Preparation and Characterization of Nanopolymeric Particles using Polymerizable Surfactants for Rock Wettability Alteration and Oil Production Improvement

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BY

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PhD. Thesis

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DEDICATION

To the Spirit of the most lovely person in my life, to my father whose spirit percolate through my spirit and his soul mixed with my soul to become one soul in tow fleshy bodies and to whom my heart pulses with his love all the time.

ABBREVIATIONS

OOIP	*Original Oil In Place*
EOR	*Enhanced Oil Recovery*
S_{or}	*Residual Oil Saturation, %*
COBR	*Crude oil/Brine/Rock System*
SAGD	*Steam Assisted Gravity Drainage*
AS	*Alkaline/Surfactant Flooding*
SP	*Surfactant/Polymer Flooding*
ASP	*Alkaline/Surfactant/Polymer Flooding*
VAPEX	*Vapor Extraction Method*
SAGP	*Steam And Gas Push*
CAGD	*Chemical Assisted Gravity Drainage*
THAI	*Toe-to-Heel Air Injection*
WAG	*Water Alternating Gas*
SWAG	*Steam Water Alternating Gas*
IFT	*Interfacial Tension*
E_D	*Displacement Efficiency*
E_S	*Sweeping Efficiency*
P_C	*Capillary Pressure*
θ	*Contact Angle*
R	*Effective Pore Radius, µm*
γ_{wo}	Water -oil interfacial tension, Dyne Cm^{-1}
N_C	*Capillary Number*
v	*Velocity of the displacing fluid*
μ	*Viscosity of the displacing fluid, cp*
AM	*Acrylamide Monomer*
HAPAM	*Hydrophobically Associated Polyacrylamides*
Cmc	*Critical Micellar Concentration, $molL^{-1}$*
PAM	*Polyacrylamide*

K_w	*Water Phase Permeability, md*
K_P	*Propagation Rate*
K_t	*Transfer Rate*
CDG	*Colloid Dispersion Gels*
S_{Wi}	*Initial water saturation, %*
S_{or}	*Residual oil saturation, %*
M	*Mobility Ratio*
λ_W	*Water Phase Mobility*
λ_O	*Oil Phase Mobility*
K_W	*Relative Permeability of Water Phase, md*
K_O	*Relative Permeability of Oil Phase, md*
μ_W	*Water Phase Viscosity, cp*
μ_O	*Oil Phase Viscosity, cp*
HPAM	*Partially Hydrolyzed Polyacrylamides*
R_h	*Pore Throat Radius*
R_g	*Gyration Radius*
C^*	*Critical Association Concentration*
HAPAM-SiO_2	*Hydrophobically Associated Polyacrylamides-SiO_2 Nanocomposite*
ppm	*Part Per Million*
R_F	*Resistance Factor*
RR_F	*Residual Resistance Factor*
SARA	*Saturates, Aromatics, Resins and Aromatics*

$\boldsymbol{\Delta H}$	*Enthalpy*
$\boldsymbol{\eta}$	*Intrinsic Viscosity, mlg^{-1}*
$\boldsymbol{\mu_{sp}}$	*Specific Viscosity= $(\mu_{solution} - \mu_{solvent}) / \mu_{solvent}$*
$\boldsymbol{\eta_{app}}$	*Apparent Viscosity, cp*
Γ	*Absorbance*
$\boldsymbol{C_0}$	*Initial Concentration, g/L*
$\boldsymbol{V}$	*Volume of the Solution, L*
$\boldsymbol{m}$	*Mass of the Adsorbent, g*
$\boldsymbol{(\Delta P)_P}$	*Differential Pressure during Polymer Flooding, psi*
$\boldsymbol{(\Delta P)_w}$	*Differential Pressure during Water Flooding, psi*
$\boldsymbol{(\Delta P)_{w\ after\ polymer}}$	*Differential Pressure during Water Flooding after Polymer Injection*
$\boldsymbol{S_{oi}}$	*Initial Oil Saturation, %*
$\boldsymbol{r}$	*Average Pore Radius for Water Flow, µm*
$\boldsymbol{\gamma_{Cmc}}$	*Surface Tension at Critical Micelle Concentration,* mN m^{-1}
$\boldsymbol{\Gamma_m}$	*The Surface Excess Concentrations, mol cm^{-2}*
$\boldsymbol{T}$	*Absolute Temperature, Kelvin =$298K^0$*
$\boldsymbol{R}$	*General Gas Constant= 8.314 J $mol^{-1}K^{-1}$*
$\boldsymbol{A_m}$	*Minimum Surface Area Occupied by a Surfactant Molecule,* nm^2

