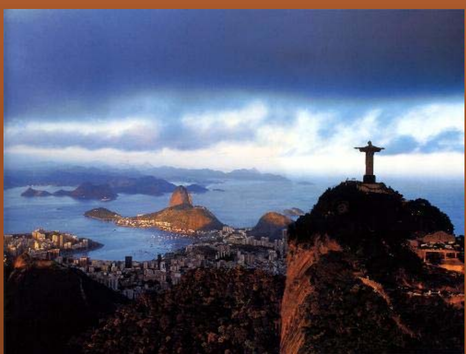
Norwegian-Brazilian Workshop on
Soft and Complex Matter:
From Basic Materials Phenomena to Technology

Pontifícia Universidade Católica do Rio de Janeiro, Brazil, November 25, 2015

The general scope of the workshop: Scientific talks and posters on flow and dynamics of soft and complex matter, such as multi-component fluids, drops, emulsions and nano-fluids, in laboratory or natural microfluidic environments. The relation between macroscopic flow patterns and underlying structures at smaller scales will be in focus. The topics are in particular relevant for energy and environment related applications such as natural fluid flow or oil-recovery including EOR.



Speakers:

Koiti Araki (USP-Sao Paulo, Brazil)
Susana Araujo (Statoil-Brazil)
Marcio Carvalho (PUC-Rio de Janeiro, Brazil)
Paul Dommersnes (NTNU, Norway)
Jon Otto Fossum (NTNU, Norway)
Kenneth D. Knudsen (Inst. for Energy Tech., Norway and NTNU, Norway)
Rodrigo Reksidler (Petrobras, Brazil)
Arne Skjeltorp (Inst. For Energy Tech., Norway, and GiaMag Technologies, Norway)
Paulo de Souza Mendes (PUC-Rio de Janeiro, Brazil)
Caetano R. Miranda (USP-Sao Paulo, Brazil)
Romulo Tenorio for Wilson Barros (UFPE-Recife, Brazil)
Giovani Vasconcelos (UFPE-Recife, Brazil)

Organizers:

Marcio Carvalho (PUC-Rio de Janeiro, Brazil)
Jon Otto Fossum (NTNU-Trondheim, Norway)

Practical information to participants:

The 1 day workshop will take place at CTC Deans office, at 12th floor of the Cardeal Leme Building, Pontifícia Universidade Católica do Rio de Janeiro, Rua Marquês de São Vicente 225, Rio de Janeiro, Brazil, starting at 08:30 am on November 25, 2015. For registration or other information about the workshop, contact (lmmp@puc-rio.br).

For submission of invited contributions, contact Jon Otto Fossum (jon.fossum@ntnu.no) or Marcio Carvalho (msc@puc-rio.br). Registration deadline for submission of contributed talk is November 15, 2015. Submission should include title + coauthors/affiliations + ½ page abstract.

SIU-UTFORSK: «Soft and Complex Matter»

RCN Petromaks2 ISP: «Particle stabilized emulsions for EOR»

