SILESIAN UNIVERSITY OF TECHNOLOGY

Faculty of Mining, Safety Engineering and Industrial Automation

Department of Geoengineering and Raw Materials Extraction

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DOCTORAL DISSERTATION

Eco-efficient technology for recovering metals from printed circuit boards

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Abstract of the doctoral dissertation

Eco-efficient technology for recovering metals from printed circuit boards

Waste electrical and electronic equipment (WEEE) is currently one of the fastest growing waste streams. Improper storage or treatment of WEEE can cause environmental problems and environmental degradation. The rapidly growing volume of this waste is becoming a challenge for companies recovering valuable substances, and the significant increase in demand for electronic devices due to COVID-19 may further increase the production of WEEE in the coming years. An element found in almost all WEEE is Printed Circuit Boards (PCBs). The most used are FR-4 type PCBs, which are constructed from a composite made of glass fibre and epoxy resin. The FR-4 Waste Printed Circuit Boards (WPCB) composite contains embedded metallic pathways containing large amounts of metals such as Cu, Fe, Al, Sn, rare earth elements, Ta, Ga and others from the lanthanide group, and the precious metals Au, Ag, and Pd. The WPCB FR-4 also contains metals hazardous to human health and life and the natural environment, such as Cr, Pb, Be, Hg, Cd, Zn, Ni. Therefore, to protect the deposits and the environment, WPCB should be processed according to the principles of a circular economy and sustainable production.

The most common recycling methods for WPCB are chemical treatment, involving their dissolution in acids or incineration. In addition to the high complexity of these methods and the high emissions to the environment, there is a loss of non-metallic parts that could be used for other production or manufacturing processes. Alternative ways of processing WPCB are mineral engineering methods. These show a much lower environmental impact, but due to the difficulty of releasing metals from the WPCB composite, involving the need for several technological processes, they are less commonly used.

In light of the aforementioned, the thesis was formulated as follows: there is a potential for the development and implementation of an eco-efficient technology for the recycling of used printed circuit boards, utilizing mineral engineering processes and adhering to the principles of sustainable production and a circular economy.

The main objective of the dissertation was to experimentally verify the applicability and optimisation of known mineral engineering methods, the integration of which will allow the development of an efficient and economically viable technology for the recycling of used printed circuit boards that is compatible with the principles of sustainable production and a circular economy.

The purpose of the dissertation was to assess the unit processes, such as disassembly, crushing, grinding, and separation. Then, the products were secured for transport. The evaluation was conducted on three levels, including process efficiency, process and investment costs, and impact on the natural and human environment. In particular, the dissertation presents the results of studies on crushing, grinding in a knife mill using liquid nitrogen, electrostatic separation, flotation, gravity separation using a cyclofluid separator and concentration table, and securing products for transport. The main achievement of the work was the development of an integrated WPCB recycling technology providing an alternative to current chemical recycling methods. A high level of release of metals from the WPCB composite was achieved using a knife mill at cryogenic temperatures, as well as an efficient separation of metals from the WPCB composite using electrostatic separation. Furthermore, based on economic analyses and environmental and human impact assessments, it has been demonstrated that the proposed technology is cost-effective and highly efficient, and it can be deemed compatible with the principles of sustainable production and a circular economy.