

AN FTIR STUDY ON SELECTIVE SEPARATION OF PYRITE FROM CHALCOPYRITE USING BACTERIA

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ABSTRACT—This paper discusses the utility of FTIR spectra in understanding the mechanism of selective separation of chalcopryrite from pyrite after biomodulation using *Acidithiobacillus ferrooxidans* cells. Consequent to interaction with bacterial cells, pyrite remained depressed even in presence of collector while chalcopryrite exhibited significant flotability. FTIR spectra indicated that the major species formed when pyrite and chalcopryrite were interacted with an aqueous solution of potassium ethyl xanthate was dixanthogen and copper(I)alkyl xanthate respectively. The observed difference in the flotability of the two minerals after interaction with the cells and collector is explained based on FTIR studies.

Keywords: Biomodulation, mineral, *Acidithiobacillus ferrooxidans*, FTIR

I. INTRODUCTION

Chalcopryrite and arsenopryrite are often associated with pyrite and selective depression of the pyrite from these would prove economically beneficial for further extraction. As against the conventional techniques, microbially induced flotation and flocculation stands out to be more effective, economically viable and an environmentally benign process for the effective separation of sulphide minerals. In a previous study of ours [1], we were able to achieve selective separation of pyrite from a mixture of pyrite and chalcopryrite by collector interaction and biomodulation using *Acidithiobacillus ferrooxidans*. In this study the utility of FTIR studies in understanding the mechanism of selective separation of chalcopryrite from pyrite by biomodulation using *Acidithiobacillus ferrooxidans* is reported.

II. MATERIALS AND METHODS

Minerals

Pyrite was obtained from Alminrock Indser Fabricks, Bangalore and Chalcopryrite from Gregory, Bottley and Lloyd, UK, as pure handpicked mineral samples. The mineral samples were dry ground with a porcelain ball mill and dry sieved to obtain different size fractions. The –

106+75 µm fraction was used for flotation studies. The purity of the mineral samples were ascertained by mineralogical studies and X-ray diffraction using JDX-8030 X-ray diffractometer system.

Microorganism

The bacterial culture used was a strain of *Acidithiobacillus ferrooxidans* that was isolated from Hutti Gold Mines (HGML). The purity was ascertained by the procedure outlined by Karavaiko [2]. The bacteria were cultured in sterile 9K medium developed by Silverman and Lundgren [3].

Microflotation studies

The flotation of the mineral samples was carried out using a modified Hallimond tube by passing nitrogen gas at the flow rate of 40 ml/min for 3 min. Prior to flotation the mineral (1 g) was conditioned with deionised double distilled water (200 ml) at the desired pH for 5 min followed by addition of activator or collector and further conditioning for 5 min. The floated and tailing samples were collected separately, filtered, dried and weighed. For flotation studies involving interaction with cells, the mineral samples were first interacted with the cells/collector at the desired pH. The supernatant was carefully removed and the interacted mineral was further conditioned with reagents, transferred to the Hallimond tube and floated as before.

III. RESULTS AND DISCUSSION

Flotation studies

The flotation recovery of pyrite and chalcopryrite after interaction with bacterial cells and further conditioning with the collector are shown in Figure. 1. When pyrite, interacted with cells (4×10^8 cells/ml), was further conditioned with 0.1 mM PIPX, the recovery was below 20% at all pH values (Figure. 1a). When conditioned with 0.5 mM PIPX, the

maximum recovery at pH 4.5 was about 34%. Contrary to this, conditioning with cells did not significantly reduce the flotation recovery of chalcopyrite (Figure 1b). When the mineral, interacted with cells (4×10^8 cells/ml), was further conditioned with 0.1 mM and 0.5 mM collector concentrations, the recovery obtained at about pH 4.5 was 65% and 73% approximately.

