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Abstract

Possibilities for Recovering Indium from Electronic Devices †

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1. Introduction

Indium as indium tin oxide (ITO) is used in a wide range of products, from transparent conducting oxide films to gas sensors and touch screens to photovoltaic panels (PVs) [1]. Most of the current indium consumption (in the form of ITO) is attributed to electronics, where 60% of the total indium is used in flat panel displays (FPDs), 11% and 9% is used in solders and PV, respectively, 7% is used in thermal interface materials, 5% is used in batteries, 4% is used in alloys/compounds, and 3% is used in semi-conductors and LEDs [2]. Due to the growing demand for electronic devices and renewable energy sources, the demand for indium (classified as technology-critical elements, or TCEs) will be systematically increasing in the coming years and is expected to gain significant growth in the forecast period of 2025 to 2030 [3]. An insufficient rate of indium recycling is currently observed. However, recycling indium, like most TCEs, is difficult due to the dispersion of metals (occurring as micro-components) in electronic components and the material heterogeneity of the components [4]. Table 1 shows the indium content in electronic equipment and PVs. The research on indium recovery includes pyrometallurgical, hydrometallurgical, and biohydrometallurgical methods [5,6]; however, a complete recycling cycle for many pieces of equipment containing this critical metal has not yet been developed.

Table 1. Content of indium in electronic devices and PVs [7].

Indium g/unit	Computer	Screen	Cellphone	LED TV	CdTe	CuInGaSe
	0.040	0.082	0.010	0.003	0.015	0.120

This paper presents the results of indium leaching from waste LCD display glass in the presence of sulfuric acid (VI). This work aimed to determine the influence of selected leaching parameters (acid concentration and O_3 concentration) on the indium digestion process.

2. Materials and Methods

This research involved the use of waste from mobile phones, which were manually disassembled to separate individual elements (housings, printed circuit boards, and batteries) and the glass material that serves as the ITO carrier from the polymer foils of the display. The glass layers closely bonded to the polarizing foil were separated using acetone (cut pieces of approx. 1 cm^2; time, 24 h). The dried, separated glass material from ITO was ground, and a selected glass fraction with a grain size of 0.2–0.5 mm was used for further research. Leaching was carried out in an open system with a mechanical stirrer (250 rpm) for 5 h using 250 mL of sulfuric acid (VI) solution and 2.5 g of a sample of ground glass material. Variable concentrations of sulfuric acid (VI) were used—1 M, 0.5 M, and 0.1 M, and ozone concentrations in the range of 1 g/h, 3 g/h, 5 g/h. A Korona L SPALAB ozone

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generator was used to produce ozone during the tests. Concentration analyses were carried out using the MPAES method.

3. Results and Discussion

Figure 1 shows the change in indium concentration for leaching systems using H_2SO_4 at different concentrations: 1 M, 0.5 M, and 0.1 M. An increase in indium concentration in leaching solutions was recorded for all tested systems. The greatest increase in concentration occurred in a 1 M solution of sulfuric acid (VI)—1.64 mg/dm^3, within 5 h.

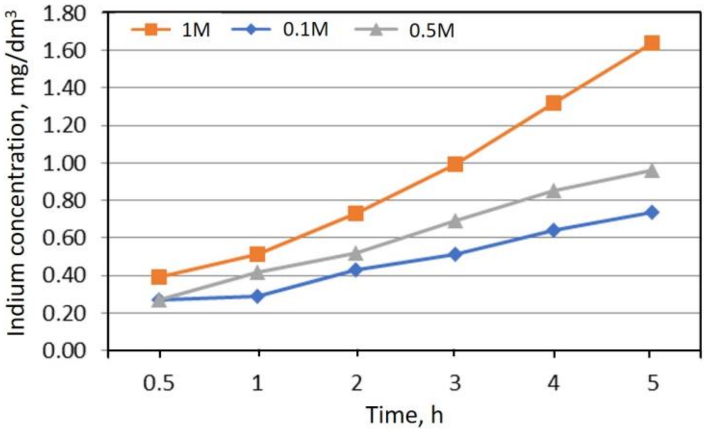

Figure 1. Indium concentration changes in solutions over time [8].

This research used ozone as an effective oxidizing factor at room temperature with negligible environmental impact, which was successfully used in the hydrometallurgical leaching of zinc, copper, antimony, silver, gold [9], or platinum group metals (PGMs) from spent auto catalyst converters [10]. The effect of ozone addition on the efficiency of indium leaching was examined for two extreme concentrations of sulfuric acid (VI): 1 M and 0.1 M (Figure 2).

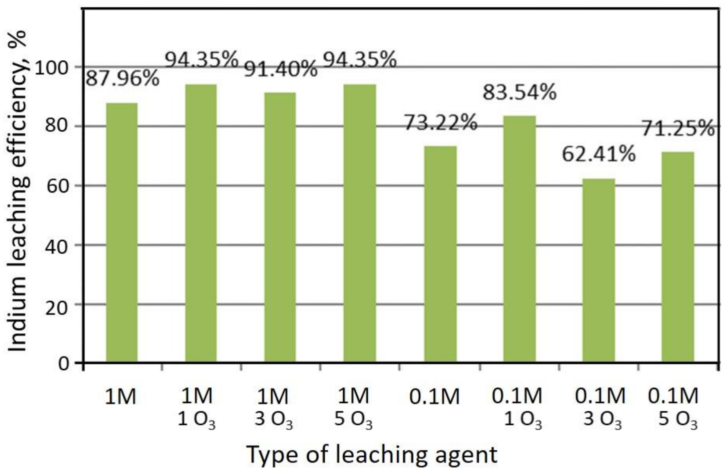

Figure 2. Indium leaching efficiency; ozone concentration g/h [8].

The highest leaching efficiency was observed in the 1 M acid systems with the addition of ozone, although the influence of O_3 on the leaching efficiency was negligible, not exceeding 1.5% compared to the 1 M system without the addition of ozone. Changing the O_3 concentration (1–5 g/h) did not affect the degree of indium transfer to solutions. For the 0.1 M acid system with the addition of ozone, the highest results were obtained using 1 g O_3/h (83.54%). The test results indicate that a higher concentration of sulfuric acid intensifies the digestion of indium, while the addition of ozone does not significantly affect the leaching efficiency. Despite its good oxidizing properties, ozone did not increase the degree of dissolution of the indium contained in the ITO LCD glass.

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