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APPLICATIONS OF NANOTECHNOLOGY IN OIL AND GAS INDUSTRY

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ABSTRACT

Nanotechnology is poised to impact dramatically on all sectors of industry. Nanotechnology could be used to enhance the possibilities of developing conventional and stranded gas resources. Nanotechnology can be used to improve the drilling process and oil and gas production by making it easier to separate oil and gas in the reservoir. Nanotechnology can make the industry considerably greener. There are numerous areas in which nanotechnology can contribute to more-efficient, less-expensive, and more-environmentally sound technologies than those that are readily available.

Introduction

Over the next 30 years, global energy demand is projected to rise as high as almost 60%, a challenging trend that may be met only by revolutionary breakthroughs in energy science and technology. The industry needs stunning discoveries in underlying core science and engineering. Breakthroughs in nanotechnology open up the possibility of moving beyond the current alternatives for energy supply by introducing technologies that are more efficient and environmentally sound. Nanotechnology is characterized by collaboration among diverse disciplines, making it inherently innovative and more precise than other technologies. Such a technology may be the cornerstone of any future energy technology that offers the greatest potential for innovative solutions.

The laws of classical dynamics begin to deteriorate at high velocities and small scales where Einstein's relativity and quantum mechanics take over, respectively. Accordingly, small particles traveling at high velocities are subject to the laws of relativistic-quantum mechanics. Amazing phenomenon begin to occur in this domain, and new technology is trying to take advantage of these phenomenon to create miraculous machines.

Quantum Mechanics becomes extremely important at these atomic scales. Quantum Mechanical uncertainty begins to play a large role in our ability to determine how a nanoscale machine such as a small robotic arm will behave in certain conditions. Effects like electrons tunneling through potential barriers can form both hindrances and advantages in creating such machines. Interestingly, the scanning tunneling microscope (STM) widely used in both industrial and fundamental research to obtain atomic-scale images of metal surfaces, itself uses the quantum tunneling effect to view and manipulate nanoscale particles, atoms and small molecules and to map surfaces. The STM, first used in the mid-1980s, allowed scientists not only to see details of atomic structures, but also to manipulate those structures.

Unlike relativity, which has remained unchanged since Einstein's formulation, quantum mechanics is still being formulated to some extent. This theory is not a result of only one person but of many people's calculations and ongoing experiments. Alongside, other theories are also developing for describing small scale and high velocity behaviors such as Superstrings which has been quite popular in the recent years. The theoretical developments are closely correlated with recent discoveries in nanotechnology that remained unexplained by older theories. The seemingly sudden new discoveries are not a result of an impulsive idea but sequences of small experiments gradually done in labs until a refined product is seen. When the new discovery comes into the attention of thousands of physicists all of a sudden, new ideas begin to evolve, and new theories and experiments are formed. Take for example, quantum dots which are still undergoing this gradual development.

Quantum dots are tiny particles of semiconductors such as cadmium selenide that behave as if they were individual atoms. They can absorb light energy, kicking their internal electrons up to higher energy levels, and then release the energy by emitting light. A quantum dot fluoresces much more brightly than a dye molecule, making it a desirable marker especially to track the moving molecules of a living organism since an electron microscope cannot be used. This process is known as *biological tagging*.

Importance of Nanotechnology in Industry

Nano" denotes a thousand millionths (10^{-9}), with a nanometer equaling a millionth of a millimeter. That corresponds to the width of 10 hydrogen atoms. A nanometer is merely ten angstroms long where an angstrom is named after Swedish astronomer and physicist, Ångström, Anders Jonas (1814–1874)**,** who was one of the early formulators of the science of modern spectroscopy. Ångström wrote extensively on terrestrial magnetism, the conduction of heat, and especially spectroscopy. He published a monumental map of the normal solar spectrum that expressed the length of light waves in units of one ten-millionth of a millimeter. This unit of length usually used to specify radiation wavelengths is now known as the angstrom (10^{-10} meters). He discovered that hydrogen is present in the sun's atmosphere, and he was the first to examine the spectrum of the aurora borealis. Although, the diameter of atoms varies and the basic unit is taken to be the Bohr radius ($5.2917725 \times 10^{-11}$ m), the diameter of an atom depending upon the element is approximately one to five angstroms. This puts from 2 to 10 atoms in a nanometer and 2000 to 10000 atoms in a micrometer. For example, there are about 3 silicon atom diameters in a nanometer.

