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Leaching of iron concentrate separated from kiln slag in zinc hydrometallurgy with hydrochloric acid and its mechanism

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Abstract: It is taken as a novel prospective process to treat iron concentrate from hydrometallurgical zinc kiln slag for comprehensive utilization of valuable metals by a hydrochloric acid leaching-spray pyrolysis method. The leaching mechanism of different valuable metals was studied. The results revealed that the leaching rates of Ag, Pb, Cu, Fe, As and Zn were 99.91%, 99.25%, 95.12%, 90.15%, 87.58% and 58.15%, respectively with 6 mol/L HCl and L/S ratio of 10:1 at 60 °C for 120 min. The action of SiO_2 in leaching solution was also studied. The results showed that the precipitation and settlement of SiO_2(amorphous) adsorbed part of metal ions in solution, which greatly inhibited the leaching of Cu, Fe, As and Zn, so it is crucial to control the precipitation of amorphous SiO_2.

Key words: kiln slag; iron concentrate; hydrochloric acid leaching; amorphous silica

1 Introduction

Zinc is primarily produced from sulfide concentrates by using roast−leach−electrowinning process in the world. A rock-ribbed problem of this process is the generation of large amounts of unmanageable zinc leaching residues containing valuable metals and toxic elements, such as lead, copper, silver and arsenic [1−3]. If the residues are not effectively treated, not only the environment will be seriously polluted, but also the resources will be wasted [4−6]. Zinc leaching residues can be treated by pyrometallurgical or hydrometallurgical processes. The hydrometallurgical-process commonly involves flotation and leaching [7], sulphation roasting-leaching [8−10], chloride leaching [11], hot acid leaching-jarosite (goethite or hematite) process, etc, [12−14]. Due to high reagent consumption, severe corrosion of equipment, a large amount of iron precipitation residues and unstable recovery rate, disposal of zinc residues is now mainly focused on pyrometallurgical processes, such as waelz kiln volatilization [1,15,16], fuming [17], top blown smelting [18,19], QSL and Kivcet [20], etc. The mostly widely used process in China is waelz kiln volatilization due to its low investment and operation cost [21].

Most of Zn, Pb and Cd are reduced and volatized from zinc residues to zinc oxide dust in waelz kiln process, Cu, Ag, Fe and part of carbon, Zn, Pb, and As are left in the kiln slag. In recent years, many domestic enterprises conducted comprehensive utilization of the kiln slag by gravity and magnetic separation, in which coke powder, iron concentrate and tailings are obtained. Coke powder is returned to the production system as fuel, iron concentrate is the raw material for iron making and tail slag is used for making cement [22]. This process has been applied to industrial production and has achieved certain economic benefits. But the problem is that iron concentrate can only be used with a small amount in iron making because of its high contents of S, Zn and As. Meanwhile, the valuable metals have not been effectively recycled, such as Cu，Ag and In [23,24].

2 Experimental

2.1 Materials and apparatus

The iron concentrate used in the present study was obtained from Zinc Smelting Company of Shangluo in

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Shanxi Province, China. The iron concentrate was dried, ground. Particle analysis found that the sizes of >90% particles were smaller than 109 μm. The ore was analyzed via a chemical method and phase-examined by using powder X-ray diffraction (XRD). The scanning speed was 10 (°)/min.

Chemical leaching experiments were conducted in batches with 100 g/L solids in a 1000 mL solution in a glass flask (total volume, 2000 mL) immersed in a thermostatic water bath agitated by a mechanical agitator. The reaction between the iron concentrate ore and hydrochloric acid was at (30±0.1) °C and the mixture was agitated at a rate of 350 r/min. The leach solutions were prepared using analytical reagent hydrochloric acid and distilled water. Hydrochloric acid concentration was 6 mol/L, and the pH value of the final solution was around 0.1 in the study. At selected time intervals, the sample was separated via centrifugation, washed three times with distilled water, and then dried in an oven at 60 °C.

