PEBA: TPE Materials for High Performance Applications

Nick DeLuca
Arkema
• What is Pebax
  → Chemistry
What is Pebax®?

ThermoPlastic Elastomer

Poly Ether Block Amide (eXTreme)

1. Polyamide rigid segment: semi-crystalline with clear melting point (133°C ↔ 172°C)

2. Polyether soft segment with a very low glass transition temperature (-60°C) providing exceptional properties at low temperature

=> 1 & 2 are phase separated => Two glass transitions (Tg)

HOOC - PA - COOH
Dicarboxylic Polyamide

+ HO - PE - OH
Polyether diol

Molten state polycondensation

Effect of PE/PA ratio on the flexibility of the polymer
Pebax® general properties

Two families depending on blocks types:

**Polyamide blocks:**
- PA12 → Mechanical properties
- PA11 → Mechanical properties + Biobased
- PA6 → PA6 compatibility

**Polyether blocks:**
- Hydrophobic
- Hydrophilic

**Hydrophobic Pebax®**: Polyamide + Hydrophobic Polyether
- Used for their mechanical properties
- Applications: Sport, mechanical and automotive industry, E&E, processing aid.

**Hydrophilic Pebax®**: Polyamide + Hydrophilic Polyether
- Used for their breathable and antistatic properties
- Applications: Breathable films, antistatic additives
Pebax® Nomenclature

**5533 SA 01**

- **Shore D hardness**
- **Series**
  - 13 = PA 6
  - 33 = PA12
  - 53 = PA11
- **Additives**
  - 0 = all use
  - 7 = black antistatic
- **Stabilization Package**
  - SA = none
  - SP = Heat & Light Stabilizer
  - SD = SP + mold release

**Special grades** have been developed to satisfy **specific needs**

- MV 1074 Antistatic
- MH 1657 Antistatic
- MP 1878 PA6 Modification

Pebax Clear is also available

*SPE ANTEC® Anaheim 2017 / 2347*
• What is Pebax?
  → Main properties (hydrophobic)
Pebax® range

**Lightness**
20% lighter than TPU or COPE.

**Flexibility**
From soft rubber-like behavior to rigid nylon-like behavior.

**Elasticity**
Best flex fatigue resistance & highest energy return.

**Weather resistance**
Best UV resistance, best chemical resistance.

**Processability**
10-30% shorter cycle time than TPU or COPE.
### Density

<table>
<thead>
<tr>
<th></th>
<th>COPE Polyester Elastomers</th>
<th>TPU Thermoplastic Urethanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft grades (&lt;shore D 64)</td>
<td>1.01</td>
<td>1.18 ~ 1.20</td>
</tr>
<tr>
<td>Rigid grades (&gt;shore D 64)</td>
<td>1.01</td>
<td>1.22 ~ 1.26</td>
</tr>
</tbody>
</table>

**COPE TPU Pebax® Pebax® Clear**

**Lightest weight among Thermoplastic Elastomer**

⇒ Save 20% weight
## Save energy for better performance

<table>
<thead>
<tr>
<th>Sport</th>
<th>Walking</th>
<th>Soccer game</th>
<th>Marathon</th>
<th>Mountain climbing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time/speed</strong></td>
<td>2h, 5km/h</td>
<td>90min, 10km/h</td>
<td>3h, 14km/h</td>
<td>8h, 3km/h</td>
</tr>
<tr>
<td><strong>Average length of 1 step</strong></td>
<td>0.8m</td>
<td>1.0m</td>
<td>1.2m</td>
<td>0.6m</td>
</tr>
<tr>
<td><strong>Total number of steps</strong></td>
<td>6250</td>
<td>15000</td>
<td>35000</td>
<td>40000</td>
</tr>
<tr>
<td><strong>TPU part</strong></td>
<td>50g</td>
<td>100g</td>
<td>30g</td>
<td>1000g</td>
</tr>
<tr>
<td><strong>Pebax® part (-20%)</strong></td>
<td>40g</td>
<td>80g</td>
<td>24g</td>
<td>800g</td>
</tr>
<tr>
<td><strong>Total weight spared</strong></td>
<td>62.5kg</td>
<td>300kg</td>
<td>252kg</td>
<td>8000kg!!</td>
</tr>
</tbody>
</table>

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Lightest weight – Save energy!

