Nanotechnology Products Hold Promise for E&P

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The oil and gas exploration and production (E&P) industry is going through an interesting transition. When new reservoirs were being discovered on land, at reasonable depths and with reasonable chemistries, the need to change materials was limited, and there was little pressure to improve the technologies used to explore for and extract hydrocarbons. How things have changed! Sour wells, complex reservoirs, high temperatures, low temperatures, high viscosities—to name just a few changing parameters. Combine this with tightening environmental regulations at the well, on the platform, and at the refinery and you have a 'perfect storm' of changing materials needs.

Some things haven't changed. E&P is still a mature industry that counts every penny. We may have discovered all of the readily extractible, large-scale reservoirs—such discoveries are now scarce at best—and hence we need to extract the remaining molecules as efficiently and as cost-effectively as possible. We certainly don't need costly "rocket science" solutions to our materials problems.

It always seems to be an exciting time in the materials business. In the 1950s it was aerospace alloys. In the 60s and 70s it was plastics and the space race, the 70s and 80s ceramics; the 90s had optoelectronics and the other materials of the information technology revolution. The last decade has been nanotechnology's time in the sun. Those who have spent careers in the materials industry recognize a number of common factors in all of these—for high performance you need pure, small-grained, and reactive materials in pure or composite form.

Nanotechnology isn't really new; it only became an area for research when we could image and measure it, and therefore manage it. New tools such as the atomic-force microscope and improved electron microscopes enable us to measure—and thus control—the size and the size-related properties of nanometer- (nm-) scale particles and structures.

Micron- (1000 nm-) sized products such as paint pigments are common; subnanometer-sized products are atoms and small molecules. So what is so special about the 1–100-nm realm? It all comes down to structure and reactivity. Small particles have relatively more surface atoms looking to form bonds with their neighbors than large particles. Their size means they are too small to scatter light (hence their use in sunscreens and automobile clear-coat). They can react at low temperatures, below 200°C, to form useful structures (as in printed electronics). Their structures may contain nanosized pores for selective absorption and controlled release (zeolites and nanotubes) or can develop exceptional strength (as seen with carbon nanotubes in sporting goods). They can have unusual biological, thermal, magnetic, optical, or electrical properties (giant magneto resistance, quantum dots).

So how is this relevant to E&P? Many of the products and applications being developed for other industries can also be exploited to benefit E&P. The recently formed Advanced Energy Consortium is looking at nanoscale applications to address sensor opportunities. There are many more potential applications areas, some of which are being pursued at Epik Energy Solutions.

Epik was formed in June 2007 as a joint venture between Shell Technology Ventures Fund 1 (managed by Kenda Capital) and NanoDynamics. Representatives of the two companies—together with staffers from Shell Global Solutions and Shell Gamechanger—worked together to identify areas where nanotechnology capabilities, often developed for other industries, could be used to address E&P "pain points."