FTIR Studies

The alkylxanthate species formed when pyrite is treated with an aqueous solution of potassium alkylxanthate is dialkyl dixanthogen, which is hydrophobic, and physisorbed to the surface in aqueous systems [4]. In case of chalcopyrite, the alkylxanthate ions are coordinated to specific Cu ion sites on the mineral surface forming solid copper (I) alkylxanthate, which is highly hydrophobic and strongly chemisorbed to the surface [5]. FTIR spectroscopic characterization of the interacted minerals was carried out to infer this and the results obtained are shown in Figure 2 and 3. Difference spectra of pyrite after conditioning with PIPX showed bands at around 1029, 1147 and 1261 cm^{-1} (Figure 2a). The broad band at around 1029 cm^{-1} is due to asymmetric stretching vibrations of C-O-C, characteristic of dixanthogen [6,7]. The band 1261 cm^{-1} is also characteristic of S-C-S stretching vibration characteristic of dixanthogen [6]. The band at around 1147 cm^{-1} is characteristic of ferric xanthate species [6]. The FTIR spectra obtained indicated that dixanthogen was the major species formed when pyrite was interacted with an aqueous solution of potassium ethyl xanthate.

Difference spectra of chalcopyrite after conditioning with PIPX showed bands at 1035, 1123, 1331, 1632 cm^{-1} (Figure 2b). The broad band at around 1035 cm^{-1} is due to the stretching of S-C-S stretching characteristic of copper(I)ethyl xanthate [5,6]. The band observed at around 1123 cm^{-1} is also due to the stretching vibrations of the C-O-C groups characteristic of copper(I)ethyl xanthate. The weak band at 1331 cm^{-1} is due to asymmetric stretching vibrations of C-O-C, characteristic of dixanthogen [8]. The xanthate species adsorbed on chalcopyrite surfaces after treatment with collector was mainly copper(I)alkyl xanthate as indicated by the characteristic bands observed. Absence of significant peaks of dixanthogen or iron alkylxanthate indicated that copper(I)ethyl xanthate was the strongly predominating alkylxanthate species on chalcopyrite surfaces treated with an aqueous solution of potassium ethyl xanthate. copper(I)ethyl xanthates are highly hydrophobic and imparts good flotability to chalcopyrite surface.

Interaction of pyrite with cells prior to collector conditioning resulted in slight shift in the band at 1019 cm^{-1} to 1021 cm^{-1} (Figure 3a). This band can still be attributed to the asymmetric stretching vibrations of the C-O-C characteristic of dixanthogen. The weak band at 1111 cm^{-1} is characteristic of ferric xanthate species [6]. The sharp band near 3440 cm^{-1} can be assigned to the free asymmetric

and symmetric N-H stretching modes. The bands around 2924 cm^{-1} and 2856 cm^{-1} is attributable to C-H stretching mode indicating the presence of alkyl groups CH_3 , CH_2 and CH. The large band around 1647 cm^{-1} is due to amide group (amide I band) [9]. The group of bands between 650 cm^{-1} and 450 cm^{-1} is assignable to CH_2 vibrations of polysaccharides [10]. All these bands can be attributed to presence of polysaccharide and protein groups on the mineral surface due to interaction with bacterial cells. The above observation indicates the strong affinity of cells for pyrite surface.

Interaction of chalcopyrite with cells prior to collector conditioning resulted in appearance of bands at 3436, 2922, 2858, 1645, 1190, 1035, 1017 cm^{-1} (Figure 3b). The sharp band around 3436 cm^{-1} can be assigned to the free asymmetric and symmetric N-H stretching modes. The weak bands around 2922 cm^{-1} and 2858 cm^{-1} is attributable to C-H stretching mode indicating the presence of alkyl groups CH_3 , CH_2 and CH. The band around 1645 cm^{-1} is due to amide group (amide I band) [9]. The group of bands around 650 cm^{-1} is assignable to CH_2 vibrations of polysaccharides [10].

All these bands can be attributed to presence of polysaccharide and protein groups on the mineral surface due to interaction with bacterial cells. However appearance of strong and broad band at around 1190 and 1035 cm^{-1} , attributable to the asymmetric stretching vibrations of C-O-C, characteristic of cuprous ethyl xanthate adsorption and the band around 1017 cm^{-1} characteristic of dixanthogen species, suggests the strong affinity of xanthate to chalcopyrite surface even in presence of bacterial cells. The FTIR observation supports the observed difference in the flotability of the two minerals after interaction with the cells and collector.

