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Nano-Science & Technology in Upstream

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Summary:

With a view to fuel security of the world, geoscientists & petroleum technologists have to play a pivotal role to enhance R/P ratio of nations. That's why enhanced oil & gas recovery is pertinent tasks before oil & gas industry. We have to pay too much attention on microbial enhanced oil & gas recovery. Nano science & technology has to revolutionise oil & gas industry as NEOR for improved oil & gas recovery between 80-90% of the original oil in place (OOIP). 4th Generation Seismic Oil & Gas Industry. 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.

Applications of nanotechnology to the exploration and production of oil and gas is bearthrough in nanogeoscience, upstream sector. 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 tubulars, 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:

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 their. 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. Nanotech can be used to develop effective surfactants which because of increased charge attraction and surface adsorption provide much stronger dynamic network and provide better result. Surfactants need to be stable at high temperatures and pressures and/or high pump rates and shear rates which may cause the fluid to degrade but nano surfactants even if they break down will pass through pores hence less number of nano particles can be used to provide same viscosity.

The pertinent task is to develop subsurface nanosensors that can be injected into oil and gas well bores. By virtue of their very small size, these sensors can migrate out of well bores and into pores of the surrounding geological structure to collect data about the physical and spatial characteristics of hydrocarbon reservoirs. Data collected could enable more efficient exploitation of hydrocarbon resources.

Possible nanotech breakthroughs for the oil and gas industry could show up in: Enhanced materials: Inclusion of nanoparticles may lead to more durable and effective drilling components, lighter and sturdier offshore platforms and a variety of corrosion-resistant materials, among other benefits.

Reservoir engineers and geoscientists describe what they want to measure, and nanotechnology scientists decide whether, and how, an appropriate nanodevice can be manufactured that will generate the required data.

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4th Generation Seismic:
Seismic Exploration: Leading (Cutting) Edge Technology

Survey index	Seismic record arguments	Data Dimensionality
1D	T	1D
2D	Lx, t	2D
3D	Lx , Ly, t	3D
4D	Lx , Ly, t , τ	4D
3D/3C	Lx , Ly, t, α_r , φ_r	5D
4D/3C	Lx , Ly, t , τ , α_r , φ_r	6D
3D/9C	Lx , Ly, t, α_s , φ_s , α_r , φ_r	7D
4D/9C	Lx , Ly, t , τ , α_s , φ_s , α_r , φ_r	8D

Where: t = time, Lx = offset on x,
Ly = offset on y, τ = date of seismic survey, α_r = azimuth of a component recorded at a receiver point, φ_r = bearing of a component recorded at a receiver point,
α_s = direction azimuth at a shot point , φ_s = direction bearing at a shot point.

New separators and nanomembranes: Stable and lightweight membranes could be used to filter impurities from heavy oil and tight gas, as well as in environmental applications.

There are particular separation technologies that will be extremely useful not only for the exploration and production industry, but also for the carbon-capture issue, added. Advanced fluid additives: Nano-scale additives might be used in everything from improved drilling fluids to more efficient and environmentally friendly fuels.

Theory:

Sensors and imaging agents: The special electrical and magnetic properties of nanomaterials make them well suited for use as injected sensors and contrast agents. Because they can withstand high temperature and pressure, nano-scale sensors could be especially useful for characterizing deep reservoirs.

The term "nano" indicates the minute size of everything related to this technology. Common terminology appearing in descriptions of this new reservoir-monitoring science includes nanodevices, nanosensors and nanorobots.

Nano Electro Mechanical Systems(NEMS) : By putting electronics, sensor materials, and nanotechnologists together with experts from the oil and gas industry to investigate how existing technologies and research might be employed to better characterize reservoirs and aid in recovery efforts. A list of promising technologies includes nanoallomorphs of carbon, magnetic nanoparticles, chemotactic micro- and nanotube structures, and nanoexplosive materials.

Even more problematic is the need to use these new nanotechnologies in complex and harsh operating environments. Such environments may be found in reservoirs at depths of thousands of feet, with operating temperatures of (250°C) or more and pressures of up to 15,000 psi. In addition, complex mixtures of oily, briny, waxy, and acidic fluids of two and three phases are often found in these reservoirs.

