Nanotechnology And Nanosensors Of Trends In Oil And Gas Industry

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Nanotechnology and Nanosensors

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Biography:

A native of India, Pavani Vattikuti graduated from Bangalore University in 2009 with Master of Science in Biotechnology. My work experience includes prestigious institutes of India such as ITC R&D and rice research institute of India. After two years in 2012, I moved to Norway. Right now I am doing course in nanotechnology through which I got a good opportunity to improve my knowledge in Nanotechnology field. I'm very grateful to prof. Haick Hossam

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Abstract:

The petroleum industry encompassing the production and utilization of oil and natural gas, has dominated the energy scene for a century and by all reasonable indications will continue to do so well into the twenty-first century. But fulfilling worldwide energy demand in the 21st century is the most challenging problem. Current technologies simply cannot meet these demands. Conventional resources and exploration and production techniques might not be sufficient to attend to this demand. Nanotechnology can offer some solutions to these challenges.

Nanotechnology has had an enormous impact in almost every industry, from consumer electronics to healthcare and telecommunications, but not in oil and gas exploration and production. The general aim is to bridge the gap between the oil industry and nanotechnology community using various initiatives such as consortia between oil and service companies and nanotechnology excellence centers, research units inside some oil companies. Although nano-sized catalysts have been used in refining and petrochemical processes for many years, the use of nanomaterial's and nanotechniques has only recently entered the upstream domain. Nanotechnology offers the promise of the intelligent oil field. Nanotechnology holds great promise, both for mapping out and manipulating fossil-fuel reserves, because of the small scales that characterize the cracks and pores where oil is stuck. Nano prospecting, Nanophysics in Oil and Gas E&P, Reservoir Surveillance and Enhanced Oil Recovery, Upstream: Exploration sensors, high performance materials; Drilling-chemical and abrasion resistant coating, production tubular, alloys for increased strength and endurance at reduced weight, nano-scale chemicals to control fluid losses, nano-composite elastomers, hydrophobic/hydrophilic properties control, novel materials responding to water presence; Production-fluid flow sensors, fluid type recognition sensors, nano-membranes; Reservoir engineering- rock porosity sensors; Well logging- wireless sensors applications of molecular simulation in the oil and gas industry: Monte-Carlo Methods.

Introduction:

The Oil and Gas exploration and production industry faces difficult challenges, as it tries to meet the growing energy demands of an increasing and more affluent population. Conventional methods of exploration and production might not be able to keep up with this growing demand; the industry needs technological innovations to successfully meet the energy challenge. Nanotechnology has had a revolutionary impact in many industries, from healthcare to aeronautics, and could potentially have a similar impact in the oil and gas exploration and production industry.

Nanotechnology is not new. Nanoparticles have been used for hundreds and even thousands of years1, even though their nature and properties were not fully understood until recently. The oil refining and petrochemical industries have used nanoparticle catalysts for almost 100 years. What has triggered a nanotechnology revolution was the developments of techniques in materials science, chemical engineering, and physical analytical methods, particularly the invention of the Scanning Tunneling Microscope2 and the discovery of Buckyballs3 that allowed a detailed understanding and manipulation of the properties of nanoparticles4. For clarity, I define nanotechnology as the understanding and control of materials and materials properties at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications. The emphasis is on control - the manipulation and engineering of materials at the nanoscale to obtain desired properties.

Recently, the oil industry has been approaching nanotechnologies as a potential solution to the above mentioned challenges, calling for the same break through effects that this relatively new branch of science has been gushing over the last 20 years in aerospace, biology and medicine. Properties of nanomaterials such as lightness, corrosion resistance and mechanical strength are and will be significant enablers, for example, for drilling and completion activities. Nanotechnology could also represent a breakthrough element for prospection, thanks to the development of innovative monitoring techniques and smarter micro/nano sensors. Other emerging applications of nanotechnology are represented by the development of new types of "smart fluids" for water shut-off and improved/enhanced oil recovery.

Developing Nano sensors for oil recovery, this can be used to detect the bypassed oil after a cycle of EOR. Which is based on the identification and excitation of chemotaxonomic markers present in them since microbes thrive on oil water interface, wherever they will be detected it is a sign of oil being present there. After any microbial, thermal or chemical recovery process microbial sensor tools can track oil directly by sensing H-C, H=C, etc. bonds present in oil.

