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Action time effect of lime on its depressive ability for pyrite

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Abstract: Two sample groups of bulk concentrates consisting mainly of pyrite and chalcopyrite from Daye and Chenghchao Mines in Hubei Province of China were used to investigate the effect of the action time of lime on its depressive ability for pyrite. The experimental results conducted with different samples and collectors showed that the action time between lime and pyrite markedly influences the depressive ability of lime. The depressive ability of lime increased with the action time increasing. It was also proved that the depressive results obtained at a large lime dosage after a shorter action time are similar to those obtained at a small lime dosage after a longer action time. The increase of depressive ability of lime after a longer action time is because that there are different mechanisms in different action time. The composition on the surface of pyrite acted for different time with lime was studied by using ESCA (Electron Spectroscopic Chemical Analysis). The results showed that iron hydroxide and calcium sulphate formed on the pyrite surface at the presence of lime in the pulp but the amounts of iron hydroxide and calcium sulphate were different at different action time. At the beginning action time the compound formed on the pyrite surface was mainly calcium sulphate and almost no iron hydroxide formed; but with the action time increasing, iron hydroxide formed. The longer the action time, the more iron hydroxide and the less calcium sulphate formed. It was considered that the stronger depressive ability of lime after a longer action time is because more iron hydroxide forms on the pyrite surface.

Key words: lime; pyrite; depressive ability; action time

1 Introduction

Lime is the most common reagent used for depressing pyrite in separating of chalcopyrite from pyrite. The mechanism of depression was studied intensively and many models were established [1-4]. But the models and mechanisms established were based on the constant action time, not considering the action time between lime and pyrite. However, industry practice has proved that the action time of lime affects the depressive ability of lime. At Daye Iron Mine in the south of China, copper and sulphur concentrates are produced. The flowsheet is that a bulk concentrate consisting mainly of pyrite and chalcopyrite is produced by bulk flotation by using butyl xanthate as a collector and pine oil as a frother. The bulk concentrate is directly pumped to the separation flowsheet where the bulk concentrate is separated to produce two concentrates by using Z-200 as a collector for chalcopyrite and lime as a depressant for pyrite. Copper concentrate is the float product consisting mainly of chalcopyrite and sulphur concentrate is the underflow consisting mainly of pyrite. In Daye Iron Mine, because of an accident, the separation flowsheet cannot work properly, so the flowsheet was changed. The bulk concentrate conditioned by the addition of lime was pumped to a thicker for storage temporally. After about 12 h, the bulk concentrate was pumped to the separation flowsheet again, and it was found that the separation efficiency increased. The grade and recovery of copper concentrate increased and the lime dosage needed was decreased. It may be a result of the longer action time of lime. The objectives of this study are to investigate if the action time of lime affects its depressive ability and what the mechanism is.

2 Samples and experimental method

In order to investigate the effect of the action time of lime, two bulk concentrates consisting mainly of chalcopyrite and pyrite were used. One was from Daye Iron Mine and the other from Chengchao Iron Mine, which located in the same region and has similar ore properties. The samples used were taken from the cleaner cell lip of bulk flotation in the concentrators of the mines and were filtrated in site and stored air-sealed in a freezer to minimize oxidation [5,6]. The bulk concentrate from Daye Iron Mine assays 8.6% copper and 38.04% sulphur, and the one from Chengchao assays 0.65% copper and 37.84% sulphur (mass fraction). The most of copper and sulphur minerals in the samples were liberated.

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Two different flowsheets were used in the tests because the qualities of the samples were different. The test flowsheet for Daye Iron Mine sample was one rougher and one cleaner, while the other for Chengchao Iron Mine sample was one rougher and two cleaners. A 0.5 L flotation cell was used. The action time of lime refers to the time interval from adding lime into the flotation cell under agitation to adding the collector. Only one collector Z-200 was used for Daye Iron Mine sample and two collectors Z-200 and BJL (a trade name for a sulphide minerals collector) were used for Chengchao Iron Mine sample.

