学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Hydrometallurgical recovery of precious metals using magnetic adsorbents
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Precious metals, such as gold (Au), silver (Ag), platinum (Pt), palladium (Pd), rhodium (Rh) and other platinum group metals (PGMs), found wide applications in various manufacturing fields due to their superior chemical and physical properties. The increasing demand for these metals coupled with the declining resources available, prompted the development of recycling technologies to recover precious metals from secondary sources. Hydrometallurgical techniques play an important role in the processing of precious metals from secondary sources and have been the focus of numerous researches and studies for many years.

One of the challenges that is yet to be resolved in the hydrometallurgical processing of precious metals from secondary sources is the separation and recovery of the dissolved precious metals in solution, specifically from non-cyanide based leach liquors, such as chloride and thiosulfate. Magnetic solid-phase extraction (MSPE) using magnetic adsorbents has been reported to show great potential in the separation of precious metal ions from aqueous solutions. Magnetic adsorbents have gained significant attention recently due to their inherent magnetic property which can be exploited to overcome problems associated with phase separation. Among the magnetic adsorbents reported in literature, magnetite (Fe3O4) seems the most promising due to its wide availability and ease of synthesis, ferromagnetic property and recyclability.

This dissertation investigated the use of magnetite derived from two different sources as adsorbent to recover precious metals (Pt, Au, Pd and Rh) from chloride and thiosulfate solutions. The effects of various process parameters were investigated and the mechanisms of adsorption were proposed. The results are presented in different chapters.

In Chapter 1, the background and the objectives of the study were presented. The main concepts and premise which led to the development of this study were discussed. The potential of magnetic materials as adsorbent for precious metals was presented and briefly reviewed.

In Chapter 2, the study on the recovery of Pt, Rd, and Pd from chloride solutions on synthetic magnetite powder is reported. The study involved batch adsorption experiments using synthetic magnetite at 298 K. The effects of different parameters, such as pH, contact time, the NaCl concentration and the PGMs concentrations were investigated. The uptake amounts of Pt, Pd, and Rh increased with time and reached a constant value over 24 h. This slow sorption kinetics indicates that the uptake is not due to a simple physical adsorption, and involves chemical reactions. The uptake amounts of Pt, Pd, and Rh were strongly affected by pH. The SEM-EDX and BSE analyses confirmed the presence of rhodium and palladium concentrated on some areas of the magnetite surface. These results signify that Fe3O4 can uptake platinum group metals and can be used as a potential selective sorbent to recover the metals

from chloride solution or chloride leach liquors.
In Chapter 3, the study on the recovery of Pt, Rh and Pd from chloride solution on magnetite derived from copper converting slag (slag magnetite) is detailed. The effects of various process parameters such as pH, contact time, NaCl concentration, and Pt, Rh and Pd concentrations, were investigated. Characterization studies conducted on the slag magnetite as revealed that it is a composite material with some amounts of metallic Cu and copper sulfide (Cu2S). Single-component batch adsorption experiments confirmed that Pt, Rh and Pd were recovered by slag magnetite. Higher recoveries at shorter contact time were observed. It was found that the slag magnetite is a more superior adsorbent than the synthetic magnetite in terms of loading capacity and kinetics. It was also found that slag magnetite can recover Pt, Pd, and Rh selectively from the solution containing a mixture of PGM ions and base metal ions, such as Cu, Ni, and Zn. The presence of copper impurities in the slag magnetite matrix may have contributed significantly to the observed results.
In Chapter 4, the utility of slag magnetite as adsorbent was extended to the recovery of gold from ammonium thiosulfate solution. Batch sorption experiments were performed to evaluate the effects of pH, contact time, thiosulfate concentration, and initial copper concentration on Au uptake amount. The results showed that slag magnetite can effectively recover gold from ammonium thiosulfate solution. Parameter studies and spectrometric analyses suggested that chalcocite (Cu2S) and metallic Cu present in the slag magnetite reduced the gold thiosulfate complex. Gold was detected on the surface of the converter slag magnetite, and the EDX images strongly suggest the Au and Cu present in same areas. It was found that the presence of O2 in the system hinders gold uptake by slag magnetite and an anaerobic condition is much preferred. It is important to eliminate O2 in the system to increase gold recovery. Gold can also be concentrated to about 10 times the original concentration through a two-step adsorption-desorption scheme with O2 control. The converting slag magnetite can be used as a selective, economical, and effective adsorbent to recover gold from secondary sources.
In Chapter 5, the summary and conclusions of the study were presented.