Int. J. Nano Dimens. 5(5): 463-471 (Special Issue) 2014
ISSN: 2008-8868

Contents list available at **IJND**

International Journal of Nano Dimension

Journal homepage: *www.IJND.ir*

The great potential of nanomaterials in drilling & drilling fluid applications

E. Kasiralvalad*

Science and Research Branch, Islamic Azad University, Faculty of Petroleum Engineering, Daneshgah Blvd, Simon Bulivar Blvd, Tehran, Iran.

Received 20 October 2013
Accepted 23 January 2014

ABSTRACT

The continuous development of global economy with decreasing in available hydrocarbon sources and increasing discovery and extraction costs due to decrease in-situ oil and gas reservoir, displays the necessity of using new techniques for the improve rate of penetration and productivity in well. Nanotechnology has already contributed significantly to technological advances in the energy industries. Nanotechnology has the potential to introduce revolutionary change in drilling industry. Nanotechnology produces nanomaterials with many attractive properties, which can play an important role in intensifying mud cake quality, reducing friction, eliminating differential pipe sticking, maintaining borehole stability, protecting reservoir, and enhancing oil and gas recovery. Nano fluids can be designed by adding nano-sized particles in low volumetric fractions to a fluid. The nano particles modify the fluid properties, and suspensions of nano-sized particles can provide numerous advantages.

This paper presents an extensive literature review of assessing the applications of nanomaterials in drilling and drilling fluids, and evaluates the potential technical benefits that these nanomaterials might provide to petroleum development and production.

Keywords: *Nanotechnology; Drilling; Drilling fluids; Nanomaterial; Shale properties.*

* Corresponding author:
Ehsan Kasiralvalad
Science and Research Branch
Islamic Azad University, Faculty of Petroleum Engineering,
Daneshgah Blvd, Simon Bulivar Blvd, Tehran, Iran.
Tel +98 9127631546
Fax +98 2177983996
Email
ehsankasiralvalad@yahoo.com

INTRODUCTION

Nanotechnology is applied to measure and manipulate matter on the nanometer scale, making it possible to create a new generation of materials with enhanced mechanical, optical and magnetic properties and build machines by using molecular building blocks, and designing properties by controlling structure. Based on nanotechnology, nanomaterials, the structure unit of which ranges from 1 nm to 100 nm, can be made.

As the dimension of nanomaterials lies in the contiguous area between the clusters and the macroscopic materials, they will not directly demonstrate atomic and macroscopic properties, but bring with their own unique effects, such as surface effect, small size effect, quanta size effect and macroscopical quantum tunnel effect [1]. As a result, nanomaterials have specific characteristics in comparison with traditional materials, greatly expanding the application range of nanomaterials in various fields [2-4].

Oil and gas well drilling involves a number of complex operations that often lead to operational problems. The success of drilling operations highly depends on selection and application of appropriate techniques that minimize drilling problems, improve rate of penetration and productivity. Selection of suitable drilling fluids and maintenance of their properties within desirable ranges are critical aspects of successful oil well drilling. Recent studies [4, 5] indicate that successful applications of nanotechnology in drilling are likely to occur with synthetic nanoparticles, where size, shape and chemical interactions are carefully controlled to achieve the desired fluid properties and drilling performance.

Nano materials have a great potential for a broad range of applications in the drilling industry [6]. Nanotechnology is not new, but its application in the oil industry is certainly in its infancy, including drilling applications [7]. Alternatively there is provided in a non-restrictive version, a drilling fluid with a base fluid including either or both of an aqueous fluid and a non-aqueous fluid as well as nanoparticles having a size less than 100 nm. Suitable nanoparticles include, but are not necessarily limited to, nano-silica, nano magnesium oxide, nano-iron oxide, nano-copper oxide, nano-zinc oxide, nano-nickel oxide, nano-alumina, nano-boron, carbon black, nano-graphene, carbon nanotube, ferromagnetic nanoparticles, nanoplates, surface modified-nanoparticles, halloysite clay nanotubes, polymer-based nanoparticles, degradable nanoparticles, nanocapsules, mesoporous nanoparticles, multistimuli-responsive nanospheres, core/shell nanoparticles and combinations of these, as well as a surfactant if required in an amount effective to suspend the nanoparticles in the base fluid.