Nanotechnology striving to help the oil and gas industry increase oil recovery by improving: chemicals used in recovery of oil, drilling materials and reservoir surveillance. Nanocoatings are used in oil and gas industries: Antiwear for drilling parts, anti-corrosion for pipelines and other exposed long term structures, lubricants and drilling mud, thermal coatings to lower deformation and anti-fouling for ships.

Literature Review:

Nanotechnology continues to develop rapidly, driven by several different industries. The main objectives of this program are (i) to introduce recent and emerging developments into the oil industry; (ii) to identify applications that could bring significant benefits to the upstream oil operations and oil recovery; and (iii) to carry out research that would enable the practical implementation of these technologies within the oil industry. Our current focus is on the use of various nano-scale materials ("nanoparticles") for certain processes that increase oil recovery and for more accurate determination of changes in fluid saturations and reservoir properties during oil and gas production.

The subsequent improvement should be the nanosensors or nanosensors clusters localization. Under this respect, the special electrical, optical and magnetic properties of nano meterials make them well suited for use as injected sensors and contrast agents. Several possible applications and exploitation schemes are currently under study with nano devices injected in to a reservoir.

Based on the available technology the path to "slightly" smart nanosensors is shorter and could introduce significant advantages for reservoir investigation. 100-1000 nm diameter passive nanoobjects could be flushed with the injection fluids through the pores of the reservoir rocks to determine the formation characteristics. No active components (sensor, data storage or transmission, 3D location, power) would be on-board, but the presence of a proper structure (multi-wall nanowires, core-shell particles,) interacting with the reservoir could retrieve threshold information (maximum temperature and/or pressure, maximum pH, salinity,). The magnetic (through a magnetic core) or electrical (as in the case of Carbon nanotubes) conductivity of such nano-dust could be exploited for recovering information. Using a core-shell structure, for example, the quantity of oil present in a reservoir could be assessed based on the amount of material lost or retained during the travel time, or the extreme conditions (temperature, pressure, and salinity gradient) at which the nanoparticles were exposed and for how long, could be determined. The idea could be to pump nano-sensors in the reservoir periodically so as to regularly monitor changes in the well/field conditions. In turn, this could result in improved production efficiency and trouble managing (Durham, 2009). An interesting and extremely efficient property which could be exploited at the nanoscale is the shape memory effect.

Project Description:

First we will talk about some basics regarding nanotechnology and why oil industry interested in nanotechnology:

The incredibly small size of the nano-scale materials creates opportunities for them to be injected into oil and gas reservoirs. Geoscientists have analyzed enough of the oil-bearing sandstones to establish that the pore throat openings commonly range between 100 and 10,000 nanometers in width. That's large enough for fluids like water, brines, and oil and gas to flow through relatively freely. So if we could put nano-scale tracers or sensors down a hole, they would be small enough to flow through these pores, and we could gain a bunch of valuable information about the rock and the fluid environment where the oil and gas is found. Fig (1)

Sensors: According to Krishnamoorti (2006), nanomaterials are excellent tools for the development of sensors and imaging-contrast agents due to the significant alterations in their optical, magnetic and electrical properties (in comparison to their bulk analogues) along with their ability to form (electrically and/or geometrically) percolated structures at low volume fractions. Such nanomaterials, when combined with smart fluids, can be used as extremely sensitive downhole sensors for temperature, pressure and stress even under extreme conditions. The ultimate evolution of devices for prospection is represented by nanorobots, which should really provide an effective mapping of the reservoir. Nowadays, nanorobots still remain a dream, shared by the medical and oil sectors. But advances in nanosensor miniaturization are occurring rapidly and numerous theoretical and experimental investigations about the flow of multiphase fluids containing nanoparticles in porous media enrich the recent technical literature.