N_A	*Avogadro's Constant*
M_H	*Initial Molar Concentration of Hydrophobic Monomer in the Feed, Mol L^{-1}.*
$X_{surf.}$	*Molar Surfmer Concentration, mol L^{-1}.*
N_{agg}	*Surfmers Aggregation Number*
N_H	*Hydrophobic Monomers per Micelle*
d	*Average Crystal Particle Diameter, ^oA*
k	*Scherrer Constant (=0.89)*
β	*Line Broadening at Half The Maximum Intensity (FWHM) , Radians*
θ	*Bragg Angle*
k	*Flow Consistency Coefficient (Pa. s^{-n})*
n	*Flow Behavior Index*
e	*Adsorbed Polymer Layer Thickness, µm*
RF_{Total}	*Total Recovery Factor (%).*
RF_{PM+SM}	*Recovery Factor Obtained by Primary &Secondary Methods (%)*
RF_{TM}	*Recovery Factor Obtained by Tertiary Method (%).*
API	*(American Petroleum Institute) defined as stock tank oil API gravity. (Liquid density measurement-degrees API).*
PV	*Pore Volume, cc*

V_B	*Bulk Volume, cc*
V_{Oi}	*Volume of Oil Injected, cc*
V_{Wr}	*Volume of water remain, cc*
V_{Or}	*Volume of Oil remain, cc*
K	*Absolute permeability of formation brine or oil, Darcy*
L	*Length of sandstone holder, cm*
A	*Cross-sectional area of sandstone holder,* cm^2
q	*flow rate of injected fluid, cc/sec*
ΔP	*pressure drop, bar*
ν_w & ν_o	*Darcy velocity for water and oil respectively*
μ_w & μ_o	*Viscosity of brine and oil respectively, cp.*
Φ	*Porosity,%*
MW	*Molecular Weight,* $gmol^{-1} \times 10^6$
MW_c	*Calculated Molecular Weight*
MW_m	*Measured Molecular Weight*
C	*Concentration,* gL^{-1}

SCOPE OF THE WORK

- The main objectives of this study can be concluded in the followings;

1. Preparation of polymeric surfmer (H-type) with active double bond to be polymerized with backbone structure of acrylamide monomer.

2. Copolymerization of surfmer with acrylamide monomer and hydrophobically cross linked moiety to form a hydrophobically associated crosslinked polyacrylamide (HAPAM) copolymer.

3. Synthesis of polymeric nanocomposite by copolymerization of silica nanoparticles with different molar ratios to the previously synthesized HAPAM copolymer.

4. Chemical structure of the prepared composites were characterized through different techniques such as FTIR, ^{1}H-NMR, ^{13}C-NMR, Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), while particle size and particle size distribution were characterized by dynamic light scattering (DLS) and thermal properties characterized by thermal gravimetric analysis(TGA) and differential scanning Calorimetry(DSC).

5. Evaluation of the rheological properties for the prepared composites at simulated severe reservoir conditions for enhanced oil recovery (EOR) applications.

6. Setting up one-dimensional sandstone model (linear model) to carry out flooding processes at simulated reservoir conditions of high temperature and salinity.