

Nanoscale Materials Make for Large-Scale Applications

Originating Technology/ NASA Contribution

Since its dawning days, NASA has been at the forefront of developing and improving materials for aerospace applications. In particular, NASA requires dramatic advancements in material properties to enhance the performance, robustness, and reliability of its launch vehicles, spacecraft, and the International Space Station. Such advancements over the years include noise-abatement materials, fire-resistant fibers, heat-absorbing insulation, and light-but-strong moldable composites.

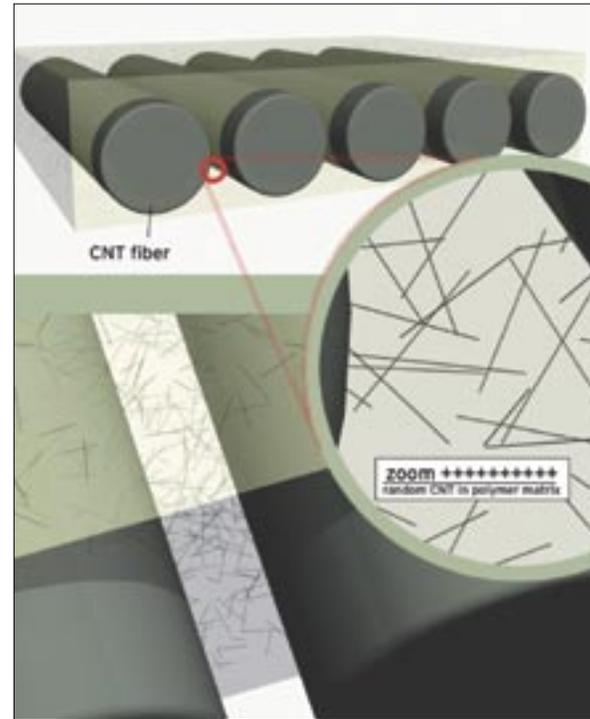
In 1991, a new carbon fiber called a carbon nanotube was discovered and fully substantiated by a Japanese electron microscopist. Its dramatic strength and low density (20 times the tensile strength and one-sixth the density of steel) were turning the heads of materials scientists and engineers all around the world, including those who developed equipment for NASA.

While NASA did not invent the carbon nanotube, it is working to advance the fibrous material for widespread, low-cost application in sending humans beyond low-Earth orbit, well into the outer reaches of the universe. Carbon nanotubes have the potential to reduce spacecraft weight by 50 percent or more, by replacing the heavier copper wires currently used, according to NASA scientists. Furthermore, NASA researchers have reported a new method for producing integrated circuits using carbon nanotubes instead of copper for interconnects. This technology has the capability to extend the life of the silicon chip industry by 10 years.

Because of this growing interest in carbon nanotubes and their perpetual possibilities, NASA has funded both internal and external research in this field.

Partnership

In 2001, [Zyvex Corporation](#), of Richardson, Texas, developed a revolutionary method of changing carbon



With assistance from NASA, Zyvex Corporation built extremely strong and light hierarchical carbon nanotube-composite materials.

nanotube chemistry without harming the molecular structure that gives the carbon nanotubes their remarkable properties. In February 2003, Johnson Space Center recognized the promise of this technology and began working with Zyvex through a Phase I **Small Business Innovation Research (SBIR)** contract to develop the rational engineering of carbon nanotube surface chemistry.

In the Phase I program, Zyvex not only demonstrated the ability to make high-concentration solutions of carbon nanotubes in organic solvents, but also demonstrated the ability to achieve excellent dispersion of the carbon nanotubes in polymers such as epoxy. These successes led to

a Phase II SBIR contract with Johnson in January 2004, to build extremely strong and light hierarchical carbon nanotube-composite materials for NASA applications.

Even though the partnership between Zyvex and NASA is still in its early stages, these modified carbon nanotubes are on the fast track for establishing new classes of materials that will meet the Space Agency's needs as it produces new, safer, and more cost-effective spacecraft. The Phase II contract with Johnson is still in progress and a new Phase I SBIR contract with Marshall Space Flight Center to develop carbon nanotube-reinforced radiation shielding is also underway.

Product Outcome

The introduction of a new material into commercial applications is usually a 5- to 10-year process. With the active support of NASA, a rigorous New Product Development Process, and a commitment to speed of execution, Zyvex took less than 3 years to go from invention to commercialization.

Shortly after conceiving and demonstrating a new way to functionalize carbon nanotubes, Zyvex filed initial patents and implemented its New Product Development Process for the carbon nanotube polymer composites.

Based on the successful results of the Phase I Johnson SBIR contract, Zyvex started offering solubilized carbon nanotubes on its Web site in September 2003. Exactly a year later—in the midst of the Phase II SBIR work—Easton Sports, Inc., announced the use of Zyvex carbon nanotube technology in its new line of bicycle parts.

