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Dechromization and dealumination kinetics in process of Na_2CO_3-roasting pretreatment of laterite ores

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Abstract: A novel process was proposed for the activation pretreatment of limonitic laterite ores by Na_2CO_3 roasting. Dechromization and dealumination kinetics of the laterite ores and the effect of particle size, Na_2CO_3-ore mass ratio, and roasting temperature on Cr and Al extraction were studied. Experimental results indicate that the extraction rates of Cr and Al are up to 99% and 82%, respectively, under the optimal particle size of 44–74 μm, Na_2CO_3-to-ore mass ratio of 0.6:1, and temperature of 1000 °C. Dechromization within the range of 600–800 ºC is controlled by the diffusion through the product layer with an apparent activation energy of 3.9 kJ/mol, and that it is controlled by the chemical reaction at the surface within the range of 900–1100 °C with an apparent activation energy of 54.3 kJ/mol. Besides, the Avrami diffusion controlled model with on apparent activation energy of 16.4 kJ/mol is most applicable for dealumination. Furthermore, 96.8% Ni and 95.6% Co could be extracted from the alkali-roasting residues in the subsequent pressure acid leaching process.

Key words: dechromization; dealumination; kinetics; Na_2CO_3-roasting pretreatment; laterite ore; nickel; cobalt

1 Introduction

The superior properties of Ni lead to an increased demand for the metal, which results in the depletion of the easily extractable Ni sulfide deposits. This has also prompted the mining industry to develop extraction technologies for lateritic Ni [1]. Of all the land Ni reserves, 30% exists as sulfide ores with the balance comprised of oxide ores [2]. The oxide ores account for about 40% of the world's Ni production [3]. Lateritic Ni deposits occur as a result of prolonged chemical weathering of ultramafic rocks containing high proportions of Fe (III) oxide [4] and minor amounts of Ni, Co, Cr and Al [5]. Laterites are mainly divided into two types, i.e., limonitic laterite ores and silicon-magnesium ores. The primary mineral in the limonitic laterite ores is α-FeOOH [6] which forms needle-shaped particles rich in Ni [7].

It is impossible to physically beneficiate Ni due to the complex mineralogy and heterogeneous nature of limonitic laterite ores. In addition, Ni extraction from these ores by traditional pyro- and hydro-metallurgical technologies is costly because of their low Ni content [8−10]. Traditional metallurgical technologies include pyrometallurgical refining [11,12], reduction roasting-ammoniacal ammonium carbonate leaching [13], high-pressure acid leaching (HPAL) [14,15], and so on. Recently, the HPAL technology for processing limonitic laterite ores has become research and industrial application hotspots in hydrometallurgy. However, when this technology was used to treat limonitic laterite ores from Indonesia, the leaching rates of Ni and Co were both low, because some of the Ni and Co were embedded in the chromite or other minerals in the laterite ores [16]. Furthermore, large quantities of acid leach residues with impurities have become unexploited resources that are a serious burden to the environment. Thus, research has been carried out to recover hematite from the acid leach residues mainly containing hematite, quartz, gibbsite and

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chromite and upgrade of the residues to a saleable Fe concentrate [17].

Keeping in mind the above situation, a new extraction technology called the alkali roasting–acid leaching (ARAL) process was developed by our research group to process limonitic laterite ores from Indonesia [18]. The general process flow of the ARAL technology is shown in Fig. 1. This technology comprehensively extracts all the valuable components of limonitic laterite ores. There are three advantages of the ARAL technology as follows [16]. First, it comprehensively extracts all the valuable components of limonitic laterite ores, and reduces costs by operating at milder acid leaching conditions and by recycling the alkali and acid media. Second, alkali-roasting activation pretreatment breaks the mineral lattices of laterites, exposing their Ni and Co, which leads to higher extraction of these two metals under milder operation conditions in the subsequent pressure acid leaching process. Lastly, the grade of pressure acid leaching iron residues is increased due to the removal of some impurities (such as Cr and Al) during the pretreatment, which makes iron-making easier.

