Proceedings of the 11th World Congress on Mechanical, Chemical, and Material Engineering (MCM'25)
Barcelona, Spain - Paris, France - August, 2025
Paper No. MMME 115
DOI: 10.11159/mmme25.115

Extraction of Gold from Sulfidic Refractory Ore by Thiosulfate Leaching Assisted by Microencapsulation Treatment

Fuki Sato[1], Ilhwan Park[1], Naoki Hiroyoshi[1], Mayumi Ito[1]
[1] Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University Kita 13, Nishi 8, Kita-ku, Sapporo 060-8628, Japan
sato.fuki.q8@elms.hokudai.ac.jp; i-park@eng.hokudai.ac.jp; hiroyosi@eng.hokudai.ac.jp; itomayu@eng.hokudai.ac.jp

Extended Abstract

Gold (Au) is an important precious metal used in a variety of applications including electronics, aerospace, dentistry and medicine due to its unique physical and chemical properties, such as exceptional electrical and thermal conductivities, superior corrosion resistance, and excellent ductility and malleability [1]. In addition, gold will play an important role in achieving a carbon neutral society due to its applications in solar cells, fuel cells, and catalyst converting CO_2 into fuels [2], and thus its demand is projected to increase consistently.

Cyanide is the most widely used lixiviant for gold extraction from ores, but its use is heavily regulated due to significant environmental and health concerns [3]. As an alternative, thiosulfate has gained increasing attention due to its low toxicity, high selectivity for gold, and fast leaching rates. However, the efficiency of gold extraction by thiosulfate leaching is dramatically reduced when processing sulfidic refractory gold ores because sulfide minerals like arsenopyrite (FeAsS) accelerate the decomposition of thiosulfate [4]. For instance, thiosulfate leaching could extract ~99% of gold in the absence of arsenopyrite, while its efficiency decreased to 16% when arsenopyrite coexisted. In addition, leach residues of sulfidic refractory gold ores contain high concentration of toxic arsenic (As), which poses a serious threat when released into the environment.

To address these challenges, this study investigated the applicability of microencapsulation (ME) treatment using ferrous (Fe^{2+}) and phosphate ($H_2PO_4^-$) ions to passivate the surface of arsenopyrite prior to thiosulfate leaching. As arsenopyrite is electrically conductive, ferrous ions can be oxidized to ferric (Fe^{3+}) ions on its surface. The ferric ions then react with phosphate ions, leading to the precipitation of ferric phosphate ($FePO_4 \cdot 2H_2O$) on the surface of arsenopyrite [5–7]. After ME treatment of arsenopyrite, dissolved iron (Fe) and phosphorous (P) concentrations decreased, and moreover, X-ray Photoelectron Spectroscopy (XPS) analysis of ME-treated arsenopyrite showed the presence of Fe^{3+} and PO_4^{3-} signals. This indicates that ferric phosphate precipitates were formed on its surface. The amounts of ferric phosphate precipitates increased with increasing concentrations of ferrous and phosphate ions as well as temperature.

The results of the thiosulfate leaching experiments indicated that gold extraction efficiency improved by employing ME treatment. This improvement occurred because the passivation of the arsenopyrite surface with ferric phosphate precipitates reduced the decomposition of thiosulfate molecules. In addition, it is important to note that the efficiency of gold extraction by thiosulfate leaching was positively correlated with the amount of ferric phosphate precipitates, showing a strong relationship (i.e., $R^2 = 0.9$); that is, gold extraction efficiency was increased from 35% to 72% as the amounts of ferric phosphate precipitates increased from 32.5 to 96.4 mg $_{FePO_4}$/g $_{FeAsS}$. Based on the relationship between the amount of ferric phosphate precipitates and gold extraction efficiency, it was confirmed that more than 110 mg $_{FePO_4}$/g $_{FeAsS}$ is required to achieve gold extraction efficiency of over 90%.

Furthermore, the effect of ME treatment on the release of As from arsenopyrite was investigated by reacting 1 g of arsenopyrite with 10 mL of deionized (DI) water. After 24 h, approximately 0.36 mM of As was released from untreated arsenopyrite, whereas this amount was reduced to 0.09 mM for ME-treated arsenopyrite. This confirms that ME treatment is effective not only in improving gold extraction efficiency by thiosulfate leaching but also in minimizing the environmental impact.

The findings of this study confirm that ME treatment, followed by thiosulfate leaching, is proven to be effective as an alternative gold extraction process for sulfidic refractory ores.

References

[1] U.S. Geological Survey, *Mineral commodity summaries 2024*. Reston, Virginia: U.S. Geological Survey, 2024.

[2] I. Ganesh, "Electrochemical conversion of carbon dioxide into renewable fuel chemicals – The role of nanomaterials and the commercialization," *Renew. Sust. Energ. Rev*., vol. 59, pp. 1269-129, 2016

[3] M. G. Aylmore, "Alternative lixiviants to cyanide for leaching gold ores," *Dev. Miner. Process*., vol. 15, pp. 501-539, 2005.

[4] D.M. Muir, M.G. Aylmore, "Thiosulfate as an alternative lixiviant to cyanide for gold ores," *Dev. Miner. Process*., vol. 15, pp. 541-560, 2005.

[5] I. Park, S. Hong, S. Jeon, M. Ito, N. Hiroyoshi, "Flotation Separation of Chalcopyrite and Molybdenite Assisted by Microencapsulation Using Ferrous and Phosphate Ions: Part I. Selective Coating Formation," *Metals*, vol. 10, no. 12, pp. 1667, 2020.

[6] I. Park, S. Hong, S. Jeon, M. Ito, N. Hiroyoshi, "Flotation Separation of Chalcopyrite and Molybdenite Assisted by Microencapsulation Using Ferrous and Phosphate Ions: Part II. Flotation," *Metals*, vol. 11, no. 3, pp. 439, 2021.

[7] I. Park, D. Uchida, S. Jeon, K. Aikawa, N. Hiroyoshi, M. Ito, "Microencapsulation-based surface modification for improving flotation separation of Cu-Zn mixed sulfide minerals," *Miner. Eng*, vol. 213, pp. 108756, 2024.