Designing specific hydrophobic or hydrophilic character into such smart fluids, Nano-Membranes (Separations) - The need to reduce interfacial tension (IFT) between crude oil and reservoir water, the nanoparticles as surrogate probes of the parameters of interest, through the use of novel organic chemistry on the surface of high-surface-area functionalized nanoparticles, will significantly alter the mode of operating and organizing waterfloods and surfactant floods. Moreover, by tailoring the responsivity of these smart fluids, they can be used either to block or to increase the porosity and tortuosity of the formations where they are injected.

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. 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.

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.

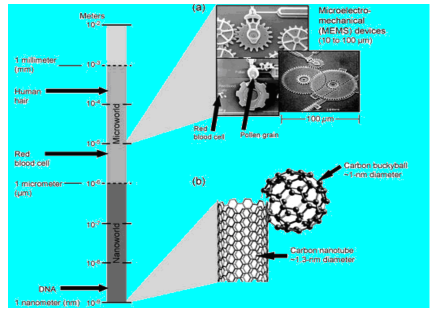

Fig.(1)Logarithmic scale on left shows size range of selected natural objects .Objects are compared with size range of manufactured nanodevices, extending from MEMS devices (top) to buckyballs (bottom).

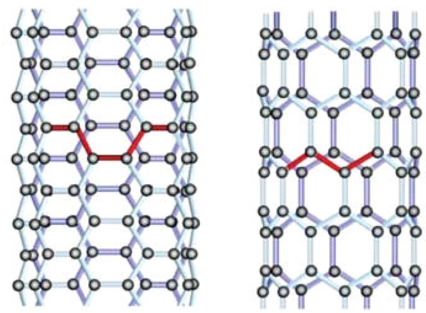

Fig.(2) —Atomic structure of carbon nanotubes.

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.

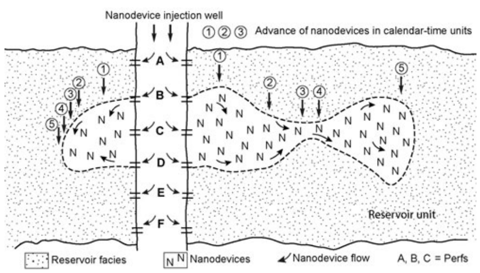

Fig.(3) – One concept for use of nanotechnology in reservoir characterization. Nanodevices (N) are injected in perfs A through F and move through a reservoir. At calendar-delay times of 1, 2, 3, 4 and 5 time intervals, spatial distribution of the nanodevices is measured by EM or seismic methods to determine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

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. For instance, Nanostructured Coatings, Improved Proppants, Nano-enhanced 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 gamechanging and would significantly increase oil recovery. Other nanobased technologies aimed at directly manipulating subsurface conditions could significantly improve current EOR techniques

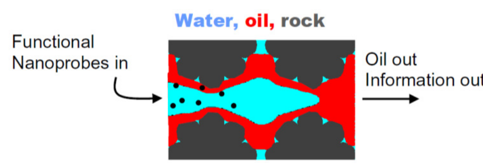

Fig.(4) : Rock properties/Petrophysics

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 micron 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 .

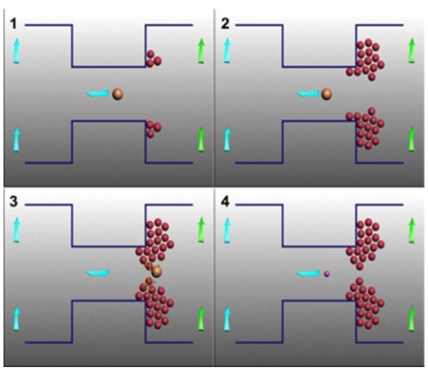

Fig.(5) : Nano manipulation of porus media

For VES(Visco Elastic Surfactant) type surfactants when its concentration exceeds Critical Micellar Concentration (CMC) in presence of an electrolyte (like KCl, CaCl2 etc.) the surfactant molecule aggregate and form elongated rod like micelle. The rod like micelles can interact to form a network exhibiting viscoelastic behavior

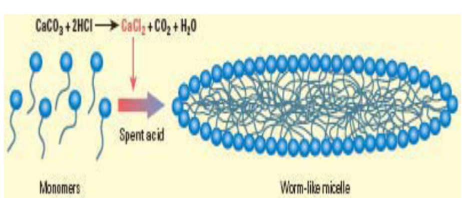

Fig.(6): Micelle without nano -particle addition

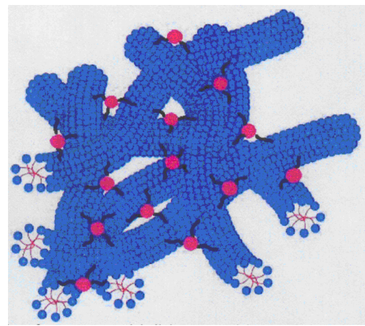

Fig.(7): Micelle with nano -particle addition

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 to 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 oil-field data, and diversity sources of supply.

