Journal of Cleaner Production 202 (2018) 1077–1084

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Synergistic effect of acidified water glass and locust bean gum in the flotation of a refractory copper sulfide ore

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ARTICLE INFO

Article history:
Received 16 February 2018
Received in revised form
19 August 2018
Accepted 20 August 2018
Available online 22 August 2018

Keywords:
Dispersion
Depression
Chalcopyrite
Talc
Serpentine

ABSTRACT

The efficient utilization of copper-nickel sulfide ores that contain multiple magnesium silicate gangue minerals by flotation is difficulty. To solve this problem, the flotation behavior of a refractory copper sulfide ore with multiple MgO gangue minerals was investigated, and the mechanism was discussed in this study. The results show that the influence mechanisms of serpentine and talc on chalcopyrite flotation are different. The serpentine has an opposite surface charge with chalcopyrite and will form slime coatings on chalcopyrite surface and depresses its flotation. The dispersant must be used to remove serpentine slime from the sulfide surface. Different from serpentine, the talc surface is hydrophobic and can float into the concentrate. Thus, high molecular depressant locust bean gum should be added to reduce the hydrophobicity of talc. When serpentine and talc coexist in the ore, the formation of serpentine slime coatings on talc surface not only reduces the flotation recovery of talc, but also interferes with talc depression by locust bean gum. Thus the serpentine and talc mixed minerals should be depressed using the dispersant acidified water glass in conjunction with the depressant locust bean gum. The bench-scale flotation results show that using acidified water glass in conjunction with locust bean gum is suitable in the flotation of a refractory copper sulfide ore that contains multiple MgO gangue minerals, and a copper concentrate with grade of 20.25% and recovery of 75.8% is achieved when the feed ore copper grade is 0.16%.

1. Introduction

Copper–nickel sulfide deposits are an important source of copper and nickel metals. Owing to their increasing demand, mining companies are today treating complex copper–nickel sulfide ores, which may be risky for their business operations (Yin et al., 2018). Such complex sulfides are considered as refractory ores, especially when they are hosted in mafic–ultramafic rocks (Wiese et al., 2007). Ultramafic ores are composed of more than 90% mafic rocks. Mafic is the term used to define igneous rocks that are rich in FeO and MgO (Hurlbut and Sharp, 1998). For sulfide deposits hosted in mafic–ultramafic rocks, the major gangue includes a variety of MgO minerals. These minerals can reduce selectivity in flotation, causing loss of copper and nickel minerals to the tails and, in some operations, reporting in significant amounts to the concentrate, thereby diluting the grade and increasing transport and smelting costs (Bremmell et al., 2005; Edwards et al., 1980).

Tailings that contain sulfide minerals, such as chalcopyrite and pentlandite, undergo rapid oxidation and produce acid drainage when exposed to humid atmospheres, which can cause severe environmental problems (Akcil and Koldas, 2006; Anju and Banerjee, 2010; Atkins and Pooley, 1982; Onuaguluchi and Eren, 2016). The environmental degradation associated with sulfide tailings disposal is a global problem and many studies have reported on the severe environmental impacts of tailings and acid mine drainage. Zhou et al. (2007) found that tailings and acid mine drainage induced toxic metal contamination of soil near the Dabaoshan Mine, Southern China. Ntengwe and Maseka (2006) found high concentrations of zinc and nickel in water and

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https://doi.org/10.1016/j.jclepro.2018.08.214
0959-6526/

sediment soils in streams located near the Chambishi Copper Mine in Zambia. Salonen et al. (2006) observed that contamination of the nearby Lake Orijarvi through acid mine drainage was still continuing fifty years after the closure of the Orijarvi Mine, Southwest Finland. Benvenuti et al. (1997) found high metal and acid concentrations in water obtained close to abandoned copper mines and mine wastes in Southern Tuscany, Italy. Andrade et al. (2006) found that discharge into the sea of tons of untreated tailings from the El Salvador mine caused the Chanaral coastline north of Santiago, Chile, to be significantly copper-contaminated.

High-grade copper–nickel sulfide concentrates are commonly treated via pyrometallurgical routes (Eric, 2004); however, copper–nickel concentrate containing high levels of MgO is not acceptable to some smelters because it can have a significant effect on transport requirements and downstream treatment. If the MgO content rises beyond a certain percentage (typically 6.8%), the melting point and viscosity of the slag increase (Dunn, 2016); as a result, higher operating temperatures are required, which increases the energy costs. Higher operating temperatures can also lead to higher refractory losses and shorter furnace crucible life.

In recent years, the rapid industrialization of China has expanded the market for copper and nickel metals. Owing to the continuous exploitation and consumption of higher-grade ores, low-grade and refractory ores become more and more important. Utilization of low-grade ores may lead to serious environmental and economic problems. The Chinese government is paying increasing attention to environmental problems and has implemented energy conservation and emissions reduction policies (Zeng et al., 2010; Zhang and Wen, 2008): cleaner production is seen as an effective way to reduce environmental impacts without impeding economic development (Guan et al., 2018).

