High Performance Polymers

VESTAMID® • VESTODUR®

ENGINEERING THERMOPLASTICS

FOR SECONDARY FIBER

OPTIC JACKETING
1 Introduction

A fiber optic cable offers many advantages. It can support a much wider range of users than any conventional copper cable. Fiber optic cables are lightweight and small yet extremely rugged.

The dielectric nature of optical fibers makes them immune to electromagnetic interference. The optical fibers in a cable must be protected against all mechanical stresses due to manufacturing and various ambient conditions during the life of the cable. This protection is achieved in a combined way:

- by the individual protection of the fibers with VESTAMID or VESTODUR
- by the protection provided by the cable construction

VESTAMID (polyamide 12; PA 12) and VESTODUR (polybutylene terephthalate; PBT) compounds are not only used for the protection of optical fibers; they can also be used for the insulation of copper wires and cable sheathings.
Fiber optic cables are designed to meet a variety of operational specifications called for by different applications. In order to limit the number of designs, a universal cable concept would be very attractive but cannot be realized.

The following cable designs are on the market:

### 2.1 Tight and semi-tight buffer cables

Tight and semi-tight jacketing is mainly used for indoor cables, patch cord cables or connector pig-tails. The outside diameter of the secondary buffered fiber is normally 0.9 mm.

**Tight buffer cable**
- Optical fiber
- Tight secondary coating VESTAMID/VESTODUR
- Aramid yarns
- Outer sheath

**Semi-tight buffer cable**
- Optical fiber
- Jelly or dry
- Semi-tight secondary coating VESTODUR X7396
- Aramid yarns
- Outer sheath

**Recommended resins:**
- VESTAMID L1670 / X7166*
- VESTAMID E62-53 / LX9104*
- VESTODUR X4159 / X9403*
- VESTODUR X7396

*with flame retardant
2.2 Loose tube cables

In the loose tube design each fiber or multi-fiber bundle is loosely held inside a polymer tube. The tube is normally filled with a moisture repellent jelly compound. The jelly-filled tube gives the fibers excellent protection against various external forces acting on the cable. None of these forces will be transferred directly to the fibers. The most important advantage of the loose tube design is, however, the strain relief effect obtained as a result of the tubes being stranded (helically or SZ) around the central strength member.

The cable core is protected by various wrappings, polymer jackets and additional reinforcements in form of strength member layers or armoring.

Recommended resins:
• VESTODUR 3000
• VESTODUR 3013
• VESTODUR X7396

Loose fiber bundle cable

Central strength member
Loose tube
VESTAMID/VESTODUR
Optical fibers & filling compound
Inner jacket
Outer strength member
Outer sheath
2.3 Central core tube cable

This cable design consists of a larger thick wall tube, located in the centre of the cable with fiber ribbons or fiber bundles. The tube is filled with a moisture repellent jelly compound. Further protection is provided by layers of plastic jacket materials and strength members.

Recommended resins:
- VESTODUR 3000
- VESTODUR 3013
- VESTODUR X7396

2.4 Slotted core cable

The slotted core design features a central strength member surrounded by an oscillating slotted polyolefin core. The slots can be filled with a moisture repellent jelly and contain loose buffer tubes or only primary coated fibers which are held by a core wrap. The cable core is then further protected by a plastic jacket and corrugated steel tape.
Hydrolysis is known as a primary cause of degradation of thermoplastic polyesters at elevated temperatures. Compared to PA 12, standard PBT resins have minor hydrolysis resistance. Since more and more cables are being installed in environments of high temperature and high humidity, the development of PBT materials with improved hydrolysis resistance became necessary.

VESTODUR 3013 is a PBT compound with very good hydrolysis resistance.

