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APPENDIX A
EXPERIMENTAL DATA OF MICROEMULSION FORMATION

1. Solubilization parameter (SP)

The solubilization parameter of oil (SP_o) and water (SP_w) are designed as:

$$SP_o = \frac{V_o}{M_s} \quad \text{and} \quad SP_w = \frac{V_w}{M_s} \tag{A.1}$$

where Vo = volume of oil solubilized

Ms = weight of surfactant

Vw = volume of water solubilized

2. Interfacial tension (IFT)

The interfacial tension of each phase of microemulsion is calculated by the following formulation:

$$IFT = e(Vd)^3 n^2 \Delta\rho \tag{A.2}$$

where σ = interfacial tension (mN/m)

n = number of revolution (rpm)

e = 3427 x 10-7 (mN cm^3 min^2/m g mm^3)

V = 0.31 (mm/sdv)

d = measured drop diameter (sdv)

$\Delta\rho$ = density difference of two liquids (g/cm^3)

3. Experiment data of Solubilization parameter (SP)

Table A-1 Volume fractions of water, middle, and oil phases and solubilization parameter of oil and water phases in microemulsion formation with 3 wt % AOT and 2 wt % Dowfax at different NaCl concentrations and initial oil to water ratio = 1:1.

Mixture of 3 wt % AOT and 2 wt % Dowfax					
NaCl conc (wt %)	Volume fraction			SPw (ml/g)	Spo (ml/g)
	Excess water	Middle phase	Excess oil		
2	0.54	0.00	0.46	19.99	1.73
4	0.58	0.00	0.42	20.00	3.34
5	0.36	0.26	0.38	5.58	4.91
6	0.39	0.24	0.36	4.25	5.54
7	0.41	0.24	0.35	3.47	5.98

Table A-2 Volume fractions of water, middle, and oil phases and solubilization parameter of oil and water phases in microemulsion formation with 4 wt % AOT and 2 wt % Dowfax at different NaCl concentrations and initial oil to water ratio = 1:1.

Mixture of 4 wt % AOT and 2 wt % Dowfax					
NaCl conc (wt %)	Volume fraction			SPw (ml/g)	Spo (ml/g)
	Excess water	Middle phase	Excess oil		
0.5	0.54	0.00	0.46	16.66	1.33
1	0.56	0.00	0.44	16.67	1.88
2	0.62	0.00	0.38	16.67	3.93
3	0.30	0.38	0.31	6.54	6.28
4	0.38	0.00	0.62	3.89	16.66
5	0.39	0.00	0.61	3.51	16.67

Table A-3 Volume fractions of water, middle, and oil phases and solubilization parameter of oil and water phases in microemulsion formation with 5 wt % AOT and 2 wt % Dowfax at different NaCl concentrations and initial oil to water ratio = 1:1.

Mixture of 5 wt% AOT and 2 wt % Dowfax					
NaCl conc (wt %)	Volume fraction			SPw (ml/g)	Spo (ml/g)
	Excess water	Middle phase	Excess oil		
1.0	0.62	0.00	0.38	14.29	3.48
1.3	0.66	0.00	0.34	14.29	4.67
1.5	0.73	0.00	0.27	14.29	6.48
1.7	0.16	0.60	0.24	9.57	7.55
2.0	0.26	0.52	0.22	6.65	8.08

3. Experiment data of interfacial tension (IFT)

3.1 Single surfactant concentration

Table A-4 Interfacial tension of each phase in microemulsion formation with 0.3 wt % AMA at different NaCl concentrations and initial oil to water ratio = 1:1.

AMA conc (wt %)	NaCl conc (wt %)	Upper density (g/cm^3)	Lower density (g/cm^3)	Upper level (sdv)	Lower level (sdv)	Speed (rpm)	IFT (mN/m)
0.3	2	0.854	1.031	26.41	19.62	8.82	0.373
	3	0.869	1.040	24.73	21.29	8.86	0.046
	4	0.864	1.025	25.19	20.65	8.06	0.121
	5	0.868	1.046	25.57	20.47	7.15	0.242
	6	0.871	1.057	25.90	20.28	6.13	0.460
	7	0.872	1.063	26.20	20.04	6.13	0.622

Table A-5 Interfacial tension of each phase in microemulsion formation with 1 wt% AMA at different NaCl concentrations and initial oil to water ratio = 1:1.

