with decorative VESTAMID films, sublimation-printed on the bottom side

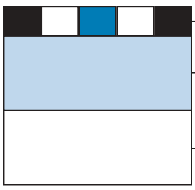


Transparent protective and decorative VESTAMID film as upper layer, decorated on the bottom side by sublimation printing

White sealing lacquer

laminated onto the ski body made of epoxy resin or polyurethane foam

Soccer shoe sole with coextrudated decorative VESTAMID film, sublimation-printed on the top side



White-diaphanous with black and blue print

Transparent VESTAMID

White VESTAMID

Films of VESTAMID EX9200 several tenths of a millimeter thick are sufficiently transparent and are frequently sublimation-printed on the bottom side. The colorants penetrate the film up to 200 micrometers. The film itself then acts as a protective layer and the print motifs are almost indestructible. Frequently the decorative films are manufactured by co-extrusion in multiple layers—sometimes made of different VESTAMID compounds—to achieve an optimum between surface protection, design and bondability with substrates. Table 7 shows some examples for the configuration and use of decorative films.

	Film design	Monofilm	Coexfilm	Coexfilm	Coexfilm	Coexfilm
	Processing comment	Printed on the bottom side with white sealing	Upper film transparent, lower film white, printed on the top side	Upper and lower film transparent, printed on both sides	Upper and lower film transparent, printed on the top side	Upper film transparent, lower film white, printed on the top side
	Characteristics	High performance decorative film for laminating and overmolding	Optical dense film for inmold decoration and laminating	3-dimensional decorative effects	excellent scratch-resistant and brilliant decorative film	excellent scratch-resistant and brilliant decoration of moldings
Film design	**Transparent protection layer**	–	–	–	–	VESTAMID X7376 [2] overmolded
Film design	**Decoration on the top side**	–	Sublimation printing	Sublimation printing	–	Sublimation printing
Film design	**Upper layer**	VESTAMID EX9200 [1]	VESTAMID EX9200 [1]	VESTAMID EX9200 [1]	VESTAMID X7376 [2]	VESTAMID X7376 [2]
Film design	**Lower layer** (if present)	–	VESTAMID EX9200 (white)	VESTAMID EX9200	VESTAMID EX9200	VESTAMID EX9200 (white)
Film design	**Decoration on the bottom side**	Screen or sublimation printing	–	Sublimation printing	Screen or sublimation printing	–
Film design	**Sealing compound**	White lacquer	Not necessary	White lacquer	White lacquer [3]	Not necessary
	Applications	Skies and snowboards, household appliances	Skies and snowboards, molded parts	Skies and snowboards, molded parts	Skies, snowboards, molded parts, exterior auto body, panels, household appliances	Sports shoe soles
	Production	Calender or chill Roll	Coexfilm only chill roll	Coexfilm only chill roll	Coexfilm only chill roll	Coexfilm only chill roll

[1] VESTAMID EX9200: high elasticity with "self-healing effect"
[2] VESTAMID X7376 (modified PA 12): higher transparent, higher scratch-resistant, higher sublimation temperature (= shorter cycle time)
[3] White sealing compound only with sublimation printing

Table 7: Designs with VESTAMID compounds.

7 Chemical and Solvent Resistance

The interactions between chemicals and polymers can vary greatly. Primarily the following actions are distinguished:

- The chemical is absorbed by the polymer of some extent, producing varying degrees of swelling.
- Frequently, the chemical does not act as a solvent until higher temperatures are reached. At lower temperatures, the chemical is only a potent swelling agent.
- The chemical causes the polymer to degrade; the rate is generally highly dependent on temperature.

