

1 **Supporting information**

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4 **Chemical reaction-driven spreading of organic extractant on**
5 **gas-water interface: Insight into controllable formation of gas**
6 **bubble-supported organic extractant liquid membrane**

7
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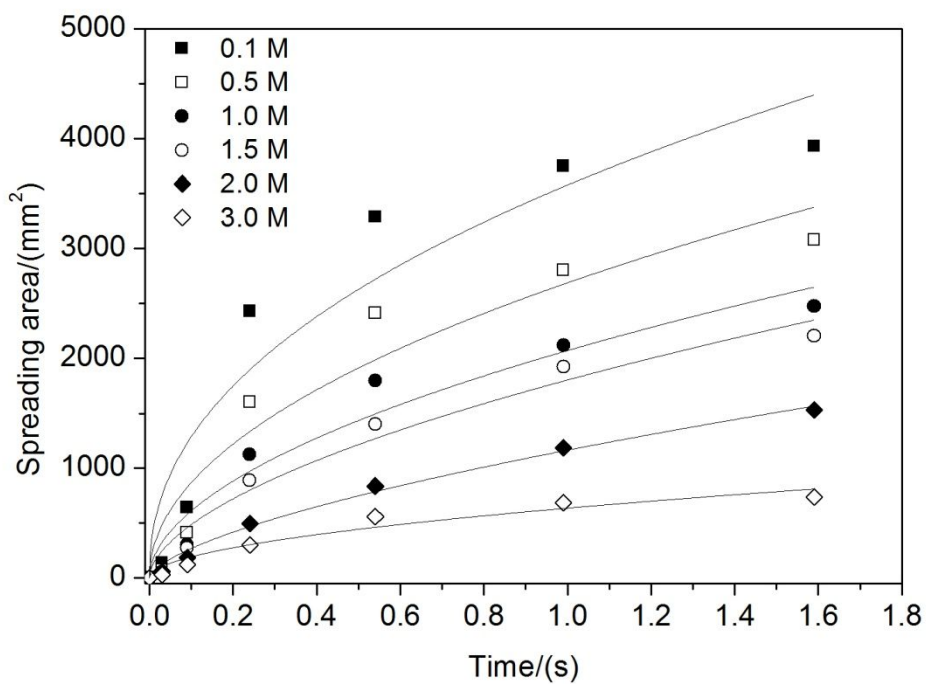
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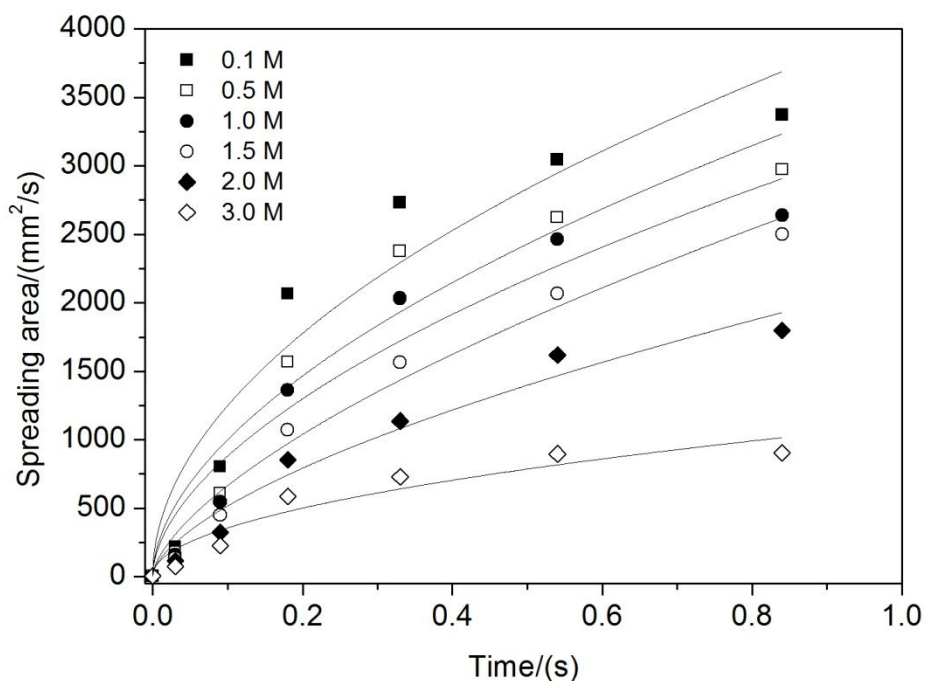
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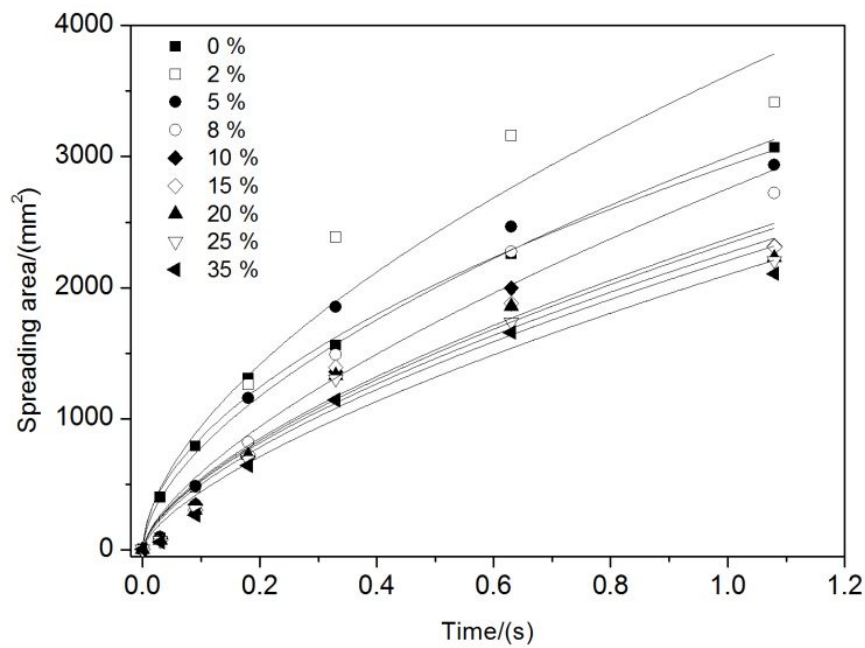
2 **Fig. S1** The time-dependent changes in spreading area of organic droplets containing
 3 different concentrations of P507 on the surface of deionized water
 4 (The saponification degrees of P507 in the organic phases were 5%. The
 5 concentration of pre-loaded Er(III) in P507 organic phases were 0 g/L.)



