Innovations in ePTFE Fiber Technology:
New Capabilities, New Applications, New Opportunities

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The amazing polymeric material, polytetrafluoroethylene (PTFE) was discovered by Dr. Roy Plunkett in 1938 while working at DuPont. Due to the molecular bonding within the polymer chains, PTFE withstands attack from the harshest chemicals — concentrated acids and bases alike. PTFE can be used over a very wide temperature range and has a constant use temperature in excess of 250°C. It has a very low coefficient of friction, is not affected by UV radiation, and is biocompatible.

PTFE has found numerous commercial uses over many years — non-stick cookware, implantable medical devices, apparel, electronics, chemical processes and automotive products, just to name a few. New, exciting applications that take advantage of PTFE’s unique properties continue to emerge. In today’s technology-driven markets that demand more and more performance, PTFE is as popular as ever, whether it is used as a coating, membrane, tape, sheet, tube, or fiber.

In 1957, Bob Gore, a sophomore at the University of Delaware, suggested the use of PTFE tape to insulate wire. Tests by Bill Gore showed that the tape offered significant advantages over earlier insulation methods. In 1958, Bill Gore began W. L. Gore & Associates, Inc., with MULTI-TET® insulated wire and cable as its first product. In 1969, Bob Gore discovered expanded polytetrafluoroethylene (ePTFE) which was introduced to the world under the trademark, GORE-TEX®. Over the past few years, the ePTFE Fiber Research Group of W. L. Gore & Associates has developed several technologies to deliver the broadest property range of ePTFE fibers. By focusing research on improving specific physical properties important to
its customers, Gore is expanding existing applications and developing new functionality for these unique GORE™ ePTFE fibers.

This paper summarizes the latest innovations, new applications and future development paths for ePTFE fiber technology, in an attempt to share our excitement about a new family of GORE™ ePTFE fibers that transform products from the ordinary to the extraordinary. At W. L. Gore & Associates, we are very excited about our new family of fibers — they were 70 years in the making!

**PTFE Fibers — Processes and Properties**

Commercial PTFE fiber is available in two main forms: a matrix-spun fiber and a paste-extruded fiber. In a matrix-spun fiber, PTFE is processed using a cellulose binder that is subsequently volatilized, resulting in a characteristic brown PTFE fiber. Inherent properties from this material are similar to generic PTFE, but these fibers are relatively weak at 1–2g/d (≤55ksi) at ambient temperatures, have very poor tensile strength at high temperatures, and are dimensionally unstable at high temperatures with excessive shrinkage (10–20%). In the paste extrusion process, PTFE resin is processed into membrane, tape, and fibers by combining extrusion and thermal stretch processes. These materials are produced under very different manufacturing processes compared to those of the matrix-spun fiber and are referred to as expanded PTFE (ePTFE) materials. The extrusion process typically delivers much better tensile performance (up to 4g/d or 110ksi), with lower shrinkage (3–5%) than that of the matrix-spun PTFE fiber. Due to the inherent stability of PTFE, its resistance to chemical, thermal, UV attack and its good abrasion resistance/low friction attributes, both matrix-spun and paste-extruded PTFE fibers are valuable in a wide range of applications, including filtration (woven fabrics, scrim, sewing threads), marine awnings/sewing threads, bearings, gaskets, and dental floss.
So what’s really NEW in ePTFE Fiber Technology?
For the first time:

NEW 100% ePTFE Fabrics with AMAZING Dimensional Stability.
Due to the inherent low coefficient of friction of ePTFE fibers, fabrics containing these fibers have suffered from significant instability. This results in fabrics which have inconsistent spacings/pore sizes, poor fray resistance and severe handling issues. To partly address these issues, solutions typically include incorporating additional fibers to increase weave density, resulting in significant fabric weight increases and reduced open area/spacing. These properties are not desirable in many application areas where ePTFE fabrics would otherwise be highly desirable for their thermal and chemical properties e.g. precision filtration meshes and membrane reinforcement or support fabrics. Using a patent-pending technology developed by W.L. Gore & Associates, highly stable 100% ePTFE fabrics are now being developed for the first time, in a wide range of weave designs from open support meshes to filtration fabrics, without the need for additional fiber incorporation. Key property benefits from this new ePTFE fabric technology include more consistent spacing control, excellent fray resistance and minimal shrinkage. Figure 1 shows a scanning electron micrograph of 100% ePTFE stabilized fabric. Using new stabilization technology, ePTFE fibers are now effectively locked into place at all fabric intersections in a 100% ePTFE weave network. Figure 2 highlights the greater thermal stability (reduced shrinkage) of GORE™ ePTFE fabrics when compared with competitive high-performance fiber meshes.
Figure 1: New stabilized 100% ePTFE fabrics