Coatings: Significant work is underway toward the transition of smart/multifunctional polymer coatings from laboratory curiosities toward the identification of commercial applications. Intelligent or smart coatings, which may combine the shielding aspect with sensor or actuator functions, rely on their capabilities to respond to physical, chemical or mechanical stimuli by developing readable signals. Nanomaterials are expected to be used not only as advanced functional materials, but also as an integral part of complete smart structures composed of various elements including sensors, actuators,control devices. Some of the key challenges in more advanced research areas are the understanding of corrosion protection mechanism imparted by conducting polymers and the advancement of Micro nanocapsulation as a means to impart selfhealing (Boura et al., 2010). Nevertheless, some innovative applications seem to be ready for commercialization in a very nearby future, such as a coating using carbon nanotubes to conduct a current for evenly heating surface, which could be used on pipelines to reduce gas hydrate formation or to de-ice the blades on wind turbines (Rassenfoss, 2011).
An innovative corrosion-resistant material solution could also be represented by nanometric thin films and composites with nanostructured fillers. Apart from the economic aspect, which is not strongly favorable yet, corrosion-resistant materials are surely the "just round the corner" nanotechnology-based applications, basically because of the combination of several conditions: relatively low risk, high effectiveness and low complexity. Nano-coated, wear-resistant probes, made of tungsten carbide or boron nitride, enhance the lifespan and efficiency of the drilling systems, thus inducing remarkable cost savings. The same applies to the nano-layered corrosion inhibitors in pipes or tanks, which act through the creation of a permanent molecular layer on the surface of metals, thus eliminating or hampering corrosion induced by HCl or H_2S.

Smartfluid /Nanofluids can provide solutions for: Enhanced Oil Recovery, enhanced fluid viscosity and molecular modification. Nanosensors deployed in the pore space by means of "nanodust" to provide data on reservoir characterization, fluid-flow monitoring, and fluid-type recognition. Exciting science referred to as nanotechnology is being introduced into reservoir characterization and monitoring. The sizes of devices and sensors that can now be fabricated to react in measurable ways when they contact a specific fluid, chemical or biological agent have been reduced so that they can be injected into some hydrocarbon reservoirs and become part of the fluid flow through the reservoir system. Common terminology appearing in descriptions of this new reservoir-monitoring science includes nanodevices, nanosensors and nanorobots. Fullerene are a family of carbon allotropes, molecules composed entirely of carbon, in the form of a hollow sphere, ellipsoid, tube, or plane. Spherical fullerenes are also called buckyballs, and cylindrical ones are called carbon nanotubes or buckytubes fig (1). Graphene is an example of a planar fullerene sheet. Fullerenes are similar in structure to graphite, which is composed of stacked sheets of linked hexagonal rings, but may also contain pentagonal (or sometimes heptagonal) rings that would prevent a sheet from being planar. The target molecule that initiates the desired reaction can, in theory, be tailored to be a wide range of molecules found in, or associated with, producing hydrocarbon systems. NanoPhysics for Sensing, Modifying and Manipulating Oil-Gas Reservoirs; A Delve Deep /Deep Dive into the Nano Domain. Fig. (2)

The demand for fossil fuels will increase in the decades to come, but the era of finding “easy oil” is coming to an end. Exploration increasingly needs to focus on hydrocarbon prone sedimentary basins that are much deeper, and more difficult to access. The detection of fossil-fuel reserves is complicated by the fact that the repertoire of methods to discover such reserves with a high probability of success is limited.

Drilling for hydrocarbons is expensive and necessarily provides only near-wellbore “local” information – there is a great need for exploring fossil-fuel reserves volumetrically.

To put the possibility of injecting nanodevices into reservoirs into perspective, a comparison between reservoir pore sizes and diameters of nanodevices is helpful.

Because nanotubes can be designed to become efficient electrical conductors, electromagnetic (EM) measurements may be the branch of geophysics that first develops applications of nanotechnology in reservoir characterization.

Nanodevices, perhaps, can be made that initiate their predesigned action after set periods of calendar time to measure how far they have progressed through a reservoir and to identify in which XYZ coordinates they reside after that time period.

A possible application is illustrated in fig. (3).

In this hypothetical case, nanodevices are injected into a reservoir, and at predesigned time delays (arbitrarily set at 1, 2, 3, 4 and 5 arbitrary calendar-time units in this example), the positions of the injected conductive nanodevices are measured by an appropriate crosswell EM or surface-based EM procedure. The objective is to determine, in three-dimensional space, the internal flow paths that exist within a reservoir system as that reservoir is being produced. If nanodevices can be designed to become miniature acoustic pingers, as some envision and hope, the progress of the nanodevices through a reservoir can perhaps be measured by crosswell seismic methods.

Nanotechnology holds great promise, both for mapping out and manipulating fossil-fuel reserves, because of the small

Scales that characterize the cracks and pores where oil is stuck. Sensors that can access these pores to determine properties and content need to be small, and manipulation of the oil/water mixtures in these pores, for example emulsification or gelation to enhance oil recovery, also has to take place on small scales. On the one hand, the study, manipulation and production of increasingly sophisticated small ``particles” with sizes ranging from less than one nm to several microns (functional colloids, janus and patchy particles, nanotubes, supramolecular complexes) has taken an enormous flight in recent years. On the other hand, nanotechnology is already finding applications in several areas related to the Oil and Gas Industry.

