

# GALVANIC INTERACTION OF CONTACTING SULFIDE PARTICLE AND ITS EFFECT ON FLOTATION<sup>①</sup>

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**ABSTRACTS** Electrochemical aspects of the interaction between galena and pyrite were shown by the corrosive wear and changes in floatability. Rest potential, mixed potential, galvanic current and mixed polarization measurements were used to study the galvanic interaction of the galena and the pyrite electrode. The Evans diagrams of galena-pyrite electrode couples in the absence or the presence of butyl xanthate were given. In any galvanic combination involving these two minerals, the preferential anodic oxidation would occur on the surface of galena, and anodic corrosion rate for galena would accelerate 8~12 times. Galvanic contact between the galena and the pyrite was found to affect the floatability of them. The results of flotation test showed that the floatability of galena contacting with pyrite is improved, and the floatability of pyrite is weakened. Possible electrochemical mechanism involved are outlined.

**Key Words** galena pyrite galvanic interaction

## 1 INTRODUCTION

Sulfide ores are generally concentrated by flotation process. The interaction of two sulfide minerals can affect the surface properties of the minerals thus influences their floatability. It has been reported that depending on the activity of minerals various sulfide minerals respond differently to the flotation<sup>[1, 2]</sup>.

The effect of electrochemical interactions between the grinding media and the mineral on the flotation response of some sulfide minerals have recently been studied for pyrite, pyrrhotite and galena<sup>[3, 4]</sup>. Some sulfide minerals generally serve as nobler electrode relative to the others, thus when two dissimilar sulfide minerals contact each other, the active one undergoes anodic oxidation whereas oxygen reduction could be the cathodic reaction at the surface of the nobler sulfide mineral<sup>[5, 6]</sup>.

Pyrite is nobler than galena and its electrochemical properties as well as its flotation behaviors are fairly well known. In this paper, gal-

vanic interaction of galena-to-pyrite and its effect on flotation response of the two minerals are shown.

## 2 EXPERIMENT METHODS

The galena and pyrite samples used in this studies were supplied by Fankou Lead-zinc Mine of Guangdong province. The purity of the galena is 94.8%, and the pyrite 95.6%, the main impurity is quartz. Sections cut out from the highly mineralized galena and pyrite were fashioned into the form of electrodes for electrochemical measurement. The cut sections of sulfide minerals were mounted on the tip of a perspex tubule of  $\phi 7$  mm using epoxy resin and the exposed outer surface was well polished. Electrical connection was achieved through a copper wires soldered on to the surface of galena and pyrite electrode. The exposed surface area of the electrode was about 1 cm<sup>2</sup>. All potentials were measured with respect to a standard hydrogen electrode (SHE). A platinum foil electrode was used as an auxiliary

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electrode in polarization studies.

An electronics potentiostat Model 273A was used in all the polarization studies. An EG&G corrosion measurement system (Princeton Applied Research Model 352) was used for measuring combination potential and galvanic current.

Initial experiments were confined to the measurement of rest potentials for the galena and pyrite electrode as a function of pH under different aeration conditions. Besides measuring the individual rest potential, the combination potential and the galvanic current between galena and pyrite were also monitored in the absence or presence of xanthate. Steady-state polarization studies were carried out using the galena and the pyrite as electrode in a 0.5 mol/L KCl solution adjusted to pH = 6.0 in the absence or presence of xanthate, then Evans diagrams were plotted and the Tafel slopes were estimated. By obtaining the values of  $J_{gc}$  (corrosion current),  $\varphi_{gc}$  (combination potential) and the Tafel slopes, the corrosion rate was calculated<sup>[7, 8]</sup>.

To investigate the effect of the galvanic interaction between these two sulfide minerals on their flotation, the following experimental procedure was used. The 37~74  $\mu\text{m}$  fraction of one mineral was mixed with the 200~150  $\mu\text{m}$  fraction of other one in a 40 mL pyrex beaker in dissimilar solution. The air was bubbled at a flow rate of 200 mL/min for 10 min. In this manner the two minerals were in intimate contact. The 37~74  $\mu\text{m}$  fraction separated on a 0.1 mm stainless-steel screen was then floated for 3 min using MS flotation machine with a 50 mL cell. In each test 2 g of 37~74  $\mu\text{m}$  fraction was used.

