An ultra-strong performance film.
From ballistic shields and airfreight cargo containers to laminated yacht sails and loudspeaker cones, Teijin Aramid’s Endumax® adds value – by protecting, supporting and empowering – in key applications across a wide range of industries. Endumax®, which is made from a special type of Ultra High Molecular Weight Polyethylene (UHMWPE), raises performance in crucial areas. So – whether a product needs to deliver extra strength, or higher ballistic or abrasion resistance – even in the most challenging conditions, Endumax® can deliver key improvements.
Endumax® allows manufacturers to transform an ordinary product into an extraordinary one. In particular, products that integrate Endumax® offer next-level performance across key criteria, including their strength-to-weight ratio and their resistance to creep and chemicals. Because of this, with Endumax®, our customers create more durable solutions that offer stable performance for many years.

Ben Rolink | Sales and Marketing Manager Endumax®
Teijin Aramid

“We with Endumax, our customers create more durable solutions that offer stable performance for many years.”

What is Endumax®?

Developed by Teijin Aramid’s materials science experts, and brought to the market in 2012, Endumax® is a high-performance UHMWPE material. Its unique physical and chemical structure makes it – weight for weight – 11 times stronger than steel. What’s more, this unique structure enables a range of superlative performance properties, including new levels of resistance to impact, abrasion, chemicals and high temperatures. In this way, Endumax® can reliably transform normal products into extraordinary ones. Over time, Endumax® has become a go-to solution across industries and around the world. That’s because this versatile material can be easily adapted to deliver high performance across a range of formats that meet different requirements.

In fact, our best Endumax® solutions are not only developed for our customers, but with our customers. As such, customer insights drive our innovation, and make sure that our research and development is purposeful and relevant.

What are the key properties of Endumax®?

- Superb strength-to-weight capabilities
- Extremely high modulus
- High abrasion resistance
- High impact resistance
- High UV resistance
- High chemical resistance
- Superior thermal-aging performance
- No brittleness at cryogenic temperatures

What are the key properties of Endumax®?

Endumax® allows manufacturers to transform an ordinary product into an extraordinary one. In particular, products that integrate Endumax® offer next-level performance across key criteria, including their strength-to-weight ratio and their resistance to creep and chemicals. Because of this, with Endumax®, our customers create more durable solutions that offer stable performance for many years.

Through its excellent performance, Endumax® adds value to a wide range of applications, driving safety and protection for real people. In short, I’m very proud to contribute to the Endumax® journey through my work.”
A unique production process

The unique properties of Endumax® are enabled by a unique production process. To start with, UHMWPE is compacted into an extremely rigid sheet. Using our special technology and equipment, this sheet is rolled and stretched to the right thickness, which is between 40 and 60 μm. In this way, the long polymer chains are aligned, giving Endumax® a unique set of mechanical properties. From here, films can be split to create narrower films or laid next to each other to form laminates with a maximum width of 1.6 m.

In line with our wider corporate responsibilities, every step of the process is undertaken with a strong respect for the environment. Specifically, unlike with other commercially available UHMWPE materials, the whole production process is solvent free. As a last step, the manufacturing process is rounded off with an intensive quality check.

“\[Customer quote\] I'm proud to be able to offer our customers the very best in UHMWPE technology. Our customers deserve the best – with Endumax®, I know that’s exactly what they'll get.”

Ramon van Rooij | Technical Sales Support
Teijin Aramid
What types of Endumax® are available?

Endumax® delivers high performance to a wide range of applications and different industries in two main formats: Endumax® film TA23 and Endumax® cross-ply SHIELD.

Endumax® film TA23 is available with a standard thickness of approximately 50 - 60 µm and in three main widths: 2 mm, 4 mm and 133 mm.

Endumax® SHIELD XF23 and Endumax® SHIELD XF33 are ready to stack and consolidate to plates, helmets or other shaped parts of varying thickness, offering excellent stiffness and outstanding ballistic protection. Compared to Endumax® SHIELD XF23, the improved Endumax® SHIELD XF33 has an even lower areal density, enabling weight reductions leading to enhanced agility and maneuverability. Endumax® SHIELD XF23 is supplied in standard lengths of 150 m and Endumax® SHIELD XF33 is supplied in standard lengths of 200 m. Both are supplied at a standard width of 1.6 m, wound on cardboard tubes.

