



Atmospheric oxygen-rich direct leaching behavior of zinc sulphide concentrate

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Abstract: The leaching behavior of main metallic sulphides in zinc concentrate under atmospheric oxygen-rich direct leaching conditions was studied through mineralogical analysis. The results show that the sulphides dissolve obviously except pyrite. Based on the relationship between elemental sulfur and the residual sulphides in the leaching residue, the dissolution of sphalerite, chalcopyrite, covellite and galena is assumed to follow the indirect oxidation reactions, where the acidic dissolution takes place firstly and then the released H₂S transfers from the mineral surface into bulk solution and is further oxidized into elemental sulfur. The interface chemical reaction is further supposed as the controlling step in the leaching of these sulphides. The direct electrochemical oxidation reactions are assumed to contribute to the dissolution of pyrrhotite, which is controlled by the diffusion through elemental sulfur layer.

Key words: zinc sulphide concentrate; atmospheric direct leaching; oxygen-rich leaching; leaching behavior; mineralogy

1 Introduction

The roasting–leaching–electrowinning (RLE) process is the primary route for zinc production and responsible for more than 85% of zinc in the world [1]. Fugitive SO₂ in the roasting causes air pollution, which is a great challenge to the RLE process [2]. In the 1980s, the innovative process of zinc pressure leach (ZPL) was industrialized, in which zinc sulphide concentrate is directly leached and the sulphidic sulfur is oxidized to elemental form rather than to SO₂, so that the pollution of SO₂ is completely avoided. The ZPL process offers an attractive alternative to roasting in the expansion plans of existing zinc plants, or in the design of new facilities. Although the ZPL process makes the zinc industries more competitive, it needs high-cost autoclave and thereby its application is limited.

In the 1990s, the atmospheric direct leaching (ADL) process of zinc sulphide concentrate was developed [3,4]. Actually, the ADL process is operated under oxygen-rich conditions, which is similar to low-temperature pressure leaching know-how [5–7]. The ADL process has been practiced at an industrial scale [8,9]. In 2008, Zhuzhou

Smelter Group, the leading Chinese zinc producer, integrated the ADL process with the existing production plant to increase zinc production capacity by 100000 t/a [10]. Compared with the ZPL process, the ADL process employs less harsh conditions and meanwhile proceeds much slower leaching kinetics. It requires 10–20 h to achieve zinc extraction more than 95% [3,9]. The ADL process is still in development to promote the leaching rate of zinc sulphide concentrate.

The acidic dissolution and the subsequent oxidation of H₂S are assumed as main reactions during the ADL process of sphalerite [11]. The slowing-down of the leaching rate of sphalerite with the increase of retention time is mostly regarded as the result of the encapsulation of elemental sulfur to the unreacted ore [12]. The rate-controlling step of leaching reaction is further suggested as the diffusion of dissolved Zn²⁺ from sphalerite to bulk solution or H₃O⁺ from bulk solution to the unreacted ore through a polysulfide layer on the mineral surface [13]. But JAN et al [14] suggested that the rate-controlling step appears to be the oxidation of H₂S which is not a homogeneous reaction in solution but a heterogeneous process occurring on the surface of sphalerite. Actually, most of the researches on the

leaching of sphalerite in sulfuric acid solution rely on the numerical analysis of kinetic data [15–20]. Besides the numerical analysis, the mineralogical analysis, such as chemical and structural description of mineral surface, is a very powerful assisting method [21]. BUCKLEY et al [22] applied the surface analysis methods in the oxidative leaching of sphalerite to support the conclusions that a surface layer of a metal-deficient sulphide forms with the dissolution of zinc in which sulfur partially presents in the elemental form and this altered surface layer protects sphalerite from further leaching. The mineralogical analysis has also already been used in further study of sulfur behavior in leaching [23–25].

We have ever combined the kinetic analysis with the mineralogical analysis in the study of low-temperature pressure leaching of sphalerite [26]. The assumption is proposed that the interface chemical reaction is the rate-controlling step for zinc extraction on the basis of calculation of apparent active energy, which is further proved by the observed microstructure of leaching residue. In this work, the mineralogical analysis on main sulphides, such as sphalerite, pyrite, pyrrhotite, chalcopyrite, covellite and galena in zinc concentrate under the ADL conditions is developed and the microstructure of the residual sulphides as well as elemental sulfur in the leaching residue is focused on the leaching behavior.

