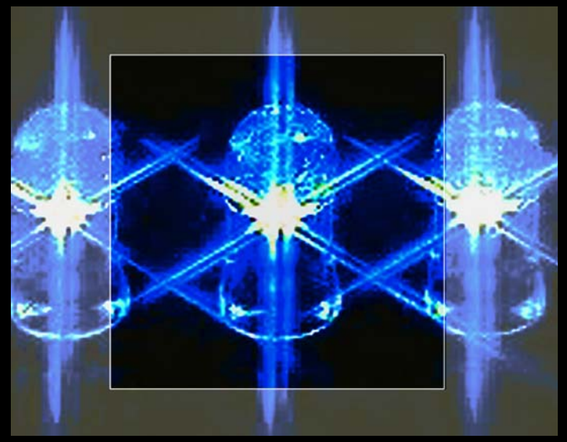
Ceramic, Composite, and Electronic Materials



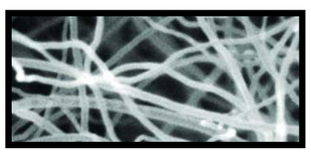
Man will occasionally stumble over the truth, but most of the time he will pick himself up and continue.

—Winston Churchill

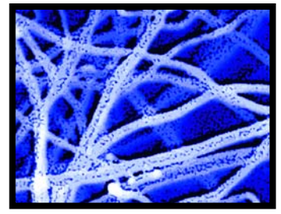
A company that manufactures polymer-based lithium-ion batteries for portable electronics would like to enhance the electrically conductive properties of an experimental polymer. It wants to maintain structural and thermal integrity while not significantly adding to the weight of a cell. Here is a product that can add conductive properties without adding weight.

Pyrograf®-III

How It Helps: Pyrograf-III provides polymers with electrically conductive properties, as do regular milled carbon fibers or carbon black. The advantage of adding nanofiber is twofold: it does not disturb the other properties of the polymer, and the nanofiber takes only up 5 to 20 percent of the volume required by bulkier additives. Another advantage is in the process of making Pyrograf-III itself. The use of sulphur dramatically improves the nucleation efficiency of carbon nanofibers. High-sulfur coal can be mined, not as a source of fuel for power plants, but rather as a chemical source of hydrocarbons.



How It Works: The Pyrograf-III composite material is produced by introducing a gas-phase catalyst into a heated hydrocarbon atmosphere. This creates carbon nanofibers having diameters of 100 to 200 nm. When added to polymers, carbon fibers convert the polymer from an insulating material to an electrically conductive material. The Pyrograf-III–based composite can be formulated to have electrical resistivities anywhere from 100 to 1010 ohm-cm. Concentrations as low as 0.5 percent have been shown to produce resistivities as low as 104 ohm-cm in injection-molded thermoplastic composites. Additionally, carbon nanofiber has a thermal conductivity of between 1,950 and 2,000 W/m-K, or close to five times that of copper.



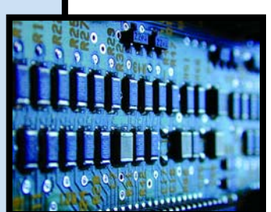
How Much It Will Cost: The price is $85 to $110 per pound or less depending on the size of the order.

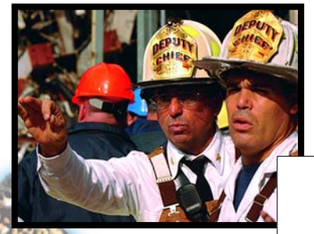
When It Will Be Ready: The product is available now. A pilot plant is producing 70,000 pounds per year of the composite. The existing production capacity from the pilot plant is sold out, but there are plans to double capacity.

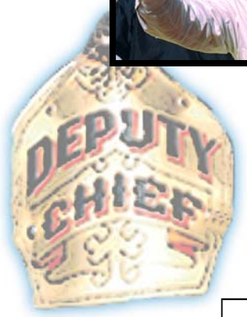
Who Is Working On It: The innovator is Applied Sciences, Inc. (ASI). ASI, which specializes in the research and development of advanced materials and their applications, incorporated in 1984. As of November 2001, the company had annual sales of $1.5 million and employed 33 people. Pyrograf Products, Inc. (PPI), created in 1996, is an ASI subsidiary. PPI operates a modern 70,000-pounds-per-year facility in Cedarville, Ohio. The Pyrograf-III pilot plant is housed in a 22,200-square-foot facility. For more information, contact Kate Monaghan of ASI at (937) 766-2020, ext. 105, or monaghan@apsci.com. The company Web site is www.apsci.com.

MDA Origins

As early as 1987, ASI received funding from SDIO, the precursor to BMDO, and MDA. Since the inception of the SDIO program, ASI has received 12 SBIR Phase I contracts, three SBIR Phase II contracts, and an STTR Phase I contract to study and develop various carbon composite technologies for structural, thermal, and electronic applications. With funding from SDIO, DOE, and the U.S. Air Force, ASI began to study applications for the nanofibers. It joined forces with General Motors (GM) and licensed all of GM's intellectual property on the composites. In 1996, ASI, GM, Goodyear Tire & Rubber Company, and others joined together in a cooperative research agreement and received funding from NIST's Advanced Technology Program.