### 3 PRINCIPLES

For an electrode couple in an electrolyte solution, the suppositions are given as follows:

- (1) Only an anodic reaction takes place on the surface of each electrode;
- (2) The cathodic reaction happened on each electrode is just the reduction of oxygen;
- (3) The reduction of metal ions in solution is regardless;
- (4) The reaction that water is oxidated to molecular oxygen would be regardless.

The anodic reaction and the cathodic reaction happened on the surface of an individual mineral are in simultaneous existence. The anodic current ( $J'_a$ ) and the cathodic current ( $J'_c$ ) are equal and opposite, namely  $J'_a = -J'_c$ .

While a sulfide mineral electrode is in contact with a nobler sulfide mineral electrode in the electrolyte solution, an electrode couple is formed. Both the active one undergoes anodic oxidation and the cathodic reaction (the oxygen reduction) happened on the surface of the nobler mineral are improved. So the anodic current ( $J_{1a}$ ) of the active one would increase, and the anodic current ( $J_{2a}$ ) would reduce. The galvanic current ( $J_{gc}$ ) is given by the following equations:

$$J_{gc} = J_{1a} + J_{1c} \quad (1)$$

$$J_{gc} = J_{2a} + J_{2c} \quad (2)$$

The effect of galvanic interaction upon the anodic and the cathodic reaction can be expressed by the  $r_1$  and  $r_2$  value,  $r_1$  can be defined as the ratio of  $J_{gc}$  and  $J'_{1a}$ ,  $r_2$  as the ratio of  $J_{2a}$  and  $J'_{2a}$ .

Based on the theory of corrosion,  $r_1, r_2$  can be calculated with the following equations:

$$r_1 = 10^{[(\varphi_{gc} - \varphi_{1corr})/b_{1a}]} \quad (3)$$

$$r_2 = 10^{[(\varphi_{2corr} - \varphi_{gc})/b_{2a}]} \quad (4)$$

where  $\varphi_{1corr}$  is the rest potential of the active mineral,  $\varphi_{2corr}$  the rest potential of the noble mineral,  $\varphi_{gc}$  the mixed potential of the electrode couple,  $b_{1a}$  the Tafel slope of the anodic reaction of the active mineral,  $b_{2a}$  the Tafel slope of the anodic reaction of the noble mineral.

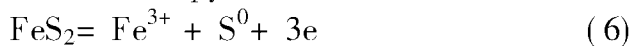
### 4 RESULT AND DISCUSSION

The steady-state rest potential values measured with galena and pyrite electrode were plotted on  $\varphi$ -pH diagrams for the  $\text{PbS-H}_2\text{O}$ ,  $\text{FeS}_2\text{-H}_2\text{O}$ ,  $\text{PbS-H}_2\text{O-C}_4\text{H}_9\text{OSSK}$  and  $\text{FeS}_2\text{-H}_2\text{O-C}_4\text{H}_9\text{OSSK}$  systems (Figs. 1, 2). Depending on the rest potential values the pyrite was found to be nobler than the galena under all conditions. Therefore, the anodic reaction taken place on the surface of galena is improved, and the anodic process of pyrite electrode may be weakened while they are in contact.

While galena and pyrite are immersed individually in 0.5 mol/L KCl solution, anodic reaction on the surface of galena is



