Prompt

You are to write a 3.5 to 4 page paper that discusses an issue or a set of issues related to the handling of electronic waste. The paper should include discussions of the

- status quo,
- future projections
- leading solutions

The format of this paper is as follows:

1. 1 inch margins all around
2. Single spacing
3. 12 point font
4. Single column

The paper may include figures, graphs and charts. If these are not original images, a reference should be included in a figure caption. The wrap around function in MS Word (or equivalent) should be used to embed images into the text.

The paper should include references but the sources are not limited to peer reviewed journals.

The paper should be your original work. You may use AI programs to gather information, but not used to write the paper or even a draft of the paper.

Notes

Current and Prospective Li-Ion Battery Recycling and Recovery Processes

- Li-ion production is growing exponentially (2632)
- 95% of li-ions are not recycled (2632)
- Making recycling closed loop will make recycling more prevalent and available, while reducing the amount of toxic waste (2632)
- lead is toxic, and thus regulated on how it can be recycled (2634)
- Not many places mandate that li-ion batterys be recycled, and even when it is, it is not often enforced (2634)
- Not much economic benefit to recycling, and thus it is not done (2634)

- Recycling was 9% before regulation in the EU (2634)
- Graph is good!!! (2634)
- Mainly laptop batteries are recycled because they are big (2634-2635)
- Main processes are pyrometallurgical (high temperatures) and hydrometallurgical (chemical leaching), typically only recover some of the input materials (2635)
- Some EV batteries are repurposed as grid stabilizers (2635)
- Second life batteries expected to grow from 16 million (2016) to 3 billion (2035)
- Some current techniques use a combination of physical and hydrometallurgical processing to reciver more of the battery (2036)
- Li-ion battery composition is ever changing and thus hard to find a process to properly recycle everything (2036)
- Another good table provided
- Summary: (2037)
    - More government regulation
    - Find processes that recover the cathode instead of just raw materials
    - Need more closed-loop solutions

Li-ion battery recycling challenges

- Many countries have electrification goals, and many car manufacturers have similar goals (2843)
- Li-ion batterys typically last 1-3 years for consumer electronics, and 8-10 years for EVs (2843)
- They create significant environmental concerns due to their high content of heavy metals (2843)
- About 1 million tons of spent Li-ions were made in 2023
- Li-ion batteries come in various shapes and compositions, making them hard to recycle (2844-2845)
    - Shapes: cylindrical, prismatic, and pouch
    - Some are bonded with epoxy
- Battery design is focused more on density than it is on its ability to be recycled (2845)
- Recycling old cathode designs into new cathode designs is a concern to have (2845)
- Anodes are extremely hard to recycle as graphite gets blocked and silicon will crack (2845)
- Modern Solid State batteries, while pushed for by the EV community, are hard to impossible to recycle (2846)
- Hard to remain economically viable as rare-earth materials are trying to be reduced in batteries (2846)
- Hard to convince battery manufacturers to accecpt recycled materials due to their decrease in quality (2847)

Challenges in Ecofriendly Battery Recycling

- Most battery recycling processes involve a mixture of multiple processes including pyro and hydrometallurgical processing. (2)
- Often slag has to be processed hydrometallurgically (2)
- Next generation batteries will have more diverse materials, requiring more research in how to recycle them (5)
- Current recycling methods undergo a long and complicated process. (3)
    - discharge
    - disassembly
    - crushing
    - drying
    - mixing
    - classification
- Modern batteries have extremely high battery densities and make handing them unsafe and difficult (8)
    - Direct electrical shock
    - Thermal runaway hazards
    - Chemical hazards
- Using an inert atmosphere is sometimes a solution to difficult batteries, which make processing them more difficult (9)
- Developing circular recycling techniques is important for reducing CO2 output (9)
- Mechanical treatments use much less energy than metallurgical processes (10)
    - Pyro (4.68 MJ) per kg
    - Hydro (0.125 MJ, 3.76L waste water) per kg
- Batteries need to be more intentionally designed to be recyclable, instead of eco friendliness being an afterthought (11)
- We need to reduce the number of steps in the recycling process, because in order to achieve a 95% effeciency overall, thats roughly 99% for 5 steps (11)
- Different materials have differen toxicities, from polymers being difficult to process to some chemicals emmitting toxic fumes (12)
- Some batteries are so cheap that they will never make a profit being recycled (13)

Key issues for Li-io battery recycling

- Cobalt is the main demand for batteries (2)

- We are still in the era of increasing our virgin demand for Cobalt, but the US is projecting to swap over to almost all recycled cobalt by 2050 (2)
- We should aim to use less rare earth minerals that are hard to recycle (2)
- Constantly rising costs of materials may help recycling efforts (3)
- Majority of costs of a battery are from the raw materials (3)
- Material collection of used or old batteries is a difficult task (9)
- Removing a high voltage battery from an EV is non-trivial and costs money up front (9)
- Transportation is difficult for hazardout materials like batteries (10)
- Many places do not mandate the recycling of LIBs (10)

Lithium-Ion Battery Recycling

- Pyro techniques allow for processing of a wider range of batteries (714)
- Refining brine takes less energy than refining ore, but takes 18-24 months and creates lower grade lithium (715)
- Disassembly typically yields the most material quickly (715)
- Hydro processes create a lot of wastewater, which is another concern for clean recyclingn (715)
- Sorting batteries before recycling is important for maximum recovery rate (716)
- Direct recycling or second life batteries are the least energy intensive way to recycle batteries (716)
- We need to have more recycling plants, as we do not have the capacity to recycle as much as we should current day (717)

Technological improvements in automotive battery recycling

- Lead toxicities (371)
    - Dust contamination
    - Contaminated waste
    - SO2 emissions
    - Chlorinated emissions
- Overall, the contaminations in recycling are worth it for the amount of environmental impact it has (379)

The importance of design in lithium ion battery recycling

- The usage of adhesives and hermetic seals makes disassembly and thus recycling difficult (7589)
- Variation of pack configurations make it difficult to consistently recycle and open battery packs (7591)
- Most batteries are not labeled with their internals, making recycling difficult (7597)

- Storage and transportation are a major concern with the recycling of batteries (7598)
- We need more legislation to make batteries designed in a way to be recyclable (7598)