Nanostructured Coatings, Improved Prop pants, Nanoenhanced elastomers, and new ceramics etc. are already under development or in the testing phase. Although applications in reservoir surveillance and enhanced oil recovery seem to be further away, it is these areas that Nanotechnology will probably have the biggest impact.

Technologies like nanoscale sensors that could travel through the reservoir generating detailed maps of the reservoir properties would be game changing and would significantly increase oil recovery. Other nano based technologies aimed at directly manipulating subsurface conditions could significantly improve current EOR techniques.

Fig. (5)

Before these types of applications become possible, a better understanding of fundamental aspects related to the flow and functionality of nanomaterials within the reservoir is crucial to develop Nano Physical approaches for Sensing, Modifying and Manipulation of (transport in) Oil-Gas reservoirs. Develop effective theory and model systems to capture these aspects of the flow and activity of (nano) particles. "Nanophysics for E&P" is to identify and study these fundamental issues necessary for exploiting the full potential of Nanotechnology for Reservoir Surveillance and Enhanced Oil Recovery. The themes addressing these fundamental challenges: 1) Transport; 2) Trigger; 3) Sensing and 4) Manipulation.

Pores can be anywhere from 10 microns to one microns in diameter. Because of their size, once the initial high pressure of the reservoir has been reduced by releasing some of the oil, this porosity can impede the flow of oil or gas through the rock formation. It can take a lot of work to get the oil out of the rock.

The researchers believe that, in addition to locating and mapping oil and gas, nanoparticles might also be able to help recover the fuels. "The trouble is that the oil in the pores sticks to the walls, even when high-pressure steam is blasted into the rock. The hope is that with the right nanoparticles, the researchers might be able to free the hydrocarbons from the rock.

The twin goals of more score in pores:

(a)“to develop innovative "in-situ" and “ex-situ” techniques”, as well as effective combinations of them, in order to assemble an innovative tool dedicated to the investigation and controlling of the evolution of the nanomaterial properties and to considerably expand the understanding of confinement phenomena in nanopores.

(b) To advance the nano-manipulation of porous materials.

For VES (Visco Elastic Surfactant) type surfactants when its concentration exceeds Critical Micellar Concentration (CMC) in presence of an electrolyte (like KCl, $CaCl_2$ etc.) the surfactant molecule aggregate and form elongated rod like micelle. The rod like micelles can interact to form a network exhibiting viscoelastic behavior.

Fig (6) Fig (7)

Nanomembranes: Inspired by the success of zeolites, which are materials capable of separating small gases such as oxygen and nitrogen, a new generation of large-scale, lightweight and sturdy nanomembranes is being developed and deployed. These nanomembranes will significantly enhance the exploitation of tight gas by providing efficient methods for removing impurities, separating gas streams and enabling GTL production. By exploiting methods common in the microelectronics industry, the cost of manufacturing highly uniform and reproducible membranes is quite competitive (Krishnamoorti, 2006). Nanoporous and nanoparticular materials are also very promising to manage the environmental, health and safety risks deriving from the presence of CO_2 and H_2S in hydrocarbon mixtures.

Nanofluids and nanomaterials for drilling and completion: Drilling and completion sectors are other two oil branches where the benefits of nanofluids and nanomaterials application are already tangible. Nanotechnology has opened the door to the development of a new generation of fluids defined as “smart fluids” for drilling, production and stimulation related applications. Thanks to the exceptionally high surface to volume ratio, nanofluids and nano-based additives exhibit major interaction with the surrounding environment even at very low concentrations. Such smart fluids will further enhance drilling by adding benefits such as wettability alteration, advanced drag reduction and sand consolidation (Chaaudhury, 2003; Wasan and Nikolov, 2003).

One specialized petroleum laboratory has developed an advanced fluid mixed with nano sized particles and superfine powder that significantly improves the drilling speed and can eliminate formation damage in near wellbore zone (Esmaeili, 2009).

Prof. Tour’s Laboratory works with M-I SWACO’s to optimize the effectiveness of graphene additives to drilling fluids Nanowerk Website, 2009, Rice University News and Media Relations Website, 2009.

