



Original Article

The collecting performance and interaction mechanism of sodium diisobutyl dithiophosphinate in sulfide minerals flotation



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ABSTRACT

The interaction mechanism of sodium diisobutyl dithiophosphinate (DTPiNa) with chalcocopyrite, pyrite, galena and sphalerite was investigated by single mineral flotation experiment, adsorption measurement and FTIR spectrum analysis. Single mineral flotation experiments showed that sodium diisobutyl dithiophosphinate exhibited a strong ability to collect chalcocopyrite and galena. For chalcocopyrite and pyrite, the recovery of chalcocopyrite can reach 96.2% when the dosage is 12 mg/L and pH value is 8. In the same situation, the recovery of pyrite is as low as 13.5%. For galena and sphalerite, the recovery of galena reached 91.7% when the dosage was 50 mg/L at pH 11, and the recovery of sphalerite was only 16.9%. DTPiNa adsorbed on chalcocopyrite and galena surfaces are more than that on pyrite and sphalerite surfaces. The adsorption capacity of DTPiNa on the minerals surface is proportional to its dosage. The FTIR spectrum analysis results showed that the adsorption of DTPiNa on sulfide minerals surface is chemical and S atoms in $-P=S$ and $-P-S$ may have taken part in the reaction. The natural ores experiments also confirmed the excellent performance of sodium diisobutyl dithiophosphinate.

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1. Introduction

Chalcocopyrite is the major and most abundant commercial source of copper [1]. It is often accompanied with pyrite, which is the most widespread naturally occurring metal sulfides. The floatability of pyrite is quite similar to chalcocopyrite [2,3]. Pyrite in copper concentrates will not only lower their quality but also increase the economic and environmental costs in the subsequent smelting process [4]. The collecting ability of traditional sulfides collectors is very strong but their selectivity

is poor; thus, usually the ideal copper–sulfur separation could not be realized by these collectors. The copper released from chalcocopyrite will activate pyrite and increase the difficulty for the separation of chalcocopyrite and pyrite as well [5,6]. There are five common copper–sulfur separation processes, which are known as high pH process, inorganic inhibitors process, organic inhibitors process, electrochemical controlling process and cyanide process [7]. High pH value process is the most widely used process [8,9]. Even though this process could get perfect flotation and separation result, a large amount of lime must be consumed and the recovery and grade of copper

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concentrate will be lowered. Meanwhile, this method often brings difficulties of activating highly depressed pyrite, environmental pollution and high depression of noble metal such as Au, Ag and Mo. What is more, the floatability of chalcopyrite will be decreased because of the formation of hydrogen bond [10]. Consequently, it has aroused wide concern that the research of reagents can realize copper-sulfur separation at acidic and neutral pH [11,12], and a series of novel reagents were prepared, some of which appeared good performance in laboratorial and industrial practice [13-17].

Some researchers found an effective method to separate pyrite from chalcopyrite. In their research, BKY-1 was used as depressant in a wide range of pH. The following researches showed that the difference in interaction energy contributes to the selective depression. So xanthate could be used as the collector to float chalcopyrite selectively [18]. Peng used a specially designed mill, which could control the pH throughout the grinding processing to investigate the influence of grinding conditions on the flotation of chalcopyrite and copper-sulfur separation. It turned out that iron oxidation species from grinding media played a key role in depressing the floatability of chalcopyrite. The floatability of pyrite was significantly improved after grinding with mild steel medium. 30 wt% chromium medium will increase chalcopyrite floatability as well as decrease the pyrite floatability to strengthen the copper-sulfur separation effects [19]. Martin demonstrated that nitrogen conditioning could enhance the floatability of pyrite because of galvanic interaction. But this effect could be reversed by raising the pulp pH or introducing air. This phenomenon could be used to separate pyrite from some other sulfide ores with air [20]. The depressing ability of small polymers with various substituted functional groups such as carboxyl, sulfonate, hydroxyl and thiourea was researched. The results showed that hydroxy had the best depressing ability for pyrite depression and carboxyl had the best mineral selectivity. Their depressing ability in pyrite was strong because of the reaction with ferric ions/hydroxides, but they had no or little depression ability for sphalerite and copper activated sphalerite [21]. Mitchell proposed that heterocoagulation with different minerals was an effective way to selectively separate minerals involved. They discovered that pyrite had a positive zeta potential (ζ) up to its isoelectric point (IEP) at pH about 2.2, while chalcopyrite has a positive ζ up to its IEP at pH about 5.5 and the heterocoagulation of chalcopyrite with pyrite will happen between pH 2.2 and pH 5.5; thus it, is impossible to separate these two minerals. Flotation tests showed that at pH=10 thionocarbamate had good selective flotation of chalcopyrite from pyrite [22]. It was revealed that pulp oxidation potential (Eh) and zinc sulfate played an important role in copper-activated pyrite recovery. At pH 9.0 the maximal recovery of chalcopyrite and pyrite realized when the Eh was 275 and 135 mV, respectively. The maximal separation effect achieved at 275 mV and the addition of zinc sulfate could increase the mineral separation by selectively depressing pyrite flotation because large amount of ferric hydroxide groups formed on the pyrite surface, while at a lower Eh, such as 38 mV, the addition of zinc sulfate would improve flotation adversely because of the large increase of Eh. So zinc sulfate is not an effective mineral depressant at lower Eh values [23]. Chen investigated the combination of