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2 **Fig. S2** The time-dependent changes in spreading area of organic droplets containing
 3 different concentrations of P507 on the surface of Er(III) aqueous solutions

4 (The saponification degrees of P507 in the organic phases were 5%. The
 5 concentration of pre-loaded Er(III) in P507 organic phases were 0 g/L. The
 6 concentrations of Er(III) in aqueous solution were 30 mg/L, and the pH of the Er(III)
 7 aqueous solutions were 5.4.)



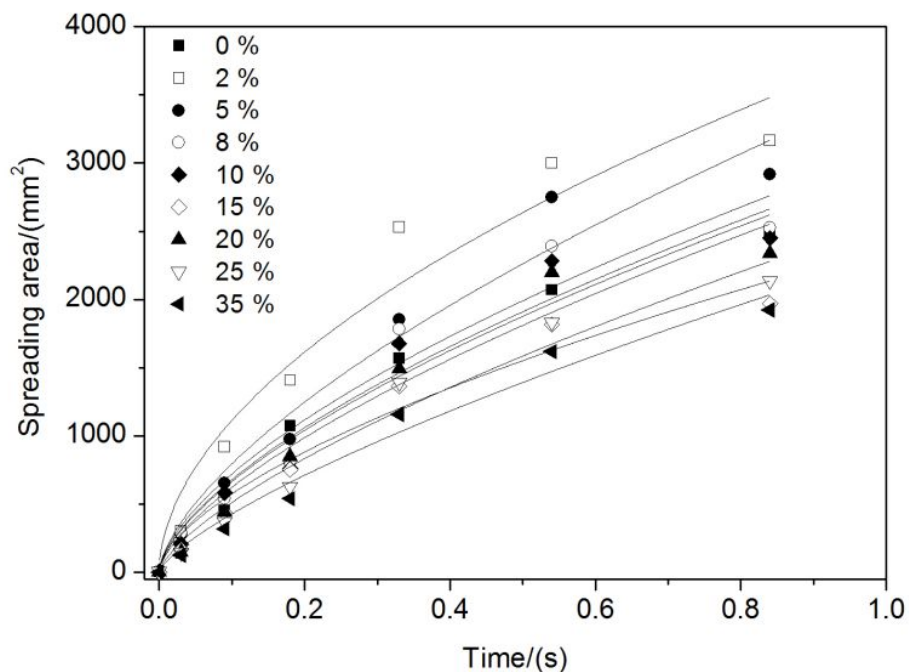
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2 **Fig. S3** The time-dependent changes in spreading area of organic droplets with
 3 different saponification degrees of P507 on the surface of deionized water