Materials which can be used for secondary fiber optic jacketing have to meet the following requirements:

- easy processability with high melt strength
- low coefficient of thermal expansion
- high flexural modulus with good kink resistance
- stress cracking resistance against filling compounds and solvents such as alcohols and ketones, used in splicing operations
- low moisture absorption
- good hydrolysis resistance
- high compressive strength

Considering the various polymers which would be appropriate for secondary fiber optic jacketing, only a few materials will meet these requirements. VESTAMID and VESTODUR compounds have consistent product quality, offering easy processability with trouble-free continuous production. These engineering thermoplastics have outstanding properties for chemical resistance, dimensional stability, and hydrolysis resistance.

Materials requirements:

- easy processability with high melt strength
- low coefficient of thermal expansion
- high flexural modulus with good kink resistance
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VESTODUR 3013 is a PBT compound with very good hydrolysis resistance.

Compared to standard PBT resins, this grade exhibits a threefold improvement in lifetime expectations. Lifetime is determined by the loss of the mechanical integrity of the material. Below the critical viscosity number of 65 cm³/g, PBT becomes brittle. The speed of degradation of PBT is determined by the carboxylic end-group concentration (CEC) of the polymer. The higher the CEC at the beginning of the aging, the faster degradation occurs.

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Materials which can be used for secondary fiber optic jacketing have to meet the following requirements:
In a study we examined the lifetime of VESTODUR in terms of ambient temperature and humidity, solution viscosity and carboxylic endgroup concentration (CEC).

With the following formula, the lifetime of a fiber optic buffer tube can be calculated for any given temperature and humidity:

\[ t = \frac{1}{\text{CEC}} \exp \left( \frac{-11400}{T} - 0.92 \frac{T}{H} - 25.3 \right) \]

Figure 1 shows the slope of the viscosity number at constant temperature and humidity for fiber optic buffer tubes produced from a standard PBT, VESTODUR 3000 and VESTODUR 3013 as a function of time.
VESTAMID and VESTODUR are semi-crystalline materials that tend to post-crystallize (= post shrinkage). The post-crystallization is prevalent above the glass transition temperature of the polymer.

The most critical step in the production of loose buffer tubes is the adjustment and control of a distinct fiber excess length, which takes into account the different coefficients of thermal expansion of the glass fibers and the polymer tube.

The crystallinity of VESTAMID and VESTODUR affects the necessary excess length and is mainly dependent on:

- Cooling rate of VESTAMID and VESTODUR
- Viscosity and type of jelly
- Fiber pay-off tension
- Production speed

Cold water quenching yields a low crystalline material, resulting in low fiber excess length. Annealing the buffer tubes above 30 °C will result in further crystallization causing (in a strain free position) further shrinkage. Because of a hindered shrinkage, tubes spooled onto a bobbin and stranded in a cable will show only a little additional shrinkage.

For the production of small central core tubes and semi-tight buffer tubes, the use of a low-shrink VESTODUR compound is recommended.
VESTODUR 3000 is a PBT compound developed for loose tubes for underground duct and direct burial cables.

VESTODUR 3013 is a fast crystallizing hydrolysis-resistant PBT compound for high extrusion speeds. This grade exhibits a markedly improved hydrolysis resistance for cables exposed to elevated temperatures and humidity.

Where critical screw configurations are encountered, grades with special granules lubrication are available.