AMA conc (wt %)	NaCl conc (wt %)	Upper density (g/cm^3)	Lower density (g/cm^3)	Upper level (sdv)	Lower level (sdv)	Speed (rpm)	IFT (mN/m)
1.0	2	0.855	1.009	26.31	19.81	11.63	0.164
	3	0.861	1.011	25.29	20.69	18.13	0.023
	4	0.871	1.030	25.45	20.44	11.07	0.085
	5	0.869	1.045	25.37	20.43	6.93	0.231
	6	0.877	1.041	25.64	19.93	6.54	0.374
	7	0.860	1.040	25.94	19.78	6.13	0.587

Table A-6 Interfacial tension of each phase in microemulsion formation with 2 wt % AMA at different NaCl concentrations and initial oil to water ratio = 1:1.

AMA conc (wt %)	NaCl conc (wt %)	Upper density (g/cm^3)	Lower density (g/cm^3)	Upper level (sdv)	Lower level (sdv)	Speed (rpm)	IFT (mN/m)
2.0	2	0.844	1.011	26.44	20.40	11.08	0.157
	3	0.851	1.022	25.41	21.35	12.82	0.036
	4	0.850	1.026	26.39	20.55	11.79	0.132
	5	0.850	1.035	26.35	20.41	7.66	0.346
	6	0.850	1.055	26.42	20.27	7.20	0.482
	7	0.850	1.059	26.37	20.18	6.15	0.687

Table A-7 Interfacial tension of each phase in microemulsion formation with 3 wt % AMA at different NaCl concentrations and initial oil to water ratio = 1:1.

AMA conc (wt %)	NaCl conc (wt %)	Upper density (g/cm^3)	Lower density (g/cm^3)	Upper level (sdv)	Lower level (sdv)	Speed (rpm)	IFT (mN/m)
3.0	2	0.850	1.023	26.31	19.54	13.92	0.145
	3	0.850	1.030	25.49	20.41	18.40	0.037
	4	0.850	1.037	25.26	20.59	8.14	0.151
	5	0.850	1.050	25.41	20.48	6.13	0.334
	6	0.850	1.048	25.63	20.41	6.12	0.394
	7	0.850	1.054	26.05	20.08	6.12	0.607

3.2 Mixed surfactant concentration

Table A-8 Interfacial tension of each phase in microemulsion formation with 3 wt% AOT and 2 wt % Dowfax at different NaCl concentrations and initial oil to water ratio = 1:1.

System	NaCl conc (wt%)	Upper density (g/cm^3)	Lower density (g/cm^3)	Upper level (sdv)	Lower level (sdv)	Speed (rpm)	$IFT_{w/m}$ mN/m	$IFT_{o/m}$ mN/m
AOT 3 wt% and Dowfax 2 wt%	4	0.8555	0.9990	4.387	3.232	1700	-	0.0065
	5	0.8495	0.9660	4.217	2.888	1123	0.0010	0.0034
		0.9660	1.0220	4.022	3.132	1552		
	6	0.8440	0.9550	4.440	3.095	1222	0.0024	0.0029
		0.9550	1.0310	4.167	3.352	2804		
	7	0.8475	0.9330	4.158	3.032	1092	0.0065	0.0020
		0.9330	1.0460	4.015	3.025	2443		
	8	0.8470	0.9090	4.147	3.088	816	-	0.0011
		0.9090	1.0530	4.180	2.927	2031		

Table A-9 Interfacial tension of each phase in microemulsion formation with 4 wt % AOT and 2 wt % Dowfax at different NaCl concentrations and initial oil to water ratio = 1:1.

System	NaCl conc (wt%)	Upper density (g/cm^3)	Lower density (g/cm^3)	Upper level (sdv)	Lower level (sdv)	Speed (rpm)	$IFT_{w/m}$ mN/m	$IFT_{o/m}$ mN/m
AOT 4 wt% and Dowfax 2 wt%	3.0	0.8402	0.9460	4.175	2.955	994	0.0009	0.0019
		0.9460	1.0050	4.050	3.025	1154		
	3.3	0.8435	0.9400	4.217	3.080	995	0.0009	0.0013
		0.9400	1.0070	4.215	3.147	1117		
	3.5	0.8425	0.9290	4.463	3.260	723	0.0015	0.0011
		0.9290	1.0100	4.235	3.103	1293		
	4.0	0.8490	0.9090	4.317	3.050	557	0.0023	0.0007
		0.9090	1.0030	4.138	3.095	1881		

Table A-10 Interfacial tension of each phase in microemulsion formation with 5 wt % AOT and 2 wt % Dowfax at different NaCl concentrations and initial oil to water ratio = 1:1.