4 (The P507 concentrations in the organic phase were 1.5 mol/L. The concentration of
 5 pre-loaded Er(III) in P507 organic phase were 0 g/L.)

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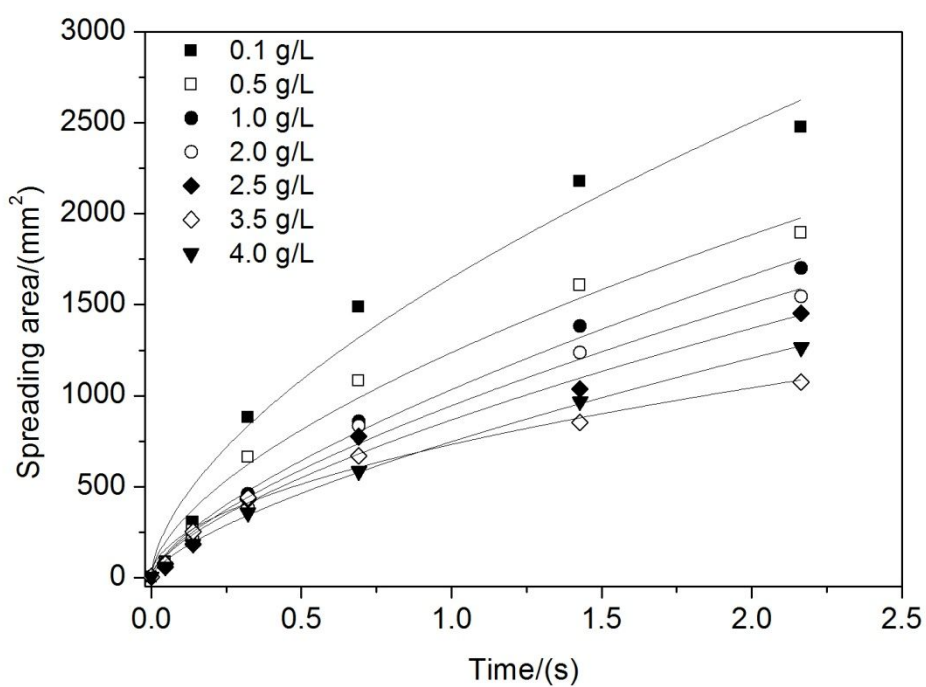
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3 **Fig. S4** The time-dependent changes in spreading area of organic droplets with
4 different saponification degrees of P507 on the surface of Er(III) aqueous solutions

