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Photocatalysis as a Potential Mean of Metallic Electronic Waste Recovery: A Review

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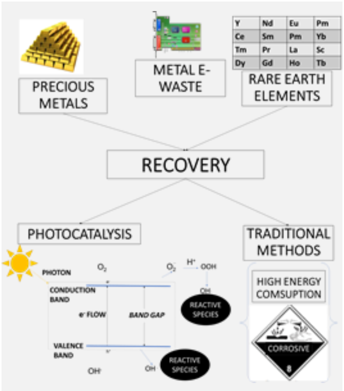

In the present work the use of photocatalysis as a mean to recover metals from e-waste is investigated to get an overview of possible answers to this problematic using photocatalysis. High value materials can be obtained from e-waste like rare earth elements and precious metals and its recovery is imperative to green energy solutions. Photocatalysis can used to recover these important materials by incorporating it and creating innovative systems with higher efficiency or by recovering high purity quantities of the metals without needing hazardous material and high energy consumption used in traditional methods. Herein we present different ways to reuse and reintroduce these strategic resources utilizing photocatalysis for an overview of a very promising field contemplating state-of-the-art technology.

Introduction

It is undeniable the necessity of electronic appliances in our society, and their innovative technologies are making them smaller and smaller and more efficient. They already use a lot of elements that have a high interest in recovery, like the precious metals (PM's) and other elements like Cu, Si, Fe. With the innovation other elements are introduced to the production cycle, like rare earth elements (REE's) [1].

Rare earth elements are a strategic resource applied in state-of-the-art technology such as microchips, permanent magnets, solar panels and high-end batteries for electric cars. That's why this important resource has been thoroughly investigated by super potencies like USA and China when it comes as a solution to carbon neutrality policies promised to be in vigor by 2060 [2].

Even though traditional methods are well known and applicable they still use a lot of reagents that may well be as bad as the residue being treated and/or may not be energy efficient, like strong acids and secondary residues like ash, slags or any hazardous waste derived from these methods. In that sense, the search for materials that are more selective and efficient and new techniques that can be used for different concentrations and types of residues are needed [3].

Photocatalysis is a well-known technique that was created in the 70's for H_2 production from water using TiO_2 as semiconductor photocatalyst irradiated with UV light [4]. Nevertheless, this technology can be utilized for multiple purposes. Its main aspect, the photogeneration of various highly reactive species created by the reaction, can be applied to various applications such as the removal of organic pollutants like pharmaceuticals and dyes from water sources, dissolution of metallic components, development of solar panels, and energy storage [5]. This study aims to provide an overview of how e-waste can be treated through photocatalysis and to compare these new techniques with traditional methods for recovering precious metals (PMs). By analyzing this information, we hope to identify trends and determine the available solutions for the recovery of rare earth elements (REEs) from e-waste.

E-waste and Photocatalysis

Photocatalytic mechanisms offer a promising avenue for enhancing the recovery of metals from e-waste through various methods. While photocatalysis can already complement current electrodeposition techniques for precious metals, its potential extends far beyond, as it enables metal recovery without the need for external current. Studies have even demonstrated the solubilization of various precious metals using just TiO_2 and light radiation. Moreover, TiO_2 exhibits high reusability, with the ability to be reused up to 100 times, making it an attractive option for scaling up operations [6]. This approach, devoid of strong acids, showcases the efficiency of photocatalysis compared to traditional methods. Furthermore, it's feasible to develop superior materials for recovering precious metals (PMs) using e-waste solutions. For instance, a study reported the formation of a heterojunction between TiO_2 nanoparticles and gold, resulting in a core/shell morphology, sourced from solutions used for gold plating electronic devices. Although the resulting material exhibited lower photocatalytic efficiency, less than 10% compared to the pristine material, it displayed more than double the capacity to leach gold from cyanide solutions typically utilized for depositing gold onto TiO_2 surfaces [7]. In other works, the efficiency of H2 evolution was increased more than 20 times compared to materials without deposition [8]. These techniques highlight the advantages of using photocatalysis, whether by increasing efficiency or creating materials better suited for other applications.

There are also methods applying photocatalysis to improve the efficiency of membranes and ion exchange techniques. By introducing a photocatalyst in membranes is possible to achieve a material that has both adsorption and photocatalysis characteristics, highlighting the strengths of both techniques that can selectively adsorb the metal and change its oxidation simultaneously. It was reported a material based on CaCr-LDH synthetized from industrial wastewater containing different metals that can achieve high extraction yields, as high as 1000 mg/L for Cr^{3+} but can also be used with further mineralization for both obtaining high value fuel, CH_4, and for reducing gold from $AuCl_4$ solutions using photocatalysis [9].

Doping materials with REE's is also a clever solution of reintegrating e-waste in the production line. presents a clever solution for reintegrating e-waste into the production line. For example, ZnO doping with Ce was reported to increase its efficiency almost two-fold. Although e-waste wasn't specifically used in this instance, it demonstrates the potential applicability of such methods across various solutions and photocatalysts. [10].

Conclusions

Traditional metal recovery techniques for e-waste are typically not energy-efficient, often involving the use of reagents composed of strong acids or complex extractors that pose hazards. In response to this challenge, an overview of recovering precious metals (PMs) and rare earth elements (REEs) using photocatalysis has been proposed. This approach showcases various techniques aimed at reintegrating e-waste into the production line, with photocatalysis playing a central role. These techniques include metal dissolution without the need for strong acids, deposition to obtain heterojunctions of photocatalysts with improved efficiency across different applications, combining adsorption and photocatalysis using e-waste solutions to leverage the strengths of both techniques, and doping materials with e-waste solutions, offering a promising avenue. Photocatalysis emerges as a shining technique in addressing the e-waste problem, enabling the reintroduction of high-value materials that would otherwise be discarded, thereby enhancing efficiency and creating new materials.

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