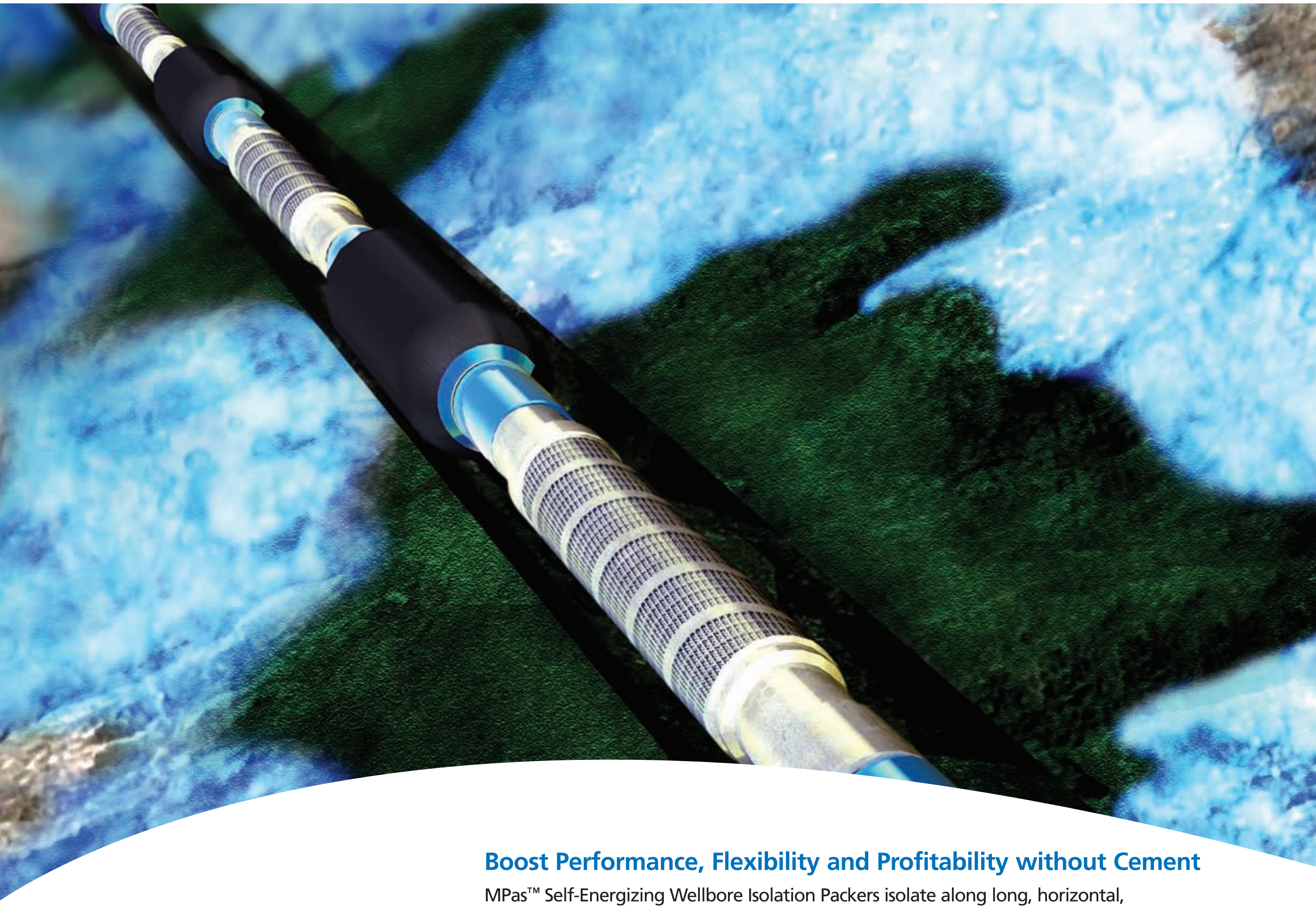
Some examples are discussed in the following paragraphs.

Water Treatment

Process water, produced water, completion fluids, and water from enhanced-oil-recovery activities present special challenges. Tightening regulations and the fact that water itself is becoming a scarce commodity in many places make the economic removal of organics and inorganic contaminants in a compact manner a critical requirement. Nanotechnology offers a number of tools that may help with this—from cellular geoceramics that host biological agents to remove organics, or nanosized reagents to remove heavy metals, to ceramic membranes for liquid and gas separation **(Fig. 1).** Such capabilities were originally developed for industrial and municipal water treatment, as well as solid-oxide fuel cells.

Fig. 1—High-integrity, nanoenabled ceramic membrane.

Isolate This!



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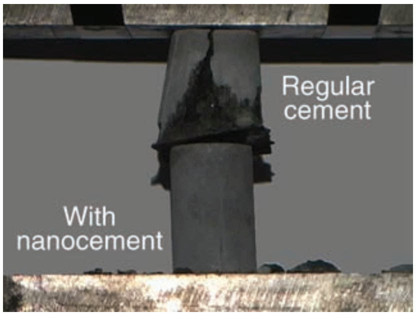

Fig. 2—Compressive testing of nano-enhanced and normal cement.

Cement

Cement is a key material in well and facility construction, where combinations of nanoadditives have shown the potential to improve set time, density, toughness, and strength, without compromising other desirable properties **(Fig. 2).** These capabilities are already being exploited by the construction industry.

High-Strength Wire

Wire is a critical component in many data-gathering and well-intervention systems. The use of nanostructured wire can lead to higher strength and corrosion resistance for many compositions in a range of applications inside and outside E&P **(Fig. 3).**

Coatings

Surface coatings are generally unpopular in E&P because of their difficult application and limited reliability—but they are widely used, nevertheless. Nanomaterials can be used to increase coating integrity, increase hardness, improve wear and corrosion resistance, and provide antimicrobial and foul-release properties **(Fig. 4).** Nanomaterials also can be used to modify the properties of elastomers, widely used in downhole applications as well as in non-E&P industries, such as automotive and aerospace engineering.

