学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Ammonium thiosulfate leaching of arsenic-bearing refractory gold ores
(ヒ素含有難処理金鉱石のチオ硫酸アンモニウム浸出)

The depletion of free milling gold deposits has made the mining industry depend on refractory gold ores to meet the gold demand. Global statistics have shown that about 2/3 of the gold resources are refractory and the exploitation of these ores is expected to increase in future as the main primary gold deposits.

In refractory gold ores, sulfide-refractory gold ores account for a substantial proportion of the refractory gold ores in which minerals like arsenopyrite and pyrite are commonly associated with gold. Gold is extracted from these ores using the conventional cyanidation process, but it has two major problems: gold recovery is usually less than 50 percent due to encapsulation of gold grains in the sulfide matrix and cyanide the reagent used during leaching is toxic to both humans and animals. To address the toxicity of cyanide, several reagents including halides, thiourea and thiosulfate have been proposed to be alternatives to cyanide. Amongst these proposed reagents, thiosulfate is the most lucrative reagent to replace cyanide.

The use of thiosulfate to extract gold from refractory ores is promising because of its non-toxicity and high selectivity but the sulfide minerals (i.e., pyrite, arsenopyrite), refractory gold ores, hinder gold extraction due to the high consumption of lixiviant. To minimize the high reagent consumption, pretreatment techniques such as ultrafine grinding, biological oxidation and roasting are applied to make the ores amenable to thiosulfate leaching. On the other hand, these pretreatment techniques have drawbacks: ultrafine grinding does not remove decomposition effects of sulfide on thiosulfate, arsenic in arsenopyrite is toxic to microbes and roasting generates toxic arsenic oxides, making the pretreatment methods not compatible for arsenopyrite containing refractory gold ores. In this study, a new pretreatment method to improve gold extraction from arsenic-bearing gold ores is proposed based on the model experiments using mixture of gold powder and arsenopyrite.

Chapter 1 describes the statement of the problem and the objectives of this study.

Chapter 2 reviewed literature on techniques to extract from refractory ores including roasting, ultrafine grinding, bio-oxidation, ultrasound enhanced oxidation, ozone oxidation and chemical oxidation. In addition, the available alternatives to cyanide are also evaluated.

In Chapter 3, model leaching experiments using gold powder and arsenopyrite leaching were conducted to determine the effects of the sulfide minerals on gold extraction. Gold extraction significantly reduced in the presence of sulfide minerals like arsenopyrite and pyrite. Surface analysis using XPS and SEM-EDS for gold in ammonia thiosulfate solutions showed that a very thin layer containing cuprous sulfide, iron oxyhydroxide and elemental sulfur was formed on gold surface. This layer was formed both in the presence and absence of sulfide minerals, indicating that the layer is not the essen-

tial cause of the suppression in gold extraction with sulfide minerals. Solution analysis using UV-Vis showed that the presence of sulfide minerals accelerated the decomposition of thiosulfate. From this, it was concluded that thiosulfate decomposition is the main cause of the suppression in gold extraction in the presence of sulfide minerals like arsenopyrite and pyrite.

In Chapter 4, a novel pretreatment was proposed to enhance the succeeding ammonia thiosulfate leaching of gold. In the proposed pretreatment, sulfide minerals like arsenopyrite and pyrite is decomposed by the oxidation using the solutions containing cupric ammine complex. Model experiments using the mixture of gold powder and sulfide minerals were conducted. The results showed that significant amounts of sulfide minerals were decomposed in the pretreatment, and this suppressed the thiosulfate decomposition in the succeeding ammonia thiosulfate leaching, causing the enhancement of gold extraction.

In Chapter 5, based on the results of model experiments outlined in Chapter 4, the effectiveness of the proposed pretreatment was evaluated using refractory gold ores obtained from Zimbabwe. Without pretreatment, 45 percent thiosulfate was decomposed and the gold extraction from the ores were less than 5 percent, while with pretreatment thiosulfate decomposition was suppressed to 25 percent and gold extraction was improved to over 45 percent.

Chapter 6 summarized the important findings of this dissertation and its implications.