Drilling fluids contribute to some of the biggest drilling and production costs associated with hydrocarbon recovery [8]. Minimization of the cost factor associated with fluids, especially nano-based fluids, is one of the major considerations in nanofluid formulation and preparation. Moreover, nanomaterials are also very costly on their own. The addition of another costly chemical as a dispersing agent could increase the cost of nano-based drilling fluids far beyond the industry acceptable economic norm. Besides cost, other factors, such as the environmental impact of such drilling fluids, come into play when developing drilling fluids. The oil and gas industry needs an economically attractive and environmentally friendly fluid additive to prepare water-based nanofluids with a view to maintain the environmental friendliness of the fluid. The industry needs a technically reliable and economically attractive method for the preparation of a stable nano-based drilling fluid to meet the current as well as future technical needs and challenges of the oil and gas industry. This paper reviews important nanomaterials developed so far in the drilling and drilling fluid, which may offer a wide range of benefits for the drilling industry.

EXPERIMENTAL

With the combination of nanotechnology and drilling fluid technology, nanomaterials can significantly increase the high temperature resistance, pollution resistance, fluid loss control as well as cuttings removal ability of drilling fluid system, improve the drilling at high temperature high pressure conditions, and strengthen the drilling of special reservoirs. For instance, with the help of high surface activity of nanomaterials, nano membrane, formed on the surface of drilling tools and borehole walls, can effectively lower the friction between drilling tools and borehole walls [9], and reduce the difficulty in drilling of highly deviated wells, horizontal wells and ERW. The use of nanomaterials in drilling fluids will enable the drilling technologists to optimize the properties of drilling fluids to suit particular drilling conditions, discourage use of some expensive additives, and provide better functionality [10]. Consequently, nanomaterials can play a very important role in

improving the drilling efficiency, saving the drilling cost, and protecting the environment. Some of these applications are examined as follows.

Nano-Sized Weighting Additive

As different formations are encountered, and depth increases, the densities of drilling fluids shall be adjusted to appropriately balance the system during the drilling process, so weighting materials should be continuously added to drilling fluids, which can produce substantial amounts of fluid and solid waste materials. Jimenez *et al.* [11] reported an effective method for adjusting the density of a drilling fluid in a manner that was environmentally friendly and easily controlled. The superparamagnetic nanoparticles with an average particle size between 0.5~200 nm were used as weighting materials to prepare a treated drilling fluid, and then they obtained drilling fluid system was exposed to a magnetic field to recover these superparamagnetic nanoparticles. More than 90% of the original nanoparticles could be recovered for reuse in treating subsequent drilling fluids. More particularly, the densities of drilling fluids could be adjusted by adding weighting materials or exposing to the magnetic field repeatedly. Therefore, a great number of weighting materials used in adjusting fluid density could be significantly reduced, a large quantity of environmentally harmful solid and liquid waste materials generated during drilling processes could be avoided, and thus a substantial source of cost could be saved.

Nanocomposite Fluid Loss Additive

Qu *et al.* [12] described a type of amphiphilic poly (styrene block-acrylamide) via RAFT polymerization approach. In order to improve the heat stability of this block polymer, some organic montmorillonite (O-MMT) was added in the preparation of the block polymer, and then polystyrene (PSt)/O-MMT were prepared. Used the obtained PSt/O-MMT as a macro RAFT agent to initiate acrylamide polymerization, a new kind of amphiphilic P(St-*b*-Am)/O-MMT nanocomposites was synthesized. The experimental results showed that the P (St-*b*-Am)/OMMT nanocomposites demonstrated better thermal stability as compared with P (St-*b*-Am).

The obtained amphiphilic P (St-*b*-Am)/O-MMT nanocomposites were added to drilling fluids, and the rheological properties of drilling fluid system were studied [13]. The experimental results indicated that this drilling fluid system had superior filtrate reducing performance, excellent thermal stability, and good inhibiting ability. Moreover, the system had high anti-salt, anti-calcium as well as anti-magnesium ability even up to 220 ؛C. As a result, the nanocomposites were an excellent fluid loss additive, and it could meet the requirement of drilling operation under extreme condition.