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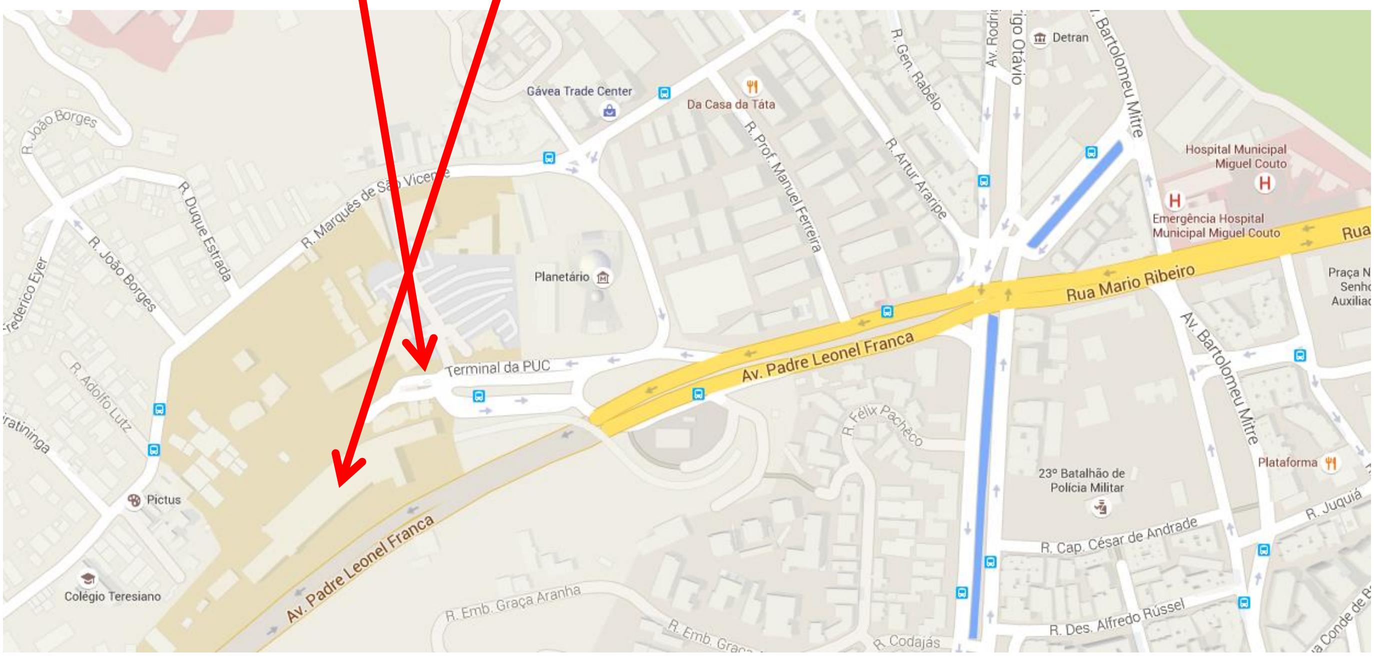
Program:	
08:30 – 08:40	***Opening*** **Marcio Carvalho/Jon Otto Fossum**
08:40 – 09:00	*The dynamics and separation of dispersed magnetic micro- and nanoparticles in magnetic fields* ***Arne Skjeltorp*** Senior Advisor, Physics Department, Institute for Energy Technology – **IFE, Kjeller**, Norway Professor emeritus, Physics Department, **University of Oslo**, Norway CTO, **Giamag Technologies** AS, Norway
09:00 – 09:20	*Nanoparticles as Platform for Oil Exploration* **Koiti Araki** Professor, Institute of Chemistry, **University of Sao Paulo**, SP-Brazil
09:20 – 09:40	*Active structuring of Pickering drops by electric fields* **Paul Dommersnes** Professor, Department of Physics, Norwegian University of Science and Technology - **NTNU, Trondheim**, Norway
09:40 – 10:00	*Magnetic Pattern of Saccharomyces cerevisiae Colonies* **Rômulo Pinto Tenório** Researcher, Centro Regional de Ciências Nucleares do Nordeste (**CRCN-NE / CNEN) Recife**, PE-Brazil
10:00 – 10:20	***Coffee Break***
10:20 – 10:40	*Intercalation and Retention of CO_2 in Clays* **Jon Otto Fossum** Professor, Department of Physics, Norwegian University of Science and Technology - **NTNU**, **Trondheim**, Norway
10:40 – 11:00	*A multiscale molecular simulation persperctive of Nano IOR and EOR* **Caetano Rodrigues Miranda** Department of Materials Physics and Mechanics, Institute of Physics - **University of Sao Paulo**, SP – Brazil
11:00 – 11:20	*Statoil emulsion and polymer projects for improved oil recovery* **Susana Araujo** Reseacher, **Statoil-Brasil**
11:20 – 11:40	*Offshore Chemical Enhanced Oil Recovery* **Rodrigo Reksidler** Researcher, **CENPES / Petrobras**, Rio de Janeiro, Brazil
11:40 – 12:00	*The QL-LAOS methodology* Alexandra A. Alicke and **Paulo R. de Souza Mendes** Researchers, Department of Mechanical Engineering, **PUC- Rio de Janeiro**, RJ-Brazil
12:00 – 13:40	***Lunch near PUC-Rio de Janeiro***
13:40 – 14:00	*Micellar structures and nanopores studied by scattering techniques* **K. D. Knudsen** Senior Scienetist, Institute for Energy Technology -**IFE, Kjeller**, Norway Professor, Department of Physics, Norwegian University of Science and Technology - **NTNU, Trondheim**, Norway
14:00 – 14:20	*Motion of multiple fingers and bubbles in a Hele-Shaw cell or porous medium* **Giovani L. Vasconcelos** Professor, Departamento de Física, Universidade Federal de Pernambuco – **UFPE, Recife**, Brazil
14:20 – 14:40	*Pore scale flow of complex liquids* **Marcio Carvalho** Professor, Department of Mechanical Engineering, **PUC- Rio de Janeiro**, RJ-Brazil
14:40 – 14:50	***Closing*** **Marcio Carvalho/Jon Otto Fossum**
15:30 – 18:30	***Discussions/Happy hour in Academia de Cachaça, Leblon***
20:00 –	***Workshop Dinner followed by discussions.*** ***For most updated info about venues, call Jon Otto Fossum at*** 981904163

