Supporting Information

Effective Separation and Beneficiation of Iron and Chromium from Laterite Sulfuric Acid Leach Residue

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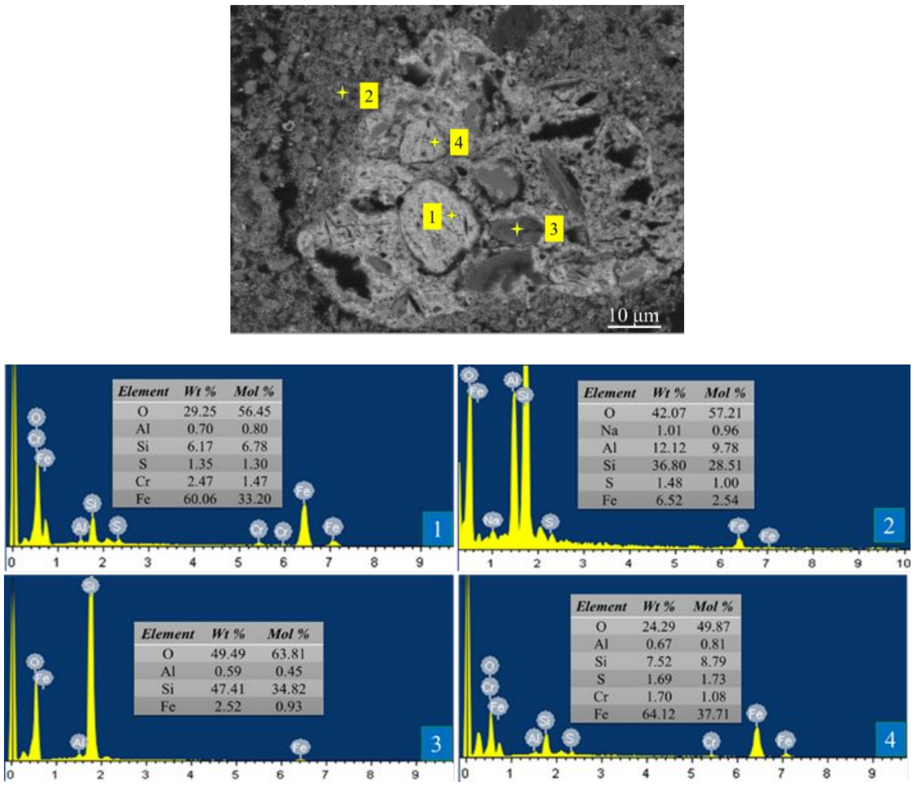
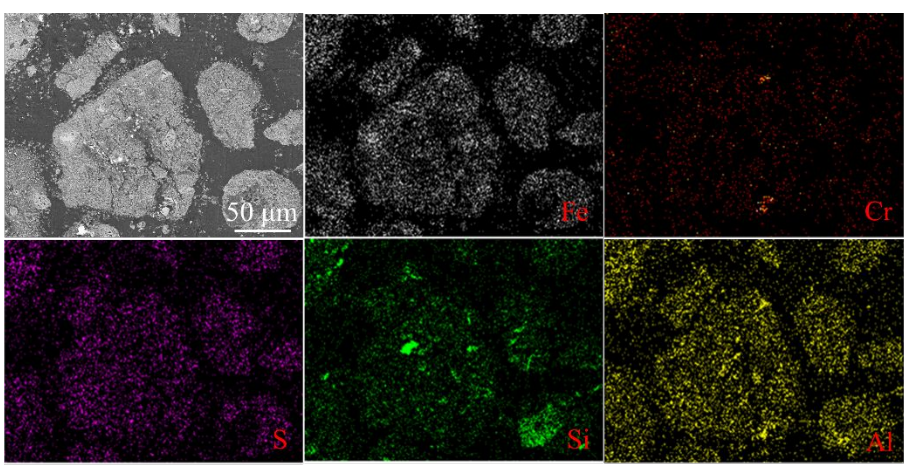
Materials.

