diesel; the fuel can be derived from natural gas and more cheaply, too. In fact, Qatar and Nigeria are building gas-to-liquid plants, and Sasol estimates that by 2014, gas-to-liquid fuel may account for at least 5 percent of the global market. But the U.S. does not have nearly as much natural gas as coal. And considering the vast coal reserves in China, which is also considering the technology, coal-derived diesel seems likely to play a bigger role in helping to liberate some countries from dependence on oil imports.

Gunjan Sinha is based in Berlin.

SHEAR-THICKENING FLUID stiffens instantly when an object is dragged through it, enabling a vial of the liquid to be lifted. It can improve Kevlar's bullet-stopping power.

KATHY F. ATKINSON *University of Delaware Photo Services*

DEFENSE

Enhanced Armor

NEW SHIELDS TO FEND OFF EVOLVING BATTLEFIELD THREATS **BY STEVEN ASHLEY**

It's an all-too-familiar scene from the war in Iraq: A video shows a convoy of combat vehicles patrolling a dusty causeway. Suddenly, a huge detonation erupts next to one, often followed by a determined ambush. Over time, the guerrillas have steadily upgraded the lethality of their roadside bombs, suicide assaults and surprise attacks. This year, however, the U.S. military plans to field several new armor systems that should better defend its vehicles and personnel.

"The need to stop multiple, ever evolving threats is a tough problem," states Tony Russell, chief technology officer at Armor Holdings, a security products maker based in Jacksonville, Fla. "The systems we develop must defeat repeated armor-piercing bullet hits as well as the fragments and blast overpressures from explosives. And no one material—metal, composite, ceramic—is best at stopping every threat." Moreover, the armor has to be as light as possible. Successful solutions often mix several different substances to achieve the best result, Russell notes.

One of the least apparent recent improvements in armor has been the development of new, ultrahigh-hardness (UHH) steels. Such alloys are as much as 20 percent harder than the hardest off-the-shelf high-carbon steels, but they tend to be brittle and can crack when hit. Russell says that Armor Holdings has introduced an optimized version called UH56 steel, which is "hard enough to fracture armor-piercing ammo but tough enough not to crack with many impacts." UH56 is also easier to shape than many of its UHH cousins. The enhanced steels are being installed on many U.S. light-armored vehicles.

Researchers are also working on better transparent materials for windows, which are typically made from multiple laminations of bonded glass. As new threats loom, "the reaction is to add another layer of glass," explains Ron Hoffman of the University of Dayton Research Institute. But extra glass can make vehicles top-heavy, fuel-thirsty and sluggish.

One promising solution is to replace the glass with significantly cheaper and more effective aluminum oxynitride (ALON), a hard, sapphirelike material developed by industry, the U.S. Army and the U.S. Air Force. ALON offers better protection against armor-piercing projectiles at roughly half the weight and half the thickness of traditional glass-based transparent armor, Hoffman reports.

ALON has been around for years, but it has always been too expensive and too limited in size for vehicle windows. Engineers at Surmet, a ceramics maker in Burlington, Mass., have improved manufacturing processes involving the heating and compressing of ALON powders to make larger pieces of the material and to lower production costs significantly. Still, at around $10 to $15 per square inch, the optical ceramic costs more than military-grade glass ($3 per square inch). Armor Holdings is expected to start installing the lightweight windows this year.

Body armor will soon be in for some significant enhancements as well. Standard-issue ballistic vests, which are reinforced by hard ceramic plate inserts, are massive and bulky but more protective than today's lighter-weight, multilayer fabric alternatives made of woven Kevlar and other high-strength fibers. A new technology called liquid armor may change that, however.

NEED TO KNOW: SHIELDS UP!

Electromagnetic armor is perhaps the most futuristic type of protection being explored. Engineers are developing it in response to shaped-charge weapons such as rocket-propelled grenades, in which a specially configured explosive forms a penetrating jet of molten copper that can bore its way through thick metal and ceramic armor. Current reactive armor—externally mounted explosives that break up the jets—is heavy and works only once. Electromagnetic armor systems, in contrast, detect an oncoming projectile and rapidly generate an intense electric field, creating a powerful magnetic field that diverts charged particles in the hot, high-speed jet, which disrupts the warhead's intended effect. Electromagnetic armor should be ready within a few years, depending on the creation of lightweight power sources.