Nanometer Shale Inhibitor

Maintaining borehole stability is of great importance to drilling operations. But most of conventional water-based drilling fluids can easily generate fluid penetration into shale formations, which will cause borehole instability problems, resulting in wellbore collapse, borehole shrinkage, and pipe sticking.

- **Shale Permeability and Porosity**

The filtration rate of shale sections is very low compared to sand sections under the same differential pressure and the drilling fluid cake is more difficult to be formed on shale sections.

- **Shale Pore throats**

The drilling fluid cake forming with ultra-low filtration requires the match between the pore throat size and the shielding/ plugging particle size. A mud cake cannot be formed for shale formations because conventional drilling fluid particle sizes are much larger than the shale pore throat size.

- **Micro-cracks of Shale**

Micro-cracks are mostly in a closed state under the high confining pressure before the shale

is drilled into. Because of the strong conductivity of cracks, if not blocked, the drilling fluid will be driven straight along the cracks rapidly into the formation. Then the supporting effect of the drilling fluid column pressure quickly disappears and causes a high collapse pressure. Therefore, the presence of cracks in shale influences the borehole stability.

Oil-based drilling fluids are used primarily due to their drilling performance and low reactivity with the shale formation while maintaining wellbore stability; however environmental agencies, from EPA to local authorities, are ensuring that the operators in the gas plays regulate their drilling operation by adhering to certain protocols and activities. Improvements in drilling performance and reduction of salt use could significantly reduce waste expenses and increase the use of water-based fluids in shale formations. A good solution based on water-based drilling fluids to shale instability problems was proposed [14]. Two different silica nanoparticles were added to water-based drilling fluids, and their influence on shale stability was evaluated. The experimental results indicated that these nanoparticles reduced the permeability of the shale significantly, and fluid invasion into the shale decreased dramatically. The reason for this was that these nanoparticles were small enough to penetrate and seal the pore throats in shale, and built an internal mud cake, resulting in the reduction of fluid penetration into the shale. Using these nanoparticles based drilling fluids to seal the shale was a very powerful and economical approach for enhancing borehole strength in problematic shale formations. In the future, this drilling fluid system might hold potential application prospect to resolve shale instability problems.

Nanocomposite Bentonite

Using acrylamide as intercalated agent, a new kind of nanocomposite bentonite was synthesized by in-situ intercalation polymerization [15]. XRD indicated that the intercalated agent had entered into the crystallite layers of bentonite, and the interlayer space of bentonite had increased greatly. TEM showed that acrylamide had good intercalated capacity for bentonite, and the bentonite lamella became smaller and looser. Due to unique intercalated structure, the nanocomposite bentonite had better heat resistance, pollution resistance and cuttings carrying capacity as compared with regular sodium bentonite. This nanocomposite bentonite was added to drilling fluids, and its influence on the properties of drilling fluid system was evaluated. The results indicated that it could improve the rheological properties of drilling fluids, and enhance the thermal stability and inhibiting ability of drilling fluid system, too. In addition, it had good compatibility with drilling fluid system, and it could offer better functionality than regular bentonite without the requirement of other expensive additives, which was critical to deep drilling.

Nanometric Lubricant

A new kind of nano-emulsion was prepared through a one-step method [16]. The experimental results showed that the nano-emulsion had good long-term stability, and its droplet size almost would not increase in six months. This emulsion demonstrated good inhibiting ability to clay swelling, as shown in Figure 1 Compared with 7% KCl; it had stronger inhibiting ability when its concentration was over 0.5%.

Meanwhile, the nano-emulsion had good lubrication. Figure 2 indicated that the friction coefficient of nano-emulsion was slightly smaller than mineral oil. Besides, this emulsion had no influence on other properties of drilling fluids. It was an environment-friendly drilling fluid additive, and could be used under complicated geological conditions. Most importantly, the nanometric lubricant had high yield, low cost, and could meet the requirement of environmental protection, so it would have extensive application prospect in drilling industry.