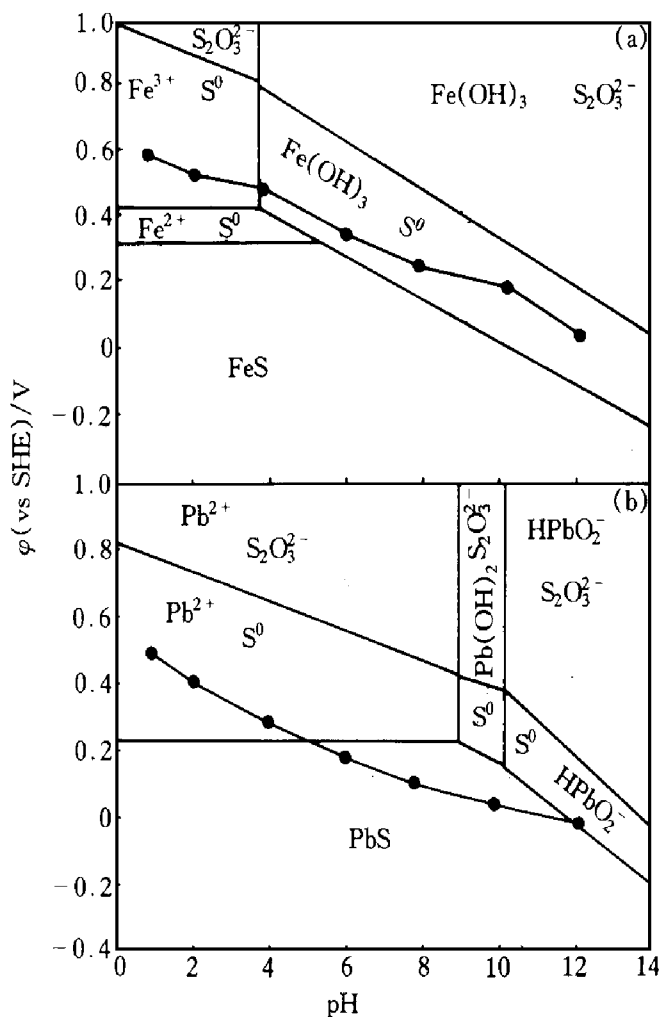
on the surface of pyrite is



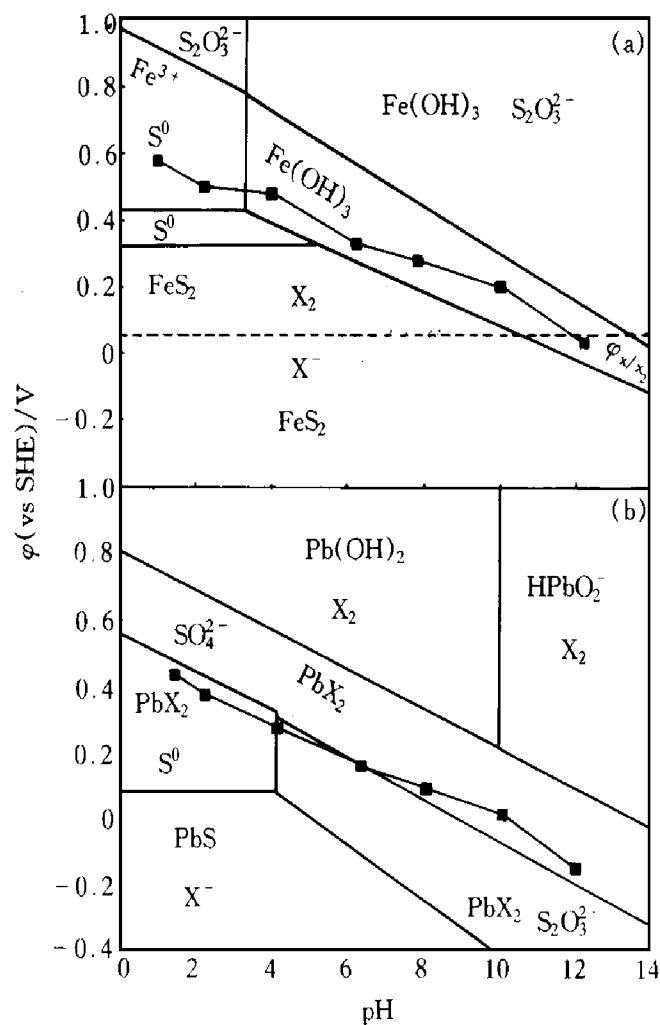
and cathodic reduction of oxygen takes place on galena and pyrite surface:



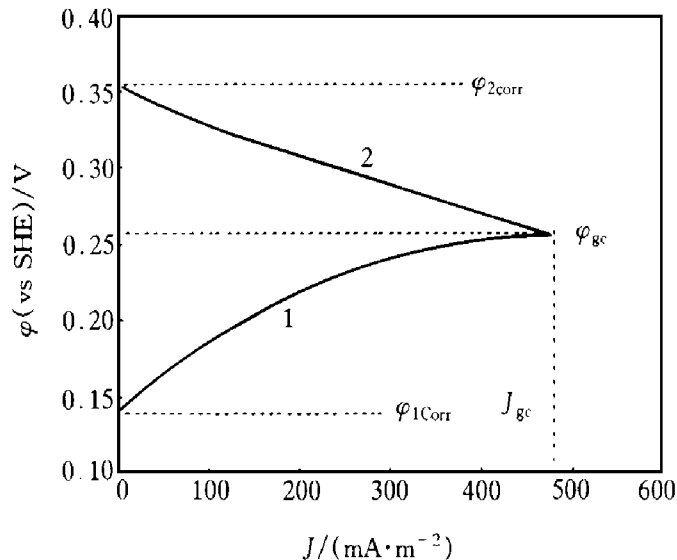
An Evans diagram, i. e. a plot of anodic and cathodic half cell potentials versus cell current, or polarization curves, results from each experiment. The Evans diagram of pyrite—galena electrode couple in absence of butylxanthate electrolyte solution is shown in Fig. 3. From the Evans diagram,  $\varphi_{\text{gc}} = 0.263 \text{ V}$ ,  $J_{\text{gc}} = 480 \text{ mA/m}^2$ ,  $\varphi_{1\text{corr}} = 0.140 \text{ V}$  and  $\varphi_{2\text{corr}} = 0.360 \text{ V}$  were obtained. The Tafel slopes of the anodic process



