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## STUDY OF SILVER REMOVAL FROM SCRAP JEWELLERY BY WAY OF THE FLOTATION PROCESS

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Preliminary Note – Prethodno priopćenje

This article is a discussion on the proposed solution of using the flotation process to separate metals from non-metallic components present in the scrap generated while jewellery goods are being ground. For the sake of the studies analysed, a dedicated laboratory station was established.

*Key words:* silver, scrap, flotation, recycling.

**Studija uklanjanja srebra iz otpadaka nakita flotacijskim procesom.** Članak je rasprava na predloženu soluciju rabljenja flotacijskog procesa za izdvajanje metala iz nemetalnih komponenti nazočnih u otpadu koji nastaju pri izradi nakita. Glede analiza studije utemeljena je odgovarajuća laboratorijska stanica.

*Ključne riječi:* srebro, otpad, flotacija, recikliranje

### SILVER AND JEWELLERY MARKET IN POLAND AND ABROAD

The main sources of silver include copper, lead and gold ores. They are extracted in Peru, Mexico, Canada, Australia, the United States as well as in Poland, the latter being one of the main global suppliers of silver from the mining production. The total quantity of 1 826 Mg of silver extracted in 2005 in the whole Europe included 1 377 Mg delivered from Poland. According to the estimates of GFMS, in 2009, 22,071 Mg of silver were mined all over the world. In this compilation, KGHM Polska Miedz S.A. was ranked second having produced 1 203,7 Mg of silver in the year 2009 [1, 2].

In 2009, the mean annual price of silver at the London Bullion Market was on the level of 14,67 USD/troz (1 troz = 31,10348 g), and hence it was slightly lower than the price from the preceding year.

The 2009 global silver supply came to ca. 27,7 thousand Mg, 80 % of which originated in the mining production and 18,5 % came from recycling of old jewellery, photographic reagents and electronic scrap. The remaining part of the supply comprised the amounts released from the state treasury reserves.

In the year 2009, the silver consumption for production of jewellery slightly increased (by 0,5 %) as compared with the preceding year, thus curbing the decrease trend observed within the recent years.

Unfortunately Poland, being the leading silver supplier in Europe, processes merely 91 Mg of the metal per

year despite the fact that our country is known of a considerably cheap workforce, large internal market, tradition of many hundreds of years, companies of international renown and good access to the European market [3].

### FLOTATION

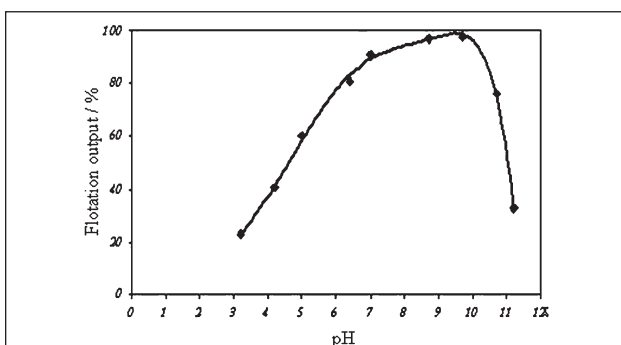
Flotation is a separation method commonly applied to the processes of enrichment of metal ores. It is an effect related to various interfacial phenomena occurring in a solid/liquid/gas system. If, under certain specific conditions, a grain shows hydrophilic properties, then it can be separated from those that do not possess such characteristics in the flotation process. The flotation intensity depends on numerous factors the most important of them include properties of the flotation froth (frothing agent type) and grain size. The flotation method can also be used to separate a metal from the grain fraction of certain oxides and carbides which was already confirmed by the results obtained while testing recovery of native gold from polymetallic copper ores at CSIRO Minerals in Australia [4].

Authors of various publications claim that SiC, Al<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub>, being the main components of the abrasive materials used in metal processing, can be separated from the metallic fraction by application of the method proposed. Iskra proved [4, 5] that silicon carbide shows good floatability provided that an appropriate collector is used. Figure 1 depicts sample results of the SiC flotation tests when a sodium oleate solution was used as the flotation reagent.