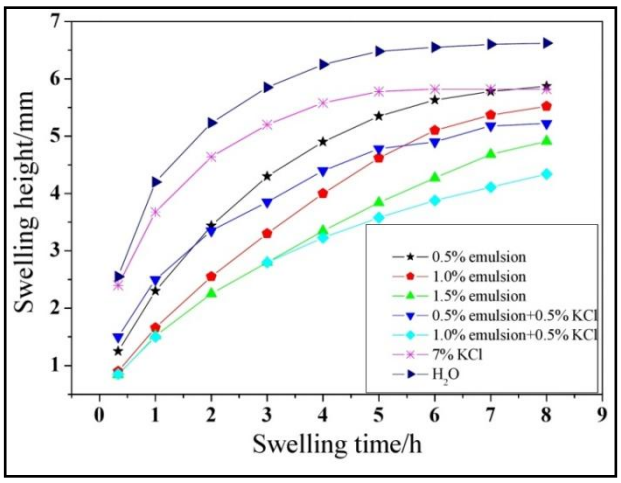

Fig. 1. The effect of various concentrations of nanometric lubricant on clay swelling [16]

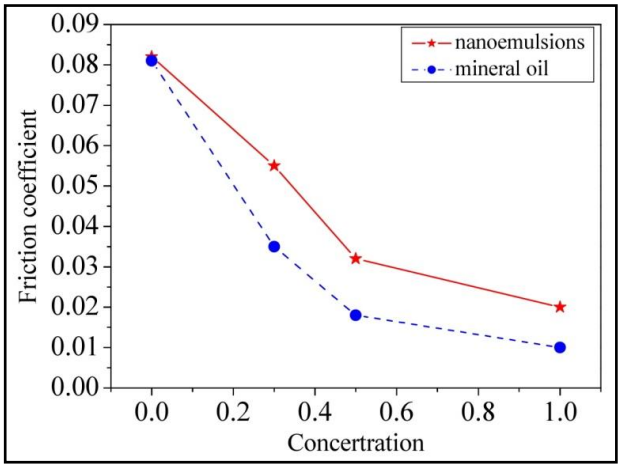

Fig. 2. Comparison of friction coefficient between nanometric lubricant and mineral oil [16]

Nanoscale Desulphurizing Additive

As a dangerous, toxic and corrosive gas, hydrogen sulfide, which diffuses into drilling fluids from formations in the drilling process, can pollute the environment, do great harm to people's health, corrode drilling equipment, and generate a great economic loss, so it must be removed from the drilling fluids. A kind of nanoscale zinc oxide with 14~25 nm size and 44~56 m^2/g specific surface area was prepared through spray pyrolysis approach [17]. Using the obtained nano zinc oxide to remove hydrogen sulfide from water-based drilling fluids, the performance of nano zinc oxide as a hydrogen sulfide scavenger was investigated. Compared with bulk zinc oxide that could only remove 2.5% of hydrogen sulfide in as long as 90 minutes, the nano zinc oxide could completely scavenge hydrogen sulfide from drilling fluids in just 15 minutes. The main reason was that these zinc oxide nanoparticles had a very high porosity, resulting in enormous surface area and high reactivity, and thus they could remove hydrogen sulfide much faster than bulk zinc oxide. As a result, the nano zinc oxide was an effective desulphurizing additive to remove hydrogen sulfide and soluble sulfides from drilling fluids. This desulphurizing additive could reduce the environmental pollution, protect the health of drilling workers, prevent corrosion of pipelines and equipments, and lower the consumption of natural resources.

RESULTS AND DISCUSSION

Nano-sized drilling fluid system is prepared by adding nanoparticles in low volumetric fractions to a base fluid. Upon the addition of the nanoparticles, the properties of the base fluid such as viscosity, filtrate reducing performance, lubricity, thermal stability, anti-pollution ability, and so on, can be tuned towards the optimum levels. The nano-enhanced drilling fluid system may have good rheologic properties, superior mud filtrate control capacity, excellent suspension stability, good lubricity and high anti-pollution ability. Therefore, the enhanced drilling fluid system can improve drilling fluid technology and meet the requirements of drilling operations under complex conditions.