So the nanotechnologist is concerned with building new structures and substances by manipulating molecules and atoms on this scale. Technically, nanotechnology is the art and science of building materials that act at the nanometer scale. It builds at the ultimate level of finesse, one atom at a time, and it does it with molecular perfection. In a general sense, nanotechnology is the ability to create and manipulate matter at the molecular level that makes it possible to create materials with improved (or, more accurately, altered) properties, such as being both lightweight and having ultrahigh strength, and greater capabilities such as in electrical and heat conductivity. Another research approach is known as top-down nanofabrication, which involves working with bulk materials and reducing them to nanometer size. This is most common in currently used technology development schemes.

Nanotechnology is poised to impact dramatically on all sectors of industry. In oil and gas applications, nanotechnology could be used to increase opportunities to develop geothermal resources by enhancing thermal conductivity, improving downhole separation, and aiding in the development of non-corrosive materials that could be used for geothermal-energy production. Nanoscale metals already have been used to delineate ore deposits for geochemical exploration.

Nanotechnology can be used to improve the drilling process. some specialized petroleum laboratory has developed an advanced fluid mixed with nanosized particles and superfine powder that significantly improve drilling speed. This blend eliminates damage to the reservoir rock in the well, making it possible to extract more oil.

Nanotechnology and Gas Industry

Nanotechnology could be used to enhance the possibilities of developing unconventional and stranded gas resources. Near-term challenges focus on liquefied-natural-gas (LNG) infrastructure and efficiency, LNG quality, and developing gas-to-liquids (GTL) technology. Midterm challenges include developing superpipelines; constructing floating GTL platforms; production, regasification, and storage issues; and compressed-natural-gas transport. Long-term issues to be addressed are production of methane hydrates and gas by wire—producing electricity at the location of the gas source and carrying the electricity by wire to market rather than the gas to market by pipeline. Nanotechnology can address the problems associated with accessing stranded natural-gas resources by developing nanocatalysts and nanoscale membranes for GTL production and creating nanostructured materials for compressed-natural-gas transport or long-distance electricity transmission .

Nanotechnology and Oil Industry

The oil industry needs strong, stable materials in virtually all of its processes. By building up such substances on a nanoscale, it could produce equipment that is lighter, more resistant, and stronger. GP Nano Technology Group Ltd. in Hong Kong was one of the first to develop silicon carbide, a ceramic powder, in nano size. It yields exceptionally hard materials. The company is now investigating other composites and believes that nanocrystalline substances can contribute to harder, more wear-resistant and more durable drilling equipment . Nanotubes have many potential applications within the oil industry. For instance, nanotubes could be used to create lighter, stronger, and more corrosion-resistant structural materials in platforms for offshore drilling. Nanotechnology could help improve oil and gas production by making it easier to separate oil and gas in the reservoir—for instance, through improved understanding of processes at the molecular level. There are many other potential clean energy sources that could be enhanced through the use of nanotechnology. The practical application of nanotechnology in the oil sector is, fortunately, less frightening. It opens interesting prospects for improved oil recovery, not least through better understanding of processes at the interface between liquids and solids. The aim is to understand how oil and water can be separated more effectively. Nanotechnology could be applied to improved oil recovery in the form of tailoring surfactants. These can then be added to the reservoir in a more controlled way than with existing substances, thereby releasing more oil. It could also help develop new metering techniques with tiny sensors to provide improved information about the reservoir.

Nanotechnology and Environment

Pollution by chemicals or gases is a difficult aspect of petroleum production, but the signs are that nanotechnology can make the industry considerably greener. Filters and particles are now being developed with a nanostructure that allows them to remove volatile organic compounds from oil vapor and mercury from soil and water. Filters and membranes designed with nanoscale precision provide full control over what flow through.
A new type of fluids, which can be labeled as “smart fluids,” is becoming increasingly available to the oil and gas industry. These nanofluids are designed by adding nanofabricated particles to a fluid in order to enhance or improve some of its properties. Essentially, nanoscale particles are suspended in the liquid phase in low volumetric fractions. The liquid phase can be any liquid such as oil, water, or conventional fluid mixtures. The nanoparticles used in the design of such fluids are preferably inorganic with properties of no dissolution or aggregation in the liquid environment. They can be designed to be compatible with reservoir fluids and are environmentally friendly. Recent experiments have shown some promising nanofluids with amazing properties such as fluids with advanced drag reduction, binders for sand consolidation, gels, products for wettability alteration, and anticorrosive coatings.