### Available Compounds

From the early days of optical fiber development, cable manufacturers worldwide have been specifying VESTAMID and VESTODUR for secondary fiber optic jacketing. These polymers have proven the best cost performance ratio for this application.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method acc. to ISO</th>
<th>Unit</th>
<th>VESTODUR 3000/3013</th>
<th>X7396</th>
<th>X4159</th>
<th>X9403</th>
<th>L1670</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>23 °C</td>
<td>g/cm³</td>
<td>1.31</td>
<td>1.28</td>
<td>1.26</td>
<td>1.31</td>
<td>1.01</td>
</tr>
<tr>
<td>Melting range (DSC analysis)</td>
<td>°C</td>
<td></td>
<td>221–226</td>
<td>220–225</td>
<td>200–205</td>
<td>175–178</td>
<td></td>
</tr>
<tr>
<td>Viscosity number</td>
<td>1628-5</td>
<td>ml/g</td>
<td>165</td>
<td>120</td>
<td>180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melt volume-flow rate MVR</td>
<td>250 °C/2.16 kg</td>
<td>cm³/10 min</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Linear thermal expansion</td>
<td>23 °C–80 °C</td>
<td>10⁻⁴ K⁻¹</td>
<td>1.3</td>
<td>0.8</td>
<td>1.7</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Water absorption</td>
<td>saturation</td>
<td>%</td>
<td>0.45</td>
<td>0.35</td>
<td>0.30</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Tensile test:</td>
<td></td>
<td>MPa</td>
<td>55</td>
<td>61</td>
<td>27</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>Stress at yield</td>
<td>527-2/1A</td>
<td>%</td>
<td>9</td>
<td>6.5</td>
<td>25</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>Strain at yield</td>
<td>527-2/1A</td>
<td>%</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Strain at break</td>
<td>527-2/1A</td>
<td>%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>527-1/-2</td>
<td>MPa</td>
<td>2600</td>
<td>2400</td>
<td>500</td>
<td>800</td>
<td>1400</td>
</tr>
<tr>
<td>Shore hardness D</td>
<td>868</td>
<td>%</td>
<td>77</td>
<td>87</td>
<td>65</td>
<td>69</td>
<td>71</td>
</tr>
<tr>
<td>CHARPY impact strength</td>
<td>23 °C</td>
<td>kJ/m²</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>-30 °C</td>
<td>179/1eU</td>
<td>N</td>
<td>300 C</td>
<td>N</td>
<td>N</td>
<td>90 C</td>
<td>N</td>
</tr>
<tr>
<td>CHARPY notched impact strength</td>
<td>23 °C</td>
<td>kJ/m²</td>
<td>7.0</td>
<td>6.5</td>
<td>30</td>
<td>6.0</td>
<td>4.0</td>
</tr>
<tr>
<td>-30 °C</td>
<td>179/1eA</td>
<td>kJ/m²</td>
<td>6.0</td>
<td>5.5</td>
<td>30</td>
<td>6.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Data are representative values, however, they are not guaranteed minimum or maximum figures.

C = complete break  N = no break  P = partial break
VESTODUR X7396 is a resin with an exceptional low post-extrusion shrinkage, good hydrolysis resistance and high heat aging stability. Recommended for semi-tight buffering or small central core tubes.

VESTODUR X4159 is a modified polyester grade with a markedly higher flexibility, suitable where the flexibility of PA 12 secondary coatings has been insufficient. Recommended for tight buffering.

VESTAMID L1670 is a semi-crystalline PA 12 grade of low melt viscosity, exhibiting very good flow characteristics. This grade offers consistent protection of the glass fiber against microbending and strain. Recommended for tight buffering.

VESTAMID E62-S3 is a PA 12 block copolymer consisting of PA 12 segments and polyester segments. The compound exhibits high flexibility and high chemical and solvent resistance.

VESTAMID L2140 black is a PA 12 grade of high melt viscosity and excellent weatherability. Cables with a covering layer of L2140 are protected against damage from ants and termites.

Flame retardant grades are described on page 15.

