Hellenic Foundation for Research & Innovation

Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

Title of the research project:
Enhanced oil recovery by polymer-coated nanoparticles (EOR-PNP)

Principal Investigator:
Dr. Christos Tsakiroglou, Research Director, FORTH/ICE-HT

Reader-friendly title:
Use of nanotechnology to the enhanced oil recovery (EOR) from underground reservoirs

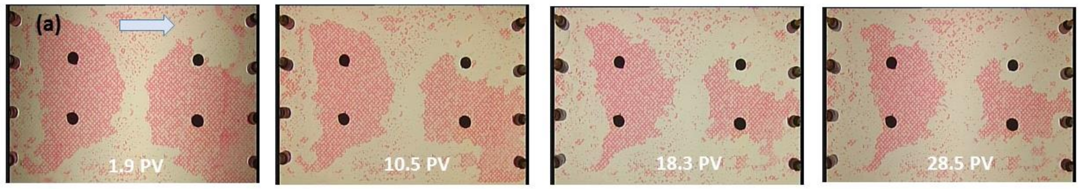
Scientific Area:
Engineering Sciences & Technology / Chemical Engineering

Institution and Country: **FORTH / ICE-HT, Greece**

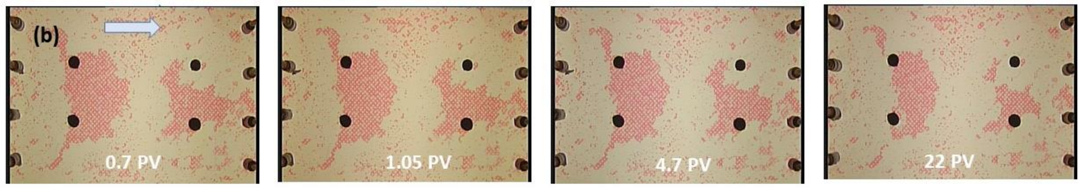
Host Institution: **FORTH / ICE-HT**

Collaborating Institution(s):
(1) Institut Francais du Petrole Energies nouvelles, Geosciences Division (France)
(2) University of Waterloo, Department of Chemical Engineering (Canada)

Project webpage: http://eorpnp.iceht.forth.gr



Water displaces n-dodecane (red colour) in a glass-etched pore network (physical model of secondary oil recovery)



Suspension of SiO_2 nanoparticles (~30 nm) at 1% w/w concentration displaces a fraction of the residual n-dodecane (enhanced oil recovery by nanoparticles)

Budget: 187 989 €

Duration: 1/1/2020-31/12/2022

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Research Project Synopsis

Globally the overall oil recovery factors for primary and secondary recovery range from 35% to 45% and a tertiary recovery method that can enhance the recovery factor by 10-30% could contribute to energy supply. The use of nanoparticles in enhanced oil recovery (EOR) processes comprise an emerging and well-promising approach. While surfactants injection into geological sites has been a commonly practiced EOR method, the injection of aqueous nanoparticle suspensions is still at its early stages. The overall objective of the proposed work is to optimize the properties of polymer-coated nanoparticles (PNPs) toward the mobilization of residual oil from reservoir rocks. Polymer-coated nanoparticles (PNPs) will be synthesized and stabilized in aqueous media with composition similar to that of brine (e.g. high salinity) in hydrocarbon-bearing rocks, and their properties will be optimized toward the mobilization of residual and trapped oil ganglia from the pore space. PNP-based aqueous suspensions, emulsions, and foams will be prepared, characterized, and tested as chemical flooding agents in porous media models (glass-etched pore networks & sandpacks), and core plugs of reservoir rocks. Based on results of EOR tests, the synthesis and properties of PNP-based agents (“smart fluids”) will be tuned successively through a feedback “adaptive control” scheme, until choosing the most efficient and cost-effective ones. In parallel, a numerical simulator of the multiphase flow and transport of PNP-based smart fluids in digital porous media, reconstructed from 3D CT-scan micro-tomographic images of reservoir rocks, will be developed, calibrated with reference to tests in porous media models, and validated with respect to tests in core plugs.