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**Wide range of hardness:**

- **Styrenics**
- **TPO**
  - 2 transparent grades
  - 7 biobased grades
- **PolyEther Block Esters (COPE)**
- **Thermoplastic Polyurethane (TPU)**
- **Polyamides**
- **Rubber**

**Hardness Range:**

- Shore A: 90A, 85A, 75A, 66A, 50A, 10A
- Shore D: 80D, 72D, 70D, 63D, 55D, 40D, 35D, 25D

**Widest and well-balanced range**

R&D work to extend the range on both sides.
### Pebax® General Properties

#### Pebax®: A full Range of Moduli (ASTM D 790, 23°C)

<table>
<thead>
<tr>
<th>Material</th>
<th>Modulus (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pebax® Clear 300</td>
<td>12, 9</td>
</tr>
<tr>
<td>pebax® Clear 400</td>
<td>21, 17</td>
</tr>
<tr>
<td>pebax® 25R53</td>
<td>86, 80</td>
</tr>
<tr>
<td>pebax® 35R53</td>
<td>170, 150</td>
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<tr>
<td>pebax® 40R53</td>
<td>212, 285</td>
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<tr>
<td>pebax® 55R53 Clear 300</td>
<td>390, 340</td>
</tr>
<tr>
<td>pebax® 63R53 Clear 400</td>
<td>513</td>
</tr>
<tr>
<td>pebax® 70R53 Clear 400</td>
<td>560</td>
</tr>
<tr>
<td>pebax® 72R53</td>
<td>633, 723</td>
</tr>
<tr>
<td>pebax® 80R53</td>
<td>723, 850</td>
</tr>
</tbody>
</table>

**Rubber - BEHAVIOR OF THE MATERIAL - Polyamide**

*Arkema INNOVATIVE CHEMISTRY*
Performance at low temperature: limited rigidity increase – keep its flexibility !!

According to standard ASTM D 1043 at 23°C

Mechanical Properties Stability at low temperature make Pebax® the polymer of choice for high performance Winter Sports applications.
Cold Impact

Cold impact conditions

- IZOD @ -40°C
- Standard D 256 A

Superior cold impact resistance at low temperature make of Pebax® the polymer of choice for high performance Winter Sports applications.
Excellent processability of **Pebax®**

- Injection molding
- Extrusion (cast film, blown film, sheet, tube...) down to 10 microns.
- Assembly process: overmolding and coextrusion

Productivity increase by **Pebax®**

- Wide processing window among TPE
- Good flowability
- Possibility to inject extremely thin part (0.8mm)
- Shorter cycle time than TPU
- Higher recyclability than TPU

► **Cycle time reduced by 10 to 30 %**

*Compare to TPU & COPE, according to our major customers on sports, automotive & industrial markets*
Assembling possibilities

Overmolding possibilities
- Hard/Soft combination
- Better aesthetics
- The cleanest assembling technology
- Avoid costly assembling

Examples of combination
- Excellent adhesion between Pebax grades
- Overmolding of Rilsan® on Pebax® grades
- Overmolding of Rilsan® Clear with Pebax® grades
- Coextrusion of Rilsan® and Pebax®
Flex fatigue for sports shoes

**UV + Ross flex test**

1. **UV test:**
   - 2 weeks
   - 60°C, 0.68W/m² at 340nm

2. **Ross flex test:**
   - -30°C, angle 90°, 100cycles/min
   - 150,000 cycles

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**Graph:**

- **Number of cycles until breaking**
- **COPE 63ShD:** 2 cycles
- **TPU:** 900 cycles
- **Pebax® Clear 400:** 145,000 cycles
- **Pebax® 7033:** No break

**Materials:**
- Competitor PEBA63D
- COPE 63ShD
- TPU 64D
- Pebax® 7033
- Pebax® Clear 400

**SPE ANTEC® Anaheim 2017 / 2358**
Peixax® “Spring effect”

A qualitative property well known from our customers in Sport Market

“Spring Effect” of Peixax®

Arkema developed a specific test to quantify superior Peixax® “spring effect” : its “snap back” behaviour
Snap back behaviour and Spring effect of Pebax®

- TPU more dissipative than Pebax®: for a same rigidity => same frequency of oscillation but a higher vibration dampening

**Snap back behavior:**

- Pebax®
  - E=206MPa, tan δ ~ 0.07
- TPU
  - E=195MPa, tan δ ~ 0.14

“Spring Effect” of Pebax®
Pebax® dynamic properties - conclusion

- Combined with a low density, a good processing and a good mechanical behavior.