Figure 2: Thermal stability improvements of GORE™ ePTFE fabrics vs. competitor fabrics.
NEW 100% ePTFE Fibers for EXTREME Abrasive Environments

For those applications which demand the ultimate abrasion resistance in an ePTFE fiber, Gore has developed a new family of highly abrasion resistant ePTFE fibers. Although abrasion resistance is good in all GORE™ ePTFE fibers, certain applications and processes demand enhanced abrasion resistance. To meet this need, textured 100% ePTFE fibers have been developed for specific applications where high abrasion resistance is critical. Figure 3 highlights the abrasion differences between ePTFE fibers during an extreme 24 hour abrasion test cycle.

![Figure 3: Abrasion resistance improvements in GORE ePTFE fibers](image)

**Figure 3 : Abrasion resistance improvements in GORE ePTFE fibers**

*TOP : Non-textured GORE™ ePTFE fibers after 24hr extreme abrasion test (extensive fibrillation)*

*BOTTOM : Textured GORE™ ePTFE fibers after 24hr extreme abrasion test (no fibrillation)*

True Monofilament ePTFE fibers

Certain ePTFE fabric applications (precision filtration weaves, woven reinforcing scrims) require very consistent ePTFE fiber diameters in order to produce fabrics of precise pore size or spacing. To date, the diameter of ePTFE fibers has not been sufficiently consistent to meet this need. For fabric applications demanding precise spacing control, GORE™ ePTFE True Monofilament fibers have been developed. Figure 4 highlights the differences in diameter
consistency between standard 1200d round ePTFE fibers and that of GORE™ 1200d ePTFE True Monofilament fibers.

Figure 4: Diameter Consistency Improvements in GORE ePTFE fibers

TOP: Standard 1200d ePTFE fiber
BOTTOM: 1200d GORE™ ePTFE True Monofilament fibers

Tensile Performance of ePTFE Fibers

Customers in the high-performance fiber markets continue to demand higher performing fibers that are stronger, tougher, more abrasion-resistant, longer flex-fatigue life, etc. For example, ePTFE fiber users clearly value higher tensile performance at actual operating temperatures. To meet this need, Gore has spent several years developing a family of fibers that retain a greater proportion of tensile performance when it matters most in these applications — at the highest temperatures. GORE™ ePTFE fibers are available with tenacities in excess of 6g/d (>170ksi) and are the highest tenacity ePTFE fibers commercially available. GORE™ ePTFE fibers are truly unique. In addition to being 50% stronger at ambient temperatures than the closest competitive ePTFE fiber, GORE™ ePTFE fibers are even up to two to three times stronger at elevated temperatures (see Figure 5). Customers benefit from
using GORE™ ePTFE fibers because they are more confident that their products meet the increasing tensile demands of applications at higher temperatures and are better fit for use.

**Figure 5**: GORE™ ePTFE fibers show superior high-temperature performance

**High-Temperature Application Example**

GORE™ ePTFE fiber is currently being used as a woven reinforcing scrim in a variety of hot gas-filtration applications due to its outstanding performance at high process operating temperatures (in excess of 200°C) and in the presence of corrosive gases. Using a variety of chopped staple fibers, this scrim is subsequently felted into a non-woven filter bag. The GORE™ ePTFE fiber scrim is a critical component typically providing more than 80% of the tensile strength of the structure. Traditionally, 400-denier PTFE fiber has been used in this application, but in this very competitive market, manufacturers want to reduce the weight of the scrim without sacrificing tensile properties at the elevated operating temperatures. Gore has developed an ePTFE fiber that, at 345 denier, is approximately 14% lower in mass than the traditional PTFE fibers used in this application and provides approximately 50% higher tensile strength than the closest competitive options (see Figure 6). Using unique GORE™
ePTFE fiber technology provides improved performance while lowering material costs. Due to ongoing fiber developments in high-temperature tensile properties, Gore also produces a 200-denier ePTFE fiber that achieves tensile strengths at 200°C comparable to those of a traditional 400-denier PTFE fiber — a 50% savings in material weight.