A violent explosion rocks a large downtown office building. Hundreds of people must be rescued. Firefighters and rescue personnel believe the area is contaminated by hazardous chemicals. Complicating matters, people evacuating the building may inhale harmful airborne particles. Here is a product that could help protect these people.

Escape Mask

How It Helps: The escape mask uses microfibrous filter technology that traps toxins and irritants ranging from sarin and anthrax to pollen and dust mites. It is lightweight, foldable, and fits inside a shirt pocket. Small and compact, it can be easily carried and distributed by the hundreds to protect people from harmful air threats. Unlike today's gas masks, the escape mask offers a lower pressure drop so it makes breathing easier—a must for the elderly or young children. The microfibrous technology can be tailored to anticipated threats such as a "cocktail" attack with a combination of chemical agents. It can be recharged simply by being reheated.

How It Works: The microfibrous filter technology contains sorbent materials in a mesh of carbon-metal composite and cellulose wood fibers that, under a microscope, resembles a wad of chicken wire. This matrix has high electrical conductivity and high surface area (about 1,000 square meters per gram). The fibers are then put through a paper machine on a roll, and the resulting sheets are sent through a furnace at 1,000°C, which melts the fibers and fuses them together. The sheets are then cut into strips and placed in canisters for use in the escape masks.

How Much It Will Cost: The target price of the escape mask is less than $150. Other types of escape masks currently on the market cost more.

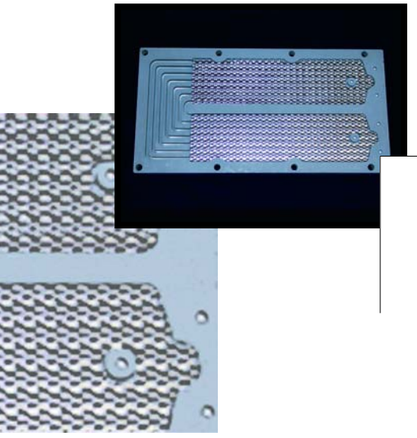
When It Will Be Ready: The escape mask will be available during the first quarter of 2003. Initially, it will be distributed to the first-responder market for use in emergency situations, such as terrorist attacks or building fires. Additional microfibrous filter products are being developed. Air security products include a chemical/biological filter for commercial and government facilities. The first air-quality product will be a replacement filter for home use.

Who Is Working On It: The innovator is IntraMicron, Inc. Formed in 2001, the company develops filter products for personal and facility protection, as well as for air quality assurance.

It has an exclusive worldwide license for the microfibrous filter technology from Auburn University, where Dr. Bruce Tatarchuk invented the technology. The company recently secured more than $1 million in early-stage venture funding. It employs seven people and occupies 2,000 square feet of office space in Birmingham, Alabama. A new 14,000-square-foot manufacturing facility with office space in Gahanna, Ohio, also has been leased. The company plans to move into this facility by mid-2003. For more information, contact John Stein of IntraMicron at (205) 443-4670 or stein@intramicron.com. The company Web site is www.intramicron.com.

MDA Origins

The carbon-metal composite used in the microfibrous filter technology originally was developed by Auburn University's Space Power Institute with funding from BMDO's Innovative Science & Technology program. The material would be ideal for use in developing advanced capacitors to power lasers, railguns, and other weapon systems. Fuel cells and batteries made from the material also could provide power for space-based platforms.



A metal foil factory with a high-speed, in-line continuous production line uses precision die-cutting equipment to reduce waste and improve profits. However, the cemented tungsten carbide cutting edges are difficult and expensive to apply. Here is a product that can affordably bond the cutting edges to the tooling.

S-Bond™

How It Helps: The S-Bond joining process bonds dissimilar materials at low temperatures, providing new joining solutions for wear surface, thermal management, and metal-to-ceramic material applications. It can replace gluing, mechanical fastening, welding, brazing, and soldering. S-Bond's advantages over gluing include ease of rebonding, lack of volatilization or lengthy curing time, and high thermal conductivity (about 50 W/m-K). The new joining method also is less environmentally damaging than competing technologies. S-Bond uses unique alloys to actively join dissimilar materials (including metals and ceramics) without the need for special atmospheres or harsh flux chemicals.

How It Works: S-Bond lead-free alloys join even dissimilar materials in a simplified and more cost-effective way than soldering and brazing, using the same fundamental procedures. The process joins composites, ceramics, and metals, as well as graphite or any other carbon-based material. The S-Bond alloys are created by adding reactive elements, such as titanium and other active elements, to conventional solder alloy bases. In the S-Bond alloys, the active elements migrate to the joint interface and react with the joint surface compounds. Once up to temperature and molten, the S-Bond alloys become "active," permitting the active elements to diffuse into the surface of the two opposing joint materials to form a metallurgical bond. S-Bond "activation" is accomplished by pressure, brushing, and vibration, or any combination of the three.

