News

Nano World News

Media-Milled Nanoparticles Improve Ceramic Armor

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With armed conflicts going on around the globe, every branch of the U.S. military is researching the use of nanotechnology to reduce the weight of personal and vehicle armor systems. While today's ceramic armor plates weigh 55 percent less than identical steel plates, using nanoparticles can provide advantages that are even more significant. Carbon nanotubes, for example, are 100 times stronger than steel and weigh about 83 percent less. Nano World News talked with Harry Way, technical director for NETZSCH Fine Particle Technology in Exton, Pa., about the manufacture and use of nanoparticles in ceramic armor.

Nano World News: How real is the current military research into nanoparticles and what is its potential impact?

Harry Way: It's very real. The Department of Defense (DOD) and Department of Homeland Security (DHS) are members of the National Nanotechnology Initiative (NNI), a federal program established in 2000 to pro¬mote nanotechnology research.

The Army Research Office has been collaborating with MIT since 2003 on nano-scale coatings, core-shell and rod-rod nanostructures, carbon nanotubes, fibers, fabrics, and layered and membrane structures. In January 2007, the U.S. Army's Research Laboratory's Survivability Branch awarded a $15 million contract to the University of Dayton Research Institute to develop armor with nanoparticle components for vehicles and soldiers.

Historically, military research has created many products that have later transitioned into mainstream commercial applications. These kinds of efforts will probably transition to advances in protective materials for domestic police and firefighters in the next couple of years.

NWN: How soon will we see these technologies in military use?

Way: There's no sure way to tell. As with most new technologies, finding cost-efficient production methods is key to getting finished goods into the end-user's hands. Media milling, or grinding, is one production method that is widely available and has been used to produce nanoparticles for large-scale manufacture. This process is both time- and cost-efficient, fully scalable from lab to production, and applicable to a wide array of materials production, including advanced ceramics that are used in existing armor technologies.

NWN: How?

Way: High-tech ceramics employ a number of different ingredients, including hot-pressed boron carbide (B4C), hot-pressed silicon carbide (SiC), and silicon nitride (Si3N4). The challenge for all current ceramic technologies is physics: porosity, even in small amounts, compromises the ballistic properties of the armor. It also interferes with the armor's ability to dissipate the kinetic energy during initial impact. Nanoparticles improve current ceramic technologies by reducing porosity and improving structural strength by increasing the surface area of molecules.

Research at CCLRC Daresbury Laboratory in conjunction with Tuskegee and Florida Atlantic universities, for example, found that incorporating spherical nanoparticles of silicon, titanium dioxide or carbon nanotubes in a plastic or epoxy matrix offers improved ballistic resistance with significantly better flexibility.

NWN: Are there other considerations?

Way: In general, candidate materials for armor should possess high hardness, high elastic modulus, low Poisson's ratio and low porosity. Low specific gravity is needed in applications where achieving the lowest possible mass is important, such as body armor and aircraft armor.

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R. Michael van Dam et al.
Siemens MI Biomarker Research, Culver City, CA, USA
Nanotech Proceedings

NWN: What are the advantages of media milling for nanoparticle production?

Way: Wet media milling using a slurry is cost-effective, provides excellent particle-size control and can limit or eliminate contamination of the active. It also provides excellent process repeatability. But materials like SiC and B4C used in ceramic armor pose numerous challenges.

NWN: Such as?

Way: These materials are extremely hard and abrasive. They can wear out grinding media, internal mill components, such as agitator discs and mill lining, and, in the case of a horizontal mill, the mechanical seal. This can lead to metal contamination.
Also, achieving particle fineness of less than 1 µm requires high energy input, more than 500 kWh/t solid.

NWN: How can these problems be overcome?

Way: Using conventional grinding media like alumina and zirconia simply isn't an option. Historically, SiC has been milled with steel media in steel-ball mills. Producers then add acid to dissolve the metal out of the slurry. But the cost and time for this process is immense.
NETZSCH Fine Particle Technology developed a unique method that uses SiC grains as the milling media, reducing the cost of continuously replacing worn beads made of alumina, zirconia or even SiC. The far-less-costly SiC grains also produce contamination-free output, since the process material and media are substance. This is referred to as autogeneous grinding.
For SiC, the process generally uses grinding media from 600 µm to 3 mm and produces slurry with viscosity below 40 PaS-1. This process yields output particles in the range of 0.5 to 1 µm.

NWN: Does this solve the entire problem?

Way: Not by itself. This process wears through the grinding media quickly, at as much as 0.15 kg of media/kg of product ground. This affects the energy input to the mill due to the decreasing level of shearing. To maintain an efficient process you have to continuously add grinding media. But conventional methods for managing this process are expensive and can cause blocking and wear.

NWN: What can be done about that?

Way: NETZSCH created a dynamic cartridge media separator (DCMS) system at the feed and discharge sites of the mill. The DCMS system centrifuges the media out of the slurry, allowing the incorporation of a vibratory feeder that runs off the mill's kilowatt draw. As the media wears down, the kilowatt draw drops.
Using a programmable logic control (PLC), the vibratory feeder turns on when the kilowatt draw reaches a set low point and turns off when the target kilowatt draw is achieved. The media-addition system is easily controlled and has no wearing parts. A peristaltic pump feeds the mill, reducing maintenance costs.

NWN: Has this been effective?

Way: In actual application this system has demonstrated wear life in excess of 2000 hours for agitator parts. And the process is easily automated for unattended operation with flow, temperature and pressure switches.

NWN: How can producers ensure the best outcome?

Way: Selecting appropriate equipment is key to developing a repeatable process and creating efficient workflow, in the lab and right through full-scale production. New mills allow for the use of media down to 100 µm in diameter. They generate adequate product throughput at slow, low-energy motor speeds, which prevents damage to the nanoparticles. Consulting with an expert on the particulars of each specific application is always the best course of action.

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