**Fig. 1**  $\varphi$ —pH diagram with the experimental points measured with a mineral electrode  
(a) — $\text{FeS}_2$ — $\text{H}_2\text{O}$ — $\text{O}_2$ ; (b) — $\text{PbS}$ — $\text{H}_2\text{O}$ — $\text{O}_2$



**Fig. 2**  $\varphi$ —pH diagram with the experimental points measured with mineral electrode  
(a) — $\text{FeS}_2$ — $\text{H}_2\text{O}$ —KBX; (b) — $\text{PbS}$ — $\text{H}_2\text{O}$ —KBX



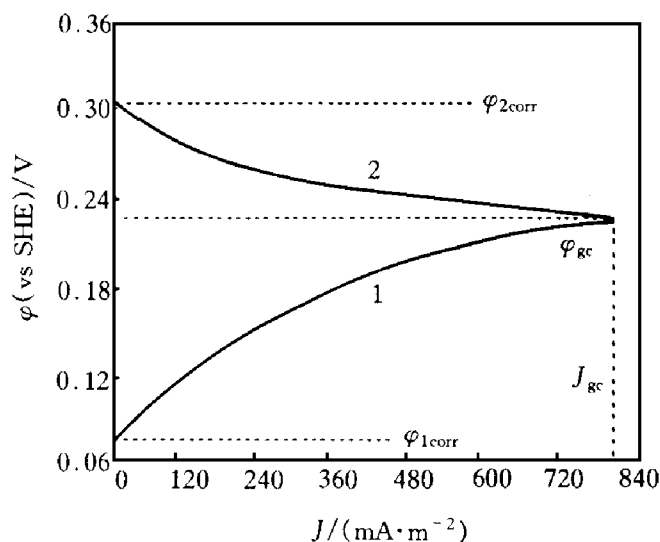
**Fig. 3** Mixed polarization diagram involving pyrite electrode in contact with galena  
(25 °C, 0.5 mol/L KCl at pH 6.0)  
1—galena; 2—pyrite

es,  $b_{1a}$ ,  $b_{2a}$  can be estimated as 0.136, 0.105, respectively.

According to Eqns. (3) and (4),  $r_1$ ,  $r_2$  can be determined as  $r_1 = 8.02$ ,  $r_2 = 0.12$ .

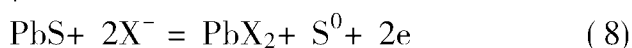
The effect of galvanic interaction upon the anodic process of each electrode can be estimated quantitatively by  $r_1$ ,  $r_1$  value. The anodic corrosion (Eqn. (5)) rate for galena would be accelerated about 8 times, and the anodic corrosion (Eqn. (6)) rate for pyrite would be weakened about 88%.

The Evans diagrams of galena—pyrite electrode couple in the presence of butyl xanthate solution was shown in Fig. 4, from which  $\varphi_{gc} = 0.234$  V,  $J_{gc} = 800 \text{ mA/m}^2$ ,  $\varphi_{1corr} = 0.077$  V and  $\varphi_{2corr} = 0.310$  were obtained. The Tafel slopes can be estimated as  $b_{1a} = 0.144$ ,  $b_{2a} = 0.172$ . So as with Eqns. (3) and (4),  $r_1$ ,  $r_2$  can be calculated as 12.31, 0.36 respectively.