![Figure 6: Comparison of 345d GORE™ ePTFE fiber and competitors’ 400d PTFE Fibers](image)

The performance of GORE™ ePTFE fiber is due to the ability to control and maximize the thermal stability within these fibers so that tensile properties previously unattainable are now available. Gore is continuing to develop GORE™ ePTFE fibers with higher tensile properties at elevated temperatures to meet its customers’ current and future needs.

**Modulus Performance of GORE™ ePTFE Fibers**

In some application areas, modulus — the stiffness of a given material — is the most important property considered by a manufacturer. For example, nylon has a relatively low modulus with high elongation (15–20%) — a tough rather than strong fiber, which makes it an ideal choice in a multitude of application areas from fishing line and climbing ropes to
ophthalmic sutures. In contrast, ultra-high molecular weight polyethylene (UHMWPE) fibers are chosen in part because of their very high modulus and low elongation characteristics (2–3%) — a strong rather than tough fiber, which is suitable for high-strength applications such as sails, ropes, kite lines, orthopedic sutures, and fishing lines. Polymeric fibers are typically classified as either high-modulus, strong materials or low-modulus, tough materials. To date, it has been difficult for a single fiber to bridge these classifications, which is why a high-modulus nylon is not commercially available today. To enhance the utility of ePTFE fibers, Gore has developed a series of ePTFE fibers with a broad range of tensile modulus values that cover both classifications (see Figure 7). This capability allows Gore to tailor the modulus of the ePTFE fibers to the specific needs of the application.

![Figure 7: GORE™ ePTFE fibers available in various modulus values](image)

**UHMWPE**: Ultra-high molecular weight polyethylene, **PE**: Polyester, **PVDF**: Polyvinylidene difluoride, **PP**: Polypropylene

Figure 7 also highlights an additional modulus feature for different GORE™ ePTFE fiber families — the ability to maintain a constant modulus with different strain/elongation features, which produces fibers with different toughness features. In addition, these modulus
property changes are achieved with no plasticizers/additives and the fiber remains 100% ePTFE. Current applications for this technology include sewing thread, where low-modulus/high-elongation characteristics provide improved shock resilience during high-speed sewing processes, thereby minimizing breaks and increasing manufacturing throughput. In contrast, where high modulus/low elongation fiber is required as a structural support in tensioned architectural fabric structures, a strong rather than tough ePTFE fiber has been developed to meet this need. Figure 8 highlights some of the dramatic changes in stress-strain characteristics within this family of GORE™ ePTFE fibers.

![Figure 8: Stress-strain changes in GORE™ ePTFE fibers](image)

**Advances in GORE™ ePTFE Density and Surface Texture**

One of the greatest features of GORE™ ePTFE technology is the unique ability to change density depending on application needs. For example, a non-porous, full-density (≈2.1g/cc) ePTFE fiber is preferred for sewing thread because of its durability, small cross-sectional area and sewing requirements. In contrast, a lower-density PTFE fiber is preferred as a dental floss due to its shred resistance and comfort/cleaning characteristics. Lower density also provides an available substructure for adding active agents, fillers, flavors, etc., into the available pore
volume, which at 0.2g/cc can be as great as 90%. In addition to offering GORE™ ePTFE fibers in a wide variety of colors, Gore has developed a range of these fibers containing various fillers for additional functionality, e.g., electrical and thermal conductivity, catalytic activity, and active agents (see Figure 9). Gore has successfully utilized our unique capability to incorporate a wide range of organic and inorganic fillers into ePTFE structures in commercial products where fillers provide specific functions. Examples include the REMEDIA™ Catalytic Filter System, where a catalytically active ePTFE-based felt has been developed to catalytically destroy harmful dioxins/furans and convert them into environmentally acceptable substances.

