

## Development and Physicochemical Study of Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> Composite Nanofluid Foam for Enhanced Oil Recovery

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### Structured Abstract

**Background:** Primary, secondary, and tertiary recovery are the three steps of oil recovery. Primary recovery relies on natural reservoir pressure which declines over time, reducing production. Secondary recovery uses water or gas injection to increase pressure but is limited due to viscous fingering and early gas breakthrough. Enhanced Oil Recovery (EOR) are tertiary recovery method that use foam injection, but foam becomes unstable under harsh reservoir conditions which reduce extraction efficiency. This study used iron oxide/silica dioxide (Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub>) composite incorporated with cocamidopropyl betaine (CAPB) surfactant to produce a nanoparticle-stabilized foam to improve oil extraction efficiency.

**Methods:** Different brine solutions using sodium chloride (NaCl) and varying CAPB surfactant concentrations were prepared. Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> solution were formulated at mass ratios of 1:1, 1:2, and 2:1 with fixed CAPB concentration. Nanofluids with fixed nanoparticle concentration and varying CAPB concentrations were prepared under both brine and without brine conditions. Foamability and foam stability were evaluated using the Ross-Miles method and visual test. Physical properties such as pH and visual stability were assessed, while chemical properties were analyzed using X-ray Diffraction (XRD) and Fourier-Transform Infrared Spectroscopy (FTIR). Foam morphology was studied to determine average bubble diameter and size distribution.

**Results:** This study shows that 2:1 Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> mass ratio generated the highest foamability and most stable foam when combined with 0.2% v/v CAPB. Visual stability test revealed that CAPB can prevent Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> aggregation by steric stabilization. Increasing salinity from 1% to 3% w/v NaCl decreased foamability but enhanced foam stability. The FTIR spectra of Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub>-CAPB showed Fe<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub> adsorption characteristics with some peak changes observed after CAPB adsorption due to interaction between CAPB and Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub>. The XRD pattern showed that the Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> have a crystalline structure of  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>, and the addition of CAPB does not alter its crystallinity. Foam morphology revealed that Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub>-CAPB in brine conditions up to 3% w/v salinity have the greatest foam stability with the smallest bubble average diameter and size distribution.

**Conclusion:** In conclusion, the combination of Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> and CAPB can enhance foam stability with salinity tolerance up to 3% w/v NaCl, making it a promising formulation for EOR lab-scale experiment.

**Keywords:** Enhanced Oil Recovery, Fe<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub>, CAPB, NaCl, Foam Stability

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