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Transformation of hematite in diasporic bauxite during reductive Bayer digestion and recovery of iron

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Abstract: The reductive Bayer digestion by using iron powder as reductant is proposed to convert hematite to magnetite and further to dissociate iron minerals from sodium aluminosilicate hydrate (desilication product, DSP) based on the differences of their surface properties. The results show that the differences of surface properties between magnetite and DSP in zeta potential, wettability and solvation trend facilitate magnetite to agglomerate, grow up and thus to dissociate from DSP. The increments of reductant amount and alkali concentration favor the transformation of hematite in digestion with the relative alumina recovery of 98.91%. Processing the resultant red mud can obtain qualified iron concentrate with iron grade of approximate 60% and recovery of about 86% through magnetic separation, resulting in reduction of red mud emission higher than 70%. The results are potential to develop a novel technology for processing high iron diasporic bauxite efficiently and provide references for comprehensive utilization of high iron red mud.

Key words: Bayer digestion; reduction; hematite; magnetite; red mud

1 Introduction

The annual output of alumina is estimated to be over 6×10^7 t nowadays in China, resulting in rapid depletion in high A/S (mass ratio of alumina to silica) bauxite. Development and utilization of low A/S, high iron diasporic bauxite with large reserves is of great significance and imperative. This kind of bauxite resource is mainly distributed in Guangxi, Yunnan and many other regions in China with the major characteristics of low Al_2O_3 content (50%−55%), high SiO_2 (~10%) and Fe_2O_3 (20%−30%) contents. In current Bayer digestion with diasporic bauxite, lime (8%−10% mass of ore) needs to be added to accelerate the dissolution of diaspore, and inevitably reacts with the impurity minerals such as hematite, silicate and anatase simultaneously to form insoluble products entering red mud through a series of complex reactions [1]. Correspondingly, the mass fractions of Al_2O_3, SiO_2, Fe_2O_3 and CaO in red mud are 15%−20%, 12%−18%, 30%−50%, 16%−20%, respectively. This denotes that iron and calcium minerals contribute above half of the total mass of red mud, leading to an inevitable large waste emission and the increase of soil salinization and water pollution risk to environment [2,3]. According to the existing technologies, this kind of bauxite cannot be economically processed neither as aluminum resource nor iron resource only. Therefore, it is necessary to recover aluminum and iron comprehensively in treating high iron bauxite. Actually, the economic separation and utilization of iron minerals from bauxite or red mud is a long-term research hotspot, which attracts much attention in the field of alumina production.

There are many methods proposed for separating iron minerals from bauxite or red mud, which can be mainly divided into the following two categories.

1) Direct beneficiation

Methods for recovery of iron minerals by direct ore dressing involve gravity concentration [4], high gradient magnetic separation [5−7], surface magnetization-magnetic separation [8], flotation [9], etc. The effective dissociation and appropriate particle size of iron minerals are required to guarantee the beneficiation effects although these methods are simple. Unfortunately, the iron minerals in bauxite and red mud are always fine-

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grained disseminated, leading to either low iron concentrate grade or low iron recovery. For example, industrial practice in Guangxi Branch of CHALCO shows that only 20%−30% iron recovery with concentrate grade of 56% can be obtained by high gradient magnetic separation [10]. This means that it is difficult to reduce the emission of red mud from current Bayer digestion (RM-C) significantly by direct beneficiation.

2) Physical−chemical separation

Bauxite or red mud is heat treated firstly to implement iron minerals conversion and enrichment followed by beneficiation, such as magnetic roasting-separation [11,12] and deep reduction sintering-magnetic separation [13−16]. These methods have favorable separation effects but also have some drawbacks hindering their industrial application such as high energy consumption and relatively complex process.

In short, there exists either low beneficiation effect or high energy consumption in these two kinds of methods. Hence, further study is necessary to develop novel techniques.