The purpose of the present work is to obtain essential information on the effect of particle size, Na_2CO_3-to-ore mass ratio, and roasting temperature on Cr and Al extraction by Na_2CO_3 roasting and then leaching with water. Moreover, the dechromization and dealumination kinetics are also investigated in the present work.

2 Experimental

2.1 Materials

The limonitic laterite ores used in the present work were collected from Indonesia. Indonesia is estimated to have this type of laterite ore reserves of around 150 million. The results of the typical composition analysis by inductively coupled plasma-optical emission spectrometry (ICP-OES, Optima 5300DV, PerkinElmer, USA) are presented in Table 1. The mineralogical analysis of the samples by XRD (Philips 1140, Cu K_α, 40 mA current, 30 kV) indicates that the major crystalline mineral of the laterite ores is goethite, with minor amounts of hematite, magnetite, chromite, gibbsite, and manganite (see Fig. 2). The laterite ores are collected for SEM observation (Electron Corporation, JSM−6700F), as shown in Fig. 3. Goethite, presenting a stalactitic shape, is the major Ni-bearing mineral. Spheroidal particles are mainly Ni oxide grains that are rich in the goethite lattice. Water for the experiment and analysis was purified using a water super-purification machine (Milli-Q, Millipore). The solid Na_2CO_3 was of reagent grade (Beijing Chemical Plant).

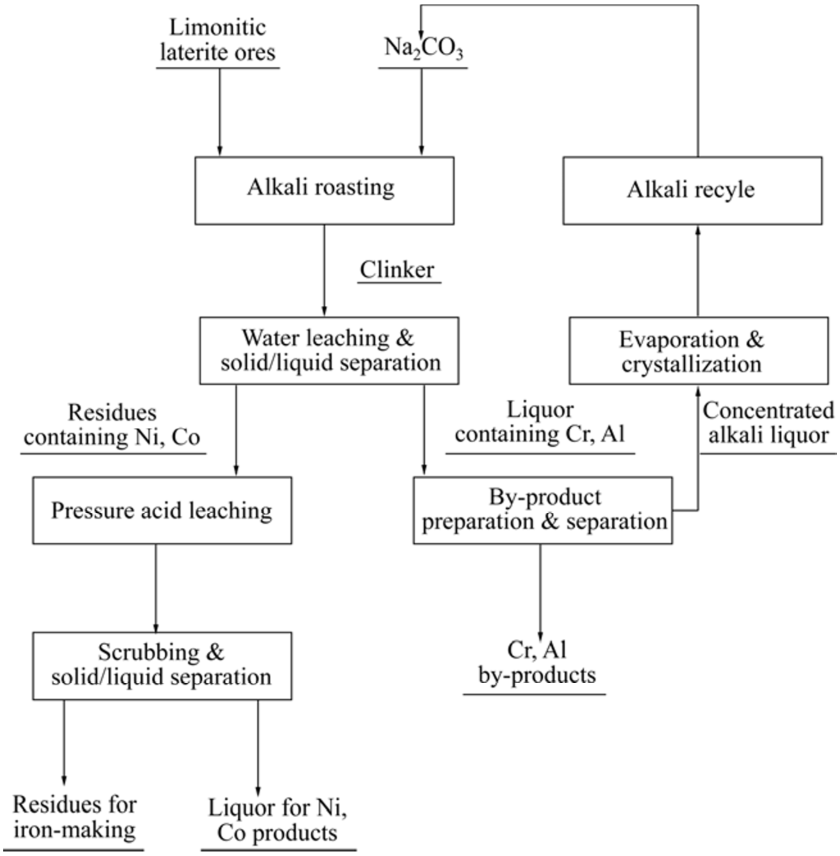

Fig. 1 General process flow sheet of ARAL technology for processing laterite ores from Indonesia