- Pebax® materials have Excellent Dynamic properties:
  - low tan delta
  - low hysteresis
  - superior spring effect
  - good fatigue behavior

On a large range of temperatures and frequencies thanks to their specific chemical structure and phase organization (2 Tg)
Pebax® in Sport applications

- **Sport shoe**
  - Outsoles for running, tennis
  - Torsion systems
  - Ankle supports
  - Airbags

- **Studded shoes**
  - Outsoles for soccer, rugby, cycling...

- **Mountain and ski boots**
  - Shell and cuff of Telemark boots
  - Outsoles of Nordic ski boots

- **Others**
  - Golf balls
  - Diving equipment

- ✔ Support and energy return
- ✔ Flex fatigue resistance
- ✔ Stability of the properties vs T°C and RH
- ✔ Lowest weight
- ✔ Complex design
- ✔ UV Resistance
Pebax® General applications

- **Sports, Leisure**
  - Sport shoes, ski boots...
  - Toys, Arrow vanes

- **Industry**
  - Conveying and transmission Belts
  - Silent gears
  - Electronics
  - Automotive
  - Active molecule carrier
  - Breathable films

- **Medical**
  - Catheters, Dental floss

- **Antistatic**
Belting

1. Power Transmission Belts
   - Mail sorting, milling equipment, lumber industry

   ✓ Adhesion Belt
     - Flat
     - V belt or Poly-V
     - Round

   ✓ Timing Belt (synchronous)

2. Conveying Belts
   ✓ Flat
   ✓ Modular (Caterpillar type)
Composite Belt Structure with Pebax®

Flat Power Transmission Belt

Pebax® Grades used: 2533 SP01, 3533 SP01, 4033 SP01, 5533SP01, 6333 SP01

Pebax®: Intermediate layer

- Mechanical properties
- Good adhesion to Fabric (Traction layer) and bondability to X-NBR Rubber (Surface layer) without glue.
- Weldability of the belt by heat melting of PEBAX® to get a flex-proof junction.
Pebax® for High Performance Belting

Key Properties

- **Low Density ➔ Increased speeds**
- **Dynamic properties ➔ Low hysteresis**
  - ➔ Low noise and vibrations
  - ➔ Low heat buildup
  - ➔ Low creep and relaxation
- **Flexural Properties ➔ Good flexibility around small pulley**
- **Adhesion ➔ Easier assembly and repair**
- **Chemical Resistance ➔ Withstand cleaning cycles or harsh environments**
- **Consistent Mech. Properties over wide temp. range ➔ Versatility**
Why Pebax®?
- Improved processability
- Good friction coefficient
- Good bonding (mechanical insert)
- Absence of plasticizer
- Soft touch
- Good temperature stability
- Chemical resistance
Excellent Processing – Hook & Loop Fasteners

- High Tensile Strength
- Good Fatigue Resistance
- Good Energy Return
- Stitchability
- Feels like textile

VELCRO® tie bands

Standard monofilament technique

Molded PEBAX
PA6 Modification

● Application
  ● Modification of PA6 films
    ● packaging
    ● vacuum bags

● Benefits
  ● Improved flexibility
  ● Improved tear resistance
  ● Improved pinhole resistance
Flexibilizer for PA6

Flex modulus as a function of Pebax content in PA6 film

wt% Pebax 5513
Improved Tear Resistance for PA6

- Parallel to the flow
- Perpendicular to the flow

<table>
<thead>
<tr>
<th>Material</th>
<th>Tear Strength (cN) Parallel</th>
<th>Tear Strength (cN) Perpendicular</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA6</td>
<td>64</td>
<td>67</td>
</tr>
<tr>
<td>5% Pebax® 5513</td>
<td>74</td>
<td>85</td>
</tr>
<tr>
<td>10% Pebax® 5513</td>
<td>96</td>
<td>98</td>
</tr>
<tr>
<td>15% Pebax® 5513</td>
<td>98</td>
<td>100</td>
</tr>
</tbody>
</table>

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Active molecules carrier (Pebax® 2533)

Main applications
✓ Perfumed lemon pannels for dishwashing
✓ Support charged with Insecticide
✓ Perfumed granules for cars
✓ Perfumed dental floss

Key properties
✓ Consistency of the substances released
✓ High level of absorption
✓ Uniform release over time
✓ Long lasting effect
✓ Easy processability and recycling

![Graph showing percentage of lavender over time]

