ANNOTATION
dissertation for the degree of doctor of philosophy (PhD) in the specialty 6D070900 – «Metallurgy»

SAPINOV RUSLAN VIKTOROVICH

STUDY OF PROCESSES OF EXTRACTION OF TIN FROM TECHNOGENIC, MINERAL RAW MATERIALS AND ELECTRONIC WASTE

Relevance of the research topic. The relevance of this work is due to the fact that in Kazakhstan, despite the presence of mineral, technogenic tin-containing raw materials and electronic waste, today the production and processing of tin is practically not carried out. In Kazakhstan, it is possible to produce tin solders for the domestic electronics industry by recycling electronic scrap. However, not a single company involved in the disposal of org. appliances and other electronic scrap does not produce products from tin. The results of this work will make it possible to comprehensively process electronic scrap, extracting, in addition to copper and precious metals, tin solders that can be used, or further processed, obtaining refined tin. These works are already being carried out in pilot production. The work carried out on the processing of tin-containing mineral raw materials will make the processing of domestic mineral raw materials more attractive from an economic and environmental point of view, due to a more complete extraction of tin. All this makes the work relevant.

The scientific novelty of the topic lies in the fact that a correlation has been found between temperature and the duration of hydrometallurgical processes and the extraction of tin under the combined action of ultrasound and vibration.

Determined that:

- in the hydrometallurgical processing of electronic scrap with an aqueous solution of HCl with a concentration of 2M, periodic ultrasonic exposure (for 5 minutes every 60 minutes) with an intensity of 35 kHz increases the degree of tin extraction from 84% to 91.6% (at 85 °C for 300 minutes), which is presumably due to a decrease in the apparent activation energy $E_{каж}$ from 27.35 to 25.8 kJ/mol;

- with continuous ultrasonic exposure with an intensity of 35 kHz, the duration of the process of carburizing tin deposition is reduced from 300 minutes to 60 minutes with the provision of tin deposition of 99.9%;

- with continuous vibration exposure with an intensity of 10 Hz, the duration of the process of carburizing tin deposition is reduced from 300 minutes to 120 minutes with the provision of tin deposition of 99.9%.

- during hydrometallurgical processing of mineral raw materials with a solution of H_2SO_4 with a concentration of 140 g/l, periodic ultrasonic exposure (for 5 minutes every 30 minutes) with an intensity of 35 kHz (at t = 85 ° C for 60 minutes) increases the degree of tin extraction from 88.8 % to 95.15%.

In the course of the work, the following new scientific and technical results were obtained:

– the possibility of gravity enrichment of the tailings of the Belogorsk GOK containing 0.005% tin, with the extraction of tin into concentrate up to 18.6%, is shown.

– the prospects for the extraction of acid-soluble forms of tin from the tailings of the enrichment of ores from the Syrymbet deposit by means of ultrasonic intensification of sulfuric acid leaching are shown. The total recovery of tin after gravitational enrichment and additional extraction of tin from enrichment tailings is 43.5%.

– the possibility of selective leaching of tin from printed circuit boards of smartphones due to ultrasonic activation has been established.

The novelty of the results of the research work is also confirmed by the utility model patent of the Republic of Kazakhstan No. 6023 dated April 30, 2021. "Method of processing electronic waste". A method for processing waste from the electronic and electrical industries, including the extraction of tin from a productive solution in metallic form by carburizing on an aluminum plate, characterized in that the separation of electronic parts from electronic printed circuit boards occurs due to the dissolution of solder in an aqueous solution of hydrochloric acid with a concentration of 2 mol/l , at a temperature of 75 °C, and the ratio by mass of solid and liquid phases S/L = 1/10, in an ultrasonic field with an operating frequency of 35 kHz for 6 hours.

The purpose of the dissertation work is to study the processes of extracting tin from various tin-containing raw materials with the development of a technological scheme for its processing.

