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**SURFACTANT-ENHANCED ALKALINE
FLOODING FOR LIGHT OIL RECOVERY**

Contract No. DE-AC22-92BC14883

Illinois Institute of Technology
Chicago, IL

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SURFACTANT-ENHANCED ALKALINE FLOODING
FOR LIGHT OIL RECOVERY

Quarterly Report for the Period
July 1 -September 30, 1995

By
Darsh T. Wasan

Work Performed Under Contract No. DE-AC22-92BC14883

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OBJECTIVE

The overall objective of this project is to develop a very cost-effective method for formulating a successful surfactant-enhanced alkaline flood by appropriately choosing mixed alkalis which form inexpensive buffers to obtain the desired pH (between 8.5 and 12.0) for ultimate spontaneous emulsification and ultra-low tension. In addition, the novel concept of pH gradient design to optimize flood water conditions will be tested.

SUMMARY OF TECHNICAL PROGRESS

The problem of characterizing emulsions in porous media is very important in enhanced oil recovery applications. This is usually accomplished by externally added or insitu generated surfactants that sweep the oil out of the reservoir. Emulsification of the trapped oil is one of the mechanisms of recovery. The ability to detect emulsions in the porous medium is therefore crucial to designing profitable flood systems. The capability of microwave dielectric techniques to detect emulsions in porous medium is demonstrated by mathematical modelling and by experiments.

This quarter the shape dependence of the complex dielectric properties of W/O and O/W type dispersions in the microwave frequency region were analyzed using the generalized effective medium theory of Hanai. The computations show that our earlier finding for spherical dispersions can now be extended to include nonspherical geometries. The computed results show that the difference in dielectric behavior of the two emulsion types are a strong function of the shape of the dispersions, with the differences vanishing when the two phases are oriented as layers parallel and perpendicular to the electromagnetic field.

RESULTS AND DISCUSSION

Fricke (1924) has developed a more general solution following Maxwell for the effective dielectric constants of dilute dispersions containing ellipsoidal particles. For ellipsoids with axes a, b , and c the depolarization factor (shape factor), L along a -axis is given by elliptical integrals and are functions of the semiprincipal axis (a, b , and c) of the ellipsoids. Solutions are obtained in closed form only when the particles are spheroids, i.e., $b=c$. For the case of spheres, $a=b=c$, all three L terms assume the value of $1/3$. For a prolate spheroid,

$$L_a = \frac{1}{2}abc \int_a^\infty \frac{ds}{(s+a^2)[(s+a^2)(s+b^2)(s+c^2)A]}^{\frac{1}{2}} \quad (1)$$

$a \gg b=c$,

$$L_a = [\ln(2a/b) - 1](b/a)^2; L_b = L_c = \frac{1}{2}(1 - L_a) \quad (2)$$

For oblate spheroids $a \ll b=c$

$$L_a = 1; L_b = L_c = \frac{1}{3} \quad (3)$$

Hanai's expression for the dielectric constant for spheres can be easily generalized to obtain

$$\frac{(\epsilon_1 - \epsilon_2)}{(\epsilon_1 - \epsilon_m)} \left(\frac{\epsilon_m}{\epsilon_2} \right)^L = \frac{1}{(1 - \phi)}, \quad (4)$$

where ϵ_1 is the dispersed phase dielectric constant, ϕ the dispersed phase volume fraction, ϵ_2 the continuous phase dielectric constant and ϵ_m the effective dielectric constant of the dispersion. For spheres, $L=1/3$ and Equation 4 simplifies to the original Hanai expression for spheres. For flat discs with their faces parallel to the field or for needles with their axes parallel to the field, L is zero and we obtain

$$\epsilon_m = (1 - \phi)\epsilon_2 + \phi\epsilon_1 \quad (5)$$

The dielectric constant is identical to that of layers of oil and water (with thicknesses smaller than the wavelength) for the case in which the field is parallel to the interface. Similarly for disks with field impressed normal to the face, $L=1$ and the equation reduces to

$$\frac{1}{\epsilon_m} = \frac{(1 - \phi)}{\epsilon_2} + \frac{\phi}{\epsilon_1} \quad (6)$$

These results are identical to those obtained by Sen et. al. (1981) based on their model for heterogeneous media with self similar geometry. The simulated results for the dielectric properties for spheres ($L=1/3$), needles ($L=0$), and plates ($L=1$) are shown in Figures 1, 2, and

3.

The computed results are for a W/O type dispersion at 23.45 GHz. The permittivity and loss factor of the plate shaped dispersions are much lower than the corresponding needle-like dispersions. The results indicate that for nonspherical dispersions, the shape of the dispersion and its orientation to the electric field has a significant effect on dispersion dielectric properties.

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2. Sen, P.N., Scala, C., and Cohen, M.H., "A Self-Similar Model for Sedimentary Rocks with Applications to the Dielectric Constant of Fused Glass Beads", *GeoPhysics*, **46**, 781 (1981).

PUBLICATIONS

1. Nikolov, A. and Wasan, D.T., "Effects of Surfactant on Multiple Stepwise Coalescence of Single Drops at Liquid-Liquid Interfaces", *I&EC Research*, **34**, 3653 (1995).

Figure 1 Loss Tangent Variation with Dispersed Phase Shape for W/O type Dispersion at 23.45 GHz

Figure 2 Loss Factor Variation with Dispersed Phase Shape for W/O type Dispersion at 23.45 GHz

Figure 3 . Permittivity Variation with Dispersed Phase Shape for W/O type Dispersion at 23.45 GHz