Graduate Student, Energy, Environment & Resource Sustainability

Investigational Study for the efficiency of $Fe_3O_4@SiO_2$ nanoparticles in the Oil Recovery Process using glass micromodel

Wamda Elhaj[1] ,PhD, Fares Al-Momani[1], PhD

[1]Department of Chemical Engineering, College of Engineering, Qatar University

ABSTRACT

There are considerable amounts of oil were produced from oil fields need to be recovered.

Aims: Investigate the efficiency of Fe_3O_4, SiO_2, $Fe_3O_4@SiO_2$ nanoparticles, and seawater as demulsifiers in oil recovery using glass micromodel.

Results: $Fe_3O_4@SiO_2$ MNPs achieved the highest removal rate (up to 90%) while the Fe_3O_4, SiO_2, and seawater attained 70.8%, 55.3%, and 76.5% respectively. Results showed that the application of these nanoparticles could significantly improve the efficiency of oil production by introducing several methods related to the use of these nanofluids in the micromodel individually.

INTRODUCTION

Magnetic nanoparticles are used for their dispersibility in aqueous solutions and simple separation. When nanoparticles are injected to the reservoir they attach to the oil/water interface, and they will be able to push simply in the pores of reservoir rocks due to their small size. The oil droplets will be coated with the nanofluids and then separated thru different mechanisms such as interfacial tension reduction, wettability alteration etc. using glass micromodel. The results of these nanofluids demulsifiers showed high demulsification efficiency.

Experimental arrangement

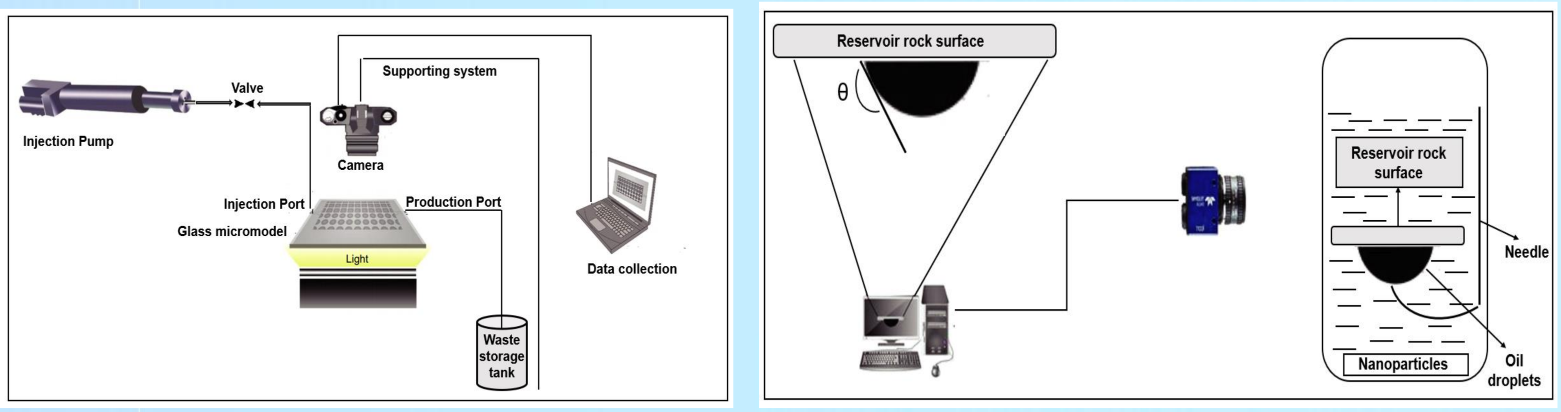


Figure 1. (a) the glass micromodel setup and (b) Wettability assessment

Table 1. The properties of the nanoparticles

NPs	Purity, %	Average diameter, (nm)	Surface area, (m^2/g)	Density, (g/cm^3)	Color	Structure	Chemical characteristics
Magnetite (Fe_3O_4)	98	20-30	30-70	7.874	Blackish brown	Spheral	Amphoteric
Silica (SiO_2)	99.8	20-40	570	2.65	White	pored	Acidic

Table 2. The properties of the crude oil used.