The SEM and EDS analysis results of laterite sulfuric acid leach residue used in this study are shown in Figure S1 and S2.



Supporting Figure S1. SEM and EDS results of the laterite sulfuric acid leach residue.



Supporting Figure S2. Map patterns analysis of the laterite sulfuric acid leach residue.

Two main phases can be roughly distinguished in Figure S1. First, a dark gray plate zone with high silica but low iron (Point.2, 3) constitutes the main gangue phase. Bright white particles or stripes with high iron content, low silicon and aluminum content (Point.1, 4) are embedded in the substrate of the gray-black phase. As can be seen from Figure S2, a large amount of elemental Fe and Cr, S, Si, and Al appeared in the same zone, and all elements in raw materials are evenly distributed.

Experimental Methods.

The condition settings in the experiment are shown in Table S1.

Supporting Table S1. Conditions of the experiment

No.	Temperature/°C	Reducing agent dosage /%	Time/min
1	800,900,1000,1100,1200,1300,1400	30	60
2	1200	20,25,30,35,40	60
3	1200	30	30,45,60,75,90

Thermodynamic analysis.

Firstly, the composition of the raw material was determined by XRD and chemical analysis. Then, 100g raw material and 20g C are supposed to be used; enter the chemical formulas and the corresponding masses in the Factsage software. Lastly, set the temperature being at the range of 600-1400 °C, and the temperature interval being 50 °C, and start the calculation.

A txt file of the calculation results can be obtained by Factsage 6.0, which mainly includes the phases at different temperatures and the corresponding masses. According to calculation, there are mainly gas, Fe_3O_4, FeS, Al_2O_3, Cr_2O_3, Fe and so on. Specially, gas means the mixture of CO and CO_2. After that, count and add the phases and their masses at different temperatures into Origin file. There are 17 data for each phase at different temperatures. Then, Figure 4 can be plotted taking the temperature as X and the phase mass as Y. The Factsage calculation results of mineral phases at different temperatures are shown in Table S2.

Supporting Table S2-1. Factsage calculation results of mineral phases with large mass at different temperatures

Temperature/°C	Phase mass/g							
	Gas	Fe	Fe_3O_4	C	$FeAl_2O_4$	FeS	SiO_2	Al_2O_3
600	15.210	0	44.732	15.429	15.797	10.182	6.93	0
650	15.700	0	44.700	14.939	15.63	10.182	6.93	0
700	33.524	29.097	4.890	8.2299	15.08	10.181	6.93	0
750	36.743	31.744	1.795	6.022	13.995	10.181	6.93	0
800	38.375	32.163	1.525	4.55	13.34	10.178	6.93	0
850	39.291	32.257	1.583	3.671	12.883	10.176	6.93	0
900	42.447	37.706	0.083	2.079	0.444	10.172	6.93	9.345
950	42.447	38.244	0	1.728	0	10.168	6.93	9.667
1000	43.073	38.247	0	1.610	0	10.163	6.93	9.667
1050	43.135	38.251	0	1.550	0	10.157	6.93	9.667
1100	43.889	39.209	0	1.211	0	8.614	6.93	9.667
1150	44.105	39.476	0	1.109	0	8.190	6.93	9.667
1200	44.163	39.546	0	1.080	0	8.089	6.93	9.667
1250	44.192	39.581	0	1.066	0	8.040	6.93	9.665
1300	44.214	39.611	0	1.058	0	7.998	6.93	9.663
1350	44.237	39.645	0	1.051	0	7.942	6.93	9.658
1400	44.270	39.697	0	1.042	0	7.852	6.93	9.644

Supporting Table S2-2. Factsage calculation results of mineral phases with small mass at different temperatures

