Recovering of zinc from solid waste bearing sphalerite or zinc ferrite by mechano-chemical extraction in alkaline solution

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Abstract

This study evaluates the efficiency of using mechanical activation for the extraction of zinc from sphalerite and zinc ferrite in lean zinc ores or EAF dusts in alkaline. The mechano-chemical leaching is more effective in comparison with the chemical leaching of non-activated samples. It was found that over 82% of Zn can be extracted from lean zinc ores containing sphalerite with lead compound as additive, and over 45% Zn in EAF dusts can be extracted by mechano-chemical leaching when the leaching process is operated in 5 mol/L NaOH solution at 90°C, and Φ5 mm stainless steel ball as activation medium, the mass ratio of ball to raw materials of 30:1.

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Keyworlds: Zinc; Sphalerite; EAF dust; Mechano-chemical leaching; Alkaline

1. Introduction

Zinc is an important nonferrous metal required for various applications in batteries, solder, dielectric materials, piezoelectric materials, etc. High grade easily concentrated ores are becoming scarcer to meet world demands on zinc. On the other hand, due to the potential health risks, solid waste containing heavy metals (such as dusts) has become a global environmental problem. It’s necessary to develop an economic and environmentally safe metallurgy technology to use lean zinc ores and secondary materials such as dust and waste bearing zinc as raw materials. However, finding a cost-effective and eco-friendly process remains the major challenge. Pyrometallurgical processes face the problems that the construction and working cost are expensive, energy consumption is high. Due to the necessity of eliminating Fe, Cd, Ni, Co etc. from the leachate, and also the large consumption of acid for iron oxides digestion, the industrial
scale utilization of acidic leaching processes has been impeded. Considering that only Zn and Pb can be dissolved effectively in caustic alkaline solution, it should be of great significance to use the alkaline processes to leach Zn selectively from Zn-bearing dusts and secondary resources. In previous research work, over 85% of both Zn and Pb, and less than 10% of Al can be leached from the ore respectively when the leaching operation is conducted at over 95 °C using 5 mol/L NaOH solution as leaching agent, the dissolution of the other elements such as Fe, Ca, etc, were negligible.[1-4].

However, the sphalerite and zinc ferrite in solid waste such as ore tailing or electric arc furnace (EAF) dust are very stable and insoluble in alkaline solution under ordinary temperature and pressure conditions. The mechanical activation of minerals represents nowadays an important contribution to different fields of solid processing technology. In extractive metallurgy, activation by intensive grinding decreases the reaction temperature in pyrometallurgy, increases leaching kinetics of several sulfide and oxide minerals in hydrometallurgy.[5-8].

The aim of this study has been to investigate the possibility of using mechanical activation for the extraction of zinc from EAF dust and lean zinc ores containing sphalerite in alkaline solution.

2. Experimental

2.1. Materials

The lean zinc ores samples containing sphalerite samples used in this investigation were obtained from Xingjiang Province of China, the average composition of the ores is given in Table 1, X-ray diffraction analysis indicated that the phase present in the sample as sphalerite accounts for 40% (Fig. 1). The EAF dust samples used in this investigation were obtained from the steel plant in Jiangsu Province, the average composition of the sample is given in Table 2, X-ray diffraction analysis indicated that the primary phase present in the sample was zinc ferrite (Fig. 2).

<table>
<thead>
<tr>
<th>Elements</th>
<th>Zn</th>
<th>Fe</th>
<th>Pb</th>
<th>Ni</th>
<th>Mg</th>
<th>Cd</th>
<th>Cu</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt. %</td>
<td>5.12</td>
<td>0.93</td>
<td>0.38</td>
<td>0.014</td>
<td>0.33</td>
<td>0.025</td>
<td>0.013</td>
<td>0.085</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Elements</th>
<th>Zn</th>
<th>Fe</th>
<th>Pb</th>
<th>Cd</th>
<th>As</th>
<th>Sb</th>
<th>Sn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt. %</td>
<td>22.21</td>
<td>23.14</td>
<td>3.45</td>
<td>0.58</td>
<td>0.12</td>
<td>0.01</td>
<td>0.23</td>
</tr>
</tbody>
</table>