Test agent	Test temperature [C°]	Test time [hr]	VESTAMID E62-S3 Mass change[1)] [%]	 Tensile modulus[2)] [MPa]	 Notched impact strength[3)] [kJ/m^2]
Comparison sample	23	–	–	353	n. b.
Sulfuric acid (0.5 mol/L)	23	1200	1.0	388	n. b.
	60	300	1.1	330	5.3
Hydrochloric acid (1 mol/L)	23	1200	2.8	383	n. b.
	60	300	1.4	289	2.0
Nitric acid (1 mol/L)	23	1200	2.4	323	0.4
	60	300	disintegrated after 170 h	–	–
Battery acid (30%)	23	1200	1.2	336	n.b.
	60	300	4.2	259	0.4
Formic acid (85%)	23	1200	83.5	60	n. b.
	60	300	disintegrated after 24 h	–	–
Acetic acid (2 mol/L)	23	1200	2.9	356	n. b.
	60	300	4.2	334	n. b.
Caustic soda (1 mol/L)	23	1200	1.1	367	n. b.
	60	300	1.0	363	n. b.
Chlorine-water solution (16%)	23	1200	0.7	372	n. b.
Ammonia water (25%)	23	1200	1.1	364	n. b.
Hexane	23	1200	2.9	387	n. b.
	60	300	4.6	311	n. b.
Toluene and benzene	23	1200	13.7	323	n. b.
	60	300	17.3	273	n. b.
Premium gasoline (ARAL®)	23	1200	8.4	226	n. b.
	60	300	15.4	216	n. b.
ASTM fuel B	23	1200	5.6	363	n. b.
	60	300	7.5	271	n. b.
ASTM fuel B + ethanol	23	1200	14.5	252	n. b.
(80:20 vol.%)	60	300	17.6	240	n. b.
Methanol	23	1200	10.2	265	n. b.
	60	300	14.3	198	n. b.
Isoamyl alcohol	23	1200	8.0	283	n. b.
	60	300	18.5	167	n. b.
Methyl ethyl ketone	23	1200	7.9	326	n. b.
	60	300	9.8	297	n. b.
Trichloroethylene	23	1200	35.1	301	n. b.
	60	300	36.8	243	n. b.
Butyl acetate	23	1200	8.0	325	n. b.
	60	300	9.0	294	n. b.
ASTM oil No. 1	23	1200	0.1	398	n. b.
	60	300	0	–	–
ASTM oil No. 3	23	1200	0.7	347	n. b.
	60	300	2.2	–	–

Table 8: Chemical resistance of PA 12 elastomers (selection).

Because they are more closely related to polyamides than other thermoplastic elastomers, VESTAMID elastomers are relatively stable toward a variety of chemicals. Noteworthy is the good stability toward diluted hydrochloric and sulfuric acid and alkalis and the low degree of swelling particularly of the harsher products when exposed to ASTM oil, even at 100°C. The same applies to hydraulic fluids. There is little swelling in aliphatic solvents and alcohols. In aromatic solvents, while the softer VESTAMID elastomers swell quite a bit, the mechanical properties are not lost dramatically. Table 8 shows a comparison of swelling data and the influence of swelling on stiffness and notched impact strength.

VESTAMID E47-S3			VESTAMID E40-S3		
Mass change[1)] [%]	**Tensile modulus[2)] [MPa]**	**Notched impact strength[3)] [kJ/m²]**	**Mass change[1)] [%]**	**Tensile modulus[2)] [MPa]**	**Notched impact strength[3)] [kJ/m²]**
–	156	n. b.	–	79	n. b.
0.7	151	n. b.	0.8	88	n. b.
1.0	132	n. b.	1.1	69	n. b.
0.7	164	n. b.	0.7	84	n. b.
2.5	78	8.2	2.2	45	6.9
disintegrated after 500 h	–	–	disintegrated after 340 h	–	–
disintegrated after 100 h	–	–	disintegrated after 100 h	–	–
1.0	17	brittle	0.8	brittle	brittle
disintegrated after 170 h	–	–	disintegrated after 170 h	–	–
disintegrated after 24 h	–	–	disintegrated after 24 h	–	–
disintegrated after 24 h	–	–	disintegrated after 24 h	–	–
4.7	142	n. b.	4.7	80	n. b.
4.3	122	n. b.	4.8	61	n. b.
0.7	158	n. b.	0.7	88	n. b.
2.2	103	n. b.	2.8	55	n. b.
0.5	156	n. b.	0.7	85	n. b.
1.2	161	n. b.	1.2	90	n. b.
6.9	135	n. b.	9.3	77	n. b.
8.6	127	n. b.	27.5	26	n. b.
37.5	93	n. b.	62.8	41	n. b.
52.7	126	n. b.	104.0	26	n. b.
30.9	102	n. b.	46.7	38	n. b.
34.9	61	n. b.	63.7	27	n. b.
15.7	118	n. b.	22.3	59	n. b.
18.9	89	n. b.	29.8	39	n. b.
37.1	51	n. b.	79.4	20	n. b.
63.0	28	n. b.	123.3	not measureable	n. b.
16.0	79	n. b.	19.8	41	n. b.
27.2	66	n. b.	61.6	12	n. b.
22.5	82	n. b.	34.0	40	n. b.
71.0	19	n. b.	disintegrated after < 24 h	–	–
18.6	94	n. b.	28.4	46	n. b.
26.5	70	n. b.	48.4	29	n. b.
102.3	84	n. b.	184.8	32	n. b.
133.7	76	n. b.	317.0	17	n. b.
18.8	101	n. b.	29.4	48	n. b.
37.7	76	n. b.	53.1	29	n. b.
0.4	145	n. b.	1.1	96	n. b.
0.7	–	–	1.5	–	–
7	129	n. b.	11	78	n. b.
9	–	–	13	–	–