Venue:

See below. If you get lost call Jon Otto Fossum at **981904163**.

CTC Deans office, at 13th floor of the Cardeal Leme Building (Take elevator to 12th floor and walk up to 13th floor)

Take taxi to main entrance of the PUC-Rio campus (near Planetario)



Abstracts:

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08:40 – 09:00	*The dynamics and separation of dispersed magnetic micro- and nanoparticles in magnetic fields* ***Arne Skjeltorp*** Senior Advisor, Physics Department, Institute for Energy Technology – **IFE, Kjeller**, Norway Professor emeritus, Physics Department, **University of Oslo**, Norway CTO, **Giamag Technologies** AS, Norway The talk will describe historical and recent advances in magnetic particle separation and manipulation using very forceful magnet systems. In 1976, John Ugelstad at Norwegian University of Science and Technology (NTNU), first succeeded in making uniformly sized polystyrene microspheres. Later the microspheres were made magnetizable by depositing nanometer-sized iron oxide in pores inside the spheres. This achievement led to the invention of magnetic bead-based biomagnetic separation technology, in which the polymer surface of the beads is utilized for biological interaction site, while the magnetic components inside the beads are used for magnetic manipulation. A new design of a magnet system denoted GIAMAG* (GIant MAgnet field Gradient) has been realized with an unprecedented value of the product of the magnetic field strength B and the field gradient ∇B. This is crucial for rapid extraction of e.g. magnetic particles in dispersions as the magnetic force acting on magnetic particles is $F \sim B \times \nabla B$. Existing magnet systems can just pull magnetic microparticles from solutions, whereas GIAMAG can extract magnetic particles down to nanosizes. * www.giamag.com
09:00 – 09:20	*Nanoparticles as Platform for Oil Exploration* **Koiti Araki** Professor, Institute of Chemistry, **University of Sao Paulo**, SP-Brazil e-mail: koiaraki@iq.usp.br, http://www3.iq.usp.br/pessoas_view.php?idDocente=57 Nanoparticles for oil exploration should be small enough to pass through the porous rock channels and influence the rock/oil/water triphasic interface displacing oil from the rock surface while keeping low enough water/oil interfacial tension to help taking it out. Also, nanoparticles that can lighten and widen the volume swept by injected water thus enhancing oil recovery are been pursued. However, the development of competitive and efficient processes for large-scale production of dispersible nanoparticles and the development of suitable and flexible functionalization processes to attach molecular species on the surface generating hybrid nanoparticles with desirable properties while maintaining the colloidal stability, remain as challenges to achieve those purposes. On the other hand, despite the development of smart water technology, conventional salty water is the most available fluid for use in secondary and tertiary oil recovery methods. However, water dispersible nanoparticles tend to be strongly destabilized by salts thus precluding the use of conventional protecting layers to enhance colloidal stability, such that new strategies ought to be pursued to overcome the bottlenecks for development of new functional hybrid nanoparticles and smart fluids for oil exploration. An efficient chemical approach for large-scale production of nanoparticles suitable for energy and environment applications, including fabrication of magnetic adsorbents for removal of undesirable contaminants such as heavy metals, hormones, pesticides, hydrocarbons, and dyes, developed in partnership with Petrobras, will be shown in this presentation.