![Figure 9: Morphology changes in high density, low density, and filled GORE™ ePTFE fibers](Images)

Recently, Gore has also developed the unique capability to texturize the surface of fibers while maintaining a 100% ePTFE structure — no additives are required that would diminish the resistance to chemical or thermal attack of the fiber (see Figure 10). Gore can tailor these products to maximize abrasion resistance, improve handling characteristics, and alter wettability and luster appearance. For the first time, GORE™ ePTFE fibers are available in a matte (flat) finish for a more textile-like appearance.
Looking toward the future and potential new applications, Gore researchers are developing new low denier / small diameter ePTFE fibers, including flat fibers and round monofilament fibers with diameters less than 50 microns, which is less than half of the diameter of a human hair (see Figure 11). New applications being considered for these fibers include technical fabrics, precision woven filters, reinforcement and membrane supports.
**Figure 11**: New developments in low denier / small diameter GORE™ ePTFE fibers

**GORE™ OMNIBEND™ Fiber for High-Performance Ropes**

One exciting application using the unique material properties of GORE™ ePTFE fibers is the GORE™ OMNIBEND™ Fiber for high-performance ropes. In high-tension, high-stress bending and lifting applications, reliability and performance of ropes are critical. Gore’s patented technology dramatically increases the bending-fatigue life of a rope by blending GORE™ OMNIBEND™ Fiber with conventional high-performance fibers (e.g. ultra-high molecular weight polyethylene, para-aramid, and liquid crystal polymers). In this case, the service life of the high-performance rope has improved by 300-500%. GORE™ ePTFE fibers stand up to the abrasion, UV-exposure, and elevated temperatures seen in environments where high-performance ropes are needed.

W.L. Gore & Associates was recently awarded the prestigious DuPont Plunkett Award (First Place) for innovation with DuPont Fluoropolymers, for GORE™ OMNIBEND™ Fiber for High Performance Ropes.

In addition to high-performance ropes, fabrics containing GORE™ ePTFE fibers dramatically improve flexural durability and reduce tensile strength degradation. Figure 12 highlights improvement in flex endurance by the addition of GORE™ ePTFE fibers to para-aramid and E-glass (fiberglass) fabrics.
Figure 12: Improvements in flex endurance in fabrics containing GORE™ ePTFE fibers
Summary

This paper has described some of the exciting new developments with GORE™ ePTFE fibers from W. L. Gore & Associates; higher tensile performance at high temperatures, improved abrasion resistance, precise diameter control, density tailored for specific applications, textured surfaces where required, controlled modulus, all in an extensive range of sizes, plus capabilities to incorporate a wide variety of fillers. In addition, new stabilized, low-shrink 100% PTFE fabrics are available for the first time using a recently developed, patent pending technology. When we discuss this broad array of GORE™ ePTFE fiber and fabric capabilities, it should also be noted that these technologies are interchangeable. For example, Gore can deliver a low-density fiber with good high-temperature performance and a surface texture. This capability to tailor properties specifically to a customer’s needs ensures that new applications for GORE™ ePTFE fiber will be identified and developed.

With such a strong technology offering, Gore is now looking for motivated joint development partners to ensure rapid technology and product commercialization in a variety of market segments.

*PTFE is an Amazing Polymer.*

**GORE™ ePTFE Fibers make it even more amazing!**

For additional information about GORE™ ePTFE fibers or to discuss a potential development partnership / specific application, please call:

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With over $2 billion in sales and more than 8,000 associates worldwide, W. L. Gore & Associates, Inc., has applied its world-renowned expertise as the inventor of expanded polytetrafluoroethylene (ePTFE) to deliver innovative, technology-driven solutions in the textile industry for over 30 years. Gore is particularly well-known for its GORE-TEX® brand — the first waterproof, breathable fabric. And behind every product and every application is a dedicated commitment to performance and reliability.

For more information about any Gore product, access the website at www.gore.com.