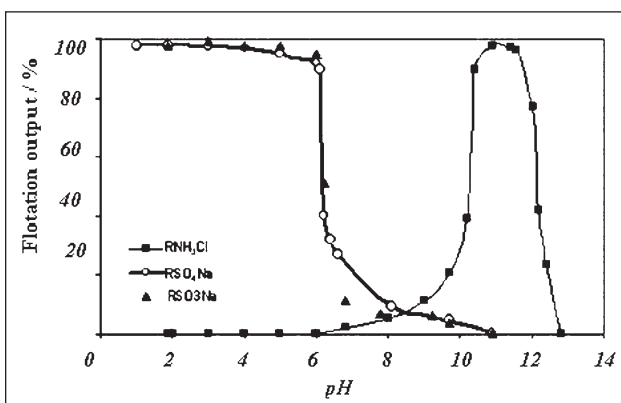
Corundum, being the second basic component of the scrap in question, can also be separated from the grain mixture by flotation. The foregoing was proved by D.

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**Figure 1** Influence of pH of the sodium oleate solution on the output of the SiC flotation process [5]



**Figure 2** Influence of the solution pH on the output of the corundum flotation process [6]

Fuerstenau who published the relevant test results in 2005 [6]. Figure 2 depicts the results of the corundum flotation process for various flotation reagents.

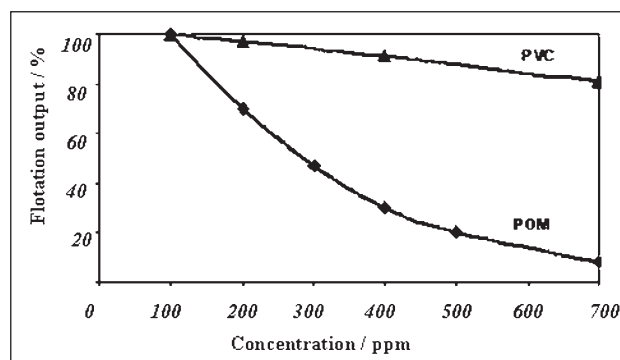
In the mix of broken-up electronic scrap, besides the metallic fraction, there are also grains of various other polymeric materials. To be able to separate these fractions by flotation, one must first select the appropriate flotation reagents, since the process itself has already been used in recycling of polymer materials. The flotation process enables separating polyolefines from the polyvinyl chloride, polystyrene and polyamides [7, 8]. Figure 3 depicts sample test results for the flotation process of the chosen polymeric materials assuming the use of sorbitan monolaurate [9].

It should be mentioned that numerous studies of the separation options for broken-up electronic components with flotation were conducted by the Department of Mining and Metallurgical Engineering at McGill University in Montreal. These studies were focused on the recovery of copper from the said materials assuming that MBC was used as the frothing agent [10, 11].

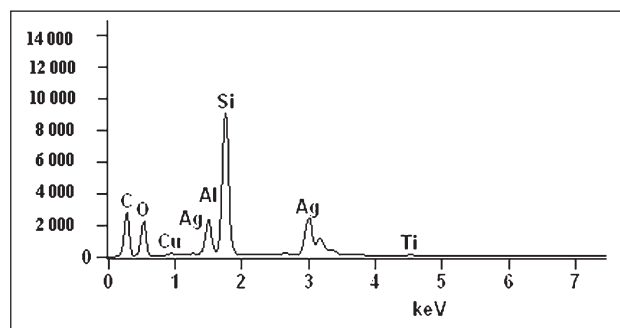
## DETERMINATION OF CHEMICAL COMPOSITION OF THE JEWELLERY GRINDING SCRAP ANALYSED

### Research methodology

Since various technological methods are applied in manufacture of silver jewellery, the composition of the scrap generated in the process in question is considera-



**Figure 3** Influence of the sorbitan monolaurate concentration on the output of the flotation process for the chosen polymeric materials [9]



**Figure 4** Sample X-ray of the scrap (sample 1)

bly diverse. In order to determine the composition of the scrap examined, 3 scrap samples were taken, analysed qualitatively by means of type JDX-7S X-ray apparatus delivered by Jeol and then quantitatively using an atomic absorption spectrometer manufactured by Unicam, namely the Solaar M6 model [11].

## Results

The X-ray of the scrap samples analysed have been provided in Figures 4-6, whereas Tables 1-3 contain a summary of their chemical composition.