3 Results and discussion

3.1 Experimental results of Daye Iron Mine sample

In order to investigate the effect of the action time of lime the experiments at different lime and collector Z-200 dosages were carried out after a fixed action time of 5 min. The results showed that the best dosage of Z-200 is 120 g/t. The lime dosage strongly affects the grade of copper concentrate and the grade increases with the lime dosage increasing. The grade is less than 18% unless the lime dosage is larger than 30 kg/t. The pH of the pulp is more than 12 when the lime dosage is larger than 10 kg/t but the pyrite cannot be effectively depressed, so the lime dosage is used instead of pH to study the effect of the action time of lime. The experiments were carried out at lime dosages of 10 kg/t and 20 kg/t respectively to understand the effect of the action time of lime because the pyrite cannot be depressed at these dosages after an action time of 5 min.

Figures 1 and **2** show that the grade of copper concentrate increases but the recovery decreases with increasing the action time of lime independent of the lime dosage. The grade of copper concentrate increases very fast. When the lime dosage is 10 kg/t and the action time is 5 min, the grade is only 10.78% copper, but the grade increases to 20.82% when the action time is 180 min at the same lime dosage. The grade increases to 23.20% (figure 1) when the lime dosage is 20 kg/t after the same action time of 180 min, while the recovery of copper concentrate decreases slightly at two dosages (figure 2). All results obtained prove that the action time of lime affects the depressive ability of lime for pyrite. The grade and recovery of copper concentrate obtained at a smaller lime dosage after a longer action time are similar to those obtained at a larger lime dosage after a shorter action time. The better results can be obtained after a longer action time at a smaller lime dosage because a too high lime dosage makes the froth sticky and more gangue is entrained in the concentrate. The pH of the pulp should change with the action time, but the pH cannot be measured by using a pH meter because the lime dosage is too larger and the pH is more than 14 even after an action time of 180 min.

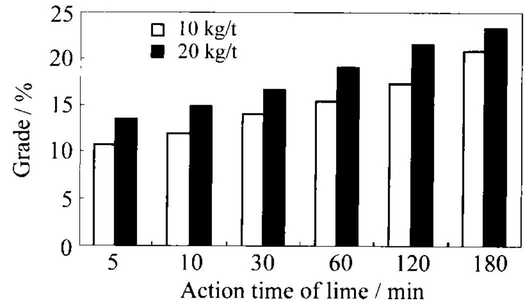

Figure 1 Effects of the action time of lime on the grade of copper concentrate at different dosages.

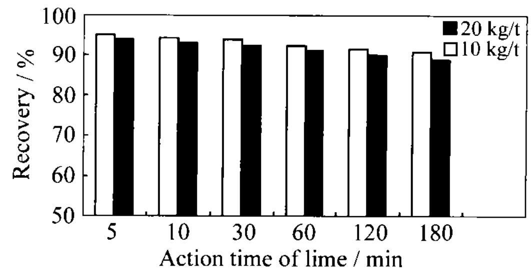

Figure 2 Effect of the action time of lime on the recovery rate of copper concentrate at different dosages.

3.2 Experimental results of Chengchao Iron Mine sample

Two collectors Z-200 and BJL were used to investigate the effect of the action time of lime on its depressive ability for pyrite with Chengchao Iron Mine sample. The optimum dosages of the two collectors were both 30 g/t. The lime dosage used was 10 kg/t and the results were shown in **figures 3** and **4**.

From figures 3 and 4, it can be seen that the action time of lime affects its depressive ability for pyrite no mater what collector is used. Also, the grade of copper concentrate increases dramatically with the action time of lime increasing. When the action time is 5 min with BJL as collector, the grade of copper concentrate only is 11.61%. But the grade increases to 21.45% when the action time is extended to 180 min. This means that more pyrite is depressed after a longer action time.