2.2. Mechano-chemical leaching of sphalerite or EAF dust

Mechano-chemical leaching was performed in a stirring ball mill under the following conditions: Φ5 mm stainless steel ball or corundum ball as activation medium, the mass ratio of ball to raw materials of 30:1, NaOH concentration of 5 mol/L, temperature 90 °C, the volume was kept constant by adding water.
The lead compound was added as additive in the mechano-chemical leaching experiments of lean zinc ores containing sphalerite to increase the extraction efficiencies of Zn in sphalerite.

Fig. 1 XRD of the lean oxide zinc ore from Xinjiang

Fig. 2 XRD of the EAF dust

2.3. Chemical analysis

After leaching, the pulp was centrifuged and the clear liquid phase was diluted and subjected to analysis by ICP-AES. The leaching efficiencies of zinc were calculated according to the following equation:

\[
\text{Zinc extraction} = \left[ \frac{(C_1 \times V_1)}{(W_1 \times C_2)} \right] \times 100\%
\]

where \( W_1 \) (g) is the mass of samples, \( V_1 \) (L) is the volume of leaching solution, \( C_1 \) (g/L) is the zinc concentrations in the leaching solution, \( C_2 \) (%) is the percent of zinc content in the samples.

The solid phase was also analyzed by dissolution using standard methods and subsequent application of ICP-AES.

3. Results and Discussion

3.1. Lean zinc ores containing sphalerite

Comparative studies have been performed with mechano-chemical leaching and chemical leaching of non-activated samples (Fig. 3). For the non-activated samples, most of zinc carbonate in the lean zinc ores can be extracted while little of sphalerite can be extracted. The results confirm the favourable influence of mechano-chemical leaching on the recovery of zinc from sphalerite. 82.37% Zn extraction can be achieved by mechano-chemical leaching with conversion by lead compounds, compared with 60.11% Zn extraction for chemical leaching of non-activated samples with conversion by lead compounds, and 61.03% Zn extraction for mechano-chemical leaching without conversion by lead compounds for 120 min.

During mechanical activation the crystal structure of a mineral is usually disordered and generation of defects or other metastable forms can be registered. These effects are not stable and have different relaxation times \(^6\). If the mechanical activation and chemical leaching are integrated into a common step all the excitation states can be utilized. Thus mechano-chemical leaching contributes to operational benefits and economics of the leaching of lean zinc ores containing sphalerite. The solubility of ZnS and PbS is \(2 \times 10^{-23}\) and \(1 \times 10^{-28}\), respectively; PbS is much more insoluble than ZnS. This relative insolubility accounts for one reason why sphalerite can be dissolved preferably by mechano-chemical leaching with lead compound as additive in alkaline solution \(^4,9\).
3.2. EAF dust

The results of mechano-chemical leaching of EAF dust are showed in Fig. 4. Compared with the chemical leaching of non-activated sample, the leaching rate of mechano-chemical leaching had obvious increase. 45.32% Zn can be extracted by mechano-chemical leaching in stirring ball mill, compared with 25.02% Zn extracted by chemical leaching of non-activated samples for 240 min.
4. Conclusions

The alkaline process is considered as a simple, cost-effective and environmental-friendly technology for Zn recovery from zinc containing secondary resources. Mechanical activation has positive influence on the alkaline leaching of the sphalerite and zinc ferrite in lean zinc ores or EAF dusts. The sphalerite in lean zinc ores can be extracted by mechano-chemical leaching in NaOH solution with lead carbonate as additive, over 82% of Zn extraction can be achieved, compared with 60.11% Zn extraction for chemical leaching of non-activated samples. 45.32% Zn in EAF dusts can be extracted by mechano-chemical leaching, compared with 25.02% Zn extracted by chemical leaching of non-activated samples. A new cleaner hydrometallurgy route for recovering zinc from second resources has been proposed.

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