Areas of potential nano-applications stand out: Nano-Sensors : Sensors are one of the most coveted prospects for nanotech innovations in the Oil-field, to extract more oil it is of fundamental importance to characterize and monitor the reservoir.

Addresses the following challenges faced by Oil & Gas: Exploration: The need to "sniff" for new pockets of oil (e.g. by using bacterial DNA,MEOR Microbial Enhanced Oil Recovery or electromagnets, MEMS & NEMS).

Enhanced resolution for subsurface imaging techniques. Reservoir Characterization: Understanding rock-fluid interaction, their chemical composition and physical characteristics at different locations inside the reservoir (pressure, flow, temperature, pH, and hydrocarbon saturation).

The need to determine adsorption/desorption of surface active materials and mineral surface charge (wettability).

The sensors need to withstand high temperature and pressure to characterize deep reservoirs. The need for better image and conductivity contrast enhancers (tracers, taggants, and nanoparticles that can change conductivity deep in the reservoir).

Reservoir Management: Enhanced remote imaging, real-time continuous monitoring of flow-rate, pressure and other parameters during production, wireless telemetry, in situ chemical sensing , Accurate early warning detection and location of leaks (preventing environmental hazards), Nano-Materials and Coatings .

Exploration, Drilling, Production: The need to increase the effectiveness and longevity of drilling components, (by corrosion-resistance for example) making them cheaper, lighter and stronger pipes and drillbits, Improve strength to weight ratio of pipes, making them more robust but flexible materials.

The need to treat and cure pipes and equipment quickly, self-healing materials (smart materials) . The need for increased drilling depths, reduce friction in drilling , to provide stability and pressure integrity for drilling , to withstand adverse weather conditions, such as strong marine currents in deep offshore locations , for barriers against sea water, chemicals and extreme elements , for frigid water pipeline insulation (undersea locations) , for thermal pipeline insulation (desert locations) , to increase heat transfer efficiency , to make offshore platforms sturdier and more light-weight, or completely remove the platforms , to minimize the damage to the well and overall environmental impact.

The need to prevent biofouling, to quantify and prevent formation damage.

Nano-scale Fluid Additives : Addresses the following challenges faced by Oil && Gas: The need to improve the effectiveness, mobility and environmental friendliness of drilling fluids, for controlled agglomeration of particles , for smart drilling fluids, for vibration control for example. Nano-Membranes (Separations) : Addresses the following challenges faced by Oil & Gas: The need to filter impurities from heavy oil and tight gas, in situ, to filter and purify water for industrial, agricultural and potable use. The need to capture carbon dioxide emissions and safely store them underground (CCS), to reduce interfacial tension (IFT) between crude oil and reservoir water, to exclude sand Chemical Delivery Systems (e.g. Targeted Delivery Vehicles) . Addresses the following challenges faced by Oil & Gas: The need to reduce interfacial tension (IFT) between crude oil and reservoir water (less than 10-2 mN m-1), to overcome capillary forces to allow more oil extraction through small pores, to stimulate the flow of hydrocarbons.

Oil – Microbe Detection Tool using Nano Optical fibres

The tool works on the principle of Resonance Raman Spectroscopy (RRS). Since the microbes used in MEOR are exactly their response to RRS on the surface can be tested and the same response from inside the reservoir can be noted. In this way the microbes can be detected down hole by the Resonance Raman Spectra which they exhibit. The microorganism detection is based on identification and excitation of chemotaxonomic markers present in them. Since microbes only survive on the oil-water interface, where microbes will be detected, it is clear that microbes are still present in that region. This depth will be sensed using depth sensor. Water being Raman inactive, at whatever depth thief zones of water are formed no spectrum will be observed and these thief zones can be detected and plugged thus deviating water to oil bearing zones. The tool will be lowered downhole by optical fibres which can also transmit the reflected light to a computer on the surface to view the spectra. The nano optical fibres will penetrate the formation and carry the laser light in porous rock matrix and receive the reflected light. The tool can also identify different microorganisms present in reservoir. This helps in knowing reservoir parameters like temperature, pressure, salinity etc. since every type of microbe has a particular environment in which it can survive.

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