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09:20 – 09:40

Active structuring of Pickering drops by electric fields

Paul Dommersnes
Professor, Department of Physics, Norwegian University of Science and Technology - **NTNU, Trondheim**, Norway
paul.dommersnes@ntnu.no

We show through very simple experiments that electro-hydrodynamic and electro-rheological effects in leaky-dielectric liquid drops can be used to structure and dynamically control colloidal particle assemblies at drop surfaces, including electric-field-assisted convective assembly of jammed colloidal "ribbons" and electro-rheological colloidal chains confined to a two-dimensional surface. Our development and understanding of such phenomena enable creation of a "pupil-like" structure that can be actively controlled, i.e. a colloidal shell that extracts and contracts as electric field strength is changed. The observed phenomena also serve as a basis for fabrication of different jammed colloidal shells, including Janus and patchy shells. The studies were published in [1], and very recently in [2]. In addition, extensions of those works that are presently in progress will be mentioned.

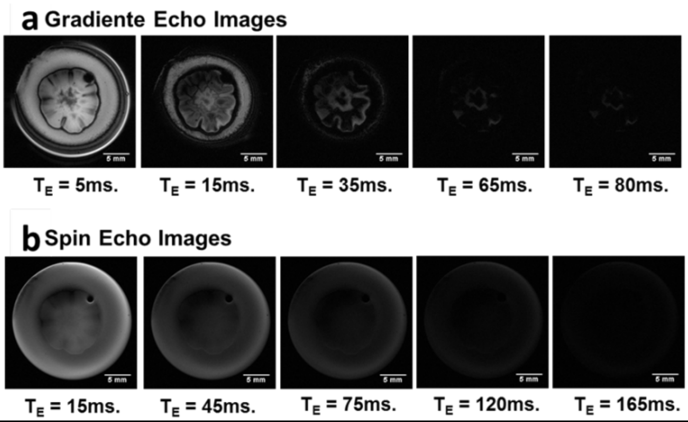
[1] *Active structuring of colloidal armour on liquid drops*, P. Dommersnes, Z. Rozynek, A. Mikkelsen, R. Castberg, K. Kjerstad, K. Hersvik and J.O. Fossum, NATURE COMMUNIUCATIONS 4:2066, DOI: 10.1038/ncomms3066 (2013)
[2] *Electroformation of Janus and patchy capsules*, Z. Rozynek, A. Mikkelsen, P.Dommersnes and J.O. Fossum, NATURE COMMUNICATIONS 5:3945, DOI: 10.1038/ncomms4945 (2014)

09:40 – 10:00

Magnetic Pattern of Saccharomyces cerevisiae Colonies

Rômulo Pinto Tenório
Researcher, Centro Regional de Ciências Nucleares do Nordeste (**CRCN-NE / CNEN) Recife**, PE-Brazil

In the last years, self-assembly phenomena and pattern formation has attracted the interest of the microbiological scientific communities, mainly due to the fantastic development of imaging technologies. Microorganisms, like fungi and bacteria, collaborate with each other in nature to build communities known as biofilms or colonies. These structures contain specialized cells in which each one plays a role in the maintenance of the biofilm, as been responsible by the cell-cell and cell-surface adherence, by the production of supporting structures like the extracellular matrix, by functions related to protection against chemicals, among others. In this work, will be shown the magnetic pattern of colonies of the yeast Saccharomyces cerevisiae observed with Nuclear Magnetic Resonance Imaging (NMRI). These patterns were generated by the hydrogen's spins manipulations, present in the colony, by the experiment of NMR and were observed for the first time. As will be discussed, the explanation of the observed pattern finds reason in the variation of the local magnetic susceptibility of the colony due to the presence of paramagnetic chemical species.



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10:20 – 10:40

Intercalation and Retention of CO_2 in Clays

Jon Otto Fossum
Professor, Department of Physics, Norwegian University of Science and Technology - **NTNU**, **Trondheim**, Norway
jon.fossum@ntnu.no

