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Sustainable Recovery of High-Purity Gallium from Electronic Waste Using Akindeju's Heat Integration Methodology and a Novel Three-Stage Crystallization Process: A Circular Economy Approach

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ABSTRACT

The increasing demand for critical minerals, particularly gallium, indium, thallium, and tantalum, necessitates sustainable recovery methods aligned with circular economy principles. This study exemplifies a circular economy approach by illustrating the successful deployment of innovative techniques to recover high-purity gallium from waste electronic circuits. By leveraging two patented methodologies—Akindeju's mixing methodology for heat integration realization and a novel three-stage crystallization process—this research achieves the recovery of 99% pure gallium as nanoparticles.

Gallium, a critical mineral with widespread applications in electronics, semiconductors, and renewable energy technologies, often ends up in landfills when electronic waste is improperly disposed of. This loss not only depletes valuable resources but also poses environmental hazards and increases the burden on virgin explorations. Furthermore, conventional gallium leach-extraction has poor efficiency and is energy intensive with long residence time. Circular economy aims to address these challenges by promoting the reuse, recycling, and recovery of materials, thereby minimizing waste and reducing the environmental impact.

Akindeju's mixing methodology, integral to this process, ensures efficient heat integration during gallium recovery. This technique optimizes thermal energy usage, reducing overall energy consumption and enhancing process sustainability. The implementation of a three-stage crystallization process further refines the recovery method, resulting in the production of gallium nanoparticles with 99% purity. This high level of purity is essential for the material's subsequent applications in advanced technological fields.

The methodology's success underscores the feasibility of circular economy approaches in chemical and process engineering. By transforming waste electronic circuits into a valuable resource, this process exemplifies the core principles of circular economy: resource efficiency, waste reduction, and environmental sustainability. Additionally, the recovery of gallium nanoparticles addresses the growing demand for critical minerals, contributing to

the resilience and security of supply chains. The deployment of Akindeju's mixing methodology and the novel three-stage crystallization process serves as a model for future efforts to recover several critical minerals from electronic waste.

KEY WORDS

Circular Economy, Critical Minerals, Gallium Recovery, Waste Electronic Circuits, Sustainable Technologies, Heat Integration, Crystallization Process, Nanoparticles, Resource Efficiency, Environmental Sustainability

BIOGRAPHY

Michael Akindeju *(Ph. D, FIChemE, FRACI, CEng, RPEQ)* is a certified business architect and adjunct associate professor at the Institute of Science, Innovation, and Sustainability at Federation University, Australia. He is the principal process engineering consultant and director at MKPro Group, where he brings expertise in research, development and engineering to the advanced manufacturing and processing of minerals and nanoparticles. He is the current chair of IChemE Mining & Minerals SIG.

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