Mighty Thoughts of Small: Nanotechnology for Upstream Applications

From opening new doors in the understanding of gas flow in low permeability shale packages to reservoir monitoring and enhanced recovery, nanotechnology’s potential is huge.

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Atomic Force Microscopy

Nanoparticles and nanopore spaces are just too small to see even with the best optical microscopes. Scanning electron microscopes (SEM) cannot obtain two-dimensional topography and mineralogy images on finished surfaces. However, rocks contain many discontinuities and their properties can be heterogeneous, even at nanoscale. Atomic force microscopy (AFM) is a unique tool for nanoscale characterization because it can provide high-resolution topography images that show both mechanical and physicochemical properties.

AFM uses a stylus tip to scan a sample in a way resembling our sense of touch which allows direct measurement of interactive forces between surfaces or molecules. AFM can measure the topography of surfaces for an examination of the geometry of the pore network at the nanoscale. Direct measurement of surface forces, such as van der Waals, and electrostatic forces between molecules of interest and mineral rocks are also possible with this instrument.

Simply put, nanotechnology is the engineering of functional systems at the molecular scale.

Big Differences

One of the exciting and challenging aspects of nanoscale particles is that the behavior can be very different from classical physics, following the much more different rules of quantum mechanics. For example, you cannot walk up to a wall and be teleported to the other side, but, at the nanoscale an electron can. Insulators (substances that cannot conduct an electric charge) can become semiconductors when reduced to the nanoscale. Thermal conductivity and other physical properties can change drastically at the nanoscale.

With particle attributes changing at the nanoscale, scientists are experimenting to learn more about their properties and ways to take advantage of them in various applications. We already use many products that employ nanotechnology such as nanoparticles of zinc oxide or titanium oxide in our cosmetics. Nanoparticles and mineral grains or fluid interfaces in the reservoir is a new field of research. We can inject a certain volume of nanoparticles with specific characteristics into a well and by analyzing the nanoparticle concentration from an observation well, we learn about the geology and reservoir characteristics.

In this case, the nanoparticles act as tracers. We can also make nanoparticles smart and perhaps bring specific information about pressure or even a fluid sample. Another example is that ferromagnetic nanoparticles can be injected into the well bore prior to petrophysical well logging. The injected particles enhance well-log readings and yield better measurements about the reservoir properties. Because of their large surface area to volume ratio, new nanoparticle-surfaced propargytes are being developed that could enhance the effectiveness of hydraulic fracturing treatments.

Dr. Javadpour is the principal investigator on a project examining particle transport in porous media, one of many projects supported by 10 major international oil companies through the Advanced Energy Consortium (AEC). The AEC was the brainchild of Dr. Scott Tinker, Texas State Geologist and Director of the Bureau of Economic Geology at the University of Texas at Austin (see GeoProfile, pages 48-50), and opened in January 2008 with Dr. Tinker serving as Director.

The AEC funds research projects of particular importance to the industry at universities, labs, and companies around the world,” says Dr. Tinker. “The primary goal is to develop intelligent subsurface micro and nanosensors that can be injected into oil and gas reservoirs to help characterize these environments and provide information to assist in recovery.”

(Editor’s note: This article is a brief introduction into nanotechnology. A more comprehensive article will appear in our issue on new technologies next year.)