1) Maximum value for the test time.
2) According to ISO 527-1/-2.
3) According to DIN 53453, standard bar 2, n.b. = no break.

8 Major Properties of PA 12 Elastomers

Property		Test method	Unit	E40-S3
Density	23 °C	ISO 1183	g/cm^3	1.01
Tensile test		ISO 527-1		
Stress at yield		ISO 527-2	MPa	–
Strain at yield			%	–
Stress at 50% expansion			MPa	9.5
Tensile strength			MPa	17
Strain at break			%	>200
Tensile modulus		ISO 527-1 ISO 527-2	MPa	80
Tensile creep modulus	1000 h	ISO 899-1	MPa	60
CHARPY impact strength[1]	23 °C	ISO 179/1eU	kJ/m^2	N
	-30 °C		kJ/m^2	N
CHARPY notched impact strength[1]	23 °C	ISO 179/1eA	kJ/m^2	N
	-30 °C		kJ/m^2	N
Shore hardness D		ISO 868		40
Heat deflection temperature				
Method A	1.8 N/mm^2	ISO 75-1	°C	
Method B	0.45 N/mm^2	ISO 75-2	°C	55
Vicat softening temperatur		ISO 306		
Method A	10 N		°C	125
Method B	50 N		°C	60
Linear thermal expansion	23 °C–55 °C	ISO 11359		
	longitudinal		$10^{-4}K^{-1}$	2.4
	transverse		$10^{-4}K^{-1}$	2.1
Relative permittivity	100 Hz	IEC 60250		7.5
	1 MHz			4.9
Dissipation factor	100 Hz	IEC 60250		700
	1 MHz			1200
Electric strength	K20/P50	IEC 60243-1	kV/mm	35
Comparative tracking index		IEC 60112		
Test solution A	CTI			600
Spec. volume resistance		IEC 60093	Ohm • cm	10^{11}
Spec. surface resistance		IEC 60093	Ohm	10^{13}
Viscosity number		ISO 307	cm^3/g	190
Flammability acc. UL94[2]	1.6 mm	IEC 60695		HB
Water absorption	saturation	ISO 62	%	1.0
Mold shrinkage		Determinated on 3 mm sheets		
in flow direction		with film gate at rim	%	0.6–0.09
in transverse direction		mold temperature 80 °C	%	0.7–1.3

Colorants may affect the properties.

VESTAMID				
E47-S3	E55-S3	E62-S3	EX9200	E50-R2
1.02	1.03	1.03	1.01	1.08
–	–	–	31	–
–	–	–	19	–
12	17	23	27	13
23	38	42	–	20
>200	>200	>200	>200	>200
120	230	370	700	170
90	100	200		
N	N	N	N	N
N	N	N	N	N
N	N	120 P	33 P	N
N	22 C	8 C	6 C	N
47	55	62	68	50
45	45	45	45	–
65	90	100	100	–
140	160	165	170	–
70	100	110	130	–
2.3	2.0	2.0	1.6	–
2.1	2.0	2.0	1.6	–
8.5	9.5	9.0	7.4	[3]
4.7	4.3	4.0	4.6	[3]
1200	950	1000	1500	[3]
1300	1100	1200	760	[3]
37	38	39	30	[3]
600	600	600	600	[3]
10^{11}	10^{11}	10^{12}	10^{11}	10^{3}
10^{13}	10^{13}	10^{14}	10^{13}	10^{4}
190	190	190	190	
HB	HB	HB	HB	HB
1.0	1.1	1.1	1.5	–
0.6–1.0	0.6–1.1	0.6–1.1	–	–
0.9–1.5	0.9–1.5	0.9–1.4	–	–

[1] N = no break
P = partial break
C = complete break; incl. hinge break H
[2] HB = horizontal burning
[3] Data cannot be determined because of conductivity of the compound

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