**Table 1** Chemical composition of the scrap in the individual measuring points of X-ray chemical analysis / wt. % (sample 1)

Measuring point	Al	Si	Ti	Fe	Cu	Ag
1	10,1	43,8	0,4	---	9,5	36,2
2	6,3	61,4		---	---	31,1
3	9,1	49,1	0,3	0,7	11,4	29,5
4	9,2	54,8	0,5	---	8,2	26,7
5	8,3	57,3	0,3	---	7,5	23,1
6	3,5	17,1	--	---	9,9	69,5

**Table 2** Chemical composition of the scrap in the individual measuring points of X-ray chemical analysis / wt. % (sample 2)

Si	Ti	Cu	Ag
51,07	0,36	3,88	44,69

The results of the chemical analysis of the jewellery scrap with the atomic absorption spectrometer are given in Table 4.

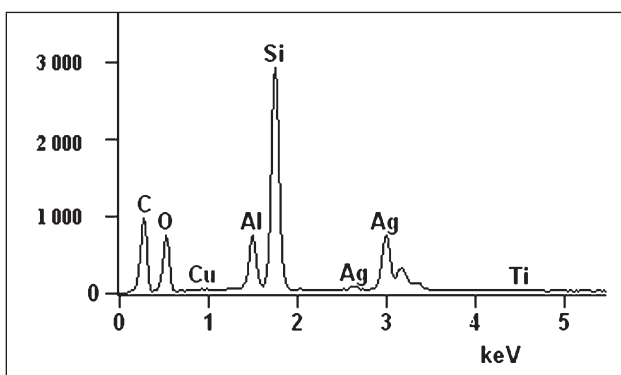


Figure 5 Sample X-ray of the scrap (sample 2)

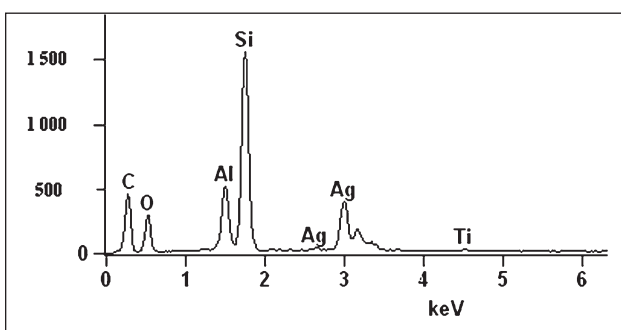


Figure 6 Sample X-ray of the scrap (sample 3)

Table 3 Chemical composition of the scrap in the individual measuring points of X-ray chemical analysis / wt. % (sample 3)

Si	Ti	Cu	Ag
50,26	0,93	3,88	44,93

Table 4 Chemical composition of jewellery scrap / wt. %

Sample no.	Ag	Fe	Cu
1	13,2	0,3	1,0
2	12,1	0,1	1,3
3	14,0	0,3	0,5

## TEST STAND

The flotation test stand prepared in this investigation was designed for laboratory tests of selective separation of the components present in the scrap generated while grinding jewellery goods.

It consisted of a flotation chamber made of acid resistant steel and an engine-propelled rotor and it enabled height control. The liquid was mixed by means of the rotor and the air was introduced using a compressor connected with the rotor. The rotor's revolutions were adjusted within the range from 100 to 1,500 rpm and the air flow was controlled using a rotameter. The scum was collected from the surface of the chamber using a mechanical rake as the process continued.

The laboratory tests were conducted using the flotation installation and scrap material obtained from wet silver jewellery grinding introduced in the quantity of 20 g into the flotation chamber. Next, the frothing agent, Corflot, was added as well as oleic acid, as collector and copper (II) sulphate (VI), as the pH regulator (industrial reagents used in enrichment of zinc and lead ores). The

mixture was topped up with water to obtain the volume of 1 dm<sup>3</sup> and then air was being introduced for 1 800 seconds using a compressor connected with the rotor. The rotor operated at 500 and 700 rpm and the air flow rate was adjusted to 2, 4, 6, 8 cm<sup>3</sup>/min. The froth accumulating on the surface was continuously removed during the process using a mechanical rake. After 1,800 seconds, the gas flow was closed, the rotor switched off, and the scum filtered and subsequently dried at 150 °C in a dryer. The sample prepared was subjected to chemical analysis using an atomic adsorption spectrometer manufactured by Unikam.

## TEST RESULTS

Tables 5-7 and Figures 7-8 contain the results obtained in the flotation tests of silver jewellery grinding scrap using Corflot as frothing agent, oleic acid as collector and copper (II) sulphate (VI) as regulator.

