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Short Communication

Recovery of Metallic Values in Smart Cards

Candeniz Uysal[1], Selim Ertürk[1], Fatma Arslan[2]* and Cüneyt Arslan[1]

[1]Department of Metallurgical and Materials Engineering, Istanbul Technical University, Istanbul, Turkey

[2]Department of Mineral Processing Engineering, Istanbul Technical University, Istanbul, Turkey

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***Corresponding author:** Fatma Arslan, Department of Mineral Processing Engineering, Istanbul Technical University, Istanbul, Turkey

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Abstract

Today, smart cards which include a small microchip are very widely used in our daily lives. The chief among these is credit cards. In addition, gift shopping card, phone card, sim card, hotel room card involves great proportions. They generally include many precious metals in their body, including noble metals, and semi-noble metals; predominantly gold, silver, copper, etc. The aim of this experimental work is to recover the metals from the smart cards by hydrometallurgical processes namely acidic leaching (HNO_3 and Aqua Regia) followed by precipitation and cementation. Three different types of smart cards; credit cards supplied from different banks, telephone cards produced for Turk Telekom, and sim cards from three different mobile service providers, are used in the experimental work. As a result of this study, almost all copper, silver, and gold are recovered according to the experimental flowsheet proposed.

Introduction

Rapid global technological developments have led to the rising production of electronic waste that presents both challenges and opportunities in its recycling. High metal values in these types of wastes make them attractive for recovery. Treatment processes for metals recovery from them are generally given in three groups as pyrometallurgy (roasting, smelting), hydrometallurgy (leaching, separation), and biohydrometallurgy (leaching, adsorption). Recycling of precious metals from WEEE (Waste Electrical & Electronic Equipment) typically combined with mechanical pretreatment (manually dismantling, separation and shredding) to segregate the valuable components followed by hydrometallurgical treatments through leaching [1-4]. Aqua regia and mineral acids such as hydrochloric acid (HCl), nitric acid (HNO_3), and sulfuric acid (H_2SO_4) are used for the dissolution of PMs (Precious Metals) from WEEE components [2]. Acidic leachates produced are further treated for the recovery of PMs using conventional separation techniques, solvent extraction, membrane filtration, cementation, ion exchange, adsorption, and so forth [3,5].

Smart cards are plastic cards which include a small microchip. This microchip has a memory between 1 and 256 kilobytes of ROM and an operating system that has been written on. The reason why these cards are named as smart cards is that they may contain and process various kinds of data [6]. A smart card, in accordance with the programming of the microprocessor's, can be used as bank card, credit card, driver's license, library membership card, code card for electronic shopping, football club membership cards, electronic wallet, etc., at the same time. Today, smart cards are very widely used in our daily lives. The chief among these is credit cards. In addition, gift shopping card, phone card, sim card, hotel room card involves great proportions. These microprocessors generally include many precious metals in their body, including noble metals, and semi-noble metals; predominantly gold, silver, copper, etc.

Metal ratio of a microprocessor has a big effect on its area of usage [7]. While the size of a smart card (86x54x0.8mm) is regulated by the ISO-7810 standard, the smart card's physical characteristics, chip's location on the credit card, the card material, magnetic stripe, signature region, the hologram on the card, picture, relief, etc. are defined by the ISO-7816 standard [8,9]. Smart cards are divided into three groups depending on the memory; memory only, security logic memory, and memory with its own processor. Additionally, they can be investigated as two groups, according to their connection type; contact and contactless.

Today, smart cards have a big area of usage. According to the data of the Interbank Card Center (BKM), as of the end of June 2021, 79.8 million credit cards, 141.5 million debit cards and 50 million prepaid cards are used in Turkey [10]. In addition, according to the research of We Are Social, the number of mobile phone users in Turkey has reached 59 million. Of these, 77 percent, or 45 million, use smartphones. Thus, it can be said that the number of SIM cards in use is around 59 million [11]. Also, the amount of phone cards, meal cards, etc., such as Sodexho and Ticket is nearly the same as others. As of December 2017, there were 20.5 billion credit, debit, and prepaid cards in circulation worldwide including global general-purpose cards [12]. With consumers worried about touching surfaces during the coronavirus pandemic, the use of mobile payments and contactless credit or debit cards has significantly increased in this term [13]. The aim of this experimental work is to recover the metals from the smart cards by using the similar processes which have used in the recycling of WEEE's.