Oil gravity, °API	Density at 25°C (g/mL)	Viscosity at 25°C, (cP)	Structure of SARA, (wt%)			
			Saturates	Aromatics	Resins	Asphaltenes
20.5	0.9250	140	40.9	48.8	7.7	2.6

Table 3. The properties and compositions of the reservoir and seawater.

Water type	Composition of ion, (ppm)							TDS (mg/L)	pH
	Na^+	K^+	HCO^{3-}	Ca^{2+}	Mg^{2+}	Cl^-	$SO4^{-2}$		
formation water	64,440	1190	990	7440	1580	122,950	430	202,1	6.2
seawater	18,800	730	230	1300	1550	300	3380	26,15	7.4

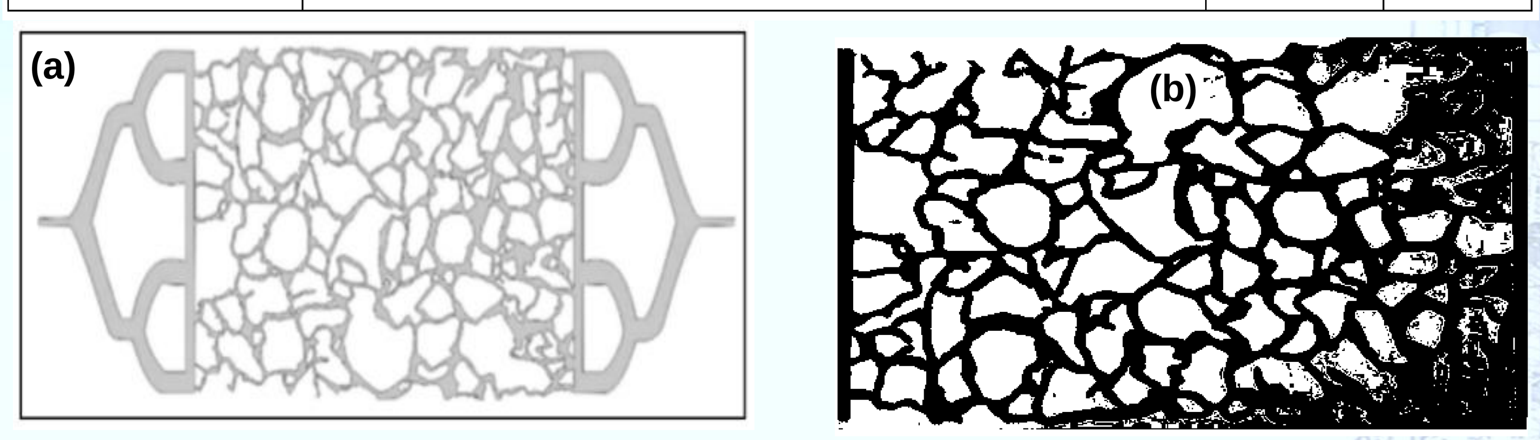
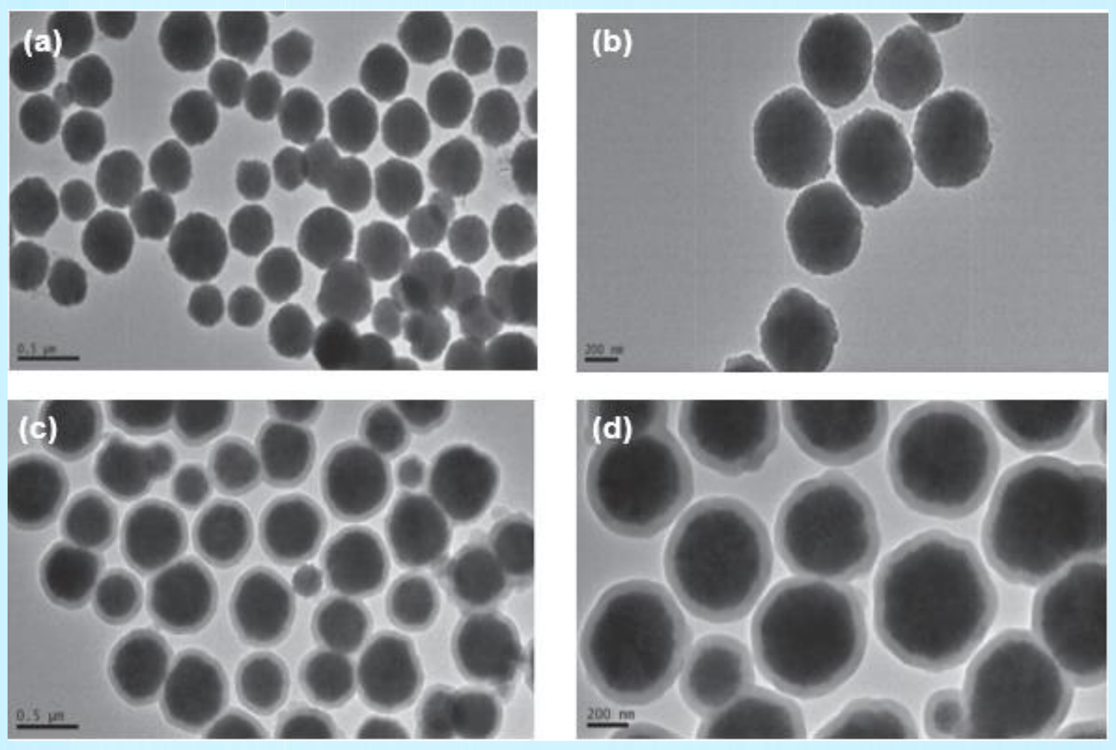