System	NaCl conc (wt%)	Upper density (g/cm^3)	Lower density (g/cm^3)	Upper level (sdv)	Lower level (sdv)	Speed (rpm)	IFT$_{w/m}$ mN/m	IFT $_{o/m}$ mN/m
AOT 5 wt% and Dowfax 2 wt%	1.3	0.8295	0.9660	3.889	3.286	2021	0.0006	0.0018
		0.9660	1.0200	3.767	3.329	1848		
	1.5	0.8280	0.9500	3.917	3.323	1979	0.0008	0.0011
		0.9500	1.0330	3.865	3.497	1653		
	1.7	0.8330	0.9560	3.997	3.312	1892	0.0013	0.0008
		0.9560	1.0090	3.900	3.048	3019		
	2.0	0.8410	0.9340	4.122	3.177	1617	0.0015	0.0007
		0.9340	1.0130	3.865	3.378	2968		

APPENDIX B

EXPERIMENTAL DATA OF FROTH FLOTATION EXPERIMENT

1. **Dynamic oil removal**

The oil removal was calculated by the following equation:

$$\text{Oil removal (\%)} = \frac{(C_t - C_i)}{C_i} * 100 \qquad \text{(B.1)}$$

where C_t = concentration of oil in a solution at time t

C_i = concentration of oil in a solution at time zero

2. **Dynamic surfactant removal**

The surfactant removal was calculated by the following equation:

$$\text{Surfactant removal (\%)} = \frac{(C_{s,t} - C_{s,i})}{C_{s,i}} * 100 \qquad \text{(B.2)}$$

where $C_{s,t}$ = concentration of surfactant in a solution at time t

$C_{s,i}$ = concentration of surfactant in a solution at time zero

3. Enrichment ratio

The enrichment ratio was calculated by the following equation:

$$\text{Enrichment ratio} = \frac{C_f}{C_i} \qquad \text{(B.3)}$$

where C_f = concentration of oil in the collapsed foam solution

C_i = concentration of oil in the feed solution

4. Effective parameter on froth flotation efficiency

4.1 Effect of surfactant concentration

Table B-1 Summary results for the system containing 0.3 wt % AMA with 3 wt % NaCl at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA0.3N3	30	-	35	46.46	16.05	1.022	0.964	2.488
	60	-	65	70.95	47.80	1.502	0.936	3.595
	75	-	78	82.11	64.40	1.602	0.945	4.575
	90	-	92	99.55	81.13	1.763	0.930	8.078

Table B-2 Summary results for the system containing 1 wt % AMA with 3 wt% NaCl at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)	Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA1N3	60 - 70	14.07	25.15	0.074	1.037	0.684
	120 - 130	11.86	50.15	0.250	1.025	0.736
	180 - 190	23.48	63.79	0.526	1.001	0.939
	240 - 250	35.39	84.15	0.922	0.960	1.642
	300 - 310	87.71	99.09	1.814	0.911	0.719

Table B-3 Summary results for the system containing 2 wt % AMA with 3 wt % NaCl at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)	Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA2N3	60 - 70	46.14	8.44	0.773	1.001	0.628
	120 - 130	59.74	17.65	0.826	0.987	0.589
	180 - 190	72.34	18.40	0.708	1.000	0.662
	210 - 220	65.43	23.49	1.442	0.968	0.669
	240 - 250	48.08	33.90	1.233	0.961	0.733

Table B-4 Summary results for the system containing 3 wt % AMA with 3 wt % NaCl at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA3N3	60	-	70	0.29	37.18	0.084	1.058	0.632
	120	-	130	33.31	39.26	0.124	1.018	0.690
	180	-	190	24.07	59.14	0.360	1.002	0.701
	240	-	250	28.12	69.79	0.395	0.971	0.644
	300	-	310	46.56	81.47	0.358	0.986	1.188

4.2 Effect of NaCl concentration

Table B-5 Summary results for the system containing 2 wt % NaCl with 0.3 wt % AMA at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant Removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA0.3N2	90	-	100	1.19	38.46	1.231	0.953	1.258
	210	-	220	12.78	69.88	0.923	0.962	0.273
	313	-	337	40.59	82.94	1.339	0.941	0.175

Table B-6 Summary results for the system containing 3 wt % NaCl with 0.3 wt % AMA at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA0.3N3	30	-	35	46.46	16.05	1.022	0.964	2.488
	60	-	65	70.95	47.80	1.502	0.936	3.595
	75	-	78	82.11	64.40	1.602	0.945	4.575
	90	-	92	99.55	81.13	1.763	0.930	8.078