Temperature/°C	Phase mass /g							
	$FeCr_2O_4$	CrS	Al_3O_4	Cr_2O_3	$AlFe_2O_4$	$AlCr_2O_4$	FeO	CrO
600	2.623	0	0.299	0	0.2488	0.098	0	0
650	2.602	0	0.337	0	0.128	0.117	0	0
700	2.510	0	0.690	0	0.23	0.120	0	0
750	2.387	0	1.282	0	0.173	0.229	0	0
800	2.312	0	1.626	0	0.195	0.294	0	0
850	2.254	0	1.857	0	0.240	0.340	0	0
900	1.318	0	0.032	0.826	0.006	0.099	0	0
950	0	0	0	1.799	0	0	0	0
1000	0	0	0	1.799	0	0	0	0
1050	0	0	0	1.799	0	0	0	0
1100	0	1.445	0	0.467	0	0	0.029	0.010
1150	0	1.829	0	0.116	0	0	0.031	0.007
1200	0	1.908	0	0.0439	0	0	0.025	0.005
1250	0	1.9331	0	0.019	0	0	0.019	0.004
1300	0	1.941	0	0.009	0	0	0.016	0.004
1350	0	1.942	0	0.004	0	0	0.017	0.004
1400	0	1.938	0	0.002	0	0	0.023	0.005

Reduction roasting.

The yield of concentrate and the tailings is shown in Table S3. It can be seen that with the increase of temperature, reducing agent dosage and time, the concentrate yield increases. This results in the iron recovery increase and the chromium recovery decrease, as shown in Figure 5 of the manuscript.

Supporting Table S3. Yield of concentrate and tailings under different conditions (wt.%)

Temperature/°C	Concentrate/ tailings	Reducing agent dosage /%	Concentrate/ tailings	Time/min	Concentrate/ tailings
800	12.5/87.5	20	36.6/63.4	30	48.5/51.5
900	14.9/85.1	25	47.5/52.5	45	50.7/49.3
1000	20.3/79.7	30	53.7/46.3	60	53.7/46.3
1100	40.3/59.7	35	56.4/43.6	75	55.4/44.6
1200	53.7/46.3	40	58.2/41.8	90	56.9/43.1
1300	58.3/41.7	-	-	-	-
1400	60.9/39.1	-	-	-	-

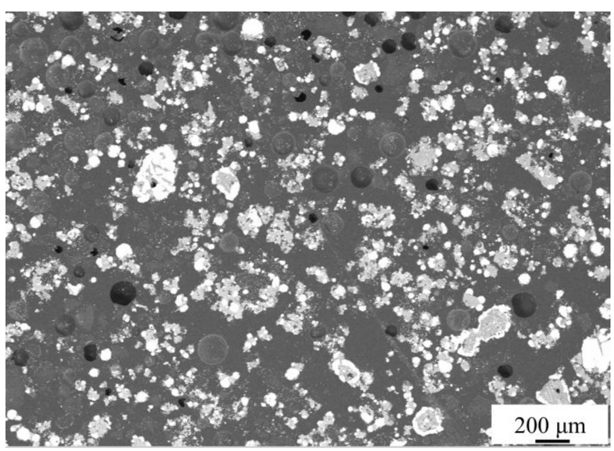
The chemical compositions of the magnetic concentrate and the tailing under the optimum conditions are analyzed and the results are shown in Table S4. The raw material composition is also listed in Table S4.

Supporting Table S4. Chemical composition analysis of the raw material and the magnetic separation products (wt.%)

Element	Fe	Cr	S	Al	Si	Mg	Mn	Ni
Raw material	44.62	1.23	3.71	5.12	6.93	0.14	0.10	0.06
Concentrate	87.97	0.44	0.70	1.10	1.46	0.02	0.04	0.03
Tailings	18.30	3.50	8.93	12.44	16.87	0.35	0.17	0.08

Process analysis.

The SEM image of the reduction product (roasting temperature of 1200 °C, reducing agent dosage of 30% and roasting time of 60 minutes) at low magnification is shown in Figure S3. The aggregation of bright white particles can be seen clearly from Figure S3. These bright white particles are mainly metallic iron.



Supporting Figure S3. SEM image of reduction product at low magnification.

(roasting temperature, 1200 °C; reducing agent dosage, 30%; and roasting time, 60 minutes)