PEBA® 2533
CELLULOSE
EVA 2825

DAYS

% LAVANDER

0 10 20 30 40 50 60 70

Arkema Innovative Chemistry

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→ Main properties (hydrophilic)
→ Applications
  → Antistatic
  → Breathable
ANTISTATIC ADDITIVES

ANTISTATIC ADDITIVES

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PLASTICS CONDUCTIVITY SPECTRUM

Conductive

Static Dissipative

Antistatic

Insulative

10^6

10^{10}

10^{14}
DISPERSION-BASED PERFORMANCE

Antistatic performance is related to:
- Morphology (continuous network)
- Additive content

![Graph showing surface resistance vs. antistatic additive content](image)

- 10%
- 15%
- 20%
- 25%
- 35%
PERMANENT ANTISTATIC PERFORMANCE

Pebax® additive…
- Forms 3D network in the matrix
- Does NOT migrate to surface
- Produces immediate & permanent antistatic effect

Pebax® additive…
- Maintains antistatic effect at high/low humidity
- Is much less sensitive to humidity than chemical agents (agents can be very inefficient)
PEBAX® ANTISTATIC PRODUCT RANGE

**PA12**
- MV Series
  - MV 1074 SA 01
  - MV 1074 SP 01
  - MV 1074 SA 01 MED
  - MV 2080

**PA6**
- MH Series
  - MH 1657
  - MH 2030

**??**
- MF Series
  - MF 5010
  - MF 5020
  - MF 5030
  - MF 5040
  - MF 5070
  - MF 5080

**PA11**
- Bio-based
  - 30R51 SA 01

**11 grades available**
- A wide set of technical solutions
- Different levels of performance
- Wide range of processing temperatures
- Compatibility with many host polymers
  - PE, PP, ABS, PS, PC blends, PMMA, and more…

Food contact approval
USP Class VI approval
UV stabilization
## RANGE OVERVIEW

<table>
<thead>
<tr>
<th></th>
<th>PE</th>
<th>PP</th>
<th>ABS, PS, HIPS</th>
<th>PC blends, PBT, PET</th>
<th>PMMA</th>
<th>PA</th>
<th>POM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV 1074 MV 2080</td>
<td>Injection molding (+) 10 – 20%</td>
<td>Injection molding (+) 10 – 20%</td>
<td></td>
<td></td>
<td>Injection molding (+) 10 – 20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MH 1657 MH 2030</td>
<td>Injection molding (+) 10 – 20%</td>
<td>Injection molding (+) 10 – 20%</td>
<td>Injection molding (++) Sheet extrusion (++) 10 – 25%</td>
<td></td>
<td></td>
<td>Injection molding (+) 10 – 20%</td>
<td></td>
</tr>
<tr>
<td>30 R 51</td>
<td></td>
<td></td>
<td></td>
<td>Injection molding (++) Sheet extrusion (++) 10 – 20%</td>
<td></td>
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<tr>
<td>MF 5010</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Injection molding (++) 7 – 20%</td>
<td></td>
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<tr>
<td>MF 5020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Injection molding (++) 8 – 20% Sheet extrusion (++) 15 – 30%</td>
<td></td>
</tr>
<tr>
<td>MF 5030</td>
<td>Injection molding (++) 7 – 20%</td>
<td>Injection molding (++) 7 – 20%</td>
<td>Injection molding (+) 10 – 20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF 5040</td>
<td>Blow molding (++) 25 – 35%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PEBAX® ANTISTATIC APPLICATIONS

- Storage containers
- Copy machines, printers
- Clean-room & anti-dust
- Electronics packaging
- Electronics equipment components
- Fibers
BREATHABLE FILM
Breathable Film Technology

What does breathability mean?

- **Impervious** to liquids but **permeable** to gases

Waterproof but permeable to water vapor
Breathable Film Morphology

Macro-morphologies

- **Non perforated**
  - **Monolithic surface** → waterproof behavior based on relative humidity gradient in one direction
  - **Hydrophilic films** → water vapor molecules transmitted through the film
  - **Molecular transport**

- **Perforated**
  - **Perforated or micro-porous film** →
    - water vapor molecules pass through holes from both directions
    - independent of relative humidity gradient
    - physical transport
Breathable Portfolio

- Breathable Pebax® resins
  - MV 1074
  - MH 1657
  - MV 3000
  - MV 1041

- Pebax® / Lotryl® blends

  - Why blend?
    - Processing improvements
    - Fine tune MVTR
    - Lower cost
Breathability Measurements