The effective separation of MgO gangue from sulfide minerals is very important in the flotation of complex copper–nickel sulfides to reduce the content of sulfide minerals in the tailings and improve the concentrate grade. Of these MgO gangue minerals, serpentine and talc are most studied. The flotation behavior and surface properties of talc and serpentine are different. The surface of serpentine is hydrophilic and it cannot report to the concentrate through true flotation; however, in neutral or weak alkaline pH ranges where copper–nickel sulfide flotation is conducted, serpentine has an opposite surface charge to that of the sulfide minerals. Coating of serpentine slime on sulfide surfaces depresses sulfide flotation and reduces the concentrate recovery and flotation rate (Bremmell et al., 2005; Edwards et al., 1980; Feng et al., 2012a, b). This slime coating can be controlled using dispersants that preferentially adsorb onto the slimes, reversing and/or increasing the surface charge and preventing electrostatic attraction. Commonly used dispersants include sodium hexametaphosphate, sodium silicate, and sodium carbonate (Feng et al., 2012b; Lu et al., 2011; Zhang et al., 2017; Zhou and Feng, 2015). Talc is a secondary mineral formed by the alteration of magnesium silicates, such as olivine, and amphiboles. Because talc is naturally hydrophobic, it easily reports into the concentrates, thereby reducing the concentrate grade (Beattie et al., 2006a, b; Ma and Pawlik, 2007). To reduce the surface hydrophobicity of talc, high-molecular-mass depressants, such as carboxylmethyl cellulose (CMC), guar gum, and starch, have been used (Morris et al., 2002; Shortridge et al., 2000; Steenberg and Harris, 1984; Wang et al., 2005).

All of the above research has only considered the separation of a single type of MgO gangue from sulfide minerals. The coexistence of various MgO minerals reduces sulfide beneficiation efficiency. The flotation separation behavior of chalcopyrite and two types of MgO gangue (i.e., serpentine and talc) was therefore studied. The mechanism, which can provide a theoretical basis for the effective separation of sulfides and multiple MgO minerals, is also discussed.

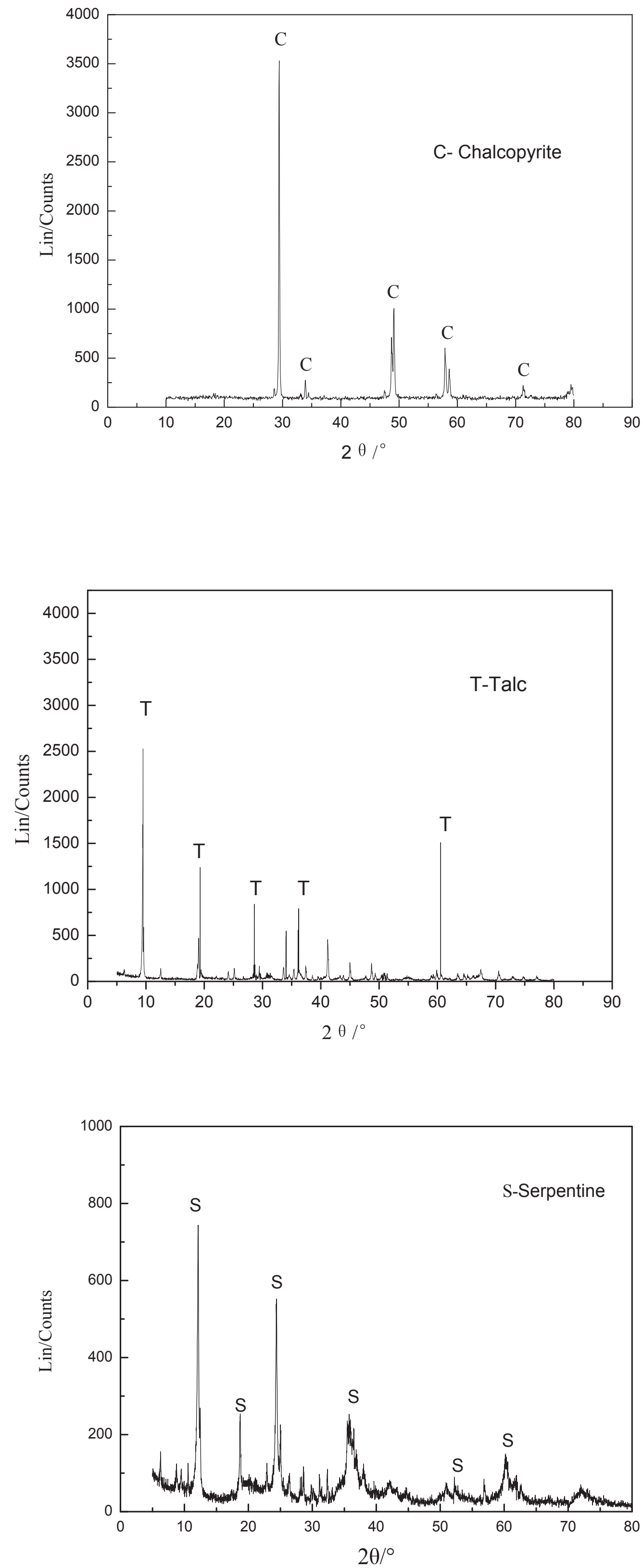

Fig. 1. XRD of chalcopyrite, talc and serpentine.