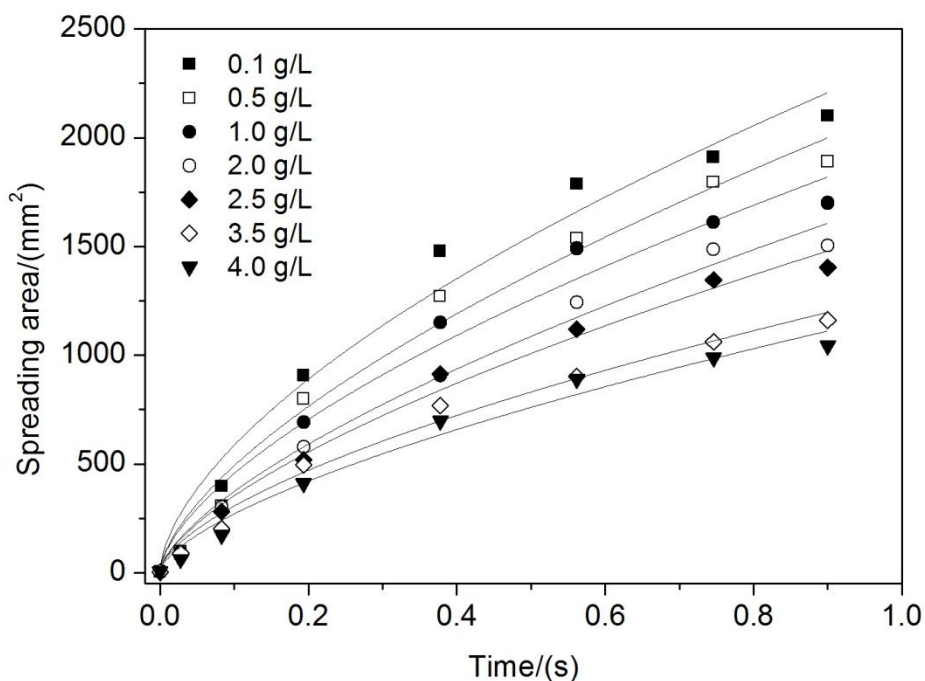
5 (The P507 concentrations in the organic phase were 1.5 mol/L. The concentration of
6 pre-loaded Er(III) in P507 organic phase were 0 g/L. The concentrations of Er(III) in
7 aqueous solution were 30 mg/L, and the pH of the Er(III) aqueous solutions were 5.4.)



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2 **Fig. S5** The time-dependent changes in spreading area of P507 organic droplets
 3 containing different pre-loaded concentrations of Erbium on the surface of deionized
 4 water

5 (The P507 concentrations in the organic phases were 1.5 mol/L. The saponification
 6 degrees of P507 in the organic phases were 5%.)

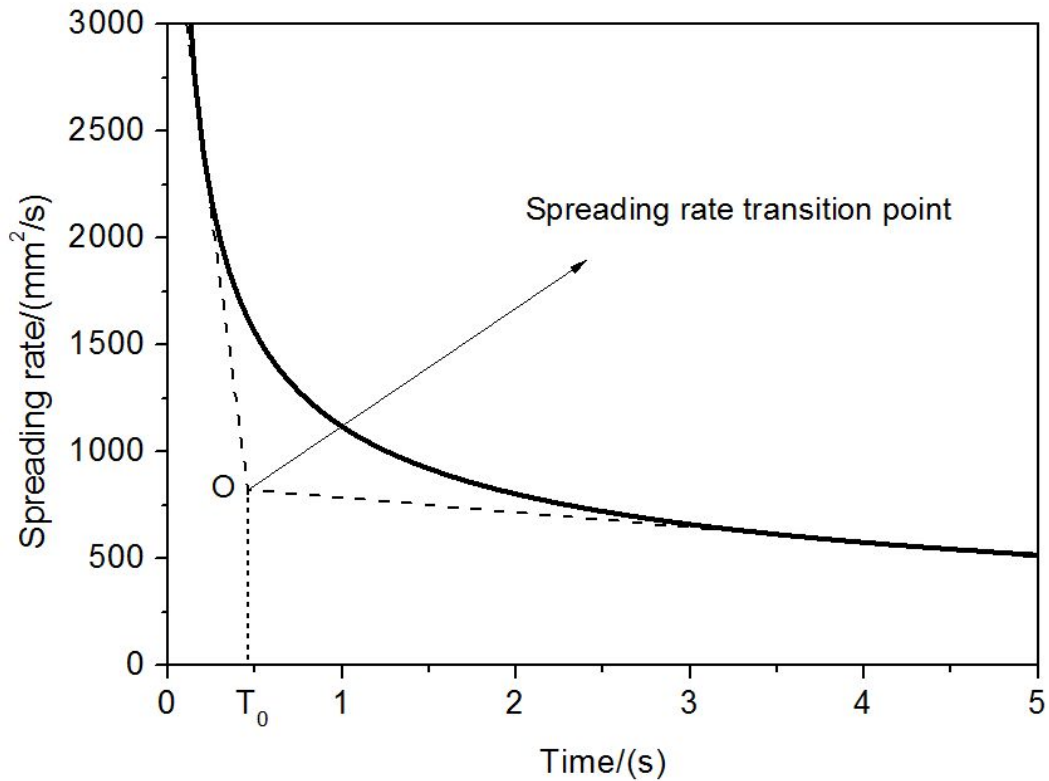


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2 **Fig. S6** The time-dependent changes in spreading area of P507 organic droplets
 3 containing different pre-loaded concentrations of Erbium on the surface of Er(III)
 4 aqueous solutions

5 (The P507 concentrations in the organic phase were 1.5 mol/L. The saponification
 6 degrees of P507 in the organic phases were 5%. The concentrations of Er(III) in
 7 aqueous solution were 30 mg/L, and the pH of the Er(III) aqueous solutions were 5.4.)