Material and Method

Three different types of smart cards; credit cards supplied from different banks, telephone cards produced for Turk Telekom, and sim cards from three different mobile service providers, are used in the experimental work. Every smart card is analyzed by wet and dry analysis methods to obtain their precious metal contents. Chemical analyses of the smart cards are shown in the Table 1.

Table 1: Chemical composition of smart cards.

Metal	Credit Card	Sim Card	Telephone Card
Cu	11.16%	14.90%	4.87%
Au	0.12%	0.14%	0.04%
Ag	0.13%	0.13%	0.03%
Ni	1.57%	1.74%	0.54%

Chips are taken from the smart cards by a specially designed apparatus and weighted. After chips are dismantled from the smart cards, they were hold in hot water for 30 minutes to separate plastic part and chip. Weights of the raw smart card, taken part (chip and plastic body) and chip only are given in Table 2 and photographs of smart cards and chips are shown in Figure 1. Recycling of the plastic residue, from which the chip is removed is not a subject of this research.

Table 2: Weight of the various smart card parts.

	Raw Card	Chip + Plastic	Chip Only
Credit card	5.25g	0.20g	0.10g
Phone card	5.30g	0.24g	0.05g
Sim card	0.38g	0.19g	0.09g

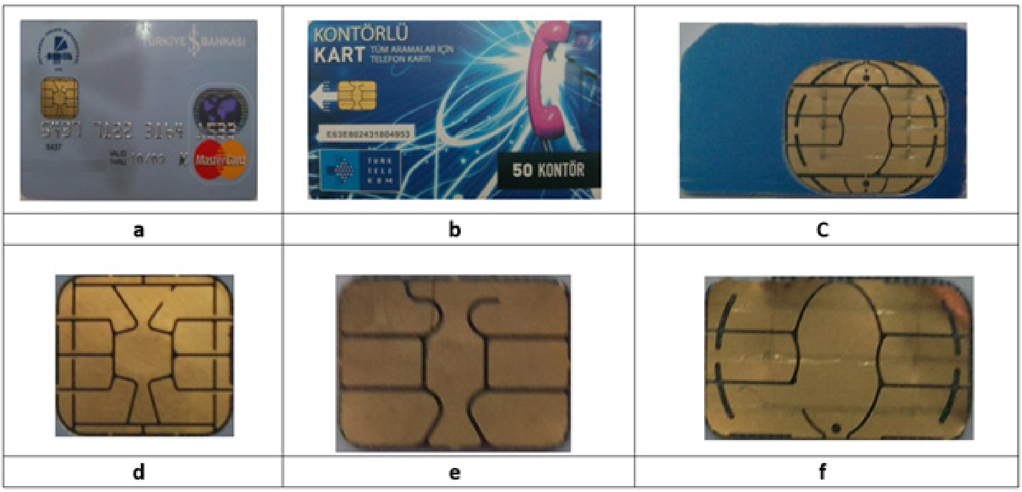

Figure 1: Photographs of the smart card and chips in different steps of the process (a) Credit card (b) Telephone card (c) Sim card (d) Credit card chip (e) Telephone card chip (f) Sim card chip.

Smart cards contain more than one metal (Au, Ag, Cu, Ni, and Zn) which exist all together. Their similar physical and chemical properties make it hard to separate them individually. At first step; silver, copper, and nickel are taken by HNO_3 leaching. After that, copper and silver are separated by cementation. Silver is precipitated by copper powder from that solution. Afterwards copper is separated by zinc powder. Residue from HNO_3 leaching is treated with aqua regia. Aqua regia is the only aqueous mixture which dissolves gold. Gold is precipitated from the acidic solution selectively. The most known chemicals for gold precipitation from acidic solutions are ferrous sulphate, sodium nitrite, sulphur dioxide, and sulphides [14]. Sodium metabisulphide is chosen as the precipitation agent. The practice of gold precipitation by sodium metabisulphide was developed in 1916 at the Nipissing mill to replace aluminum precipitation [15,16]. Flow sheet that has been applied on the experiments is given in Figure 2.

