

Biocompatible Materials for Separation of Precious and Critical Metals

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論文内容の要旨

Precious metals (PMs) are elements with high economic values. Gold and palladium are two examples of PMs that are essential in electronic products such as mobile phones and computers. Critical metals (CMs) are essential elements in the emerging clean energy technology. Nickel and cobalt are two critical metals that are used in batteries for electric vehicles. Another reason that makes both metal groups precious and critical is that these metals are facing scarcity due to the depletion of natural resources and the increase in the application rate. These conditions have created a global concern about supply stability and environmental impacts. Urban mining or metal recycling from the end-of-life products has become a significant alternative to maintain a stable supply. My concern is that the ongoing metallurgy research mostly focuses only on extractability. In fact, a typical metallurgy flowsheet tends to use a lot of dangerous chemicals like strong acids and volatile organic solvents in the purification and recovery steps, potentially causing environmental and health issues for massive and long-term use. Therefore, this thesis aims to develop a biocompatible separating agent for precious and critical metals.

In Chapter 2, a naturally derived material, silk fibroin, has been prepared for the selective recovery of gold from discarded mobile phones. Adsorption of gold in a single metal solution achieved an equilibrium after one hour of adsorption at 25°C with a maximum capacity of 5.800 g/mg. The kinetics and isotherm studies suggest that the adsorption mechanism followed pseudo-second order and Langmuir models, respectively. In the presence of other metal ion impurities (Pt^{4+} , Pd^{2+} , Al^{3+} , Cu^{2+} , Ni^{2+} , Zn^{2+} , Pb^{2+} , and Fe^{3+}), silk fibroin showed a remarkable selectivity toward gold. Almost no metal impurities were co-adsorbed into the silk fibroin despite the concentration of metal impurities being much higher than the concentration of gold in the leachate of the discarded mobile phones. The gold uptake from the actual leachate of discarded cell phones was approximately 95%. The gold loaded on the silk fibroin was completely desorbed by 0.1 mol/L thiourea.

Chapter 3 introduces newly less toxic ionic liquids (ILs) based on amino acid ester cations and carboxylate anions (L-leucine propyl linoleate and L-leucine propyl oleate), as extractants for Ni^{2+} , Co^{2+} , and Mn^{2+} . The selectivity order of both ILs was $\text{Ni}^{2+} > \text{Co}^{2+} > \text{Mn}^{2+}$. The two ILs extracted all those three metal ions satisfactorily at pH equilibrium > 7 . To evaluate the toxicity, ecotoxicity prediction against bacterium *Aliivibrio fischeri* was carried out using a machine learning model with an eXtreme Gradient Boosting regressor algorithm. An evaluation of the proposed regression model by cross-validation indicates that the model is reliable, with an R^2 value of 0.71. The ecotoxicity prediction results showed that the resulting ILs have much lower ecotoxicity compared to commercial IL (Aliquat 336) used for the extraction of Ni and Co.