sodium humate and lime in a low pH medium. By adding sodium humate to the pulp and adjusting the pH to 10-10.5, the recovery of Cu and combined Au, Ag and Mo in the copper concentrate was enhanced due to the reduced pH of the pulp. The following research showed that sodium humate was chemically adsorbed on the surface of pyrite and there was a strong hydrophilic interaction between sodium humate and the surface of pyrite [24].

For galena and sphalerite separation, there are two commonest processes, which are known as high pH process and inorganic inhibitors process. High pH process has significant disadvantages, such as decreasing the recovery of associated rare and precious metals and causing pipe blockage. Zinc sulfate is the commonly used inhibitor; its exorbitant price is the biggest drawback. Thus, the development of cheap inhibitors has aroused concerns. Rath investigated the influence of guar gum on the separation of galena and sphalerite by flotation. It was found out that at the pH 7.5 and 11.5 sphalerite and galena could get their maximum adsorption capacity, respectively. After the addition of guar gum, the recovery of galena was less than 20%, while the recovery of sphalerite did not have obvious change. Thus, it was possible to use guar gum as a depressant for galena [25].

DTPINa is the main efficient ingredient of Aerophine 3418A, and it is mainly recommended to float copper and lead sulfide ores compared with rare and noble metal [26]. Some researchers had investigated the interaction mechanism of DTPINa for its excellent flotation performance. Piantadosi used TOF-SIMS method to investigate the amount of DTPINa adsorbed onto the surface of galena and pyrite. The result showed that the affinity of DTPINa on galena was much higher than that onto pyrite and the presence of hydrophobic DTPINa and PbDTPINa were the key factors for flotation [27]. The inaction mechanism of DTPINa was investigated with activated and inactivated galena and pyrite. The research demonstrated that DTPINa was adsorbed onto galena and pyrite surface by a chemical absorption way and DTPINa displayed a strong affinity toward galena. The floatability of pyrite will be enhanced if it was activated by Pb-ions [28-30]. Güler investigated the influence of pH on the flotation for chalcopyrite through electrochemical control method. According to his research, slight oxidation was essential for a hydrophobic chalcopyrite surface; the increase of pH would result in excess oxidation and then decrease the floatability of chalcopyrite [31]. Liu used density functional theory (DFT) calculations to investigate the structure-reactivity relationship of diisobutyl dithiophosphate (DIBDTPA), diisobutyl dithiophosphinate (DIBDTPI), diisobutyl monothiophosphate (DIBMTPA) and diisobutyl monothiophosphinate (DIBMTPI) which are all used as sulfide minerals collectors. It showed that O atom(s) in the regents could significantly affect S atom(s), which made a critical difference in the flotation performance. Among the four collectors, DIBDTPI had the strongest reactive power to mineral surface and the ionized thiophosphorus collectors exhibited the strongest affinity to mineral surfaces in aqueous phase [32].

In this study, the collecting abilities and interaction mechanism of DTPINa with chalcopyrite, pyrite, galena and sphalerite were investigated through flotation experiments, adsorption capacity measurements and FTIR spectrum

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