CO_2 is one of most unwanted greenhouse gases. Currently a lot of research time and money is invested in finding and developing new materials and solutions for CO_2 filtering, capture, transport methods, and long term storage. For example, large projects are underway focusing on Capture, Sequestration and Storage of CO_2 (CCS) in underground reservoirs often naturally capped by clayey geo-formations. In materials science several new and old materials are being developed or revisited for these purposes, and it still is an open question which could the best solution to this interconnected complex problem. Recently we estimated that smectite clay easily can take up 15% of its weight of CO_2 [1], and that the clays need to be heated above ambient conditions in order to release the captured CO_2 again [2]. Clays are nano-porous materials with more than 1000 $(km)^2$ of available surface area in $1m^3$ clay sample. Our recent work [2] has shown that it is not the clay surfaces that attract CO_2 but rather that the CO_2 molecules are captured by charge compensating ions that are attached to the surfaces. The most conservative estimate we can do is thus that smectite clays with standard cations, such as Na^+ or Li^+, capture 0.22 tons of CO_2 per m^3. This is already a high number, which is comparable to that of "competing materials", considering that the density of liquid CO_2 is about 0.75 tons/m^3. We will discuss this and other improved directions for CO_2 capturing by clays.

[1] *X-ray Studies of Carbon Dioxide Intercalation in Na-Fluorohectorite Clay at Near-Ambient Conditions*, H. Hemmen, E.G. Rolseth, D.M. Fonseca, E.L. Hansen, J.O. Fossum and T.S. Plivelic, LANGMUIR 28, 1678 (2012)
[2] *Intercalation and Retention of Carbon Dioxide in a Smectite Clay promoted by Interlayer Cations,*
L. Michels, J.O. Fossum, Z. Rozynek, H. Hemmen, K. Rustenberg, P.A. Sobas, G.N. Kalantzopoulos, K.D. Knudsen, M. Janek, T.S. Plivelic, G.J. da Silva, SCIENTIFIC REPORTS 5 : 8775 (2015)

10:40 – 11:00

A multiscale molecular simulation persperctive of Nano IOR and EOR

Caetano Rodrigues Miranda
Department of Materials Physics and Mechanics, Institute of Physics - **University of Sao Paulo**, SP – Brazil
Email: cmiranda@if.usp.br

With increasing demand and necessity to improve oil production, a great deal of attention has been given to potentiality of nanoparticles as efficient oil recovery processes. Here, we explore the potentialities of Improved(IOR) and Enhanced (EOR) oil recovery processes at nanosacale. For any possible application of hard nanoparticles as an enhanced oil recovery agent, it is necessary to have a stable wettability modifier with improved mobility properties under broader oil reservoir conditions. Similarly, thermodynamic and fluid dynamics in confined nanoporous media differs greatly from those in bulk. This talk will present a multiscale view of fluid-solid interactions from nano to oil reservoirs. We will explore the application of computational nanoscience techniques to characterize mineral/oil/brine interfaces under broader oil reservoir conditions through an integrated computational multiscale approach from First Principles, Molecular Dynamics and Lattice Boltzmann methods. Our studies include the interface between materials at nanometer scales and in nanoporous environments with crude oil and fluids typically found in the oil & gas industry. The understanding of physical and chemical processes taking place at the interface of fluids and in nanoconfined environment is of paramount importance to understand and design new techniques for Oil exploration, which can have a significant economic impact and provide new opportunities in Interfacial science.

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<td>11:40 – 12:00</td>
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The QL-LAOS methodology
Alexandra A. Alicke and Paulo R. de Souza Mendes
Researchers, Department of Mechanical Engineering, PUC- Rio de Janeiro, RJ-Brazil
pmendes@puc-rio.br

Recently we proposed a novel approach for using large amplitude oscillatory shear flow experiments (LAOS) to determine---in a simple, direct and robust manner---the mechanical behavior of soft solids [1]. While at present all LAOS analyses focus on motions during which the microscopic state changes periodically, our methodology---quasi-linear LAOS or QL-LAOS---relies for the most part on data obtained from constant-microscopic state motions, which simplifies dramatically the experiments and the analysis, and provides material functions the physical meanings of which are quite evident. Here we present the results and conclusions of an investigation the goal of which was to verify the range of applicability of the QL-LAOS methodology. To this end, we selected different elasto-viscoplastic and viscoelastic systems, namely a hair gel, an aqueous solution of polyacrylamide and an aqueous solution of xantham gum. We performed measurements at several different combinations of stress amplitude and frequency. The results demonstrate that the methodology is suitable to both elasto-viscoplastic and viscoelastic liquids.