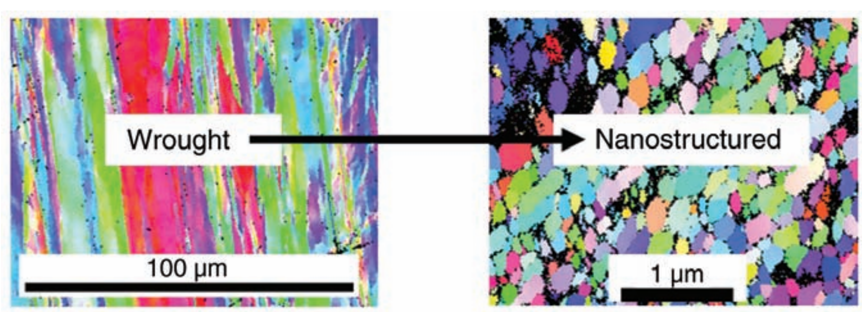

Fig. 3—Nanostructured wire grains after large-strain-extrusion machining, compared with a wrought-grain structure.

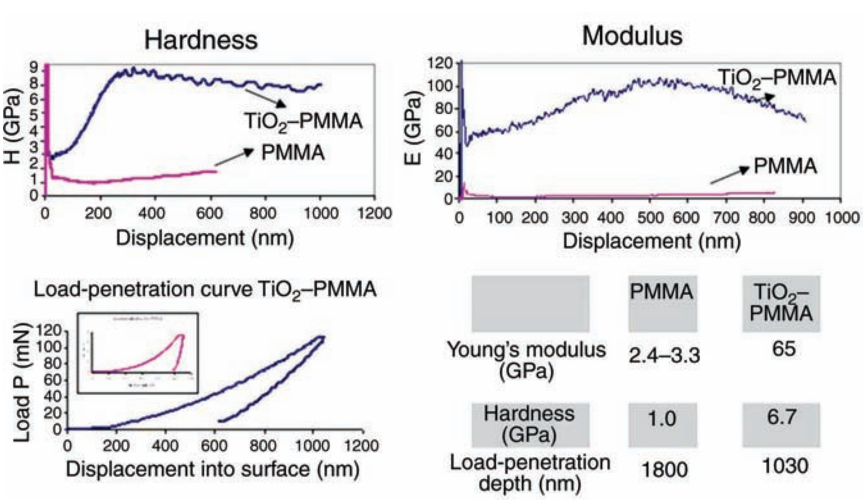

Fig. 4—Hardness, Young's modulus, and load permeability increase in coatings with the addition of nanomaterials.

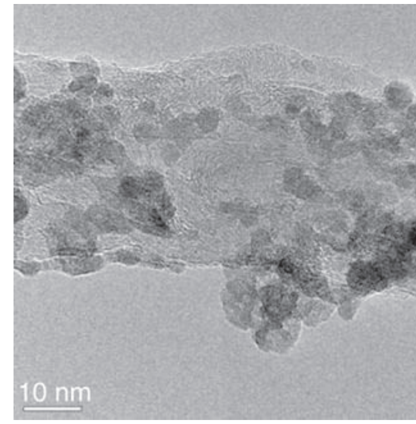

Fig. 5—A section of a 10-nm tin on a carbon-nanotube-composite anode that facilitated an increase in specific capacity of a Li ion battery from 372 to 960 mA hr/g.

Batteries

Rechargeable lithium batteries cannot withstand the downhole temperatures routinely encountered in today's wells. The use of nanomaterials for anode and cathode, combined with novel separator and electrolyte technology, can make them more reliable and extend their application to deeper, hotter environments, saving time and money by reducing the frequency at which they must be retrieved and replaced **(Fig. 5).** High temperature-resistant batteries of this type are also applicable to the automotive industry.

Summary

Many of these technologies are being fast-tracked to market, and the promise that they hold is generating a lot of interest throughout the supply chain. Everyone—national and international oil companies, service companies, and system providers and their materials suppliers—is waking up to the possibilities that nanotechnology holds for E&P. We can expect to hear a lot more about nanoenabled products at work in the E&P industry in the next few years. **JPT**