Water-based Film-Forming Drilling Fluid

Using nano-latex particles NM-1 and inorganic nanoparticles NMTO as main agents, a novel nanometer water-based drilling fluid was developed [18]. The experimental results indicated that the semi-permeable film efficiency of this drilling fluid was about 65%, and thus this drilling fluid could form an isolation layer that was

completely impervious to water. In addition, API filter loss was almost constant with time, and the resistance to pressure increased up to 3.5 MPa. Therefore, this drilling fluid system had good isolation effect.

The film-forming cores were cut into slices, the semi-permeable film of which was analyzed by SEM. The results demonstrated that the semi-permeable film was generated by the pore blocking of micelles together with the contribution from network structure produced by latex particles and polymers. Based on the semi-permeable film, the isolation layer with an average thickness of 50~60 μm was generated through the deformation, filling and cementation of nanoparticles at high temperature [18]. Therefore, good semi-permeable film and isolation layer were produced at the interface of drilling fluid system and borehole walls. Using its film forming property to seal water sensitive reservoir offered an effective method to prevent formations from invasion of extraneous substances, and thus it could play an essential role in stabilizing borehole walls and protecting reservoir.

Nano-based Drilling Fluid

A new kind of nano-based drilling fluid with desirable rheological and filtration properties as well as good mudcake quality was synthesized by using a blend of several commercial nanomaterials and nanostabilizer [19]. Due to the ultra-thin, tight and well dispersed mudcake deposited on the borehole wall, relative stability of the formations, effective cleaning of the borehole wall and significant reduction of differential pipe sticking in highly permeable formations could be achieved [20]. In addition, the frictional resistance between the pipe and borehole wall could be reduced [21], so the nano-based drilling fluid could play a positive role in lowering the torque and drag in deviated, horizontal, extended reach and multi-lateral drilling operations.

The extremely high surface area to volume ratio of nanoparticles (see Figure 3) can provide several other technical benefits for safe and economic drilling operation [22]. Hence, the enhanced thermal conductivity of drilling mud will provide efficient cooling of drill bit leading to a significant increase in operating life cycle of a drill bit. Due to the presence of an astronomical high number of extremely tiny particles with huge surface area, high heat tolerance, high thermal conductivity, high mobility, effective interaction with external and internal rock surfaces, nano-based drilling mud systems are expected to play a pivotal role in current and future HTHP (high temperature and high pressure) drilling operations, complex drilling conditions, deep water drilling operations, etc [19].

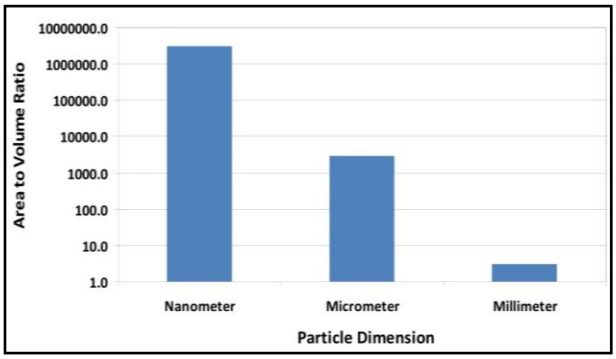

Fig. 3. Surface Area to Volume Ratio of Same Volume of Materials [9, 10]

Solids content of drilling mud is one of the factors that increases formation damage, reduces productivity index and decreases ROP. Figure 4 shows the effect on ROP with increasing solids content of drilling mud. Superior nano-based fluids are also expected to reduce the non-desirable solids content significantly by preventing the rock-fluid interactions and the cuttings disintegration and dispersion [8].

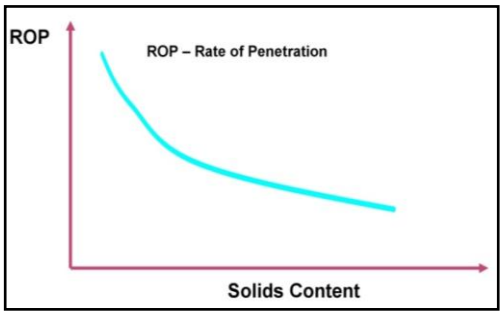

Fig. 4. Mud Solids Content and Its Effect on ROP

Compared with conventional drilling fluids, the water-based nanofluid could reduce formation damage in the oil and gas reservoirs significantly, control loss circulation well, and

enhance the rate of penetration in hard rock formations greatly [10]. As a result, the nano-based drilling fluids were expected to possess a wide prospect of application in drilling industry.