[1] P. R. de Souza Mendes, R. L. Thompson, A. A. Alicke, and R. T. Leite, The quasilinear large-amplitude viscoelastic regime and its significance in the rheological characterization of soft matter, J. Rheol. 58(2) 537-561 (2014)
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<td>13:40 – 14:00</td>
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Micellar structures and nanopores studied by scattering techniques
K. D. Knudsen
Senior Scienetist, Institute for Energy Technology -IFE, Kjeller, Norway
Professor, Department of Physics, Norwegian University of Science and Technology - NTNU, Trondheim, Norway

Two examples of nanostructured systems related to energy applications will be briefly presented, where the detailed character is elucidated by scattering techniques. The first are nanosized micellar structures typically created at the interface between oil and water, responsible for subsequent creation of large aggregates and finally clogging of transport pipes. The second are nanosized porous materials, as potential candidates for storage or encapsulation of CO_2. Investigations have recently been made of CO_2 absorption in different types of porous nanostructures, including clay materials, using small-angle neutron scattering as the main technique. An in-situ setup is now available, allowing controlled introduction of supercritical CO_2 under varying pressure and temperature (up to 450 bars and 125 degC).
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14:00 – 14:20	*Motion of multiple fingers and bubbles in a Hele-Shaw cell or porous medium* **Giovani L. Vasconcelos** Professor, Departamento de Física, Universidade Federal de Pernambuco – **UFPE, Recife**, Brazil The penetration of a fluid into a porous medium or Hele-Shaw cell containing a more viscous liquid has been a problem of great interest since the pioneering work by Saffman and Taylor [1,2]. Besides its practical relevance (e.g., in the context of oil recovery), Hele-Shaw flows also have deep mathematical connections to other interface problems, such as dendritic crystal growth, directional solidification and bacterial colony growth. Another important aspect of the dynamics of interfaces in a Hele-Shaw cell is that it is amenable to analytical treatment in terms of conformal mappings, and using this formalism many exact solutions for fingers and bubbles have been found [1, 2, 3]. In all these previous solutions the fluid domain is simply (or at most doubly) connected, whereby the problem can be solved by standard conformal mapping techniques. The situation is much more complicated in the case of multiple interfaces, because conformal mappings between multiply connected domains are notoriously difficult to obtain. In this talk, I will describe a generalized method of images that we recently developed [4] by which one can solve the problem of multiple bubbles moving in a Hele-Shaw cell. The solution is given by a conformal mapping from a multiply connected circular domain to the fluid region exterior to the bubbles. The desired mapping is written explicitly in terms of certain special transcendental functions, known as the secondary Schottky-Klein prime functions. Possible applications of our formalism to other interface problems will also be briefly discussed. [1] P. G. Saffman and G. I. Taylor, Proc. R. Soc. Lond. A **245**, 312 (1958). [2] G. I. Taylor and P. G. Saffman, Q. J. Mech. Appl. Maths **12**, 265 (1959). [3] G. L. Vasconcelos, J. Fluid Mech. **444**, 175 (2001). [4] G. L. Vasconcelos, J. Fluid Mech. **780**, 299 (2015).
14:20 – 14:40	*Pore scale flow of complex liquids* **Marcio Carvalho** Professor, Department of Mechanical Engineering, **PUC- Rio de Janeiro**, RJ-Brazil The most common oil recovery method used for displacing the oil and maintaining the reservoir pressure is water injection. However, in most cases, the recovery efficiency of this method is limited by the high fluid mobility ratio and reservoir heterogeneities. The non-linear flow properties of complex fluids through porous media give rise to multiphase flow displacement mechanisms that operate at different scales, from pore-level to Darcy scale. Experiments have shown that injection of oil-in-water emulsions and viscoelastic polymer solutions can be used as an effective enhanced-oil recovery (EOR) method, leading to substantial increase in the volume of oil recovered. The mechanisms responsible for increasing the recovery factor in different EOR methods are not fully understood. Here, we study the effect of oil-water emulsion and viscoelastic polymer solution flooding in the pore flow scale. Visualization of the flow of complex fluids through a transparent network of micro-channels, which serves as a model of a porous media, reveals how the flow behavior improves the pore-level displacement efficiency, leading to lower residual oil saturation. Capillary network model is also used to study the effect of pore-scale flow phenomena in the meso-scale flow characteristics.