**Fig. 4** Mixed polarization diagram involving pyrite electrode in contact with galena (25 °C,  $10^{-3}$  mol/L KBX, 0.5 mol/L KCl at pH 6.0)  
1—galena; 2—pyrite

In a galena—pyrite galvanic combination in the presence of KBX solution (pH 6.0, 0.5 mol/L KCl), the anodic oxidation of galena would take place as follows:

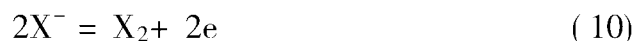


Its rate would be accelerated about 12 times. The  $\text{PbX}_2$  would be adsorbed at the galena surface and lead the surface to be hydrophobicity, thus the floatability of galena is promoted.

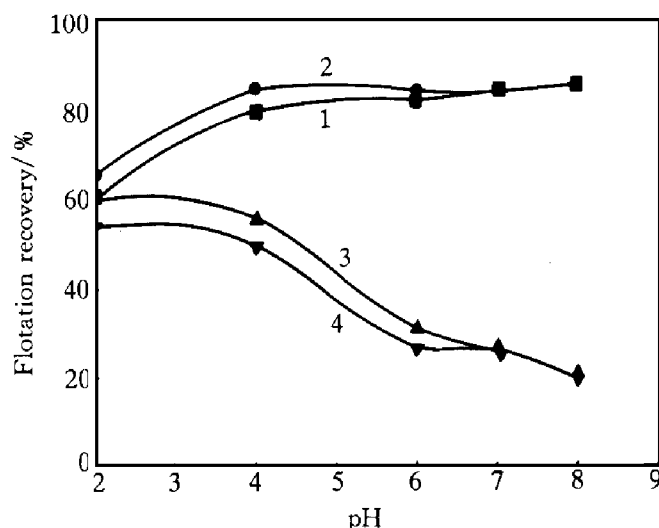
The presence of oxygen would accelerate the corrosion reaction by promoting the cathodic reaction (Eqn. (9)) at the surface of the nobler pyrite.



At the same time, the anodic reaction (Eqn. (10)) at the surface of pyrite would be weakened about 12%.



The results of collectorless flotation tests are illustrated in Fig. 5. It can be observed that the collectorless floatability of galena contacted with pyrite was improved appreciably at the pH value range from 2.0 to 7.0, the flotation response of pyrite decreased. In the presence of butyl xanthate ( $10^{-3}$  mol/L) during contact, the flotation response of galena increased at the pH value from 2.0 to 8.0, and the flotation response of pyrite decreased, the flotation results are shown in Fig. 6. Hydroxyl ion generated by the reduction reaction of oxygen at cathodic sites of pyrite would be adsorbed on the pyrite surface and results in the change of pyrite surface from hydrophobicity to hydrophilicity, so its floatability would be weakened.

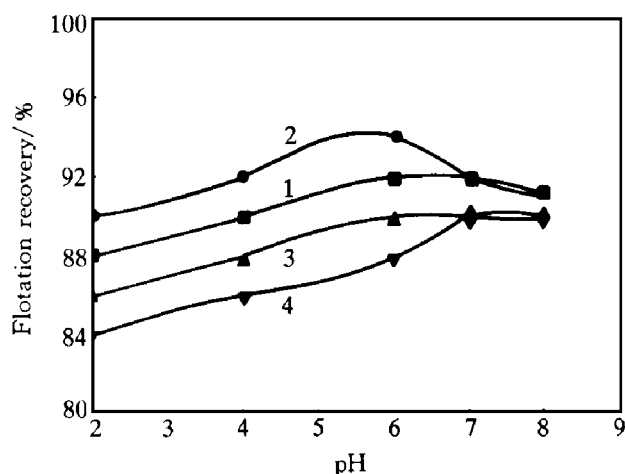


**Fig. 5** Collectorless flotation behavior of pyrite and galena  
1—PbS-FeS<sub>2</sub>; 2—PbS; 3—FeS<sub>2</sub>; 4—FeS<sub>2</sub>-PbS

## 5 CONCLUSIONS

(1) Pyrite is nobler than galena under all conditions. In any galvanic combination involv-

ing these two electrodes, the preferential anodic oxidation happened on the galena surface can be expected. It was observed that the corrosive wear of galena contacted with pyrite increases.



**Fig. 6** Flotation behavior of pyrite and galena

1 —PbS-FeS<sub>2</sub>; 2 —PbS; 3 —FeS<sub>2</sub>; 4 —FeS<sub>2</sub>-PbS

(2) Galvanic contact between galena and pyrite deleteriously affects the subsequent flotation response of the pyrite, and improves the flotation of galena.

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