BATTLE TESTED
High-performance fiber makers respond to demand from military and security users

SUIT OF ARMOR Dyneema fiber composite protects the Sikorsky CH-35 helicopter.

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DuPont, Honeywell, DSM, and Teijin are all building new capacity to supply the high-performance fibers that make flexible, lightweight, and bulletproof fabrics. It is all about gaining an edge. These big fiber makers and a newcomer—Magellan Systems International—mean to increase the chances that soldiers, first responders, and others will survive in war zones or in case of terrorist attacks.

Not surprisingly, it is military and civil defense organizations that provide much of the driving force for fibers research and capacity increases. According to the U.S. Army Natick Soldier Center (NSC), which develops equipment to support soldiers, body armor has saved dozens of lives in Afghanistan and Iraq.

p-Aramid and high-performance polyethylene (HPPE) fibers incorporated into helmets, flexible vests, and rigid chest plates have done their job well, but they are among the heaviest items worn or carried by troops.

To be sure, protective gear has come a long way since ground troops wore nylon "flak" vests and steel helmets in the 1960s. In the 1980s, p-aramid vests and helmets came into use and provided a much higher level of protection. Improved versions of HPPE and DuPont's Kevlar p-aramid fiber further improved ballistic protection and were 25% lighter than an earlier generation.

But now the Army is on the hunt for even lighter fibers to reduce the load on a soldier and add further protection. Civil defense and first responders also have an interest in such new developments. A superfiber called M5, made by eight-year-old Magellan, may be part of the solution. In the meantime, existing fiber producers are competing to ramp up capacity and provide fiber for military and security gear.

High-strength fiber producers have issued regular capacity increase announcements in recent years. In June 2004, DuPont said it would spend $70 million to boost global capacity for Kevlar p-aramid fiber by more than 10%. The expansions, to be completed by the middle of 2006, follow three other expansions completed between 2000 and 2003 at DuPont sites in Richmond, Va., and Maydown, Northern Ireland. The firm cites safety and security needs as the motivation for the expansions.

Teijin, which expanded its aramid fiber business when it purchased Akzo Nobel's Twaron...
The DuPont competitor started the third expansion since 2000 of Twaron capacity in Emmen and Delfzijl, the Netherlands. The $185 million, 20% capacity increase is to be completed in the second half of 2006. It will come on top of a 50% boost in 2003 and a 10% boost in capacity set to be completed by the end of September.

When all the projects are completed, Teijin says it will have 23,000 metric tons of Twaron capacity. Bullet-resistant vests and helmets, vehicle armor, and blast mitigation materials are among the growing markets Teijin cited as being responsible for increased fiber demand.

DSM, which produces Dyneema HPPE fiber in Heerlen, the Netherlands, opened its first U.S. Dyneema fiber plant in Greenville, N.C., in May 2004. The line has a capacity of up to 750 metric tons per year. Initial output was dedicated to U.S. military requests, "due to the current situation of increased demand for personal security and protection against terrorism in the U.S.," according to a DSM announcement.

A second fiber line that a spokesman says will begin operating by the end of this year is under construction in Greenville. And this past February, DSM said it would spend $50 million to build yet a third fiber line in Greenville. When the final line opens in the third quarter of 2006, DSM claims, it will be "the largest manufacturer of HPPE fiber on U.S. soil."

Honeywell, producer of Spectra brand HPPE and a DSM competitor, has also announced a capacity increase. Both DSM and Honeywell developed technology to produce HPPE fiber in the early 1980s. Until recently, DSM produced its fiber only in Europe and in a Japanese joint venture with Toyobo. Honeywell was the sole U.S. producer.

Just after DSM opened its first fiber line in Greenville, Honeywell said it would spend $20 million to boost production of Spectra. That expansion, now on-line, is primarily devoted to serving U.S. military requirements.

While the big multinationals compete in tried-and-true high-performance fibers, Magellan has something totally new. In December, the firm completed construction of a pilot facility to produce up to 60 metric tons annually of a soft, silky, blue fiber, poly{2,6-diimidazo-[4,5b-4',5'e]pyridinylene-1,4(2,5-dihydroxy)phenylene}. An Akzo scientist developed the ultra-high-strength fiber in the late 1990s just as the company was losing interest in the fiber business. Akzo code-named the fiber M5, most likely because the
chemical name doesn't exactly roll off the tongue.

Akzo transferred its Twaron \( p \)-aramid business to Acordis, which sold it to Teijin in 2000. And 2000 was also the year when Eugene H. Vetter, Magellan's president, acquired the M5 project from Akzo. Natick Soldier Center is interested in M5 for use in personnel and vehicle armor, flame and thermal protection, and composites. According to Magellan, M5 is lighter and stronger than \( p \)-aramid and HPPE fibers and has better fire resistance than \( m \)-aramid fibers such as DuPont's Nomex. It is unaffected by ultraviolet light, so it better resists environmental degradation.

In a recent overview of the fiber, NSC pointed out that M5's "mechanical properties are less than optimal under current processing conditions." Even so, in ballistic tests using composites incorporating bench-produced M5 fiber, NSC found that the composites "provide performance almost as good as the best composite materials ever prepared for fragmentation protection." NSC says it expects armor systems based on M5 to be at least 30% lighter than a Kevlar-containing composite.