Liquid armor refers to "ballistic fabric infused with a shear-thickening fluid," a substance that stiffens temporarily less than a millisecond after impact, says Norman Wagner, a chemical engineer at the University of Delaware. Co-developed by Wagner's research group and a team led by Eric Wetzel at the U.S. Army Research Lab in Aberdeen, Md., shear-thickening fluid is a mixture of hard nanoparticles (often silica or sand) suspended in a nonevaporating liquid such as polyethylene glycol. Although the fluid adds only about 20 percent to the weight of the fabric, it greatly augments its resistance to puncture by high-speed projectiles. It also reduces the effect of blunt trauma by helping to transmit the impact energy to a larger portion of the ballistic fabric, Wagner explains. Certainly, in today's Iraq, allied forces need all the protection they can get.

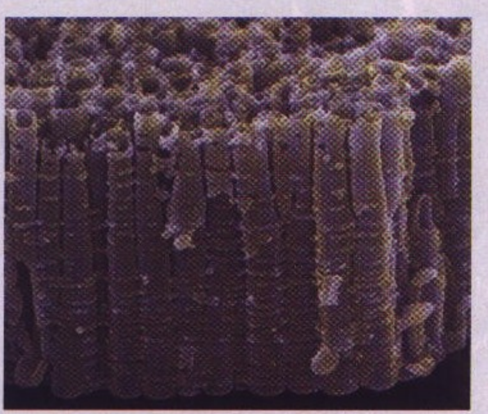
NANOTECH

Light Work

BETTER SOLAR NANOTUBES TO SPLIT WATER FOR HYDROGEN BY ERIC SMALLEY

The path to the hydrogen economy is getting visibly brighter—literally. Nanotubes that break apart water molecules to liberate hydrogen can now do so more efficiently and could soon use the optical spectrum of sunlight.

In dissociating water with sunlight, engineers have available three technologies: One is solar cells, which hold the record for water-splitting efficiency but are comparatively expensive. Another approach uses microorganisms, which are inexpensive but so far produce only minuscule amounts of hydrogen. The third option is photocatalysis, which relies on momentarily freed electrons in a semiconductor. Electrons that encounter water molecules replace the electrons in the bonds between hydrogen and oxygen. They thus break water apart and generate hydrogen gas. Photocatalysts are potentially less expensive than solar cells and produce more hydrogen than microorganisms.



NANOTUBES of titanium dioxide can be modified to respond to visible light in splitting water for hydrogen.

The trouble is, photocatalysts that split water must work in water, and those that do respond only to ultraviolet light, which makes up about 4 percent of sunlight. Materials that absorb the much more abundant visible portion of solar radiation tend to break down in water.

Scientists have turned to nanotubes of titanium dioxide to address efficiency. The tube form of the compound is about five times as efficient as the more typical film form, because the tubular shape enables electrons to stay free longer. Hence, an electron has a greater chance of splitting a water molecule.

Pennsylvania State University electrical engineer Craig Grimes and his team have pushed ultraviolet-to-hydrogen conversion efficiencies just beyond 12 percent using six-micron-long titanium dioxide nanotubes. The nanotubes generate 80 milliliters of hydrogen per hour per watt of ultraviolet light, a record for a photocatalyst-only system.

Now two teams, University of Texas at Austin chemist Allen Bard and his colleagues and the Penn State investigators, have begun formulating titanium dioxide nanotubes that respond to visible light. They have added carbon to titanium dioxide nanotubes to shift the wavelengths of light the tubes absorb to the visible portion of the spectrum. This shift as much as doubles the efficiency under an artificial mixture of ultraviolet and visible light, Bard says. The next step is coming up with a nanotube material that has a high efficiency in pure visible light.

The teams aim to boost the titanium dioxide nanotubes' water-splitting efficiency in visible light above the Department of Energy's 2010 goal of 10 percent. If the average U.S. rooftop were covered with a visible-light, 12 percent–efficient photocatalyst, it would generate the hydrogen equivalent of about 11 liters of gasoline a day, Grimes calculates.

Eric Smalley edits Technology Research News, *an online news service.*