Project originality

Till now, no effective combination of the advantages of nanomaterials used in EOR processes has been established and no systematic efforts have been made to reduce nanoparticle aggregation through molecular weight control and polymer architecture. Although nanoparticles alter rock wettability and reduce the oil/water or water/gas interfacial tension, leading to more stable emulsions and foams, their effectiveness as agents for EOR processes is still questionable.

- ***Polymers with a designed and fine-tuned architecture (comb-like, di-block copolymers, post-grafted) will be synthesized to: (i) optimize the properties of polymer-coated nanoparticles (PNPs); (ii) generate PNP-stabilized O/W emulsions and CO_2 foams; (iii) use the PNP-fluids ("smart fluids") for the enhanced oil recovery from porous media models and reservoir rocks under progressively adverse conditions (high salinity, high concentration of divalent cations).***
- ***The classification and selection of best PNPs will rely upon a feedback scheme ("adaptive control") and accounting for: (a) the PNP stability in harsh environment (e.g. high salinity, high concentration of divalent ions); (b) the capacity of PNP to adsorb on oil/water & gas/water interfaces and change the interfacial properties; (c) the capacity of PNPs to generate stable O/W emulsions and CO_2 foams; (d) the mobility of PNP and generated emulsions/foams in porous media of increasing complexity (glass-etched pore networks, sandpacks, core-plugs); (e) the capacity of PNPs-based chemicals to stimulate the mobilization of trapped oil ganglia.***
- ***EOR by PNP-fluids will be simulated in 3-dimensional μCT-reconstructed pore networks, the simulated transient multifluid pattern of residual oil will be evaluated against experiments performed on core samples, and the properties of PNP along with the multi-scale characteristics of the pore structure will be correlated with EOR displacement efficiency.***

Expected results & Research Project Impact

Expected scientific results.

- Development of polymer-coated nanoparticles (PNPs) by grafting adequately synthesized polymers to the surface of nanoparticles so that their colloidal stability/longevity is optimized.
- Development of Pickering oil-in water emulsions and CO_2 foams by using the PNPs as stabilizing agents.
- Correlation of the stability & longevity of PNP-based suspensions / emulsions / foams with the composition (pH, ionic strength, salinity, divalent ion concentration) of the aqueous medium.
- Correlation of the PNP properties with their capacity to mobilize oil ganglia from glass-etched pore networks and sandpacks.
- Correlation of the PNP properties (nanoparticle type/ polymer type/ composition of aqueous phase) with the EOR efficiency in reservoir cores.
- Numerical modeling of multiphase PNP-nanofluid transport in 3D pore networks reconstructed from μCT-tomographic images of reservoir rocks.
- Cost benefit analysis and selection of the most efficient "smart fluids" for EOR processes.

Scientific Impact. The methodologies of PNP-EOR will contribute not only to the development of cost-effective and high-performance EOR methods, but also on the generation of innovative knowledge for other application areas, such as the remediation of soils and aquifers contaminated by hydrocarbons.

Economic Impact. Presuming that oil prices will start rising, and upstream oil sector will start recovering, the chemical EOR market is expected to witness a high growth. In long-term basis, the EOR-PNP might lead to the patenting of new polymer-coated nanoparticle-based chemicals and their commercialization as "smart fluids" for chemical flooding applications to oil-bearing rocks

Social Impact. The southeastern Mediterranean is at the epicenter of investors' interest, following hydrocarbon findings in neighboring countries. Tenders for hydrocarbon exploration in the Ionian Sea, Western Greece, and southwest of Crete was launched by the Greek government. PNP-EOR might contribute to the creation of a "knowledge-based" society by training a new generation of scientists and engineers able to work in either the developing Greek upstream industry, or abroad.

The importance of this funding

- Availability of resources for basic and applied research in the area of oil reservoir engineering, not commonly funded by other National or European Programs
- Utilization of know-how, experience and infrastructure developed in the scientific area of multiphase transport in porous media and applied to the spreading of pollutants in the subsurface and development of in-situ soil and groundwater remediation technologies
- Development and strengthening of international collaborations with Research Institutions and Universities that are pioneers in studies of physicochemical processes in porous media and advanced methods of hydrocarbon production from underground reservoirs
- Training of young postgraduate and undergraduate students in the interfaces of Materials Chemistry and Transport Phenomena / Fluid Mechanics, with application to the exploitation of hydrocarbon reservoirs and the protection of the environment

COMMUNICATION

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