


Chapter 10


New Technologies for Lithium–Ion Battery Treatment

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ABSTRACT

The rapid adoption of lithium-ion batteries in electric vehicles, portable devices, and renewable energy systems has created an urgent need for effective, secure, and sustainable end-of-life treatment methods. Traditional recycling methods like hydrometallurgy and pyrometallurgy are energy-intensive and environmentally costly, prompting the development of innovative alternatives. This chapter explores advanced treatments such as cryogenic processing, direct recycling, and AI-powered diagnostics. Second-life applications, particularly for grid storage, are gaining traction. Automation and robotics are increasingly used in disassembly and material recovery, while green solvents and eco-friendly chemical methods aim to reduce environmental impact. These innovations align with circular economy principles and support the global shift toward sustainable energy systems.

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INTRODUCTION

The increasing growth of electric vehicles (EVs), portable gadgets, and renewable energy integration are driving the global spike in demand for lithium-ion batteries (LIBs). These batteries are essential in contemporary energy storage systems due to their high energy density, extended cycle life, and comparatively low rates of self-discharge (Gaines, 2014). However, as batteries approach the end of their useful lives, the exponential rise in LIB usage also brings up serious resource and environmental issues. For recycling LIBs, traditional treatment techniques including hydrometallurgy and pyrometallurgy have been extensively employed. Although these techniques are successful in recovering precious metals like nickel, cobalt, and lithium, they are energy-intensive, produce harmful pollutants, and frequently lead to the loss of important minerals (Li et al., 2013; Zang et al., 2018). Furthermore, a global quest for more sustainable alternatives has been sparked by the negative effects of existing recycling procedures on the environment and their economic inefficiency.

Innovative technologies have surfaced in recent years with the potential to revolutionize LIB end-of-life management. By maintaining the structural integrity of battery components, direct recycling procedures allow for reuse with little processing (Harper et al., 2019). During disassembly, cryogenic processing lowers the dangers of thermal runaway and flammable electrolytes (Fan et al., 2021). To improve recycling pathways, developments in machine learning and artificial intelligence (AI) are being incorporated into battery diagnostics, sorting, and state-of-health prediction (Sun et al., 2022). Additionally, second-life applications are becoming more popular as a way to prolong the useful life of retired batteries in less demanding settings like backup systems and stationary grid storage (Bobba et al., 2018). In addition to improving safety, the integration of automation and robots into disassembly lines also makes treatment procedures more scalable. By using low-energy chemical processes and biodegradable solvents, green chemistry concepts are being used concurrently to reduce the environmental impact of material extraction (Li et al., 2020). The creation and use of such cutting-edge treatment technologies are critical to the shift to circular economy models, which reuse, repurpose, and recycle materials. It is becoming more and more important to overcome the technological, financial, and policy obstacles related to LIB recycling as regulatory regimes change and battery demand keeps growing.

LITERATURE REVIEW

Interest of lithium-ion battery (LIB) end-of-life (EoL) treatment has grown as a result of the batteries expanding use in a variety of applications. Historically,

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