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Lithium-ion Battery Cathode Material Recycling using Deep Eutectic Solvent Based Nanofluids

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A B S T R A C T

The lithium-ion battery industry has been expanding rapidly since its initiation. As the materials used in batteries continue to evolve, the applications for Li-ion batteries have become increasingly and showing a great deal. As the demand for Li-ion batteries continues to rise, finding sustainable solutions for their end-of-life management becomes increasingly important. Li-ion battery recycling is indeed crucial for both environmental and economic reasons, considering the growing use of these batteries in various applications. The recycling industry is struggling, 95% of Li-ion batteries are dumped and end up instead of recycling. The low recycling rates of Li-ion batteries are significant. Improving recycling processes not only reduces waste but also helps recover valuable materials, which decrease the reliance on mining for these resources. Developing a process for recovering cathode materials like Li,Ni,Mn&Co is an important step toward more efficient and sustainable battery recycling. Implementing a flexible recycling system that operates in a closed-loop recycling system can have several benefits. To further encourage the adoption of these recycling technologies, collaboration between researchers, battery manufacturers, policymakers, and waste management facilities is essential. That can drive the growth of this industry and mitigate the negative environmental impact of discarded batteries

Keywords: Recycling, Li-ion batteries, sustainable, waste management.

1. INTRODUCTION

The various waste battery streams are often subjected to either a mechanical or chemical pre-treatment procedure in order to prepare them for later processing. Pre-treatment also increases the efficiency of the overall battery recycling process. The subsequent processes will be more fluid if thorough pre-treatment is administered. Dismantling, crushing, screening, heat treatment, mechanochemical technique, dissolving, and other pre-treatment procedures are the primary pre-treatment processes. Due to their vastly differing physical qualities, several valuable metals, components or materials, such as Cu, Al, and carbonaceous anode, are simple to recover and recycle through pre-treatment. Pre-treatment processing plays a significant role in separating and recovering active cathode materials and organic binders from the current collector as they make subsequent process execution much less energy and time intensive.

A single-stage pre-treatment process in which the spent Li-ion batteries were directly crushed to an appropriate size, followed by fine crushing and sieving to remove aluminum foil which would affect the leaching process. At the conclusion of the process, metallic material was collected using magnetic separation. The pre-treatment technique requires the removal of the organic binder, which is crucial. Thermal treatment, ultrasonic cleaning, and dissolution in an organic reagent are the ideal processes for undertaking such a task.

2. LITERATURE SURVEY

The global sales of electric vehicles are projected to reach 140 million units by 2030, leading to an expected increase in waste lithium-ion batteries (LIBs) to over 11 million tons by the same year.

However, the current recycling rate for LIBs is less than 5% of the total amount used, resulting in environmental and health concerns

Traditional recycling methods for LIBs have high energy consumption, low efficiency, and cause pollution.

This paper proposes a mild and efficient approach to recycle spent cathode materials of LIBs using deep eutectic solvent-based nanofluids. The nanofluids, consisting of deep eutectic solvents and nano additives, achieve 100% liberation efficiency under mild conditions.

The presence of nano additives in the deep eutectic solvents doubles the metal leaching efficiency compared to pure solvents.

The recycling process is enhanced by the mass transfer facilitated by the deep eutectic solvents. The deep eutectic solvents can be reused at least five times without affecting their recycling activity.

3. METHODOLOGY

Fig-1: Flow diagram of eutectic solvent based nanofluids.

The Deep eutectic solvents (DESs) with different molar ratios were prepared using a heating and magnetic stirring process.

The reaction was carried out in a 100 ml round bottom with a magnetic stirrer. EG/ChCl DES (30 ml) was mixed with six nanoparticles (depending on the mass fraction of nanofillers) and then the mixture was heated to 100 °C and stirred for 2hours.

After the reaction, the mixture was cooled to room temperature. Subsequently, the solution was sonicated (53 kHz) for 2 h to obtain the final nanofluid.

The liberation process involved cutting the cathode materials into 1 cm2 size, followed by a reaction in an oil bath at a specific temperature and speed. Liberated cathode materials were collected through vacuum filtration and dried. Leaching efficiency was calculated based on ICP analysis.

4. RESULTS

The paper presents a mild and efficient approach for recycling spent cathode materials of lithium-ion batteries (LIBs) using deep eutectic solvent-based nanofluids.

The collaboration of deep eutectic solvents (DESs) and nano additives achieved 100% liberation efficiency of cathode materials under mild conditions.

The presence of nano-additives in DESs doubled the metal leaching efficiency compared to pure DESs.

The liberation rate of cathode materials could be enhanced by 15% with a 0.8% thermal conductivity enhancement when boron nitride (BN) was employed as a nano additive.

Computational fluid dynamics (CFD) simulation indicated that mass transfer plays a key role in enhancing the recycling rate of LIB materials.

DESs could be used at least five times without affecting their recycling activity.

The liberation rate was calculated based on the mass of the pristine cathode, mass of the cathode after reaction and drying, and the total mass of isolatable active species in pristine cathode materials.

Equations and formulae should be typed in Math type, and numbered consecutively with Arabic numerals in parentheses on the righthand side of the page (if referred to explicitly in the text). They should also be separated from the surrounding text by one space.

Tabel-1: Leaching efficiency of DES based nanofluids in each cycle run

Run	Leaching efficiency of Ni%	Leaching efficiency of Co%	Leaching efficiency of Mn%
1	7.23	0.72	1.22
2	5.6	0.44	1.02
3	3.2	0.34	0.97

5. CONCULUSION

Profitability of Li-ion battery recycling is marginal in developed economies and not economically feasible in regions with low Li-ion battery feedstocks.

Lack of consistent supply of spent batteries is a significant economic barrier for the emerging Li-ion recycling industry. High-volume inception of Li-ion batteries into EVs in the near future is expected to increase the recycling of Li-ion batteries globally.

Hydrometallurgical, pyrometallurgical, or an integration of both processes are used for the recovery and recycling of valuable metals from spent Li-ion battery waste.

Traditional metallurgical procedures are less competitive in terms of economic value compared to more recent, quicker methods. Physicochemical changes in the recycling process need to be thoroughly investigated. Comprehensive Li-ion battery recycling schemes and future research are required.

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