Nanotechnology and Exploration

In high-temperature/high-pressure conditions, old electrical sensors and other measuring tools often are not reliable. But researchers currently are developing a set of reliable and economical sensors from optical fibers for measuring temperature and pressure, oil-flow rate, and acoustic waves in oil wells. These new sensors are small in size, work safely in the presence of electromagnetic fields, are able to work in high temperatures and pressures, and can be changed at a sensible cost without interfering in the procedure of oil exploration.changing and displacing old sensors in oil wells is very costly. But this technology could, with its accurate and reliable measurements, make a great improvement in oil exploration. In the future, the industry may be using nanoscale sensors for probing properties deep in the reservoir, allowing us to unravel the complex nature of the rock/fluid interactions and their effects on multiphase flow and providing the ability to design a suitable exploitation plan for the asset. Another area of significant challenge lies in the upgrading of bitumen and heavy crude oil. Because of their high density and viscosity, it is difficult to handle and transport them to locations where they could be converted into valuable products. Significant resources and intense research activities have been devoted to develop processes and specifically designed catalysts for on-site field upgrading combined with hydrogen/methane production. These processes would incorporate a minimized and controlled carbon rejection, in conjunction with a catalytically enhanced hydrogen generation performed on the rejected carbon from the upgrading process. This central activity will be complemented with an effort to integrate the research for ultradispersed catalytic formulas for the in-situ upgrading of bitumen as well as for hydrogen generation from coal/coke or petroleum pitch. The former requires research on specifically designed adsorbents and catalysts to be introduced into the reservoir porous media in nanosized form. The latter requires extensive research on both catalytic active phases and process setup as well as adopting different catalytic forms for effective contact with the gasifying materials. This research has the potential to generate significant technology to convert bitumen and heavy-oil reserves into products cost-effectively .

Nanomaterial Application

People have wanted to be rich for centuries. People have been trying to create gold ever since gold became the measure of wealth. People have also been trying to make diamonds because not only are they expensive and a display of aristocracy, but also rare, and quite useful in industrial applications such as cutting. Unlike gold, diamonds are constructed of carbon which is readily available at dirt cheap prices. If anyone could cheaply put carbon atoms together to form diamonds, he would become rich instantly.

Some of the possible benefits of nonomaterials are the outcome of miniaturization, while others are the result of change in the property of the material. As readily accessible reserves become depleted, the oil and gas industry faces increasing technical challenges, which lead to increased costs and limit the operating envelope of drilling and production technologies. This represents a significant market opportunity for nanomaterial-based solutions, which contend with corrosive impurities, high temperatures and pressures, shock loads, abrasion, and other hostile environmental conditions. However, very few nanomaterial-based products have yet to appear in the oil and gas technology basket. This can be attributed to a number of factors, including:

- Lack of innovation in the E&P sector.
- Barriers to entry and adoption.
- Perceived cost and risk.
- Lack of awareness.

To facilitate this, oil and gas companies should enter into partnerships with nanomaterial developers at an early stage. Both sides need to accept that some necessary investment risk must be taken to bring nanomaterials into the market. There are numerous areas in which nanotechnology can contribute to more-efficient, less-expensive, and more-environmentally sound technologies than those that are readily available. Although the most significant contributions may be unglamorous applications such as better materials for exploration equipment or improved catalysis, nanotechnology is being proposed in numerous energy domains. Considering the substantial budgets for research dedicated to nanoresearch, much of this potential is likely to be realized in the coming decades.

In the future, nanotechnology will let us take off the boxing gloves. We'll be able to snap together the fundamental building blocks of nature easily, inexpensively and in most of the ways permitted by the laws of physics. This will be essential if we are to continue the revolution in computer hardware beyond about the next decade, and will also let us fabricate an entire new generation of products that are cleaner, stronger, lighter, and more precise.

Results and Conclusions

We identified the following possibilities of nanotechnology in the petroleum industry:

- Nanotechnology-enhanced materials that provide strength and endurance to increase performance and reliability in drilling, tubular goods, and rotating parts.
- Improved elastomers, critical to deep drilling and to improve drilling in high-temperature/high-pressure environments.
- Designer properties to enhance hydro-phobic or hydrophilic behavior, to enhance materials for waterflood applications.
- Nanoparticulate wetting carried out using molecular dynamics, which shows promise in solvents for heterogeneous surfaces and porous solids.
- Lightweight, rugged materials that reduce weight requirements on offshore platforms, and more-reliable and more-energy-efficient transportation vessels.
- Nanosensors for improved temperature and pressure ratings in deep wells and hostile environments.
- New imaging and computational techniques to allow better discovery, sizing, and characterization of reservoirs.
- Nanosensors deployed in the pore space by means of “nanodust” to provide data on reservoir characterization, fluid-flow monitoring, and fluid-type recognition.
- Small drill-hole evaluation instruments to reduce drilling costs and to provide greater environmental sensitivity because of less drill waste.

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