The above experimental results prove that it is a common phenomenon that the action time of lime effects its depressive ability and the longer the action time is, the stronger the depressing ability of lime is. Other factors which affect the processing history of depressing pyrite seem to not have obvious effects on such an phenomenon. The similar depressive ability of lime can be realized at a smaller lime dosage after a longer action time or at a larger lime dosage after a shorter action time.

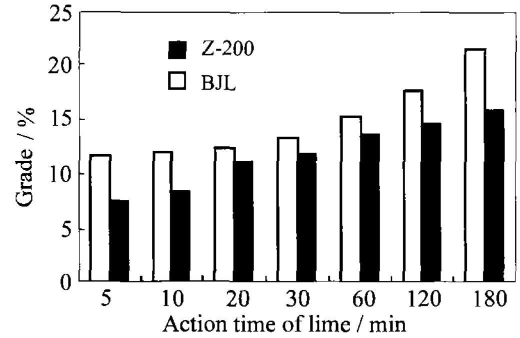

Figure 3 Effects of the action time of lime on the grade of copper concentrate with different collectors.

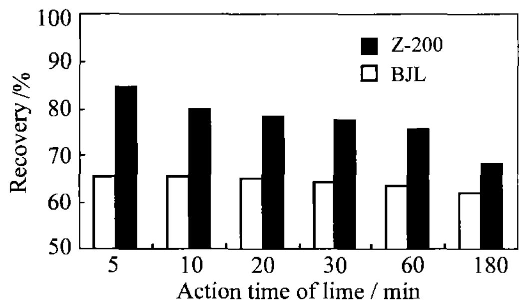

Figure 4 Effects of the action time of lime on the recovery rate of copper concentrate with different collectors.

4 Mechanisms

To explain why the action time of lime affects its depressive ability, the mechanisms were studied by Electron Spectroscopic Chemical Analysis (ESCA). The pyrite sample used was from the Geological Museum of China and the purity is more than 92%. The pyrite was crushed and ground to –50 μm and scoured with diluted HCl solution to clean the surface. The samples for ESCA were prepared with the following procedure: The pyrite samples were put into a beaker in which the same content lime milk as that used for flotation was present. Then the slurries were agitated for different time. The resulted slurries were filtered and the samples were dried at about 40°C. Thus the pyrite samples acted with lime for different time were obtained and examined by ESCA for the composition on the surface. The results are shown in **table 1** and **figure 5**.

Table 1 shows the electronic energy differences of Fe, S, and Ca obtained from the pyrite samples acted with lime for different time. From the data it is found that the electronic energy of Fe increases with the increase of action time, but the difference is very small when the action time is less than 20 min. When the action time is more than 20 min, the difference increases continuously along with the increase of action time. The difference increases to 0.75 eV at an action time of 180 min. This meant that the chemical surrounding of Fe on the surface of pyrite changes with increasing the action time of lime. The data in figure 5 show that the content of Fe on the pyrite also increases from 40.44% before action with lime to 60.65% after an action time of 120 min. This is probably due to the formation of $Fe(OH)_3$ or $Fe(OH)_2$ on the surface of pyrite and the amount of them increasing with the increase of the action time.

Table 1 Electronic energy of elements on the surface of pyrite acted with lime for different time

Action time /min		Electronic energy / eV		
		Fe 2p	S 2p	Ca 2p
0	Standard (I)	713.05	168.95	—
5	Measured value	713.18	169.00	354.50
	Difference with (I)	0.13	0.05	0.0*
20	Measured value	713.26	168.65	354.45
	Difference with (I)	0.21	–0.30	–0.05*
40	Measured value	713.65	169.00	354.05
	Difference with (I)	0.55	0.05	–0.15*
120	Measured value	713.85	169.40	354.55
	Difference with (I)	0.75	0.40	–0.10*

Note: Because there is no Ca on the surface of pyrite before being acted with lime, the values marked with * were obtained by comparing the measured value with the values acted for 5 min.