2 Experimental

The chemical composition of zinc sulphide concentrate is listed in Table 1. The X-ray diffraction (XRD) pattern is presented in Fig. 1. As shown in Fig. 1,

Table 1 Chemical composition of zinc sulphide concentrate (mass fraction, %)

Zn	Fe	Pb	S	Si	Cu	Others
46.83	7.62	2.41	28.08	1.96	0.32	12.78

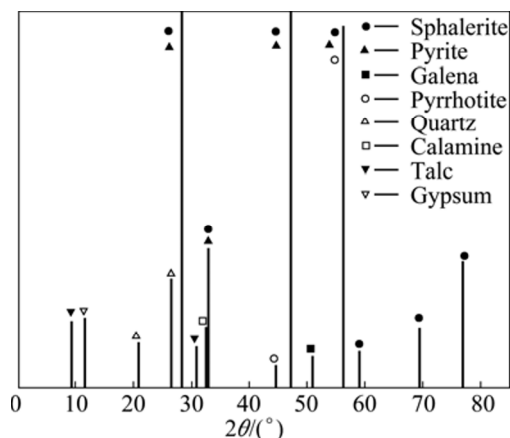


Fig. 1 XRD pattern of zinc sulphide concentrate

sphalerite is the most important sulphide in the concentrate. In addition to sphalerite, the concentrate contains other sulphides, such as pyrite, pyrrhotite and galena. A small quantity of chalcopyrite and covellite are further observed through optical microscope. The microstructures of the sulphides are given in Fig. 2. As shown in Fig. 2, pyrite and pyrrhotite mostly present in single and free form, while chalcopyrite and galena mostly adhere to sphalerite and form a large intergrowth. Moreover, the concentrate contains smithsonite, quartz, talc and gypsum. Quartz and talc are the original gangue minerals, while gypsum is introduced in the flotation process.

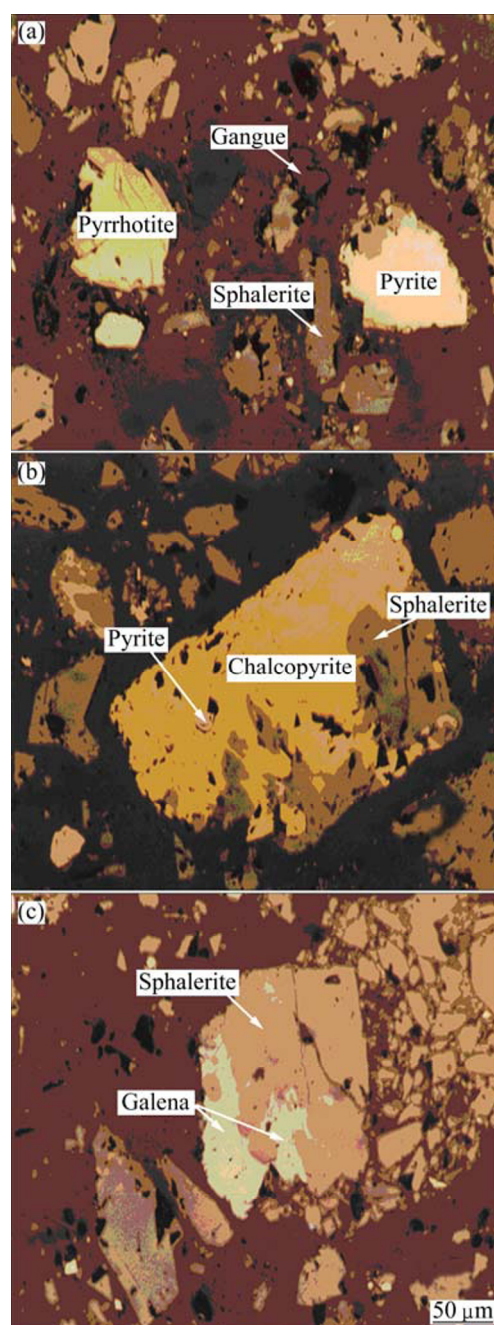


Fig. 2 Micrographs of pyrite and pyrrhotite (a), pyrite and chalcopyrite (b) and galena (c) in zinc sulphide concentrate

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