Figure 2. (a) The design of micromodel (b) Micromodel filled with oil indicating the residual water after oil injection.

Characterization of $Fe_3O_4@SiO_2$



- The particle has a properly-characterized core/shell structure by light difference silica shells and dark disparity cores of Fe_3O_4
- $Fe_3O_4@SiO_2$ nanoparticles have a significantly smoother surface and greater particle size (around 45 nm).

Figure 3. TEM images of (a) Fe_3O_4 MNPs at low magnification (b) at high magnification and TEM images of (c) $Fe_3O_4@SiO_2$ at low magnification (d) $Fe_3O_4@SiO_2$ at high magnification

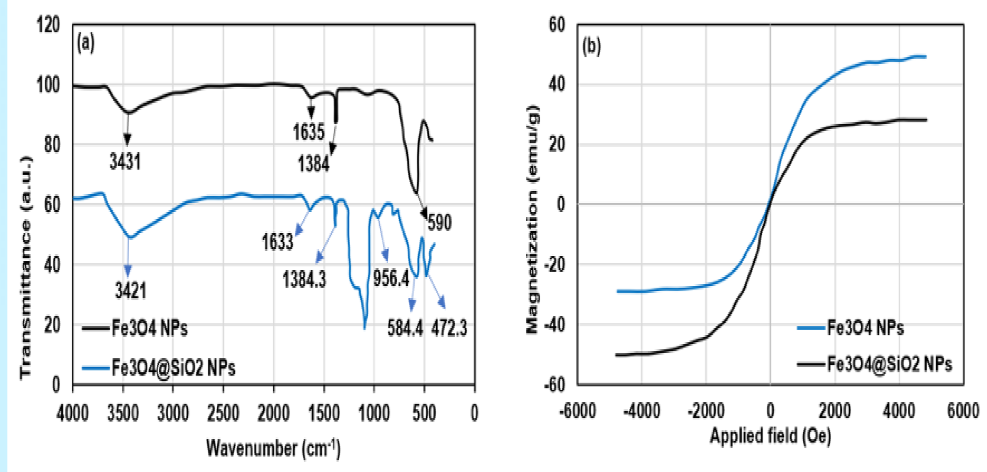
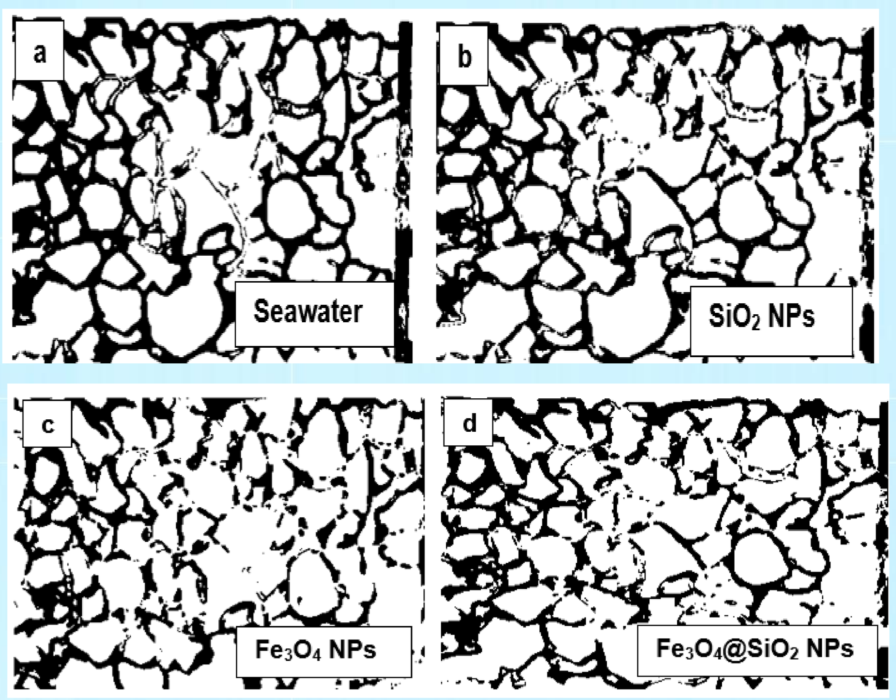


Figure 4. (a) FTIR spectrum of Fe_3O_4 and $Fe_3O_4@SiO_2$ (b) Magnetization analysis for the two nanoparticles.

At 590 cm^{-1} the absorption peak is assigned to the Fe-O bond. The bands aligned on 3431.1 cm^{-1}, 1635.3 cm^{-1}, and 1384.3 cm^{-1} are, respectively, allocated to the O-H expanding, bending, and deforming vibrations of adsorbed water

the magnetization analysis of magnetite (Fe_3O_4) and magnetite/Silica ($Fe_3O_4@SiO_2$) NPs. For Fe_3O_4 NPs, the magnetic saturation (Ms) value is 58.110 emu g^{-1} and the coercivity (Hc) is 45.245 Oe

EOR Using glass micromodel



The colors (black, white, and grey) are corresponded to oil, water, and emulsion, correspondingly. As noticed in Figure 5, the micromodel was filled with oil and a small formation water, which indicated that the water was stuck and stayed in throats and pores. After injecting the oil, the sea water and the nanoparticles presented in Table 1 were inserted individually at 0.6 mL/h into the micromodel

Figure 5. Micromodel images after four hours for the four demulsifiers.