The electronic energy changes of S on the surface of pyrite have a complex relationship with the action time (table 1). This may be because there are different valences of S on the surface of pyrites acted with lime for different time. The data in figure 5 showed that the content of S on the surface of pyrite decreases with the increase of the action time. Before action with lime, the content of S is 59.56%, while it decreases to 36.11% after 120 min action with lime. This is why that the pyrite is depressed by lime. The decrease of S on the surface of pyrite is because the surface is covered by a film of $Fe(OH)_3$ or $Fe(OH)_2$ which makes the pyrite surface hydrophilic.

The data in table 1 also show that the electronic energy of Ca on the surface of pyrite does not change obviously with increasing the action time but the content of Ca changes (figure 5). At the action time of 5 min the content is 7.32% and then it decreases with the increase of the action time. The content of Ca decreases to 3.33% when the action time is 120 min.

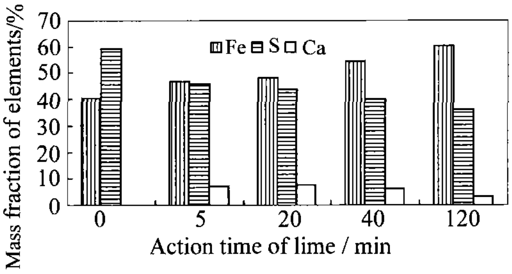

Figure 5 Effect of the action time of lime on the contents of elements on the surface of pyrite.

The mechanisms of lime depressing pyrite were investigated extensively [1-3]. Among them there are two different views. One is that the depression of lime for pyrite is due to the formation of $Fe(OH)_3$ or $Fe(OH)_2$ on the surface which makes pyrite hydrophilic. The other believed the reason of depressive effect of lime is that the hydrophilic $CaSO_4$, $Ca(OH)_2$ or $CaCO_3$ forms on the surface of pyrite when it acts with lime.

All of these previous researchers did not consider the effect of action time of lime when they studied the mechanism. But in this study it was proved that the depressive ability of lime is associated with its action time and the mechanisms of depression at different action time may be different, too. When the action time is shorter, the pyrite is depressed by the adsorption of $CaSO_4$, $Ca(OH)_2$ or $CaCO_3$ which forms when lime is added on the surface of pyrite. This can be supported by the data in table 1 and figure 5. That the chemical surrounding of Fe does not change meant that no $Fe(OH)_3$ or $Fe(OH)_2$ forms on the surface of pyrite when the action time is less than 20 min (table 1). But at this time, the content of Ca on the surface of pyrite is high. So it is suggested that the depressive effect is due to the physical adsorption of $CaSO_4$, $Ca(OH)_2$ or $CaCO_3$ on the surface of pyrite. With the action time increasing, the depression mechanism also changes, the $CaSO_4$, $Ca(OH)_2$ or $CaCO_3$ adsorbed are desorbed by agitation, but $Fe(OH)_3$ or $Fe(OH)_2$ forms on the surface of pyrite because the chemical surrounding of Fe changes (table 1) and the content of Ca decreases (figure 5) at a longer action time.

5 Conclusions

(1) The experiments carried out with two different samples from Daye Iron Mine and Chengchao Iron Mine proved that the depressive ability of lime for pyrite is related to the action time of lime. The longer the action is, the stronger the depressive ability of lime is. The depressive ability, obtained at a larger lime dosage after a shorter action time, is similar to that obtained at a smaller lime dosage after a longer action time.

(2) The depression mechanisms are different at different action time of lime. When the action time is shorter the depression mechanism is due to the adsorption of $CaSO_4$, $Ca(OH)_2$ or $CaCO_3$ on the surface of pyrite; however, the depressive effect is mainly due to the formation of $Fe(OH)_3$ or $Fe(OH)_2$ on the surface which makes pyrite hydrophilic when the action time is longer.

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