According to NSC, only one other fiber--poly \( p \)-phenylene-2,6-benzobisoxazole, or Zylon--has come close to M5's performance. The Air Force developed Zylon in the 1980s and sold the technology to Japan's Toyobo. However, Zylon does not have the environmental resistance that M5 boasts. In a 2003 test, an NSC engineer found that Zylon broke down with exposure to light, heat, and humidity.

No wonder, then, that DuPont has been an investor in Magellan since 2002. In April of this year, DuPont upped the ante and signed a definitive agreement to acquire a majority stake in Magellan for an undisclosed sum.

Magellan's Vetter says he first heard about M5 from contacts at Georgia Institute of Technology in the late 1990s. Vetter, a former military officer, worked for defense contractors in the 1980s. Along with business partners, he set up Magellan in 1997 to bring technologies to the U.S. that would make a difference for homeland security. He and his partners looked at several promising technologies before settling on Akzo's M5 in 1999.

It was then that he approached Akzo, met with Doetze Sikkema, the fiber's inventor, and learned about its great potential in security applications. Akzo had already decided to divest its fibers operations. While Teijin ultimately got Akzo's \( p \)-aramid business, Vetter bought the rights to M5. He also hired Sikkema, who moved from the Netherlands to work for Magellan in the U.S.

Early on, Magellan obtained financial support from its original partners and later from "angel" financial investors. NSC contracts worth nearly $3 million also advance the development of M5. But Magellan believed it needed an investor and collaborator from the high-performance-fiber world.

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**SLINGSHOT** Ten times stronger than steel, Spectra fiber nets an iceberg in tow.

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**AS WORD** circulated that Magellan had acquired the M5 patent portfolio, "all the high-performance fiber guys were in touch with us," Vetter says. Soon after it located its research and production in a former Reynolds Aluminum facility in Richmond, Magellan decided that DuPont would be an ideal investor and collaborator to help the firm in taking M5 from bench to pilot plant production. An added bonus was that DuPont's own aramid research and production facilities were only five miles away.

The science and engineering assistance Magellan has received from DuPont has been invaluable, according to Vetter. "Dreams are made of this," he says. Work is proceeding on
optimizing the fiber-making process at the new M5 pilot plant, Vetter says.

Because of its versatility, M5 could be developed for a number of markets. First and foremost, Vetter says, is bulletproof vehicle armor and protective clothing for U.S. troops. Its heat resistance makes it a good candidate for use in fire protective gear. Because of its strength, the fiber might be braided into cables and tethers, or woven into fabric and then included in a resin matrix. Incorporated into the skin of aircraft, the fiber might help outfit a new generation of lighter and stronger radar-transparent fighter planes.

Alexa Dembek, global business director for DuPont Life Protection, says M5 "complements our aramid fiber business and provides more options and solutions for our customers." Although M5 is similar to Kevlar, she says, it is likely to be "a better solution for the next generation" of bullet-stopping and shrapnel-protective garments. Dembek expects that DuPont will provide Magellan more marketing assistance as quantities of the fiber become available to the market.

Also in Richmond is Honeywell, which produces Spectra HPPE fiber and has a fiber technology center there. Indeed, Richmond is at the center of a U.S. high-performance fiber corridor. DuPont, Honeywell, and Magellan are in Richmond itself. DSM produces its fiber just 130 miles to the south in Greenville, N.C. NSC conducts its assessment of the latest fiber technology about 500 miles north in Massachusetts.

"We meet with Natick Center officials on a regular basis to discuss new uses for Spectra," says Lori Wagner, Honeywell technology manager for advanced fibers and composites. As threat levels increase, demand for Spectra has increased for armor and other security applications. They include blast-containment blankets, blast-resistant suits, and ordnance carriers.

Honeywell is in the vanguard of suppliers of fiber and systems to protect many of the relatively lightweight vehicles used in Iraq against bullets and blasts. Heavy armor, such as steel, would overload the vehicles and cause frequent vehicle breakdown and increase tire wear, points out Tim Swinger, Honeywell global marketing manager for armor.

Like Honeywell's Spectra, DSM's Dyneema HPPE fiber has a number of security-related applications, including commercial airline cockpit doors and armor plating for police and military vehicles. QinetiQ, a U.K. security systems developer, recently designed a Dyneema-based system to quickly halt vehicles suspected of carrying bombs or terrorists.

When laid out on a road in front of oncoming cars, vans, or light trucks, QinetiQ's X-Net surrounds the vehicle's front wheels. Carbon steel-barbed spikes attached to the fiber puncture the tires while the fiber wraps around the wheels, bringing the vehicle to a halt in a straight line.

X-Net can be used at checkpoints, secure facilities, or other vulnerable sites. It weighs about 40 lb and does not have to be anchored to the ground to be effective, DSM says.

All the major fiber suppliers say they continue to research new applications for their materials. Work includes nonmilitary uses such as ropes, cut-resistant garments, fishing tackle, orthopedic sutures, tire reinforcement, brake pads, seals and gaskets, and optical fiber cable reinforcement. But in these times of heightened security, military and civil defense concerns are the greatest impetus in the development and ramp-up of bullet-resistant superfibers.