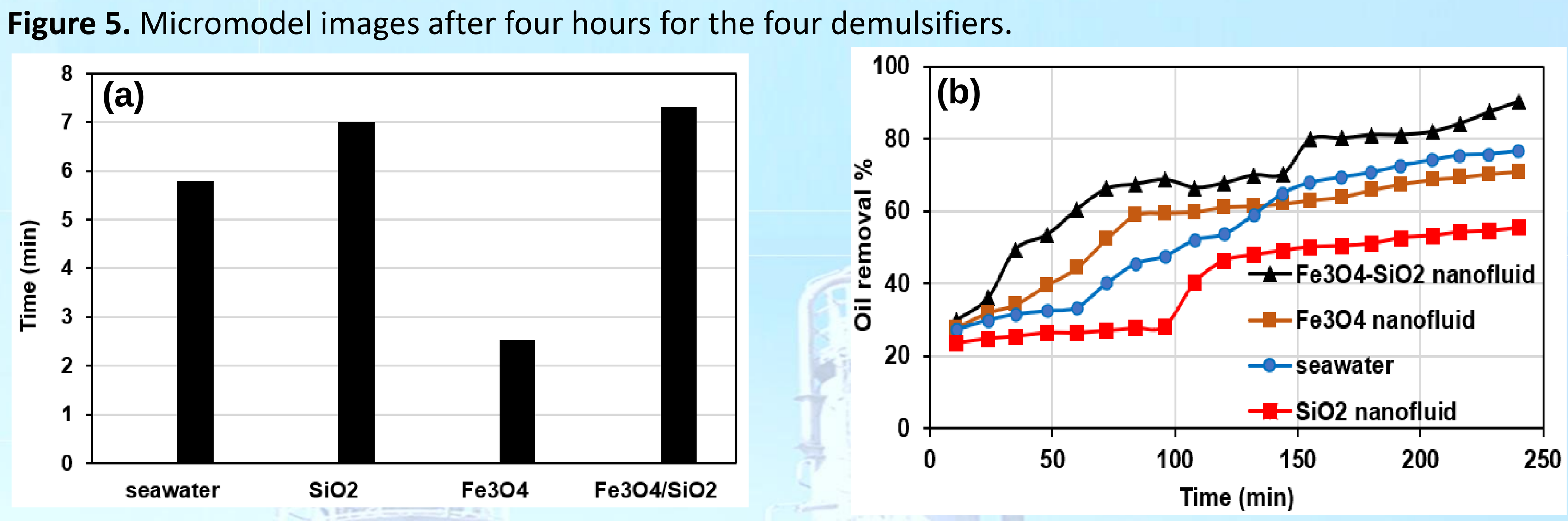


Figure 6. (a) Breakthrough time for the four demulsifiers (b) oil recovery rate using the four demulsifiers.

Figure 6a,b demonstrates that the modified nanoparticles ($Fe_3O_4@SiO_2$) have the lengthiest separation time which implies that a comparatively prolonged period was needed for this MNPs prior the initial water drop leaves from the exit of the micromodel. Fe MNPs has great capabilities for asphaltenes particles absorption on their surfaces owing to their great specific surface area (SSA).

the $Fe_3O_4@SiO_2$ NPs has the greatest behavior in the process of oil production compared with other nanofluid types applied. Beside the reason that these nanocomposites stay in the permeable medium with a great separation time causes high oil generation, but also there are certain alternations in the stated oil production rates which related to the high capability of these nanoparticles in changing the system wettability.

CONCLUSION

- This work demonstrated the production of $Fe_3O_4@SiO_2$ NPs at room temperature utilizing Modified Stober method.
- Applied demulsifiers showed high demulsification efficiency and high asphaltene precipitation.
- The four nanofluids applied classified according to their removal efficiency as follow: $Fe_3O_4@SiO_2$, seawater, Fe_3O_4, and SiO_2.
- The results indicated that a small dosage of $Fe_3O_4@SiO_2$ NPs (10 mg/L) has the greatest final oil recovery reached about 90.2% while a 76.5%, 70.8%, and 55.37% oil recovery rates were achieved when applying seawater, Fe_3O_4, and SiO_2, respectively.
- The water fluid be able to change wettability, decrease the IFT, manage the sedimentation of oil and provide increase to variable emulsions creating owing to its effective ions.