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Extracting Alumina from Low Grade Bauxite with Ammonium Bisulfate Leaching

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Abstract

Using ammonium bisulfate solution to extract alumina from low grade bauxite process was developed. Most alumina and ferric oxide of the bauxite was leached into the solution. All of silica was retained in solid phase. The separation of aluminum and silicon was realized by this method. The conditions were studied in the lab, which are leaching temperature, leaching time, concentration of the ammonium bisulfate solution and mass ratio of ammonium bisulfate and the gibbsite. Metallurgical grade sandy alumina, ferric hydroxide and residue with high silica were gotten. The alumina extracted rate can be about 82% to process low grade gibbsite from Indonesia.

Introduction

Bauxite is the main raw material to produce alumina in the world[1-3]. With the rapid development of aluminum industry, the shortage of suitable resources of bauxite has attracted considerable attention, especially in China. The bauxite A/S supplied to some Chinese refineries has continuously been reducing from 10 to less than 5.5 in the past 10 years even below 5 this year[4-5]. Therefore, the utilization of low grade resources becomes imperative. Extracting alumina from resources which are low grade and refractory, such as low grade bauxite, red mud and fly ash, has become a research focus in alumina area[6-8].

Using traditional Bayer process or sintering process to treat low grade bauxite (A/S＜4) for producing alumina is uneconomical, and more red mud would be produced, which is useless and environmentally harmful. In this paper, alumina and ferric oxide are leached by ammonium bisulfate solution. The final products are metallurgical grade sandy alumina and ferric hydroxide that is the raw material of steel smelting. The residue is less than the traditional processes let out. And the main composition of the residue is silica, which can be used to make white carbon black and other chemical products. Alumina, ferric oxide and silica of the bauxite are used comprehensively.

There are mainly three types bauxite in the world, which are gibbsite, diaspore and boehmite. Gibbsite is the most. In this paper, low grade gibbsite is researched as the raw material. The whole process to produce metallurgical sandy alumina had been accomplished, and the conditions of ammonium bisulfate solution leaching low grade gibbsite were studied in detail.

1 Experimental

1.1 Materials and Reagents

The low grade gibbsite in the experiments was from Indonesia. The main composition of the gibbsite is listed in Table 1.

Table 1 Composition of the low grade gibbsite (mass fraction, %)

Item	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	LOI	others
Content	40.71	27.57	7.40	0.69	22.57	1.06

The water in the experiments is redistilled water.
The reagents are analytical.

1.2 Experimental and Analytical Instruments

The sealed muffle furnace (KFB11Q, China) is used in heating and sintering experiments.

The different concentration ammonium bisulfate solution was gotten on the magnetic stirrer (RCT S25, IKA, Germany).

Steel bombs (6×150ml), which were heated by hot oil, were used in leaching experiments. The temperature can reach 200℃ mostly.

Buchner funnel and vacuum pump were used to separate liquid and solid after leaching and washing.

The phase composition and microstructure were observed by XRD (D/max-2500PC, Rigaku, Japan).

The XRF (SX100e, Rigaku, Japan) is used to analyze chemical content in the solid samples.

1.3 Methodology

The ammonium bisulfate, which would be used to leaching the gibbsite, was gotten by sintering ammonium sulfate at 300℃ in the sealed muffle furnace. The low grade gibbsite was crushed and grinded below 200 mesh and mixed with different concentration ammonium bisulfate solution. The bauxite slurry was put into the steel bombs, and put the bombs into oil bath to heat to the temperature required. The slurry was separated between the solid and the liquid. The residue, the solid part, was washed by hot water. Then, the residue samples were analyzed chemical content. The formula used for calculating the extracted rates of alumina and ferric oxide is expressed below.

$$\eta_A = \frac{(A/S)_{Gibbsite} - (A/S)_{Residue}}{(A/S)_{Gibbsite}} \times 100\%$$

$$\eta_F = \frac{(F/S)_{Gibbsite} - (F/S)_{Residue}}{(F/S)_{Gibbsite}} \times 100\%$$

η_A – extracted rate of alumina, %
η_F – extracted rate of ferric oxide, %
A/S – mass ratio of alumina and silica of sample
F/S – mass ratio of ferric oxide and silica of sample

The influence of leaching conditions on extracted rate of alumina an ferric oxide were studied by experiments.
The low grade gibbsite and leached production were identified by XRD.
The main compositions, including alumina, silicon oxide, ferric oxide and etc., of the gibbsite and the residue were detected with XRF machine.
The Al^{3+} and Fe^{3+} content of solutions were detected with chemical analysis methods [9].