Target properties of Endumax® film TA23

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>2 mm</th>
<th>4 mm</th>
<th>133 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear density</td>
<td>dtex (denier)</td>
<td>950 (855)</td>
<td>1,900 (1,710)</td>
<td>62,000 (55,800)</td>
</tr>
<tr>
<td>Breaking tenacity</td>
<td>N/tex (g/den)</td>
<td>2.2 (23)</td>
<td>2.1 (24)</td>
<td>2 (23)</td>
</tr>
<tr>
<td>Breaking strength</td>
<td>N (lbs)</td>
<td>208 (46.8)</td>
<td>400 (89.9)</td>
<td>12,400 (2,788)</td>
</tr>
<tr>
<td>Modulus</td>
<td>N/tex (g/den)</td>
<td>188 (2,129)</td>
<td>175 (1,981)</td>
<td>172 (1,947)</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>%</td>
<td>1.7</td>
<td>1.7</td>
<td>1.7</td>
</tr>
</tbody>
</table>

That's not all

Some applications for particular industries require specific textual properties. That's why Endumax® can be supplied with the following optional extras: woven structures, color, pressure-sensitive adhesives, thermoplastic layers and/or scratch-resistant layers. We also deliver twisted film in various constructions.

Endumax® Cross-ply SHIELD

Endumax® SHIELD XF23 and Endumax® SHIELD XF33 are ready to stack and consolidate to plates, helmets or other shaped parts of varying thickness, offering excellent stiffness and outstanding ballistic protection. Compared to Endumax® SHIELD XF23, the improved Endumax® SHIELD XF33 has an even lower areal density, enabling weight reductions leading to enhanced agility and maneuverability. Endumax® SHIELD XF23 is supplied in standard lengths of 150 m and Endumax® SHIELD XF33 is supplied in standard lengths of 200 m. Both are supplied at a standard width of 1.6 m, wound on cardboard tubes.

Target properties of Endumax® film TA23

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>SHIELD XF23</th>
<th>SHIELD XF33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areal density</td>
<td>g/m² (oz/yd²)</td>
<td>198 (5.84)</td>
<td>146 (4.3)</td>
</tr>
<tr>
<td>Ballistic performance (v50)*</td>
<td>m/s (ft/s)</td>
<td>≥ 400 (1,312)*</td>
<td>≥ 400 (1,312)**</td>
</tr>
<tr>
<td>Length</td>
<td>m (yards)</td>
<td>150 (164)</td>
<td>200 (218)</td>
</tr>
<tr>
<td>Visual defects</td>
<td>Defects / meter</td>
<td>≤ 0.1</td>
<td>≤ 0.1</td>
</tr>
</tbody>
</table>

* The V50 test is performed with a 9 mm DM41 bullet. The Endumax® SHIELD XF23 test pack contains 18 layers, it is pressed according to our handling recommendations and the shot is fired accordance with the Teijin Aramid test method (HE3.04.01).

** The V50 test is performed with a 9 mm DM41 bullet. The test package of Endumax® SHIELD XF33 contains 21 layers, it is pressed according to our handling recommendations and shot according to our Teijin Aramid test method (HE3.04.01).
Different formats, same outstanding properties

**Extremely high modulus**
For a material of low density, Endumax® has an unparalleled high modulus, enabling performance that is above and beyond other reinforcement materials.

**Chemical and fire resistance**
The unique chemical and physical structure of Endumax® enables performance even under challenging conditions that include exposure to fire and chemicals.

**Superior weathering**
In every weather condition, Endumax® will keep on performing from start to finish. Unlike other reinforcement yarns, Endumax® demonstrates much lower performance loss when exposed to ultraviolet light. Endumax® ensures the lifetime of its end product.

**Performance at extreme temperatures**
In particular, Endumax® performs well at extreme temperature ranges. As the graph shows, Endumax® maintains its unique properties at an extremely wide range of temperatures, meaning that products with Endumax® will keep on delivering, no matter what.