Table 5 Results of the flotation tests for silver jewellery grinding scrap using Corflot as frothing agent

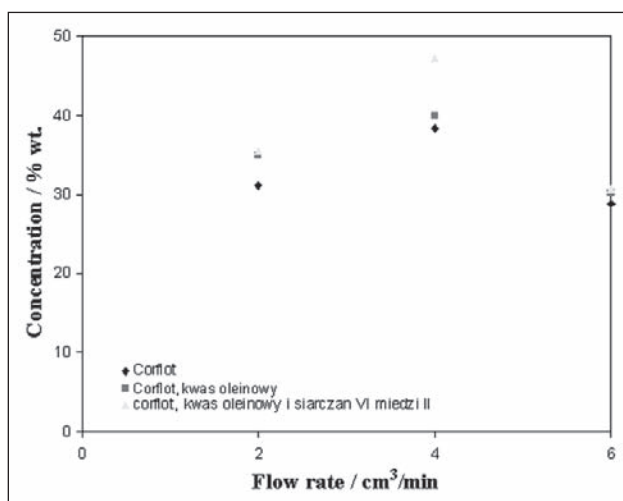
Flow rate / dm <sup>3</sup> / min	Mixer revolutions / rpm	Frothing agent / cm <sup>3</sup>	Collector / cm <sup>3</sup>	Ag concentration in Scum / % wt
2	500	2	----	31,2
4				38,4
6				28,8
2	700	2	---	24,8
4				27,9
6				23,8

Table 6 Results of the flotation tests for silver jewellery grinding scrap using Corflot as frothing agent and oleic acid as collector

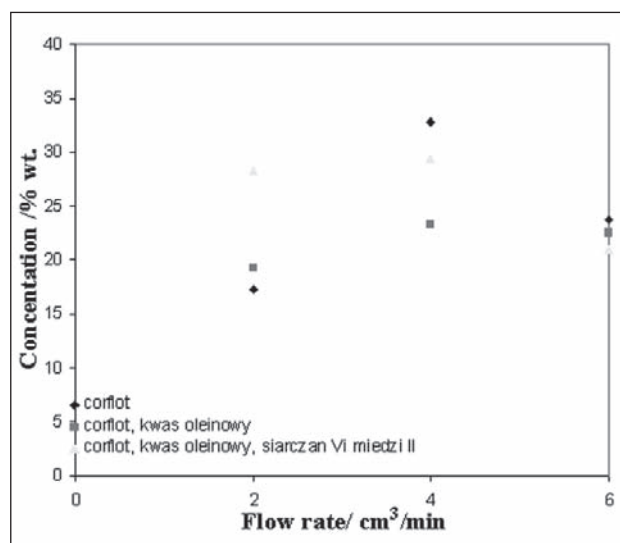
Flow rate / dm <sup>3</sup> / min	Mixer revolutions / rpm	Frothing agent / cm <sup>3</sup>	Collector / cm <sup>3</sup>	Ag concentration in scum / % wt
2	500	2	0,25	34,9
4				36,0
6				30,3
2	700	2	0,25	21,4
4				19,5
6				17,1

Table 7 Results of the flotation tests for silver jewellery grinding scrap using Corflot as frothing agent, oleic acid as collector and copper (II) sulphate (VI) as regulator

Flow rate / dm <sup>3</sup> / min	Mixer revolutions / rpm	Frothing agent / cm <sup>3</sup>	Collector / cm <sup>3</sup>	Regulator / cm <sup>3</sup>	Ag concentration in Scum / % wt
2	500	2	0,25	1,55	35,48
4					47,18
6					30,74
2	700	2	0,25	1,55	23,45
4					27,54
6					23,16



**Figure 7** Changes in silver concentration in scum the independence of increase of air flow rate (500 rpm)



**Figure 8** Changes in silver concentration in scum the independence of increase of air flow rate (700 rpm)

## CONCLUSIONS

1. Based on the analyses of the chemical composition of material samples collected from jewellery grinding scrap, it was determined that its main components are aluminium and silicon in form of oxides as well as silver in metallic form.
2. The analysis conducted using an atomic adsorption spectrometer showed that the silver content in the samples tested was ca. 15 %.
3. The optimum air flow rate for silver enrichment in the process is of 4 dm<sup>3</sup> per minute and the optimum rotational speed of the mixer was 500 rpm.
4. The average content of silver in the post-flotation liquid was ca. 35 % which could be claimed to prove the process useful for the recovery of silver from such materials.

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**Note:** Nowak P. is responsible for English language, Katowice, Poland