Exploration technology

April 2011

Interfacial tension measurement

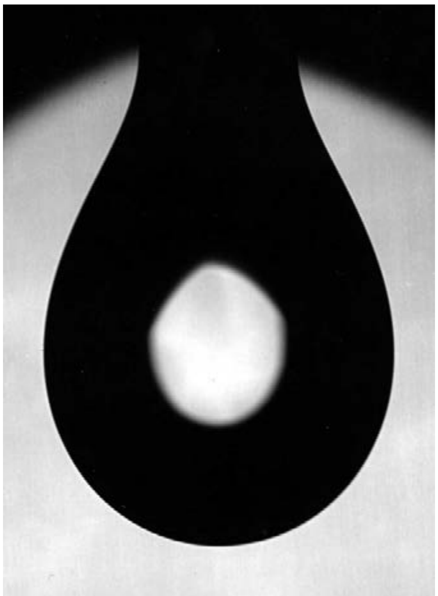
Capillary pressure, caused by interfacial tension (IFT) between reservoir fluids is the most basic rock-fluid property in multiphase flow. Capillary forces resist externally applied viscous forces and hence, to large extent govern the mobility of the reservoir fluids. For example, capillary forces can cause large quantities of oil to be left behind in well-swept zones of waterflooded oil reservoirs. This trapping is best expressed as a competition between viscous forces, which mobilise the oil, and capillary forces, which trap oil. The most common experimental observation is the capillary desaturation curve, a relationship between residual oil saturation and the capillary number, a dimensionless ratio of viscous to capillary forces. At low capillary numbers, the residual oil saturation is roughly constant. However, above some critical capillary number the residual saturation begins to decrease. Hence, additional oil can be recovered by lowering the IFT. For significant effect, though, the IFT must be lowered by several orders of magnitude. Measurement of low IFTs at reservoir pressure and temperature is therefore required for evaluating the potential of EOR processes where lowering of IFT is the primary means of oil recovery.

Two complementary techniques are currently used at SINTEF Petroleum Research for measurement of IFT at high-pressure/high-temperature (HPHT) conditions. High to moderately low IFTs are measured by a drop shape method whereas moderately low to ultralow IFTs are measured by a light scattering method.

HPHT IFT analysis by pendant-drop method

Two pendant drop IFT measurement cells are currently in use in the SINTEF laboratory. Their maximum working pressure and temperature are 500 bar/ 150°C and 1200 bar/ 200°C, respectively. Digitized image processing and full-contour drop-shape analysis allows measurement of IFTs down to 10^{-2} mN/m. The 1200 bar set-up is equipped also for contact angle measurement. Both advancing and receding contact angles can be measured.

Auxiliary IFT measurements at ambient pressure and temperature (or slightly elevated temperature) are usually obtained by use of a Krüss ring tensiometer. The lower IFT range obtainable with this instrument is 10^{-1} mN/m.



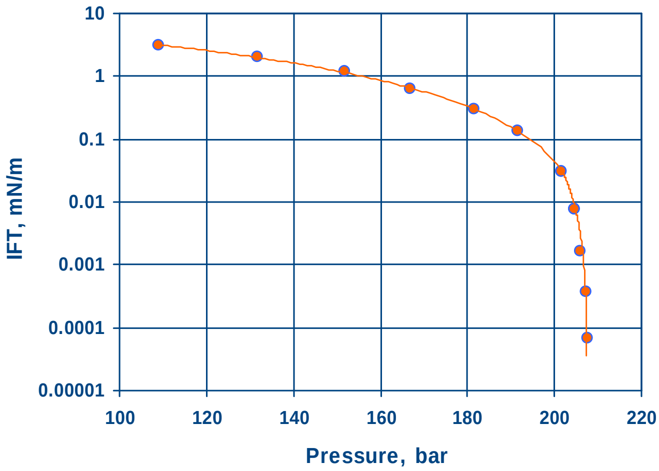
Pendant drop of formation water in reservoir gas at pressure 1100 bar and temperature 190°C.

HPHT interface laser-light scattering

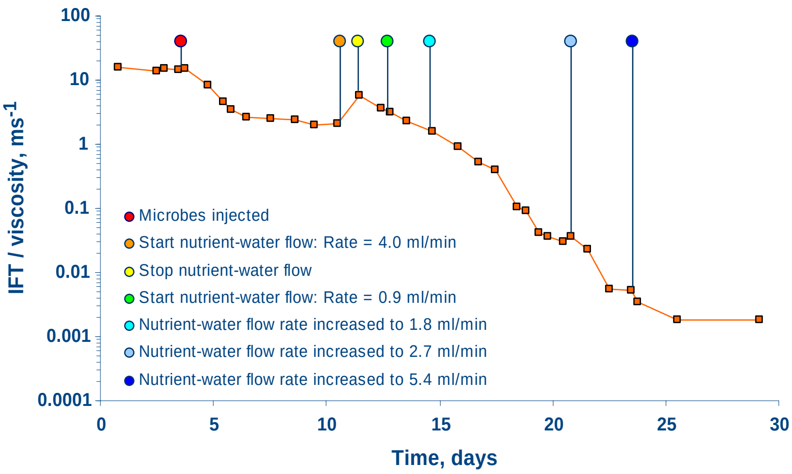
SINTEF Petroleum Research has cooperated with the Physics Department at the Norwegian University of Science and Technology since the mid 1980s in applying laser light scattering for HPHT IFT measurements in hydrocarbon fluid systems. The technique, which main strength is increasing sensitivity with decreasing IFT, is in many ways complementary to the more conventional pendant drop method. For several years, we have used the technique to great advantage in studies of both natural and synthetic low-IFT gas condensates. Recently, the technique has also been shown to offer unique possibilities for monitoring IFT decrease in oil/water systems during microbial activity (relevant to MEOR operations).

- IFT range down to 10^{-4} mN/m
- Maximum working pressure 700 bar
- Maximum working temperature 180°C

Laser-light scattering cell (shown without surrounding thermostat bath). The (red) laser beam can be seen exiting the cell.



IFT vs. pressure in near-critical synthetic gas condensate measured by laser light scattering.



Decrease in the ratio between IFT and viscosity in an oil/water/bacteria system monitored by laser-light scattering.

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