Thanks to the synthesis of a new class of elastomeric composites filled with carbon nanotubes or other strongly anisotropic nano-objects, stronger, tougher and more resistant drilling tools and apparatus will be manufactured in the coming years. At the same time, these tools will ensure a significant weight reduction and the potential to originate self-sensing elements to be interrogated for the real-time monitoring of the most critical parts.

Another important technique in the development of super-hard materials is the use of nanostructured dispersed-hardened materials (Terranova *et al*., 1999). The superiority of physical-mechanical properties of diamond polycrystalline nanocomposites (Terranova *et al*., 1999), boron nitride nanocomposites (Dubrovinskaia *et al*., 2007) and 2WC/Co/diamond nanocomposites (Jain, 2001) in comparison with their traditional counterparts has been reported in the literature.

First generation of nanotech applications for improving hydraulic fracturing are represented by Baker Hughes's nano-structured metal composites, combined by magnesium, aluminum and other alloys, which offer both strength at lower weight and the ability to "dissolve" away under certain conditions. Another example is the proppant produced by Oxane Materials, constituted by nano-structured ceramic material which is as strong as but lighter as ceramic proppant.

A possible solution for mitigating fine migration problems is represented by the commercialized nanocrystals for treating hydraulic fracture proppant packs to fixate formation fines. The mechanism of fixation of the formation fines depends on the high surface forces of the nanoparticles, such as Van der Waals and electrostatic forces, which also attach the nanoparticles to the surface of proppant during fracpacking and fracturing treatments (Huang *et al*., 2008).

Conclusion:

Nano science & technology is an emerging technology for petroleum industry.Applications of nano physics is revolutionary step for upstream/exploration & production of oil & gas. To enhance R/P ratio of nations, we have to pay too much attention on enhanced oil & gas recovery.It signifies to convert plentiful resources of mature oil & gas field as an asset to E & P sector. By applying nanotechnology, we can recover 90% oil & gas from the reservoir in place of 40-50% recovery at present. Nanofluids score more from pore of core/sweet spot of the oil & gas reservoir. Nanofluids are being used in Ultra-Deep Drilling Fluids. Drilling fluids, commonly referred to as drilling muds, are an integral part of drilling oil and natural gas wells. This action not only cools and lubricates the drill bit, it also helps to convey rock debris and drill cuttings from the drilling area to the surface. The drilling fluids can also help prevent blowouts and wellbore cavings by creating hydrostatic pressure that stops formation fluids from entering the well prematurely. Nanotechnology provides solutions for: By providing solutions for sensing and intervention nanotechnology can help find and recover more conventional oil, improve oilfield data, and diversity sources of supply.

The future of nanotechnology seems to be bright. Nevertheless, several issues are to be considered and the following actions should be taken to transform a big opportunity into reality: favour multi-disciplinarity, improve convergence between the top-down and the bottom-up approaches (namely, miniaturization and the creation of smart materials by exploiting their selforganisational capacity), be careful with the "nano" hype (often nano erroneously comprises traditional physics and chemistry) and, finally, consider the usual long-term research and investment time frame for targeting business properly.

