Title of the Paper: Microwave-Enhanced Pyrometallurgical Processing for Sustainable E-Scrap Recycling

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Primary Topic: Emerging Recovery & Recycling Technologies
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Abstract:

Electronic scrap (e-scrap), particularly printed circuit boards (PCBs), is an invaluable resource for recovering transition metals and critical elements essential for modern technologies. However, conventional recycling methods often suffer from high energy consumption, environmental degradation, and reliance on chemical-intensive processes. This paper presents an innovative, scalable approach to e-scrap recycling using a patented microwave-enhanced pyrometallurgical process, which offers significant environmental and economic advantages. By employing microwave electromagnetic waves, the process selectively recovers high-value metals from carbon-rich by-products generated through advanced thermalizing processes, such as those developed by our REMADE partner, CHZ Technologies.

The developed method focuses on refining key transition metals, including cobalt (Co), copper (Cu), nickel (Ni), tin (Sn), and zinc (Zn), as well as low-concentration critical elements like tantalum (Ta). This process achieves purities of 95–98% where the main product of this process is a metal sponge material that can be easily refined using secondary processes. This high level of purity is achieved without the use of harsh chemicals, relying instead on electricity-driven operations that significantly reduce greenhouse gas emissions and hazardous waste generation. Moreover, the process is modular and energy-efficient, making it ideal for distributed recycling hubs and contributing to the development of a regional circular economy.

This paper provides a comprehensive overview of the thermodynamic principles governing microwave-material interactions, supported by experimental data from bench-scale operations. Process optimization was achieved through a CALPHAD-based thermodynamic modeling approach, coupled with Multiphysics simulation to enhance reactor design and process efficiency. X-ray diffraction (XRD) and inductively coupled plasma mass spectrometry/optical emission spectrometry (ICP-MS/OES) were employed to characterize the purity of the samples collected at various stages of the process. Key experimental results demonstrate the technology's capability to overcome challenges such as lead contamination and the effective recovery of low-volume critical materials. Additionally, strategies for scaling the technology to industrial levels are discussed.