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2 **Fig. S7** The schematic diagram about how to obtain the time T_0 for the transition point
 3 of the spreading rates

4 (The transition points of the spreading rates from the initial fast-speed decreasing to
 5 the following slow-speed spreading are defined as the intersections of the two straight
 6 lines, respectively corresponding to the linear fitting of those points in the initial
 7 fast-speed decreasing stage and those in the final slow-speed decreasing stage of the
 8 spreading rate-time curve. Here, the so-called final slow-speed decreasing stage is
 9 defined as that in which the change in the spreading rates with the time is very slowly
 10 or even not changed any more. The intersection of the two straight lines is depicted as
 11 the O point. The time corresponding to the O point is defined as the time T_0 for the
 12 transition point of the spreading rates.)

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3 **Table S1.** The fitting equations of the spreading areas of the organic droplets with
4 different P507 concentrations on the surface of deionized water

Concentration of P507 in the organic phase /(mol/L)	The fitting equations of spreading area with time	The coefficient R ² for the fitting
0.1	$y= 3574.14*x^{0.55}$	0.87
0.5	$y= 3139.68*x^{0.56}$	0.89
1.0	$y= 3084.26*x^{0.53}$	0.92
1.5	$y= 2932.87*x^{0.57}$	0.96
2.0	$y= 1825.59*x^{0.54}$	0.99
3.0	$y= 3084.26*x^{0.53}$	0.93

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2 **Table S2.** The fitting equations of the spreading areas of the organic droplets with
3 different P507 concentrations on the surface of Er(III) aqueous solutions

Concentration of P507 in the organic phase /(mol/L)	The fitting equations of spreading area with time	The coefficient R ² for the fitting
0.1	$y = 4073.31 * x^{0.51}$	0.88
0.5	$y = 3711.25 * x^{0.55}$	0.90
1.0	$y = 3328.17 * x^{0.56}$	0.91
1.5	$y = 3207.63 * x^{0.65}$	0.97
2.0	$y = 2144.47 * x^{0.62}$	0.95
3.0	$y = 1102.13 * x^{0.55}$	0.86

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5 Note: The concentrations of Er(III) in aqueous solution were 30 mg/L. The pH of the
6 Er(III) aqueous solutions were 5.4.

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2 **Table S3.** The fitting equations of the spreading areas of the organic droplets with
3 different saponification degrees of P507 on the surface of deionized water

Saponification degrees of P507 /(%)	The fitting equations of spreading area with time	The coefficient R ² for the fitting
0	$y= 2730.74*x^{0.57}$	0.96
2	$y= 3304.28*x^{0.59}$	0.89
5	$y= 2908.40*x^{0.59}$	0.94
8	$y= 2770.03*x^{0.66}$	0.95
10	$y= 2541.13*x^{0.64}$	0.94
15	$y= 2423.66*x^{0.64}$	0.95
20	$y= 2334.02*x^{0.64}$	0.95
25	$y= 2260.04*x^{0.65}$	0.96
30	$y= 2143.74*x^{0.66}$	0.97

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2 **Table S4.** The fitting equations of the spreading areas of the organic droplets with
3 different saponification degrees of P507 on the surface of Er(III) aqueous solutions

Saponification degree of P507 /(%)	The fitting equations of spreading area with time	The coefficient R ² for the fitting
0	$y= 2907.63*x^{0.65}$	0.97
2	$y= 3504.19*x^{0.53}$	0.92
5	$y= 3343.75*x^{0.60}$	0.95
8	$y= 2931.59*x^{0.58}$	0.92
10	$y= 2844.87*x^{0.60}$	0.93
15	$y= 2490.24*x^{0.53}$	0.95
20	$y= 2610.34*x^{0.58}$	0.94
25	$y= 2265.75*x^{0.64}$	0.95
30	$y= 2018.06*x^{0.52}$	0.97

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5 Note: The concentrations of Er(III) in aqueous solution were 30 mg/L. The pH of the
6 Er(III) aqueous solutions were 5.4.