Provisions submitted for defense:

1. Optimal parameters of gravity enrichment of the tailings of the Belogorsk GOK to ensure the extraction of 18.6% of tin when using a concentration table with an oscillation frequency = 310 min $^{-1}$, stroke length - 12 mm, S/L = 2/8 and an ITOMAK-2K centrifugal concentrator with water pressure - 0.1 atm and a rotation speed of 240 rpm.

2. Positive effect of ultrasound with an intensity of 35 kHz and vibration of 10 Hz on the process of hydrometallurgical extraction of tin up to 91.6% from mineral, technogenic raw materials and electronic waste.

3. An integrated scheme for the processing of mineral and technogenic tin-containing raw materials, with integrated hydrometallurgical processing of electronic waste.

Practical significance – a technology for the processing of electronic waste by the hydrometallurgical method has been created, which has passed pilot testing.

Approbation of work : The main scientific results of the dissertation work are presented in four publications published in the Republic of Kazakhstan and abroad, including in publications recommended by the logo

Committee for Quality Assurance in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, three articles were published:

1. Сапинов Р.В., Куленова Н.А., Суюндиков М.М., Олейникова Н.В. Перспективы получения олова из техногенного сырья в Казахстане // Вестник

ВКГТУ имени Д.Серикбаева, №3 – Усть-Каменогорск, ВКГТУ им. Д.Серикбаева 2019 – С. 155–160.

2. Сапинов Р.В., Куленова Н.А., Саденова М.А., Суюндиков М.М. Извлечение олова из электронных отходов с помощью гидрометаллургических методов // Вестник ВКТУ имени Д.Серикбаева, №4 – Усть-Каменогорск, ВКТУ им. Д.Серикбаева 2020. – С. 173–178.

3. Sapinov R.V., Kulenova N.A., Sadenova M.A., Varbanov P.S., Klemeš J.J. (2021) Комплексное использование минерального сырья №2 – Алматы, 2021. – С. 37– 45.

article in a journal included in the Scopus database (Q3(percentile 37))

1. Sapinov R.V., Sadenova M.A., Kulenova N.A., Oleinikova N.V. Improving Hydrometallurgical Methods for Processing Tin-containing Electronic Waste // Chemical Engineering Transactions, – 2020.– 81. C. 1021–1026.

2. received one utility model patent KZ No. 6023 published on 04/30/2021. "Method of processing electronic waste".

The main results were reported at three international conferences:

1. Сапинов Р.В., Куленова Н.А., Суюндиков М.М., Олейникова Н.В. Современные способы электролитического рафинирования чернового олова полученного из техногенного и природного сырья // Недра Казахстана – основа стабильности и процветания страны// Материалы научно-практической конференции посвященной 120-летию К.И. Сатпаева. Усть Каменогорск 2019. – С. 228–231.

2. Sapinov R.V., Sadenova M.A., Kulenova N.A., Oleinikova N.V. 23rd Conference on Process Integration, Modelling, and Optimisation for Energy Saving and Pollution Reduction (PRES'20). PRES20.0511. Improving hydrometallurgical methods for processing tin-containing electronic waste. 17th to 21st August 2020 at Xi'an,China.https://docs.google.com/spreadsheets/d/1WvdnNXldfUxjEdcmytnIAuStj7DXSpRSNSJ1CCOj8lA/edit#gid=0

3. Sapinov R.V., Sadenova M.A., Kulenova N.A. 4th Sustainable Process Integration Laboratory Scientific Conference: Energy, Water, Emission & Waste in Industry and Cities. SPIL20.0161 Influence of ultrasound on the hydrometallurgical extraction of tin and lead from electronic waste. 18th to 20th November 2020 at Brno,CzechRepublic(Online).http://registration.sdewes.org/c_includes/SPIL2020/export_abstracts.php

Scope and structure of the dissertation. The dissertation consists of introduction, 4 chapters, conclusion and 4 appendices. The work is presented on 105 pages of typewritten text, contains 28 tables, 50 figures. The list of sources used includes 112 items.