<table>
<thead>
<tr>
<th>Product</th>
<th>Modulus (GPa)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endumax® film</td>
<td>170</td>
<td>0.97</td>
</tr>
<tr>
<td>Conventional UHMWPE yarn</td>
<td>113</td>
<td>0.97</td>
</tr>
<tr>
<td>Carbon</td>
<td>230 - 540</td>
<td>1.78</td>
</tr>
<tr>
<td>Para-aramid</td>
<td>60 - 120</td>
<td>1.44</td>
</tr>
</tbody>
</table>

**Effect of temperature on strength of Endumax®**

**Weathering: Decline in strength over time – Endumax® shows best weathering**

**Table showing comparison of modulus and density**

- Endumax® film: 170 GPa, 0.97 g/cm³
- Conventional UHMWPE yarn: 113 GPa, 0.97 g/cm³
- Carbon: 230 - 540 GPa, 1.78 g/cm³
- Para-aramid: 60 - 120 GPa, 1.44 g/cm³

**Graph showing modulus and breaking tenacity over temperature**

- Tensile modulus (GPa)
- Breaking tenacity (GPa)
- Time (years)
- Temperature (°C)
How is Endumax® used?

**Aquaculture nets**

Often located far away from replacement nets or maintenance operatives, aquaculture nets need to be built to last and offer total reliability to fish farmers. Netting durability can directly impact on the netting operation quality for aquaculture farmers. Endumax® net products not only offer long-lasting performance and have low shrinkage, they also decrease bio-fouling and improve cleaning efficiency.

**Ballistic protection**

Protective composites made from Endumax® are used in insert plates, protective panels and helmets, and offer a very high energy absorption capability, giving them a remarkably high stopping power for bullets and fragments. Due to their flat form, films require the use of less matrix material than ordinary, round fibers. As a result, more active material can be used in the applications for the same weight, providing better protection.

**Cargo containers**

The excellent impact resistance of Endumax® in ballistic applications, combined with its stiffness and low weight, can easily be translated into other fields. For instance, air cargo containers need to be as light, strong and as impact resistant as possible, to protect cargoes, save fuel and reduce maintenance costs. A solution using any other product would require more material and involve extra weight. We do not limit ourselves to the delivery of films, but take it a step further to supply complete panels for this application.

“Thanks to Endumax®, the weight of our Herculight S AKE container has been brought down, while the durability of the panels has increased even further.”

Jasper van Gelder | Sales Director
Zodiac AirCargo Equipment

Read more on our website
www.teijinaramid.com/endumax
“The high performance of 4T Forte membranes is mainly due to the qualities of Teijin Aramid’s UHMWPE Endumax® film.”

Laminated sails

Endumax® film offers a very high modulus, good UV resistance, and good flex fatigue, making it very suitable for use in laminated sails. Sails made of Endumax® keep their shape even under severe forces, they are not damaged by ultra-violet light, and they can be endlessly folded and unfolded. Unlike the round shape of ordinary fibers, the flat form of Endumax® film lends itself naturally to the flat surface of sails. Fibers require the use of more resin, and carbon fibers tend to be too brittle to be used for sails, which need to remain flexible for as long as possible. Processing temperatures can be higher for Endumax® than for ordinary UHMWPE fibers.

Loudspeakers

Endumax® has excellent sound-damping properties, so in combination with its high modulus and low density, it is ideal for use in loudspeakers. Endumax® speakers will reach higher frequencies than similar sized speakers of other materials. They will also deliver more output for the same input power. Endumax® short-cut fibers are used for paper-based cones. Endumax® fabrics are used for thermoformed cones.

Ropes, cables and slings

Endumax® is an excellent choice for manufacturers of ropes and cables. Because of the film shape Endumax® is intrinsically more durable than any UHMWPE fiber. The good abrasion resistance makes it ideal for use in demanding applications like forestry. What is more, although Endumax® is flexible, its inherent stiffness means it offers high responsiveness and direct contact between payload and operator. Finally, the low weight of Endumax®-based products reduces the chance of injuries, and with their low coefficient of friction, high corrosion resistance and high UV resistance, they resist failure due to degradation and abrasion.
At Teijin Aramid, everything we do is guided by our ambition to shape a better future for generations to come. Day after day, we move forward, continuously improving our processes, our technology and ourselves. As market leaders, we drive progress through collaboration and set new standards for high performance. We connect with our customers at every level, wherever they are in the world. Because we believe that, together, we can be something bigger. Together, we can challenge conformity.

From automotive and oil & gas, to civil engineering, ballistic protection and beyond, our products are empowering excellence in diverse markets and applications around the globe. By enabling lighter, stronger and more resistant materials. And by taking durability, protection and efficiency to new levels. Whether you choose Twaron®, Teijinconex®, Technora® or Endumax®, our high-performance materials are an enduring guarantee of reliability. You can be sure of that.

For more information
Please e-mail us at:
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www.teijinaramid.com/endumax