2 Results and Discussion

The alumina extracted rate can be stabilized about 86% and the ferric oxide extracted rate can be about 82% under the optimum conditions. The Figure 1 is the XRD spectra of the low grade gibbsite. It shows that the main phase of Al is aluminum hydroxide, the phases of Si are quartz and kaolinite, the phase of Fe is goethite. Figure 2 is the XRD spectra of the leached product. It shows that the solution leached product was ammonium aluminum sulfate.

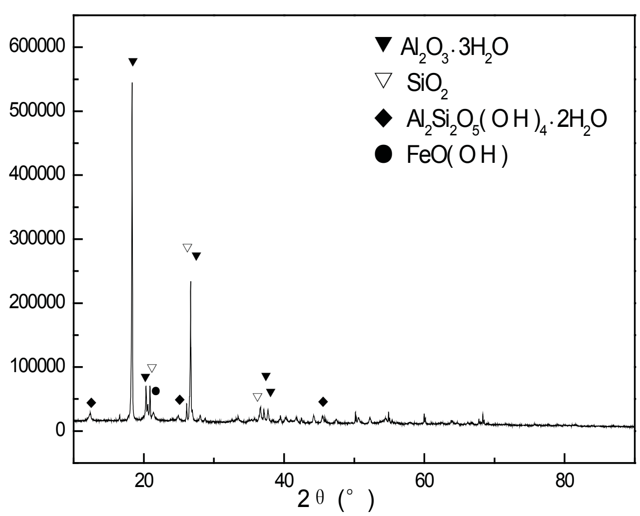

Fig.1 XRD spectrum of the low grade gibbsite

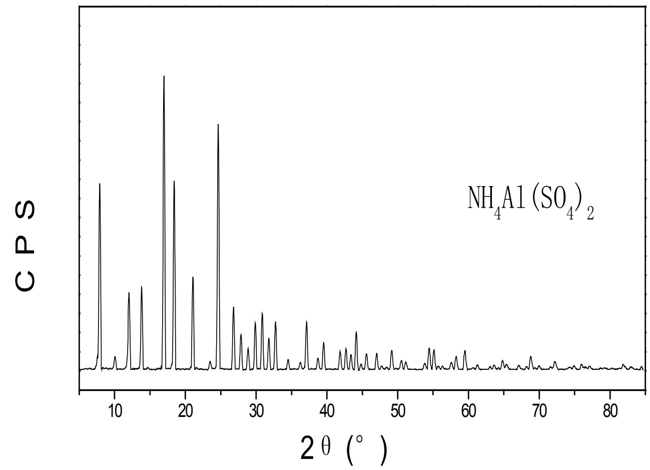

Fig.2 XRD spectrum of leached product

2.1 Influence of the concentration of ammonium bisulfate solution on Alumina Extracted

The relation between the concentration of ammonium bisulfate solution and the alumina extracted rate is shown in Figure 3.

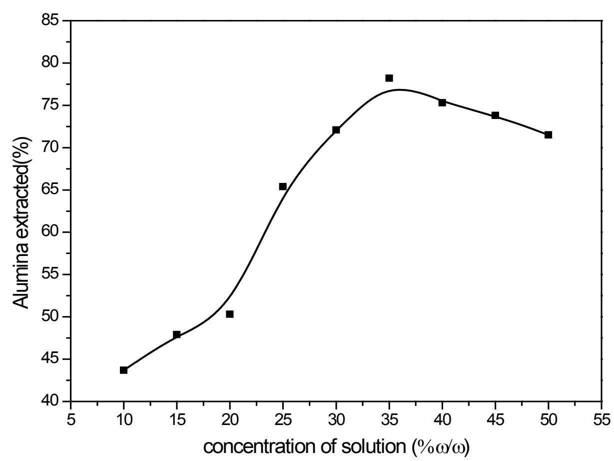

Fig.3 Influence of ammonium bisulfate solution and the alumina extracted

The extracted rate increases with the concentration of the solution increasing firstly, then it decreases with the concentration increasing. The concentration of the solution lower the concentration of H^+ is lower, so the extracted rate is small with low concentration solution. On the other hand, if the concentration of the solution is too high, H^+ is not ionized completely, so the extracted rate is also low with high concentration. The best concentration is 35% as shown in the figure 3.

2.2 Influence of the leaching temperature on Alumina Extracted

The experiments were at the conditions which were concentration of the solution 35%, leaching time 30min, the mass ratio of ammonium bisulfate and the gibbsite 5. The results are shown in figure 4.