4.3 Effect of air flowrate

Table B-7 Summary results for the system containing 0.3 wt % AMA and 3 wt % NaCl at air flow rate of 200 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA0.3N3	30	-	35	52.45	30.40	0.380	0.939	1.205
	60	-	65	57.75	35.82	0.584	0.930	1.017
	75	-	78	76.87	75.04	0.464	0.928	0.928
	90	-	92	86.63	82.22	0.706	0.919	1.949

Table B-8 Summary results for the system containing 0.3 wt % AMA and 3 wt % NaCl at air flow rate 250 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA0.3N3	30	-	35	54.38	34.71	0.193	0.973	1.378
	60	-	65	63.29	54.40	0.605	0.943	1.996
	75	-	78	86.05	85.31	0.559	0.929	2.946
	90	-	92	89.27	96.74	0.762	0.940	5.622

Table B-9 Summary results for the system containing 0.3 wt % AMA and 3 wt % NaCl at air flow rate of 300 mL/min, and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA0.3N3	30	-	35	46.46	16.05	1.022	0.964	2.488
	60	-	65	70.95	47.80	1.502	0.936	3.595
	75	-	78	82.11	64.40	1.602	0.945	4.575
	90	-	92	99.55	81.13	1.763	0.930	8.078

Table B-10 Summary results for the system containing 0.3 wt % AMA and 3 wt % NaCl at air flow rate of 350 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
AMA0.3N3	30	-	35	59.99	14.67	0.132	1.009	2.287
	60	-	63	73.58	40.26	0.496	0.957	3.677
	75	-	77	79.14	93.29	0.547	0.929	7.100
	90	-	91	97.42	88.52	0.988	0.927	10.334

4.4 Effect of equilibration time

Table B-11 Summary results for the equilibrium system with 2 wt % NaCl and 0.3 wt % AMA at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
Eq-AMA0.3N2	20	-	22	52.87	15.57	0.545	0.922	3.589
	40	-	42	67.00	28.17	0.942	0.911	3.234
	70	-	72	61.49	45.77	1.181	0.904	2.399
	90	-	92	65.42	53.96	1.020	0.928	2.279
	110	-	112	99.29	63.18	1.020	0.921	1.990

Table B-12 Summary results for the induced-equilibrium system with 2 wt % NaCl and 0.3 wt % AMA at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
Induced-Eq AMA0.3N2	12	-	15	37.82	25.45	0.710	0.938	2.279
	25	-	28	35.28	29.68	1.018	0.920	1.961
	35	-	40	27.50	47.29	1.099	0.919	1.241
	70	-	74	83.84	56.57	0.968	0.914	1.399
	150	-	155	87.79	64.39	1.153	0.911	1.321

Table B-13 Summary results for the non-equilibrium system with 2 wt % NaCl and 0.3 wt % AMA at air flow rate of 300 mL/min and initial oil to water ratio = 1:1.

System	Time interval (min)			Oil removal (%)	Surfactant removal (%)	Enrichment ratio	Foam wetness (g/mL)	Foam flowrate (mL/min)
Non-Eq AMA0.3N3	30	-	35	46.46	16.05	1.022	0.964	2.488
	60	-	65	70.95	47.80	1.502	0.936	3.595
	75	-	78	82.11	64.40	1.602	0.945	4.575
	90	-	92	99.55	81.13	1.763	0.930	8.078

APPENDIX C
ANALYTICAL METHOD

1. GC-Headspace conditions used for analysis

- Substance : Ethylbenzene
- Injector temperature : 70 °C
- Oven temperature : 100 °C
- Detector temperature : 250 °C
- Carrier gas : N_2
- Flowrate of carrier gas: 4 mL/min

2. Titration method [ASTM D1681-92 (1997)]

This titration method used for finding the amount of anionic surfactant

- Material : cationic surfactant, indicator, and chloroform
- Cationic surfactant : Hyamine or CPC 0.02 N
- Indicator : 4 mL of Methylene blue chloride
- Chloroform : 1.5 mL
- Sample : 2 mL (but can be changed)

The amount of anionic surfactant was calculated by the following equation:

$$N_1V_1 = N_2V_2 \qquad (C.1)$$

where N_1 = normality of cationic surfactant at initial time (N)

V_1 = volume of sample at any time (mL)

N_2 = normality of cationic surfactant at time t(N)

V_2 = volume of sample at any time (mL)

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