Nano-Enhanced Drilling Fluids

Abdo *et al*. [23] reported an approach to overcome drilling problems by controlling the drilling fluid rheology by using nanoparticles. New nanoscale material ATR was added to drilling fluids, and the rheological properties of drilling fluid system were investigated. The experimental results indicated that ATR could maintain low viscosity without compromising the requirement of density. In addition, the obtained drilling fluid had a high gel strength, which was very essential for eliminating severe drilling problems such as poor hole cleaning, high torque and drag, pipe sticking, wellbore instability, lost circulation and formation damage, which could reduce the drilling efficiency significantly.

Macromaterials have the lowest surface area to volume ratio, higher imperfection and thus possess inferior mechanical, chemical, physical, and thermal properties compared to micro and nanomaterials. The macros and micros posses the material is characteristics very similar to the parent materials. However, the nanomaterials have significantly different properties compared to the parent materials.

Due to the possibility of incorporation of a huge number of functional groups in the same volume of nano-material compared to micro and macromaterials, nano-based fluid additives can improve fluid performance dramatically.

CONCLUSIONS

Due to their unique characteristics, nanomaterials are widely used in the fields of drilling and they can promote the development of drilling fluid technology. Nanomaterials have potential for oil well drilling operations in the forms of nanoscale drilling fluid additives and nanofluids. The use of nanomaterials in drilling fluids offers many potential solutions to resolving drilling problems that cannot be solved with traditional approaches and it can enable to push the limits of the existing drilling technology and endow with economically and technically viable drilling operations.

Future drilling operations require new materials that can meet the special requirements of the drilling in highly deviated wells, horizontal wells, ERW and complex deep wells. Nanomaterials are expected to possess a wide prospect of application in drilling operations. In the near future, nanomaterials will have an essential application value in the preparation of new additives and drilling fluids. In addition, it will make a new breakthrough in enhancing efficiency of drilling operations, and improve the overall competitiveness of the oil and gas industry.

REFERENCES

[1] Nabhani N., Emami M., Moghadam T., (2011), Application of Nanotechnology and Nanomaterials in Oil and Gas Industry. *AIP Conference Proceedings*. 1415: 128-131.

[2] Ju B. S., Dai S. G., Luan Z. A., Zhu T. G., Su X. T., Qiu X. F., (2002), A Study of Wettability and Permeability Change Caused by Adsorption of Nanometer Structured Polysilicon on the Surface of Porous Media. SPE 77938, SPE Asia Pacific Oil and Gas Conference and Exhibition, Melbourne, Australia.

[3] Morales D., Gutiérrez J. M., Garcia-Celma M. J., Solans C., (2003), A Study of the Relation between Bicontinuous Microemulsions and Oil/Water Nano-emulsions formation. *Langmuir*. 19: 7196-7200.

[4] Krishnamoorti R., (2006), Extracting the Benefits of Nanotechnology for the Oil Industry. *J. Petrol. Technol*. 58: 24-26.

[5] Pourafshary P., Azimipour S. S., Motamedi P., Samet M., Taheri S. A., Bargozin H., Hendi S. S., (2009), Priority Assessment of Investment in Development of Nanotechnology in Upstream Petroleum Industry. SPE 126101, SPE Saudi Arabia

Section Technical Symposium, Al Khobar, Saudi Arabia, 9-11 May.

[6] Zhang T., Roberts M. R., Bryant S. L., Huh C., (2009), Foams and Emulsions Stabilized With Nanoparticles for Potential Conformance Control Applications. SPE 121744, SPE International Symposium on Oilfield Chemistry, The Woodlands, Texas, 20-22 April.