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2 **Table S5.** The fitting equations of the spreading areas of the organic phase with
3 different pre-loading concentrations of Erbium on the surface of deionized water

Concentration of the pre-loaded Erbium /(g/L)	The fitting equations of spreading area with time	The coefficient R ² for the fitting
0.1	$y = 1644.07 * x^{0.60}$	0.96
0.5	$y = 1232.51 * x^{0.61}$	0.98
1.0	$y = 1080.36 * x^{0.66}$	0.99
2.0	$y = 977.05 * x^{0.66}$	0.99
2.5	$y = 876.97 * x^{0.65}$	0.98
3.5	$y = 727.39 * x^{0.64}$	0.98
4.0	$y = 742.50 * x^{0.66}$	0.99

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2 **Table S6.** The fitting equations of the spreading areas of the organic phase with
3 different pre-loading concentrations of Erbium on the surface of Er(III) aqueous
4 solutions

Concentration of the pre-loaded Erbium /(g/L)	The fitting equations of spreading area with time	The coefficient R ² for the fitting
0.1	$y = 2474.48 * x^{0.61}$	0.97
0.5	$y = 2274.96 * x^{0.64}$	0.97
1.0	$y = 2092.70 * x^{0.63}$	0.97
2.0	$y = 1861.86 * x^{0.67}$	0.98
2.5	$y = 1684.12 * x^{0.66}$	0.99
3.5	$y = 1318.39 * x^{0.62}$	0.98
4.0	$y = 1177.22 * x^{0.66}$	0.97

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6 Note: The concentrations of Er(III) in aqueous solution were 30 mg/L. The pH of the
7 Er(III) aqueous solutions were 5.4.

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3 **Table S7.** The interfacial elasticity modulus and viscous modulus of the organic
4 droplets with different P507 concentrations

Concentration of P507 /(mol/L)	0	0.1	0.5	1.0	1.5	2.0	3.0
E' /(mN/m)	2.96	3.13	1.20	1.32	1.22	0.95	2.41
E'' /(mN/m)	2.15	2.33	3.10	5.23	5.14	6.15	13.36
E''/ E'	0.73	0.75	2.57	3.95	4.22	6.47	5.55

5 Note: E' – the elasticity modulus; E'' – the viscous modulus. E''/ E' - the ratios of
6 viscosity to elasticity.

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3 **Table S8.** The interfacial elasticity modulus and viscous modulus of the organic
4 droplets with different saponification degrees of P507 extractant

Saponification degree of P507 /(%)	5	8	10	15	20	25	35
$E' /(\text{mN/m})$	0.70	0.55	0.28	0.21	0.15	0.09	0.04
$E'' /(\text{mN/m})$	1.04	1.47	1.49	0.91	0.92	0.85	0.89
E''/ E'	1.50	2.68	5.32	4.38	6.27	7.35	21.23

5 Note: E' – the elasticity modulus; E'' – the viscous modulus. E''/ E' - the ratios of
6 viscosity to elasticity.

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3 **Table S9.** The interfacial elasticity modulus and viscous modulus of the organic
4 droplets with different pre-loading concentrations of Er(III)

Concentration of the pre-loaded Erbium /(g/L)	0.1	0.5	1.0	2.0
E' /(mN/m)	1.08	1.29	0.62	0.40
E'' /(mN/m)	2.02	3.05	2.95	2.75
E''/ E'	1.87	2.36	4.79	6.93

5 Note: E' – the elasticity modulus; E'' – the viscous modulus. E''/ E' - the ratios of
6 viscosity to elasticity.

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Table S10. The viscosity of the organic phase with different P507 concentrations

Concentration of P507 /(mol/L)	0.0	0.1	0.5	1.0	1.5	2.0	3.0
Viscosity (mpa·s)	3.01	3.06	3.69	4.85	6.21	8.74	24.24

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3 **Table S11.**The viscosity of the organic phase with different saponification degrees of
4 P507 extractant