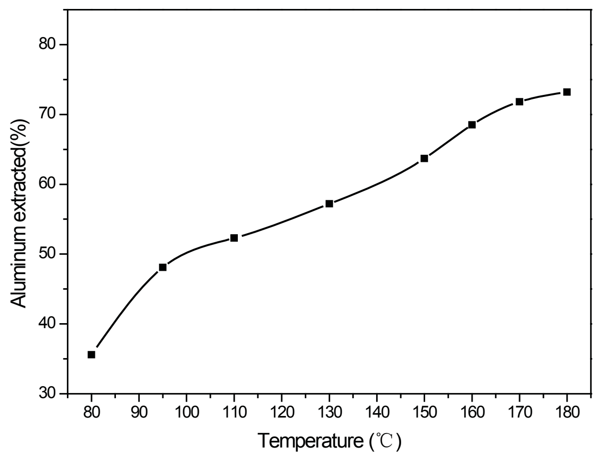

Fig.4 Influence of the leaching temperature on alumina extracted

The extracted rate increases with the leaching temperature increasing. The leaching capacity of H^+ is improved by high temperature. At 180℃, the extracted rate can reach 73.2%.

2.3 Influence of the leaching time on Alumina Extracted

The experiments were at the conditions which were concentration of the solution 35%, leaching temperature 160℃, the mass ratio of ammonium bisulfate and the gibbsite 5. The results are shown in figure 5.

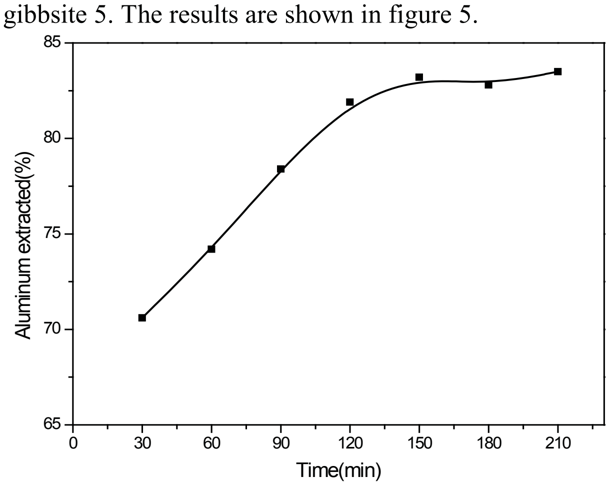

Fig.5 Influence of the leaching time on alumina extracted

The extracted rate increases with the leaching time longer and the curve is flatting after 120min. The extracted rate can reach 83.2%

2.4 Influence of the mass ratio of ammonium bisulfate and gibbsite on Alumina Extracted

The main reaction of ammonium bisulfate solution leaching the gibbsite is as follow,

$3NH_4HSO_4(aq)+Al(OH)_3(s)=NH_4Al(SO_4)_2(aq)+(NH_4)_2SO_4(aq)+3H_2O(aq)$

As per the composition of the gibbsite, the mass ratio of ammonium bisulfate and the gibbsite is 3.07 in theory. The experiments were at the conditions which were concentration of the solution 35%, leaching temperature 160℃, leaching time 120min. The results are shown in figure 6.

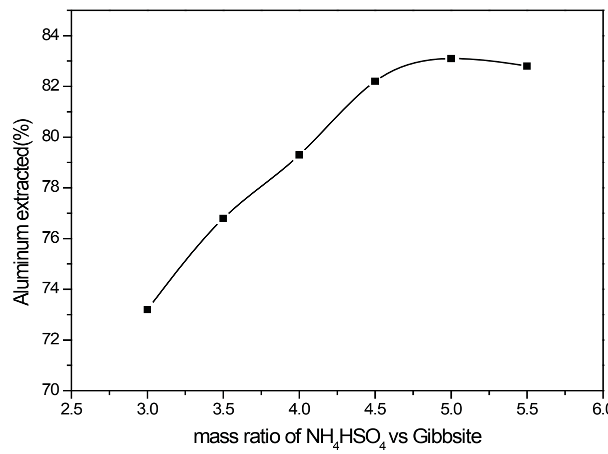

Fig.6 Influence of mass ratio of ammonium bisulfate and gibbsite on alumina extracted

It showed that the molar ratio higher the extracted rate higher and the curve is flatting after the ratio is 4.5.

2.5 Confirmatory Experiments

The confirmatory experiments were at the conditions which are the mass ratio 4.5, the leaching temperature 160℃, the leaching time 120min and the concentration of the solution 35%. The alumina extracted rate was about 82%. Ammonia water was added into the solution that was separated from the slurry after leaching and adjusted the pH to 5-5.5 to precipitate aluminum hydroxide. The ammonium sulfate solution was recycled after evaporation.

3 Conclusions

(1) A new process is presented to extract alumina from low grade bauxite. Metallurgical grade sandy alumina, ferric hydroxide and residue with high silica were gotten.

(2)Alumina had been prepared with the gibbsite leached by ammonium bisulfate solution. ammonium sulfate can be recycled.

(3) The alumina extracted rate can be stabilized about 82% at the conditions of the mass ratio 4.5, the leaching

temperature 160℃, the leaching time 120min and the concentration of the solution 35%.

Acknowledgements

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