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ROZPRAWA DOKTORSKA

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Określenie stopnia odzysku miedziowców z odpadu płyt obwodów drukowanych metodą mechaniczną i termiczną

Determining the level of recovery of copper group metals from waste printed circuit boards using mechanical and thermal methods

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Abstract

With the increasing technological development of societies, the number of devices containing electronic printed circuits boards is also increasing. The growing supply and shorter usage time of these devices lead to the generation of a growing amount of waste electrical and electronic equipment (WEEE). According to current law, such waste is classified as hazardous and must be selectively collected and processed. The issue of e-waste is a global problem, primarily caused by the increasing number of newly sold devices each year, which need to be processed after their use. Otherwise, they will have a negative impact on the natural environment, and valuable resources such as precious metals contained in them will be lost. This study focuses on determining the amount of electronic waste generated worldwide, in Europe, and in Poland, with particular emphasis on waste printed circuit boards (WPCB). The construction and production specifics of new PCBs are discussed, along with the significance of base metals in electronic scrap, including WPCBs, and their global consumption in electronics manufacturing. The value of Au/Ag/Cu in Polish zlotys [PLN] as of 03-04-2023 is determined to assess their worth in the waste printed circuit boards prepared for the research. Mechanical, pyrometallurgical, and hydrometallurgical processes are characterized as global technologies for managing WPCBs. Three research stations have been prepared for the doctoral research:

1. General WPCB sample preparation station - all equipment in the station is provided by the Secondary Raw Materials Laboratory at the Metallurgical Department of Łukasiewicz Research Network - Institute of Non-Ferrous Metals in Gliwice.
2. Thermal analysis station - Thermal process installations are available in the Secondary Raw Materials Laboratory at the Metallurgical Department of Łukasiewicz Research Network - Institute of Non-Ferrous Metals in Gliwice.
3. Mechanical analysis station - The water table SwP 1-0.5 used for testing is owned by Phoenix Surowce company.

The study focuses on investigating the physicochemical properties of printed circuit boards, particularly their calorific value and mass loss impact using two methods: thermogravimetric analysis coupled with differential scanning calorimetry (TG-DSC) and a prototype DL2 apparatus for mass loss measurement. The study describes the chemical analysis methods employed in examining waste printed circuit boards. The principles of preparing average samples for direct thermal and mechanical tests from WPCB materials K1 and WPCB T1 are schematically presented. During the preparation of average samples, tests for bulk density and sieve analysis of the research materials were conducted. The chemical composition of the average samples was determined using WD XRF, volumetry, FAAS, and ICP-MS methods.

The value of Au/Ag/Cu in Polish zlotys [PLN] was determined for the WPCB K1 and WPCB T1 average samples. Eight pyrolysis tests were performed, four for WPCB K1-T and WPCB T1-T each, at two set temperatures of the pyrolysis chamber: 450°C and 600°C. The process parameters, mass results, temperature ranges, and gas concentrations are presented in process tables. After the thermal process, chemical analyses were conducted, and the values of copper-based metals [PLN] in the carbonates of WPCB K1 and WPCB T1 were calculated.

The study also conducted 16 enrichment process tests for material from waste printed circuit boards on a water table within the particle size classes <2 mm and <1 mm. Eight tests were performed for WPCB K1-M and WPCB T1-M using different parameter settings on the SwP 1-0.5 table. The value of copper-based metals [PLN] in the individual fractions obtained during the water-based enrichment process was determined. The results of the enrichment of WPCB K1 and WPCB T1 materials using the pyrolysis method in the DL1 apparatus and the water table SwP 1-0.5 were compared. It was determined which results showed the highest concentration levels of copper-based metals and generated the highest level of recovery. Possible further research and commercial steps regarding the management of WPCBs were outlined in the study.