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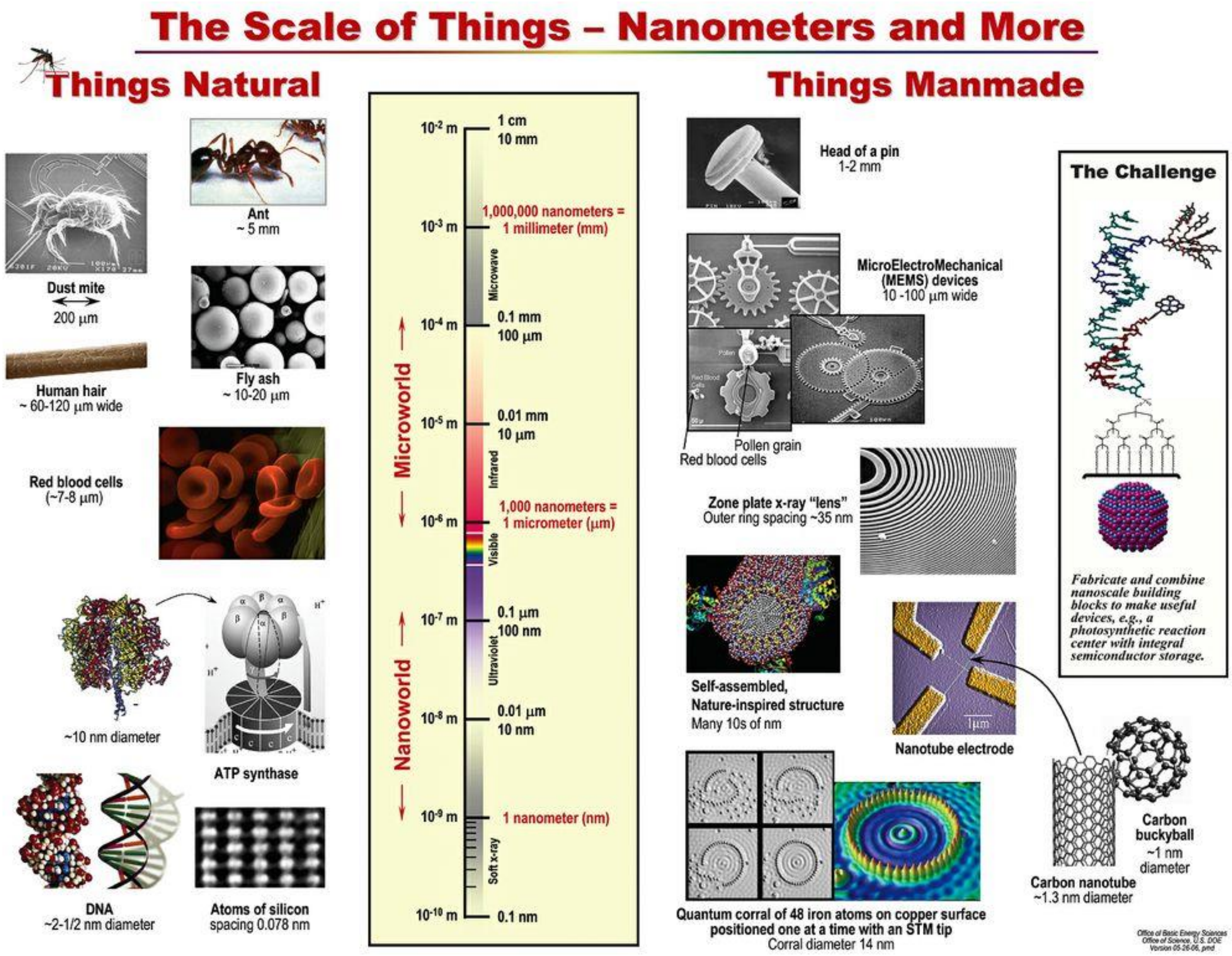
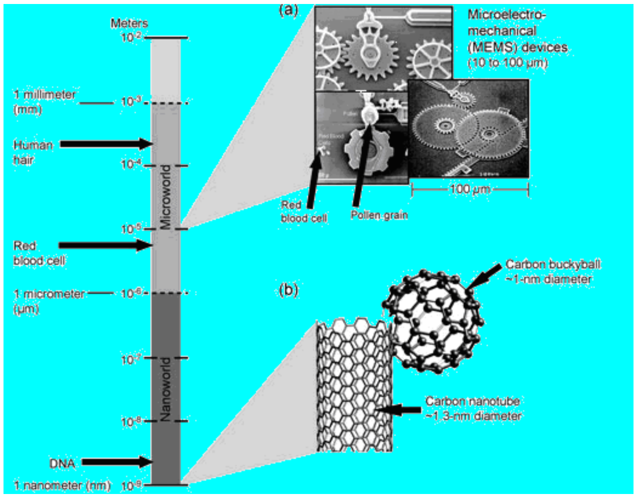
Figures:

Fig((1)

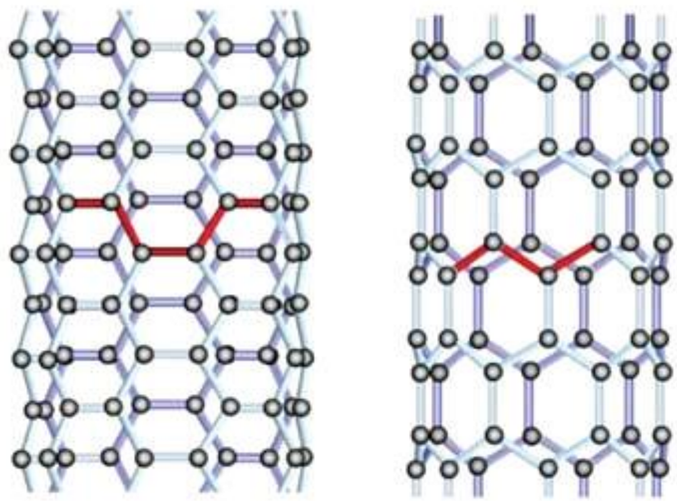


Fig(2)