[7] Singh S., Ahmed R., Growcock F., (2010), Vital Role of Nanopolymers in Drilling and Stimulations Fluid Applications. SPE 130413, SPE Annual Technical Conference and Exhibition, Florence, Italy.

[8] Amanullah M., Al-Tahini A. M., (2009), Nano Technology: It's Significance in Smart Fluid Development for Oil and Gas Application. SPE 126102, SPE Saudi Arabia Section Technical Symposium, AlKhobar, Saudi Arabia, 9-11 May.

[9] Abdo J., Danish M., (2010), Nanoparticles: Promising Solution to Overcome Stern Drilling Problems.Nanotech Conference and Exhibition, Anaheim, California, 6-8 August.

[10] Bicetano, J., (2009), Drilling Fluid, Drill-in Fluid, Completion Fluid and Workover Fluid Additive Compositions Containing Thermoset Nanocomposites Particles and Applications for Fluid Loss Control and Wellbore Strengthening. United States Patent 20090029878.

[11] Jimenez M. A., Altos S. A., Genolet L. C., (2002), Method for Treating Drilling Fluids Using Nanoparticles. United States Patent 20020123431 (September 5).

[12] Qu Y. Z., Su Y. N., Sun J. S., Wang K. C., (2008), Preparation of Poly (styrene-block-acrylamide)/Organic Montmorillonite Nanocomposites via Reversible Addition-Fragmentation Chain Transfer. *J. Appl. Polym.Scie.*110: 387-391.

[13] Qu Y. Z., Sun J. S., Su Y. N., (2007), Study on Properties of Nanocomposite Poly (styrene-*b*-acrylamide). *Petrol. Drill. Tech.* 35: 50-52.

[14] Sensory T., Chenevert M. E., Sharma M. M., (2009), Minimizing Water Invasion in Shale Using Nanoparticles. SPE 124429, SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana.

[15] Jiang L., Yuan L., Zheng Q. G., (2009), Researches and Applications of Nanometer Bentonite Complex, *Petrol. Drill. Tech.* 37: 57-60.

[16] Mei Z., Liu S. Y., Wang L., (2011), Preparation of Positively Charged Oil/Water Nano-emulsions with a Sub-PIT Method. *J. Coll. Interface Scie.* 361: 565-572.

[17] Sayyadnejad M. A., Ghaffarian H. R., Saeidi M., (2008), Removal of Hydrogen Sulfide by Zinc Oxide Nanoparticles in Drilling Fluid. *Int. J. Environ. Scie. Technol.* 5: 565-569.

[18] Bai X. D., Pu X. L., (2010), Formation Mechanisms of Semi-permeable Membranes and Isolation Layers at the Interface of Drilling Fluids and Borehole Walls. *Acta Petrol. Sinica*. 3: 854-857.

[19] Amanullah M., Mohammad K. A. A., Ziad A. A., (2011), Preliminary Test Results of Nano-based Drilling Fluids for Oil and Gas Field Application. SPE 139534, SPE/IADC Drilling Conference and Exhibition, Amsterdam, The Netherlands, 1-3 March.

[20] Kong X. L., Ohadi M. M., (2010), Applications of Micro and Nano Technologies in the Oil and Gas Industry-Overview of the Recent Progress. SPE 138241, Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, UAE, 1-4 November.

[21] Amanullah M., Ziad A., (2010), Preliminary Test Rresults of a Water-based Nanofluid, *The 8th International Conf. & Exhib.on Chemistry in Industry*, Manama, Bahrain.

[22] Del Gaudio L., Bortolo R., Lockhart T. P., (2007), Nanoemulsions: A New Vehicle for Chemical Additive Delivery. SPE 106016, International Symposium on Oilfield Chemistry, Houston, Texas, U.S.A. 28 February-2 March.

[23] Abdo J., Haneef D. M., (2012), Nano-Enhanced Drilling Fluids: Pioneering Approach to Overcome Uncompromising Drilling Problems. *J. Energy Res. Tech.* 134: 1-6.

Cite this article as: E. Kasiralvalad: The great potential of nanomaterials in drilling & drilling fluid applications. ***Int. J. Nano Dimens.*** 5(5): 463-471 (Special Issue) 2014.