IV. CONCLUSIONS

The FTIR spectra obtained indicated that the major species formed when pyrite was interacted with an aqueous solution of potassium ethyl xanthate was dixanthogen, which is hydrophobic, and physisorbed to the surface in aqueous systems. The xanthate species adsorbed on chalcopyrite surfaces after treatment with collector was mainly copper(I)alkyl xanthate, copper(I)ethyl xanthates are highly hydrophobic and imparts good flotability to chalcopyrite surface. The FTIR observation supports the observed difference in the flotability of the two minerals after interaction with the cells and collector.

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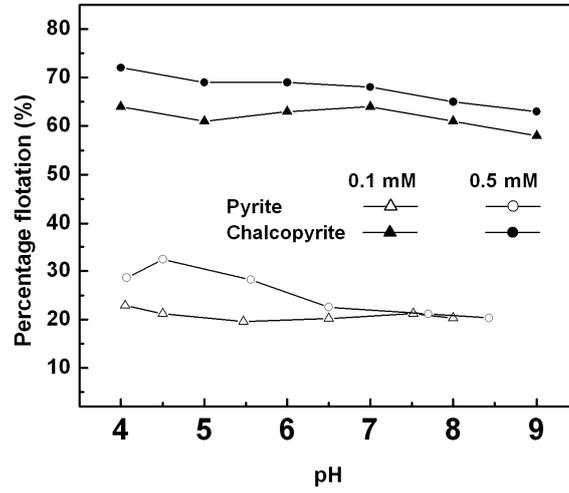
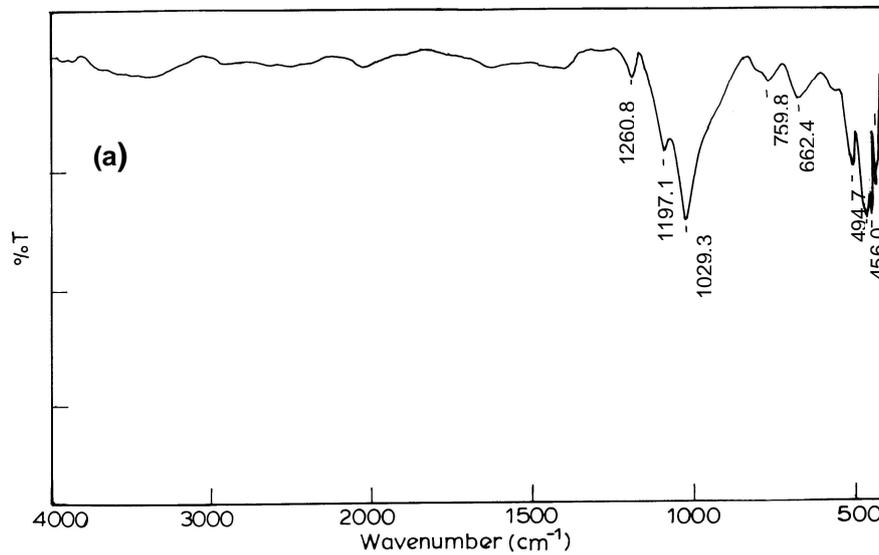


Fig. 1: flotation recovery of pyrite and chalcopyrite after interaction with bacterial cells and further conditioning with the collector