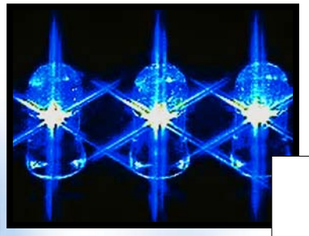
How Much It Will Cost: Prices for S-Bond kits range from $280 to $995; prices for S-Bond materials range from $190 to $450 per pound.

When It Will Be Ready: The technology is available now. S-Bond materials are sold to electronics, electronic and optoelectronic packaging, heat exchanger, and industrial companies that are joining aluminum, stainless steels, other metals, ceramics, and composites. S-Bond's ability to behave like a glue while being a metal filler offers many opportunities for the sale of S-Bond alloys, equipment, and services. S-Bond sales were in excess of $250,000 in 2002.

Who Is Working On It: In 2002, Materials Resources International (MRi) created S-Bond Technologies (SBT) to focus on commercial opportunities for its active solder technology. MRi employs six people and occupies approximately 6,500 square feet of office space and manufacturing facilities. In North America, SBT is responsible for the technology of lead- and flux-free, active solders that can join almost any combination of materials. While SBT benefits from MRi for its research needs, SBT serves major markets in electronics, ceramic metal joining, and simple dissimilar metals-intermetallics joining. SBT offers equipment, engineering services, and manufacturing/joining for customers. For more information, contact Dr. Ronald Smith of S-Bond Technologies at (215) 631-7111 or solution@mri-bluebell.com. The company Web site is www.s-bond.com.

MDA Origins

Throughout the 1990s, BMDO's Innovative Science and Technology program funded JPL to develop QWIP technology for use in ground-based and space-based infrared surveillance at long wavelengths. The technology could detect unheated objects such as ballistic missiles in mid-course when the hot rocket engine is not burning and most of the emission peaks are between 8 and 9 micrometers.



Blue light-emitting diodes (LEDs) based on gallium nitride (GaN) can be used to make new lighting products that consume power much more efficiently and last many years longer than conventional incandescent light bulbs. But the price of the GaN devices will be much higher than that of traditional bulbs because, during their manufacture, throughput is reduced and costly substrate materials must be used. Here is a product that could increase throughput and lower the cost of production for blue LEDs.

GaN-on-Sapphire Wafers

How It Helps: GaN-on-sapphire wafers can improve the mass production of blue LEDs. Using these wafers reduces growth time by more than 30 and allows an increase in production throughput of 30 to 50 percent—without incurring extra cost. The blue LED is grown directly on the surface of the substrate, eliminating the need for sapphire nitridization, GaN low-temperature nucleation deposition, and thick GaN buffer layer growth. The quality of the GaN LED structure is ensured by pre-growth inspection of the wafer, which is not possible with other methods of fabrication.

How It Works: GaN-on-sapphire wafers are fabricated using a technology called hydride vapor phase epitaxy (HVPE). HVPE involves reacting gallium metal with hydrogen chloride to make gallium chloride. The gallium chloride reacts with ammonia gas, and blue LED structures can be grown directly on the surface of the substrate. The HVPE process usually is carried out at atmospheric pressure in a quartz walled reactor heated by a resistive furnace.

How Much It Will Cost: The price of the GaN-on-sapphire wafers ranges from $150 to $700, depending on product specifications and purchase volume.

When It Will Be Ready: GaN-on-sapphire wafers are available now. These products are being manufactured at a rate of more than 1,000 per month, and that capacity is expected to increase by mid-2003. Clients include companies in the United States as well as in Japan, Korea, and Taiwan.

Who Is Working On It: The innovator is Technologies and Devices International, Inc. (TDI). Founded in 1997, TDI develops, manufactures, and markets bulk crystals, epitaxial structures, and devices using SiC, aluminum gallium nitride, and GaN semiconductor materials. The company employs 25 people and recently moved to a new 32,000-square-foot development and manufacturing facility in Silver Spring, Maryland. For more information, contact Dr. Slava A. Maslennikov of TDI at (301) 572 7834 or slava@tdii.com. The company Web site is www.tdii.com.

MDA Origins

In 1999 and 2000, TDI received SBIR Phase I and II contracts from BMDO to develop the HVPE process to deposit high-quality GaN layers onto sapphire and silicon carbide substrates. GaN devices could significantly improve BMDO communications systems. For example, radar and satellite-communications links, which operate at frequencies of hundreds of megahertz to tens of gigahertz, often have high power-amplification requirements that can be satisfied using GaN devices. GaN transistors would work in many of these units, conferring on them the solid-state advantages of ruggedness and portability.