| VESTODUR | | VESTAMID | | |
|---|---|---|---|---|---|---|---|
| X4159 | X9403 | L1670 | X7166 | E62-S3 | L39104 | L2140 |
| 1.26 | 1.31 | 1.01 | 1.06 | 1.01 | 1.12 | 1.02 |
| 25 | 200–205 | 175–178 | 175–178 | 175–178 |
| 10 | 30 | 60 | 20 | 36 |
| 1.7 | 1.5 | 1.3 | 2.0 | 1.4 |
| 0.35 | 0.30 | 1.4 | 1.3 | 1.5 | 1.5 |
| 27 | 30 | 45 | 47 | 24 | 27 | 45 |
| 25 | 17 | > 50 | > 50 | > 50 | > 50 | > 50 |
| 500 | 800 | 1400 | 1800 | 360 | 750 | 1400 |
| 65 | 69 | 71 | 62 | 73 |
| N | N | N | N | N | N | N |
| 30 C | 6.0 C | 4.0 C | 3.0 C | 120 P | 6.0 C | 16 C |
| 8.0 C | 2.5 C | 5.0 C | 5.0 C | 8.0 C | 3.0 C | 9.0 C |
VESTAMID and VESTODUR can be processed on most conventional single-screw extruders with a minimum L/D ratio of 24:1. Three-stage screws with feed : compression : metering zones of approximately 1:1:1 and with 2.5:1 to 3:0:1 channel depth ratios or barrier type screws (Figure 2) are preferred.

A very homogeneous melt is obtained by the use of fine mesh screen packs. The draw down ratio (DDR) of die and tube cross-sectional area should be maintained below 10:1 for loose tubes. The draw ratio balance (DRB) should be kept at 1 (Figure 3). At extrusion speeds of higher than 150m/min, the draw ratio balance, the draw down ratio and the processing temperature should be increased.

Figure 2: Screw design

Figure 3: Sleeve coating die
### 7.1 Example for processing loose tubes

**VESTODUR 3000 and 3013**

<table>
<thead>
<tr>
<th>Dimension of tubing:</th>
<th>2.5 x 1.7 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extruder:</td>
<td>45 mm/24 D barrier type screw</td>
</tr>
<tr>
<td>Crosshead:</td>
<td>die opening = 7.5 mm mandrel = 5.1 mm DRB = 1 DDR = 9:1</td>
</tr>
<tr>
<td>Temperature profile:</td>
<td>hopper = die 240 · 245 · 250 · 250 · 250 °C</td>
</tr>
<tr>
<td>Line speed:</td>
<td>150 m/min</td>
</tr>
<tr>
<td>Cooling:</td>
<td>cold water (&lt;20 °C)</td>
</tr>
</tbody>
</table>

### 7.2 Example for processing tight buffer

**VESTAMID L1670**

<table>
<thead>
<tr>
<th>Fiber diameter:</th>
<th>0.25 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extruder:</td>
<td>35 mm/24 D 3-section screw (or barrier type screw)</td>
</tr>
<tr>
<td>Crosshead:</td>
<td>die opening = 3.2 mm mandrel = 1.0 mm</td>
</tr>
<tr>
<td>Fiber tension:</td>
<td>150 g</td>
</tr>
<tr>
<td>Fiber preheating:</td>
<td>150 °C</td>
</tr>
<tr>
<td>Temperature profile:</td>
<td>all zones 210 °C</td>
</tr>
<tr>
<td>Line speed:</td>
<td>100 m/min</td>
</tr>
<tr>
<td>Cooling:</td>
<td>hot water (&gt;60 °C)</td>
</tr>
</tbody>
</table>

### 7.3 Example for processing wire coating

**VESTAMID L1670**

<table>
<thead>
<tr>
<th>Wire diameter:</th>
<th>0.4 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extruder:</td>
<td>45 mm / 24 D 3-section screw (or barrier type screw)</td>
</tr>
<tr>
<td>Insulation thickness:</td>
<td>0.1 mm</td>
</tr>
<tr>
<td>Crosshead:</td>
<td>die opening = 2.3 mm mandrel = 1.4 mm</td>
</tr>
<tr>
<td>Temperature profile:</td>
<td>hopper = die 8 x 120 °C</td>
</tr>
<tr>
<td>Vacuum:</td>
<td>250 mbar</td>
</tr>
<tr>
<td>Line speed:</td>
<td>1,800 m/min</td>
</tr>
<tr>
<td>Cooling:</td>
<td>cold water (&lt;20 °C)</td>
</tr>
</tbody>
</table>

### 7.4 Clean out

When changing dies and for brief shut-down periods (15–20 minutes), it is not necessary to lower the temperature or to purge the machine. When shutting down for cleaning, the extruder should be purged with polypropylene or high density polyethylene until the barrel is empty. Remove screens and clean breaker plate, crosshead and mandrel.

