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Electrochemical bioleaching of high grade chalcopyrite flotation concentrates in a stirred bioreactor

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ABSTRACT

The main objective of this study is to improve the basic understanding of electrochemical bioleaching as an advanced hydrometallurgical process suitable for the treatment of high grade complex sulfide ores and to use this understanding for analyzing the potential of this process for copper recovery from high grade chalcopyrite ores and flotation concentrates. Using a typical flotation concentrate from the Sarcheshmeh copper processing complex (located in the south-east of Iran) and mixed mesophilic as well as moderately thermophilic microorganisms, leaching experiments were performed in a stirred bioreactor. The emphasis was given on the comparison between the results of bioleaching and that of electrochemical bioleaching tests. From the results of this study, it can be pointed out that compared to the conventional bioleaching; the electrochemical bioleaching of chalcopyrite flotation concentrate leads to about 35% more copper recovery. It seems that the main reason for increasing copper recovery by electrochemical bioleaching is the control of redox potential between 400 and 425 mV. Under this condition, the precipitation of iron oxy-hydroxides on the surface of chalcopyrite, which can act as a diffusion barrier and prevents chalcopyrite dissolution, is significantly reduced. This leads to a higher electrochemical reduction of chalcopyrite and its improved dissolution.

1. Introduction

Chalcopyrite is the most important copper-bearing mineral in the world. This mineral is known to be recalcitrant to hydrometallurgical processing. Much effort has been directed towards developing a hydrometallurgical process suitable for the treatment of high grade chalcopyrite ores with very limited success. It was believed that biohydrometallurgical techniques could offer one of the better alternatives for treatment of such ores. In the last three decades, microbial leaching operations have been developed into an emerging biotechnology. During this period, bioleaching has been applied successfully to the extraction of copper from low grade and secondary copper sulphides such as chalcocite and oxidation of refractory gold ores in both uncontrolled dumps and designed bioheaps. Also during this period of time, stirred tank bioleaching has been commercialized for cobalt recovery and for biooxidation of refractory gold concentrates. However, in the case of chalcopyrite ores and concentrates, biohydrometallurgy remains a promising technology (Olson et al., 2003; Watling, 2006; Ranjbar et al., 2007; Van-Aswegen et al., 2007).

Among the various microorganisms used in the bioleaching of metals, mixed thermophilic cultures have shown higher potential for copper recovery from chalcopyrite compared to mesophiles. In practice, moderate thermophilic microorganisms are being preferred, because they are more resistant to higher pulp densities and higher heavy metal concentrations than extreme thermophiles (Rodriguez et al., 2003; Olson and Clark, 2004; Cancho et al., 2007). The main hindrance to the commercial application of microbial processing of chalcopyrite concentrates is its low dissolution rate. (Watling, 2006; Pradhan et al., 2008). Several studies have shown that even in high acidic solutions, surface passivity of chalcopyrite at solution potential above a certain level, is the most important problem for dissolution of chalcopyrite (Hiroyoshi et al., 2001, 2008; Pinches et al., 2001; Third et al., 2002; Cordoba et al., 2008). The nature of this passive layer is not well known, but it is believed that a compact sulfur layer (Munoz et al., 1979; Dutrizac, 1989), a metal deficient chalcopyrite-like sulfide layer (Waren et al., 1982), a polysulfide like Cu_xS_y (Biegler and Horn, 1985) or an iron-bearing precipitate like jarosite (Stot et al., 2000) is responsible for passivity of chalcopyrite surface, which can lead to slow and incomplete extraction of copper. To overcome the problem, the formation of the passive layer must be prevented. One of the most discussed solution for this problem, is the possible control of pulp oxidation reduction potential (ORP) during the bioleaching process which can be achieved either electrochemically by applying a potential from an external source through a working

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