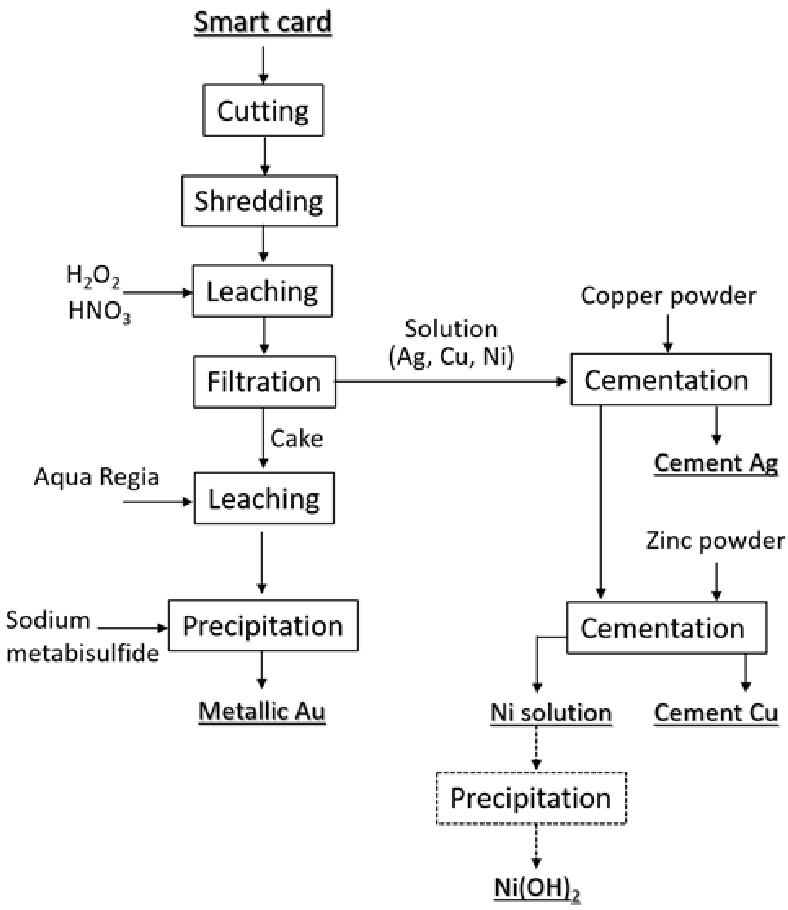

Figure 2: Flow sheet to recover metallic values in smart card chips.

Results

Nitric acid leaching and cementation experiments

In the nitric acid dissolution experiments five different solutions (1-5%) are prepared and shredded chips are boiled for 30 minutes in that solutions separately. As a result, silver, copper, nickel, and zinc in the chip dissolve completely. After that, these metals are separated selectively by precipitation methods. Metallic ion concentrations after HNO_3 leaching are given in Table 3.

Table 3: Metal concentrations after 5% HNO_3 leaching (in ppm).

	Ag	Cu	Ni
Credit Card	6.845	456	50.4
Sim Card	2.475	600	84.6
Telephone Card	0.804	760	88.7

Aqua regia leaching and gold precipitation experiments

Aqua regia (a mixture of acids containing 3 units of HCl and 1 unit of HNO_3) is a highly oxidizing acid in which gold dissolves easily. HNO_3 leach residue is leached in 5% aqua regia solution and all of the metallic parts in chip dissolve after 15 minutes of reaction time. Results are given in Table 4.

Table 4: Metal concentrations after 5% aqua regia leaching (in ppm).

	Au	Ag
Credit Card	3.561	0.166
Telephone Card	7.393	0.109
Sim Card	6.297	0.206

One of the most known chemicals for gold precipitation is the sodium metabisulphide. Precipitation reaction with sodium metabisulphide is given below:

$$2\ AuCl_3 + 3\ Na_2SO_3 + 3\ H_2O \rightarrow 2\ Au + 6\ HCl + 3\ Na_2SO_4$$

1M sodium metabisulphide solution is added to the aqua regia solution after dissolution and stirred at 600-800rpm for 15 minutes. At the end It was found that gold is fully precipitated.

Conclusion

It can be seen from the experiments conducted in this work, silver and copper can be separated from nitric acid solutions by cementation successfully. Gold is precipitated by sodium metabisulphide from aqua regia solution with more than 90% for all the smart card types. Nickel in the solution can also be precipitated as nickel hydroxide. It can be concluded that, although a single smart card's metallic value may seem to be very low, it could present enormous economic value when we look at the amount of its global production.

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