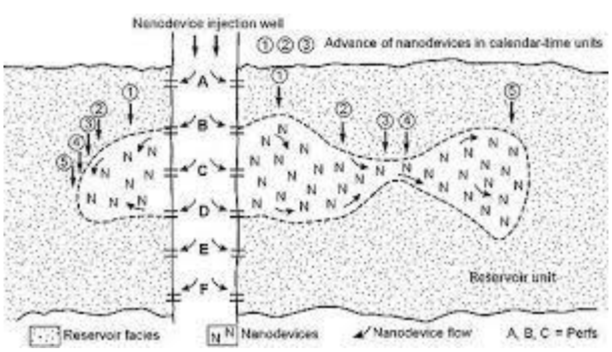
Logarithmic scale on left shows size range of selected natural objects .Objects are compared with size range of manufactured nanodevices, extending from MEMS devices (top) tobuckyballs (bottom).

Fig (3) :



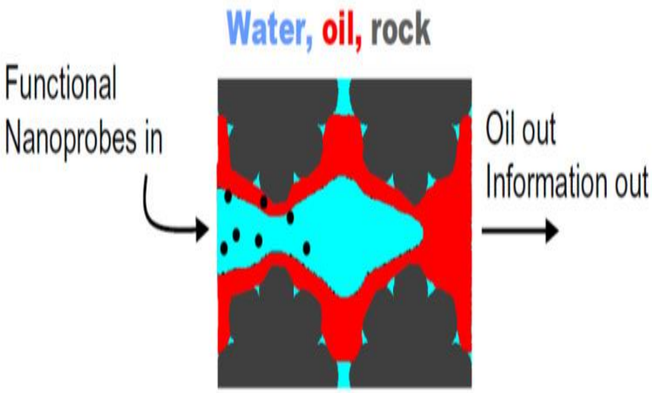
Atomatic structure of carbon nanotubes

Fig (4):



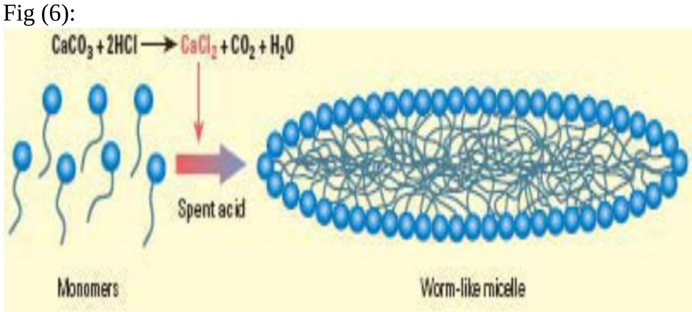
One concept for use of nanotechnology in reservoir characterization. Nanodevices (N) are injected in perfs A through F and move through a reservoir. At calendar-delay times of 1, 2, 3, 4 and 5 time intervals, spatial distribution of the nanodevices is measured by EM or seismic methods to determine their XYZ coordinates, allowing inferences to be made about fluid-flow paths, compartment boundaries and reservoir connectivity

Fig (5):



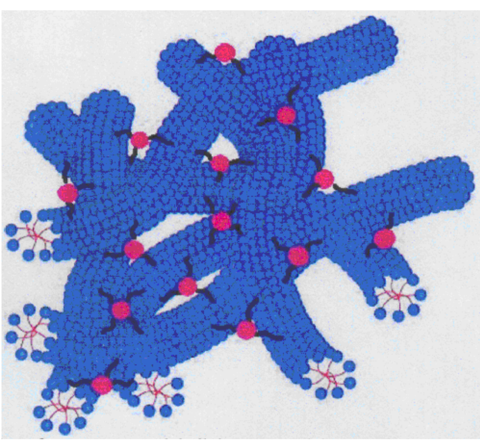
Rock properties/Petrophysics

Fig (6):



Micelle without nano -particle addition

Fig (7):



Micelle with nano -particle addition