2.2 Sample characterization

The iron concentrate was characterized via powder XRD analysis using a Japan Rigaku Model TTRIII+ 40 kV/250 mA with Cu K_α radiation. The different diffraction peaks were analyzed for various phases and compared with the ASTM standard.

IR spectra were obtained using an America Nicolet IS 10 spectrometer with a smart endurance single-bounce diamond ATR cell. The samples were prepared using the KBr pellet method. The spectra over the range from 4000 to 400 cm^{-1} were obtained at a resolution of 4 cm^{-1} and a mirror velocity of 0.6329 cm/s. The spectra were coadded to improve the signal-to-noise ratio.

Both crude and leach residues were also analyzed via SEM. The samples were mounted on a copper stub, and the analysis was performed using a Japan Jeol JSM−6360LV instrument equipped with a spectrometer for microanalysis based on an energy dispersive X-ray spectroscopy (EDS) system (EDX-GENESIS 60S, EDAX, USA) with an accelerating voltage of 0.5 kV to 30 kV.

The thermal analysis and mass loss were measured via thermogravimetric analysis (TGA) using a differential scanning calorimetry (DSC)-TGA SDT.Q600 instrument at a heating rate of 5 °C/min to reach the maximum temperature of 1000 °C in air atmosphere (100 cm^3/min).

3 Results and discussion

3.1 Characterizations of iron concentrate

The kiln slag iron concentrate sample was obtained from Shangluo Smelter, Shanxi Zinc Industry Co., Ltd., Shanxi Province, China. Table 1 shows that >90% particles were smaller than 109 μm.

Table 1 Particle size distribution of kiln slag iron concentrate sample

Particle size/μm	Content/%
<47	52.57
47−53	6.01
53−62	10.74
62−80	14.00
80−109	13.68
>109	3.00
Total	100

The chemical and iron-containing phase compositions of the sample are shown in Tables 2 and 3, respectively. The XRD pattern of the kiln slag iron concentrate sample, as presented in Fig. 1, shows only four main phases of Fe_3O_4, $CuFe_2O_4$, Fe_2O_3 and SiO_2 with no evidence of other phases, probably due to their less content or lower crystallinity. Figure 2 indicates that the sample was composed of aggregates of micron-sized particles with some massive and dense bulks present, which may be the agglomeration of semi molten kiln

Table 2 Chemical composition of kiln slag iron concentrate sample (mass fraction, %)

Fe	Zn	Cu	Pb	As	S	SiO_2	Al_2O_3	MnO	Ag*
56.4	2.51	2.51	0.99	0.49	4.75	2.31	1.85	1.28	265

* The mass fraction of Ag is in g/t.

Table 3 Composition of iron-containing phases in kiln slag iron concentrate sample (mass fraction, %)

FeS	$FeSO_4$	Fe	Fe_3O_4	Fe_2O_3	$FeSiO_3$
6.63	1.38	16.63	67.85	2.39	5.08

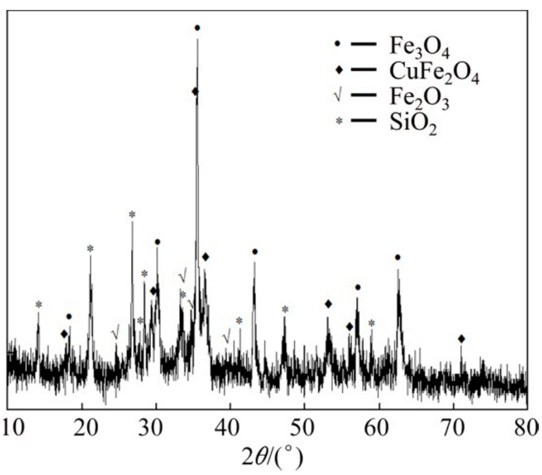

Fig. 1 XRD pattern of kiln slag iron concentrate sample