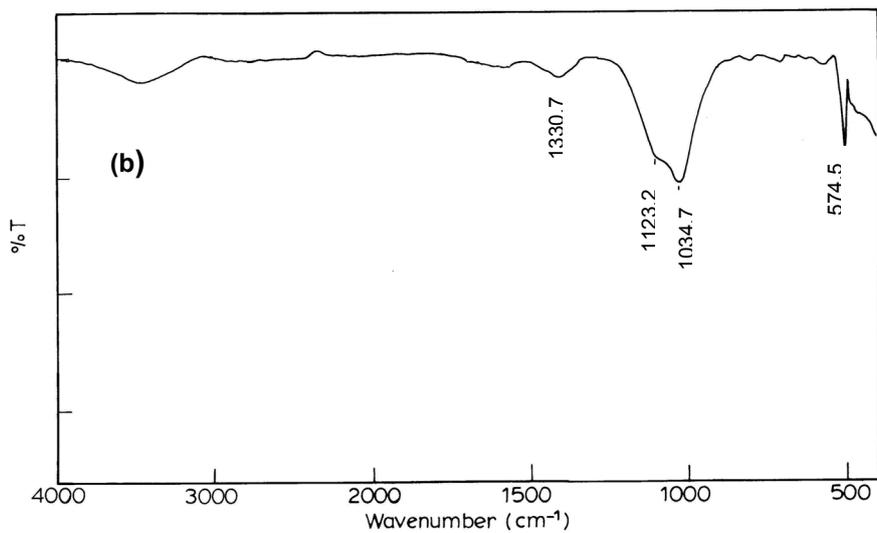
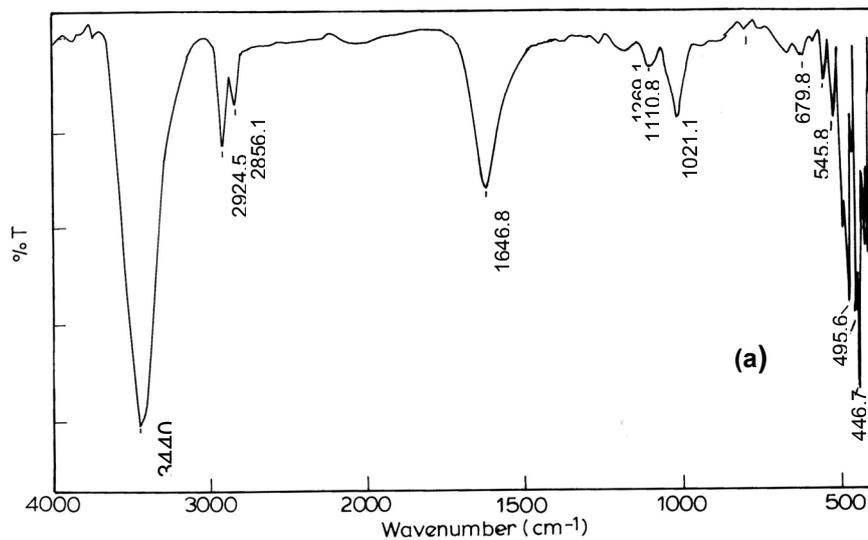


Figure 2. Difference FTIR spectra of (a) Pyrite and (b) Chalcopyrite after interaction with potassium isopropyl xanthate (PIPX)



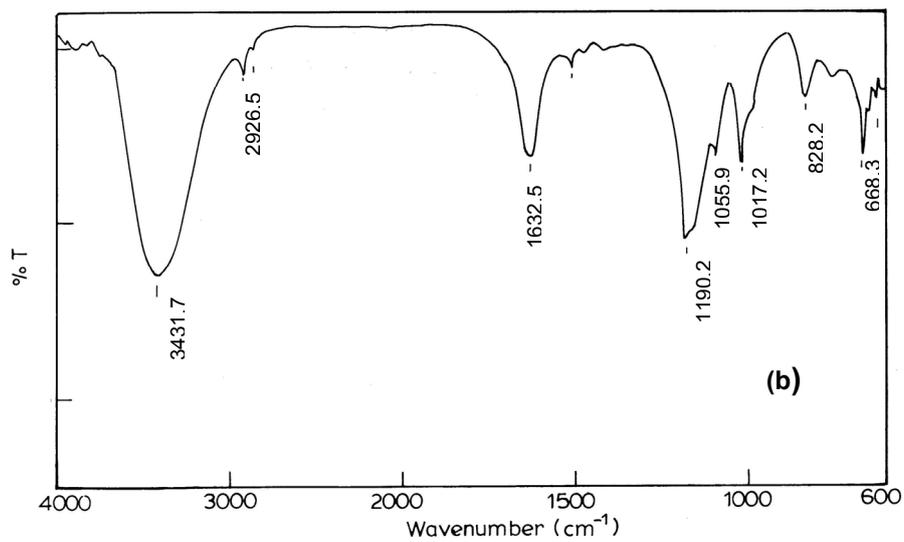


Figure 3. Difference FTIR spectra of (a) Pyrite and (b) Chalcopyrite after interaction with *Acidithiobacillus ferrooxidans* cells followed by interaction with PIPX.