Saponification degree of P507 /(%)	5	8	10	15	20	25	35
Viscosity (mpa·s)	7.34	7.59	8.48	8.86	9.57	12.87	13.67

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3 **Table S12.** The viscosity of the organic phase with different pre-loading
4 concentrations of Er(III)

Concentration of the pre-loaded Erbium /(g/L)	0.1	0.5	1.0	2.0
Viscosity (mpa·s)	7.16	7.25	7.36	7.39

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3 **Table S13.** The surface tension and interfacial tension of the organic phase with
4 different P507 concentrations on the surface of deionized water

Concentration of P507 /(mol/L)	γ_{aw} /(mN/m)	γ_{ao} /(mN/m)	γ_{ow} /(mN/m)
0.0	72.20	22.34	21.47
0.1	72.20	23.30	20.71
0.5	72.20	24.95	18.99
1.0	72.20	25.64	18.53
1.5	72.20	26.12	17.18
2.0	72.20	26.57	17.31
3.0	72.20	27.40	16.25

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3 **Table S14.** The surface tension and interfacial tension of the organic phase with
4 different saponification degrees of P507 extractant on the surface of deionized water

Saponification degree of P507 /(%)	γ_{aw} /(mN/m)	γ_{ao} /(mN/m)	γ_{ow} /(mN/m)
0	72.20	22.31	19.88
2	72.20	22.68	17.51
5	72.20	23.83	13.50
8	72.20	24.69	10.62
10	72.20	25.61	9.56
15	72.20	25.91	6.23
20	72.20	25.83	4.50
25	72.20	25.96	3.40
35	72.20	26.05	2.20

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3 **Table S15.** The surface tension and interfacial tension of the organic phase with
4 different pre-loading concentrations of Er(III) on the surface of deionized water

Concentration of the pre-loaded Erbium /(g/L)	γ_{aw} /(mN/m)	γ_{ao} /(mN/m)	γ_{ow} /(mN/m)
0.1	72.20	26.40	17.63
0.5	72.20	26.54	17.41
1.0	72.20	26.71	17.01
2.0	72.20	26.71	17.14
4.0	72.20	26.79	17.14

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3 **Table S16.** The surface tension and interfacial tension of the organic phase with
4 different P507 concentrations on the surface of Er(III) aqueous solution

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Concentration of P507 /(mol/L)	γ_{aw} /(mN/m)	γ_{ao} /(mN/m)	γ_{ow} /(mN/m)
0.1	79.03	23.30	21.43
0.5	79.03	24.95	20.39
1.0	79.03	25.64	18.85
1.5	79.03	26.12	17.21
2.0	79.03	26.57	16.89
3.0	79.03	27.40	16.07

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7 Note: The concentrations of Er(III) in aqueous solution were 30 mg/L. The pH of the
8 Er(III) aqueous solutions were 5.4.

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3 **Table S17.** The surface tension and interfacial tension of the organic phase with
4 different saponification degrees of P507 extractant on the surface of Er(III) aqueous
5 solution

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Saponification degree of P507 /(%)	γ_{aw} /(mN/m)	γ_{ao} /(mN/m)	γ_{ow} /(mN/m)
2	79.03	22.68	18.98
5	79.03	23.83	14.61
8	79.03	24.69	12.37
10	79.03	25.61	10.40
15	79.03	25.91	7.30
20	79.03	25.83	5.54
25	79.03	25.96	4.31
35	79.03	26.05	2.24

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8 Note: The concentrations of Er(III) in aqueous solution were 30 mg/L. The pH of the
9 Er(III) aqueous solutions were 5.4.

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4 **Table S18.** The surface tension and interfacial tension of the organic phase with
5 different pre-loading concentrations of Er(III) on the surface of Er(III) aqueous
6 solution

Concentration of the pre-loaded Erbium /(g/L)	γ_{aw} /(mN/m)	γ_{ao} /(mN/m)	γ_{ow} /(mN/m)
0.1	79.03	26.40	20.47
0.5	79.03	26.54	19.97
1.0	79.03	26.71	19.97
2.0	79.03	26.71	21.66
4.0	79.03	26.79	22.06

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8 Note: The concentrations of Er(III) in aqueous solution were 30 mg/L. The pH of the
9 Er(III) aqueous solutions were 5.4.

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