**Standards and Methods**

Breathability = Moisture Vapor Transmission Rate (MVTR) in g/m²/24h
Construction market: MVTR (ASTM E96E) expressed in perms (1 perm ~ 7 g/m²/24h)

**ASTM E 96 Standard**

- **ASTM E 96 B**
  - (Water method)
- **ASTM E 96 E**
  - (Desiccant method)
- **ASTM E 96 BW**
  - (Inverted method)

**MVTR Measurements**

MVTR value depends on the film thickness, the method and the conditions used
Set up conditions: temperature (T) and relative humidity (%RH)
**MVTR Values**

Breathability values depending on the method (@ 15µm)

<table>
<thead>
<tr>
<th>Grades</th>
<th>ASTM E-96 Method</th>
<th>50% RH, 23°C</th>
<th>50% RH, 38°C</th>
<th>90% RH, 23°C</th>
<th>90% RH, 38°C</th>
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</thead>
<tbody>
<tr>
<td>MV3000</td>
<td>B-Water Method</td>
<td>1,900</td>
<td>2,900</td>
<td>650</td>
<td>1,300</td>
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<tr>
<td></td>
<td>E-Dessicant Method</td>
<td>300</td>
<td>1,600</td>
<td>1,500</td>
<td>3,100</td>
</tr>
<tr>
<td></td>
<td>BW-Water Invert Method</td>
<td>13,700</td>
<td>19,000</td>
<td>3,300</td>
<td>6,200</td>
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<tr>
<td>MH1657</td>
<td>B-Water Method</td>
<td>1,900</td>
<td>4,000</td>
<td>650</td>
<td>1,300</td>
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<tr>
<td></td>
<td>E-Dessicant Method</td>
<td>500</td>
<td>1,600</td>
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<td></td>
<td>BW-Water Invert Method</td>
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<tr>
<td>MV1074</td>
<td>B-Water Method</td>
<td>1,900</td>
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<td>19,000</td>
<td>4,400</td>
<td>6,200</td>
</tr>
</tbody>
</table>

Grade Selection

- Pebax MV3000: standard grade, soft touch, easier to process, translucent
- Pebax MV1074: high breathablity, good sealability, very good transparency
- Pebax MH1657: high T resistance, better melt strength, high breathability
Markets for Breathable Films

Disposable Applications

Medical & healthcare products
- Surgical gowns
- Bed encasement
- Surgical drapes, masks, gloves
- Diapers
- Mattress and pillow protectors
- Protective work wear garments
- Packaging (desiccant, produce)

Durable Applications

Housewrap membranes
Carpet pads
Equipment covers
Performance textiles
Mattress and pillow protectors
Shoes
Selective membranes
Breathable Market – Housewrap

Housewrap Facts

- Every new home needs to be built with housewrap
- A housewrap needs to have an MVTR of 5 perm or greater
- Canadian homes cannot be built with perforated housewraps
- Tyvek is not the only housewrap
- Brands are regional

Key Parameters

- >5 perm MVTR after lamination to a PP or Polyester nonwoven
- Good processability
- Good durability and adhesion to nonwoven substrate
Breathable Market – Medical Gowns

Breathable laminate

- optimum comfort
- barrier performance
- resistance to liquid penetration (ASTM F1671)

Advantages of Pebax®

- High performance gown - high breathability and also, lightweight
- Can be laminated → eliminates the need for adhesives → increases efficiency
- Low noise and very soft laminate
- Better sealability
Advantages of Monolithic over Microporous

**Monolithic films**
- Adjustable MVTR (product performance, thickness, relative humidity)
- No loss in performance over time (no plugging)
- Excellent liquid and odor barrier
- Better perception on the market → more sophisticated technology

**Microporous films**
- A narrow range of MVTR
- Variable performance overtime, holes can be plugged
- Not a barrier to liquids (water) → Heat loss → Mold due to water condensation
**Breathable applications**

Compact surface → **water proof**
Hydrophilic Pebax → **moisture vapor permeability**

- **Main applications**
  - Medical: Disposable surgery gown or gloves
  - Roofing films for individual houses or Agricultural films for fruit preservation

- **Key properties**
  - Barrier against liquids and bacteria
  - Toughness
  - Comply with USP class VI (SA grades)
  - High tear resistance
  - Extrudable in thin films
  - Good weather resistance