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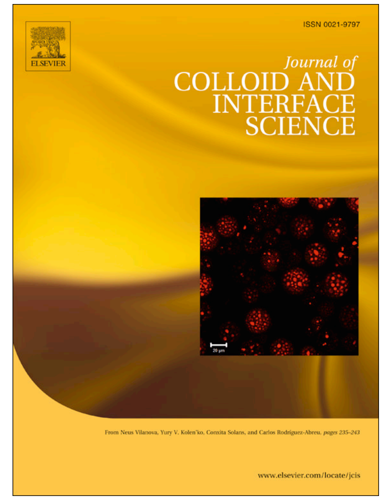

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ABSTRACT

The combination of nanoparticles (NPs) and surfactant may offer a novel technique of generating stronger foams for gas mobility control. This study evaluates the potential of silica NPs to enhance the foam stability of three nonionic surfactants. Results showed that the concentration of surfactant and NPs is a crucial parameter for foam stability and that there is certain concentrations for strong foam generation. A balance in concentration between the nonionic surfactants and the NPs can enhance the foam stability as a result of forming flocs in solutions. At fixed surfactant concentration, the addition of NPs at low to intermediate concentrations can produce a more stable foam compared to the surfactant. The production of small population of flocs as a result of mixing the surfactant and NPs can enhance the foam stability by providing a barrier between the gas bubbles and delaying the coalescence of bubbles. Moreover, these flocs can increase the solution viscosity and, therefore, slow the drainage rate of thin aqueous film (lamellae). The measurements of foam half-life, bubble size, and mobility tests confirmed this conclusion. However, the addition of more solid particles or surfactant might have a negative impact on foam stability and reduce the maximum capillary pressure of coalescence as a result of forming extensive aggregates.

1. Introduction

Despite the successful results that have been reported from gas injection, the poor volumetric sweep efficiency is the major challenge facing the gas injection technique. The low density and viscosity of injected gas compared to the reservoir fluids, in addition to the presence of reservoir heterogeneity such as high permeability and heavily fractured zones are the major causes of gas poor volumetric sweep efficiency. The high mobility of injected gas compared with the other fluids in reservoirs, may lead to early breakthrough of gas, and leaving most of the residual / trapped oil untouched and increase the gas to oil ratio (GOR) which make the overall injection inefficient [1-3]. The use of foam is one of the most promising techniques to overcome gas mobility challenges in petroleum reservoirs [4]. Foam can decrease the gas mobility in porous media by two effects: increasing the apparent gas viscosity and reducing the gas relative permeability [5]. Surfactants are commonly used to stabilize gas-liquid foams [6]. However, the stabilization of foam generated by surfactants at reservoir conditions is strongly affected by reservoir temperature, salinity, and surfactant adsorption to the rock. These conditions might result in weak foam generation and, therefore, poor volumetric sweep efficiency [7-10]. Coated NPs have been used to replace surface-active agents to stabilize gas–liquid [11-12] at harsh conditions such as high temperature, high salinity, and supercritical CO_2 [13-16]. These particles, being solids, can withstand the harsh conditions and mitigate the adsorption to reservoir rocks. Another proposed method to stabilize foams is to mix NPs with surface-active agents. The objective of this method is to modify *in situ* the surface of NPs through physio-chemical interactions, which has been reported to be cost-effective [17]. This technique has been reported to produce a more stable foam than using surfactant alone. Several studies have been conducted showing the importance of NPs on enhancing the foam/emulsion stability [18-26]. For example, laponite particles and a surfactant, tetraethylene glycol monododecyl ether, were found to enhance foam stability under some conditions [27]. Mixing non-modified silica NPs (NexSil™ 20) and caprylamidopropyl betaine (CAPB) surfactant was reported to produce a stable CO_2-in-water foam even though neither of these materials could stabilize foam individually [28]. Also, a strong foam was produced by mixing $CaCO_3$

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