---

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VESTAMID and VESTODUR compounds are delivered dry, in airtight, moisture-proof bags or in octabins. Therefore, further drying before processing is not required. Both compounds will absorb moisture from the atmosphere. The amount absorbed depends on the ambient conditions of the area where it is used. A dehumidifying hopper dryer is, therefore, recommended during processing. The temperature may be set at 60 to 80 °C.

Granules from opened or damaged bags must be dried for 2 hours minimum at 120–125 °C for VESTODUR and at 90–100 °C for VESTAMID in a desiccant type dryer, or on trays in layers not exceeding 2–3 cm thickness for about 5 hours at a temperature of 120 °C for VESTODUR and 90–100 °C for VESTAMID in a circulating air oven. The moisture content must not exceed 0.05% for VESTODUR resp. 0.10% for VESTAMID.

In Japan and Southeast Asia PA 12 is also sold under the trademark DAIAMID®. Daicel-Degussa, a joint venture company founded by Daicel Chemical Industries, Ltd. and Degussa AG, manufactures DAIAMID with the same grade designation as VESTAMID.
VESTAMID L1670 is a low-viscosity compound available in natural color or colored. It can be processed into very thin copper wire insulation with very high haul-off extrusion speeds.

VESTAMID X7166 is a non-halogenated, phosphorus-free, self-extinguishing PA 12 compound of flammability class V-0 according to UL 94 and a LOI >32%, optimized for thin wire insulation.

VESTAMID LX9104 is a halogen-free flame-retardant and flexible PA 12 compound of flammability class V-0 at 0.8mm according to UL 94 and a LOI of 28%.

VESTODUR X9403 is a non-halogenated, self-extinguishing PBT compound of flammability class V-2 according to UL 94. The material can be used for highly flexible cables.

VESTAMID L2140 black is a high-viscosity, heat- and light-stabilized compound for cable sheathing. Telephone operators in Australia, India, Brazil and Thailand have specified PA 12 compounds as a protective cladding for underground cables. In addition to its particularly high weathering resistance, rigid VESTAMID compounds have a high degree of anti- and termite-resistance. The high toughness protects telecommunication cables also against attacks by rodents.

Special compounds for jacketing of polymer optical fibers (POF) are available on request. Please contact our Technical Marketing.

VESTAMID and VESTODUR are not only used to protect optical fibers, these engineering thermoplastics are also processed into copper wire insulation and outer-sheatings of anti-, termite- and rodent-resistant cables.

VESTAMID grades are distinguished by their:
- exceptional high mechanical strength
- outstanding chemical resistance
- low coefficient of sliding friction
- exceptional abrasion resistance
- excellent weathering resistance

9 Other Applications

Growing intensity of rats:

PE sheath after 3 days
PA 12 sheath after 6 days
Please involve us in solving your problems, give us a call.
Your contact partners:

Jürgen Eickholt
Phone +49 (0)2365/49-5720
Fax +49 (0)2365/49-5992
e-mail: juergen.eickholt@degussa.com

Uwe Kannengießer
Phone +49 (0)2365/49-5720
Fax +49 (0)2365/49-5992
e-mail: uwe.kannengiesser@degussa.com

System solutions from the planning stage …

- Advice on materials.
- Support in processing technology.
- Analyses and tests.
- Issues concerning standardization and approvals.
- Availability of material samples.
- Recommendation of suitable suppliers for machines or parts.
- Safety questions.
- Intensive project support through close co-operation.
- Products of a consistently high quality standard (ISO 9001).

… to the production stage

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Degussa AG
High Performance Polymers
45764 MARL · GERMANY
Phone +49 (0)2365/49-9878
Fax +49 (0)2365/49-5992
www.degussa-hpp.com