Generally, lime is required to eliminate the retardation of anatase on the diaspore digestion and reduce consumption of alkali to a certain degree, but it also brings many adverse effects: 1) causing about 5% alumina loss; 2) increasing 200−300 kg red mud emission per ton of alumina; 3) transforming sodium hydroxide to sodium carbonate by the impurities like $CaCO_3$ in lime; 4) leading to complexity of phase composition and fine-grained dissemination of minerals in red mud, which enhances the difficulty of iron minerals separation.

Our recent studies have shown that, in high pressure Bayer digestion, adding reductant instead of lime can not only ensure alumina recovery [17] but also convert Fe_2O_3 to Fe_3O_4 [18]. These findings may resolve the problems caused by adding lime and benefit iron recovery from red mud. In addition, it is proposed that the formation of Fe_3O_4 is mainly attributed to the reactions in alkaline solution according to formulae (1) and (2).

$$Fe_2O_3+2OH^-+3H_2O = 2Fe(OH)_4^- \tag{1}$$

$$2Fe(OH)_4^- + Fe(OH)_3^- = Fe_3O_4+3OH^-+4H_2O \tag{2}$$

The above studies were conducted in a simple digestion system simulated by using chemicals, and only concerned either substitution of lime or conversion of iron minerals. Specifically, the dissociation and separation of minerals in red mud were not taken into considerations.

Thus, this work focuses on adjusting transformations of minerals in bauxite and mineralogical reconstruction of red mud directionally and synchronously during reductive Bayer digestion process with adding iron powder instead of lime, aiming to accomplish the efficient digestion of diaspore, conversion of hematite to magnetite, and dissociation of iron and silicate minerals in red mud.

2 Experimental

2.1 Materials

Hematite (Sinopharm Chemical Reagent Co., Ltd., China) and iron powder (Tianjin Kemiou Chemical Reagent Co., Ltd., China) were analytical pure, while magnetite was hydrothermally synthesized with hematite (5 g) and iron powder (1 g) under Bayer digestion process conditions (265 °C, 60 min, $\rho(Na_2O_k)$=230 g/L, α_k=3), where Na_2O_k denotes caustic alkali in Na_2O, and α_k is the molar ratio of Na_2O_k to Al_2O_3 in the solution. The kaolin (Hebei Yanxi Minerals Co., Ltd., China) contained 35% Al_2O_3 and 46% SiO_2 according to the chemical components analyses, and mainly consisted of kaolinite and quartz as shown in Fig. 1. Sodium aluminosilicate hydrate (desilication product, DSP) was obtained by kaolin reacting with sodium aluminate solutions ($\rho(Na_2O_k)$=230 g/L, α_k=3, liquid−solid ratio L/S=4) at 265 °C for 90 min. Sodium aluminate solutions were prepared by dissolving aluminum hydroxide (CHALCO, technical grade) and sodium hydroxide (Xinjiang Tianye Group Co., Ltd., China, technical grade) in boiling water.

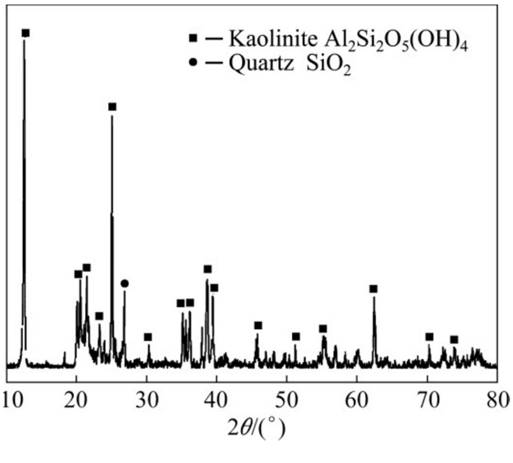

Fig. 1 XRD pattern of kaolin

High iron diasporic bauxite was provided by Guangxi Branch of CHALCO, with the chemical compositions of 51.46% Al_2O_3, 23.93% Fe_2O_3, 6.77% SiO_2 and 3.92% TiO_2 (mass fraction). The mineralogical analysis (Fig. 2) indicates that the main minerals in the bauxite are diaspore, hematite, kaolinite, halloysite, quartz and anatase. The average particle size (d_{50}) of the bauxite is 30.38 μm.

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