Van Nuys, California-based Easton Sports has an 82-year history of leading its market by developing new materials to achieve enhanced performance in sporting goods. The company's bicycle division has incorporated the Zyvex technology, commercially known as NanoSolve, in its 2005 line of bicycle components, including handlebars.

Robert Folaron, Zyvex's director of product development, noted, "The Easton-Zyvex partnership offers an

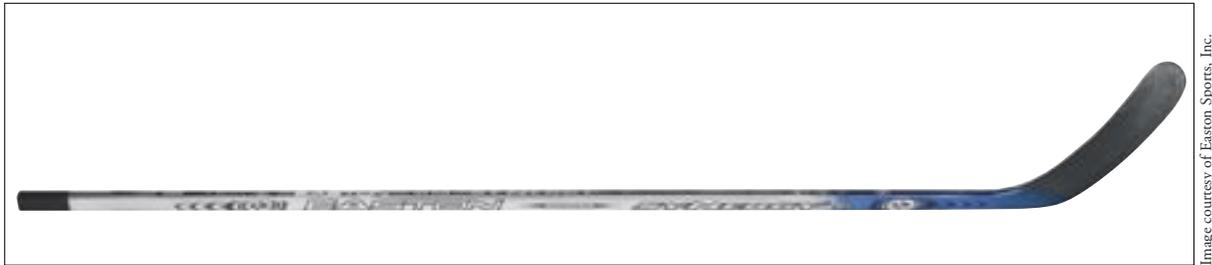


Image courtesy of Easton Sports, Inc.

The manipulation of materials on a molecular scale is leading to lighter-but-stronger hockey sticks. Pictured here is Easton Sports, Inc.'s Synergy SL product, featuring Zyvex Corporation's NanoSolve technology.

opportunity for two leaders to rapidly develop a carbon nanotube-enhanced composite and quickly adopt it into a product line.”

John Harrington, vice president of Easton Sports's bicycle division, agreed, saying, “We saw a large increase in the strength and toughness of the composite when the nanotubes were properly functionalized. With that achievement, we were able to create lighter and stronger bicycle components.”

Easton Sports again looked to Zyvex and its NanoSolve technology in February of this year, to take hockey and baseball equipment to the next level.

The revolutionary Easton Synergy SL composite hockey stick increases stick strength while reducing weight. It is lighter (420 grams) and stronger than its Synergy predecessor, and has a new blade design that yields “unmatched performance,” according to Easton Sports.

“We view the incorporation of carbon nanotubes into our sticks as a critical step in further developing the world's best hockey sticks,” said Ned Goldsmith, vice president of Easton Sports's hockey division. “The Synergy SL is the first stick to utilize carbon nanotube's stronger and more durable material design. Keeping with our tradition of putting Easton sticks in the hands of the world's best players, Peter Forsberg has already adopted this new design while playing in Sweden for Modo,” he

added. Forsberg is also a member of the National Hockey League's Philadelphia Flyers franchise.

Easton Sports is touting its NanoSolve-reinforced Stealth baseball bat as the “best bat in the game today.” The NanoSolve technology enhances the company's Opti-Flex composite handle technology, providing maximum handle flex, up to 3 times greater than aluminum bats. Additionally, NanoSolve provides better responsiveness and more “kick” through the hitting zone.

Zyvex recently partnered with several other major corporations to introduce NanoSolve in multiple markets. These businesses include Boston Scientific Corporation; IBM Corporation; Honeywell International, Inc.; Nantero, Inc.; Fiat; and DuPont.

The success realized to date is just the beginning for Zyvex, as it is committed to continuing the development

of NanoSolve for both commercial and government applications. Based on the company's preliminary commercial analysis for market segments, it estimates that the potential niche markets for its composites will be modest in the beginning years, but its growth will reach \$400 million to \$800 million, 10 years after commercialization. Zyvex acknowledges that the market for advanced composites is competitive; but, since its goal is to develop composite materials with strength superior to any material produced today, it believes it will be in a unique position to partner with companies that manufacture carbon and composite fibers.

According to Thomas A. Cellucci, Zyvex president, the company's ongoing relationship with NASA is especially important: “We are extremely pleased to be working with NASA. A large portion of our success in nanomaterials is due to their involvement.”

The Federal Aviation Administration will be referencing the Johnson SBIR Phase II contract, according to Zyvex, in a congressional report that highlights the future benefits of carbon nanotubes. Zyvex also has monetary and hands-on support from the Defense Advanced Research Projects Agency to develop high-strength materials. ❖

NanoSolve™ is a trademark of Zyvex Corporation.
Sc900™ is a trademark of Easton Sports, Inc.



The addition of carbon nanotube technology, made possible by NanoSolve materials and exclusive to Easton Sports, Inc., strengthens composite structures in baseball bats to provide improved handle designs with optimized flex, responsiveness, and more “kick” through the hitting zone, for maximum performance. Pictured here is the Easton Stealth Sc900.