Lithium Ion Battery Recycling— A CR3 Communication

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TMS has forged cooperative agreements with several carefully selected organizations that actively work to benefit the materials science community. In this occasional series, JOM will provide an update on the activities of these organizations. This installment features the Center for Resource Recovery & Recycling (CR3), a research center established by Worcester Polytechnic Institute, Colorado School of Mines, and KU Leuven

Lithium ion batteries are currently the system of choice, offering high energy density, flexible and lightweight design, and long lifespan in comparison to competing battery technologies.¹⁻³ The demand for lithium ion batteries will increase, and the need to recover and recycle them is pivotal.

At present most lithium ion batteries, such as the ones found in cell phones and laptops, are not recycled. At the Center for Resource Recovery and Recyclability (CR3), we believe that such an open loop industrial cycle is not sustainable; it is our strong conviction that we must develop and establish viable lithium ion battery recycling methodologies. The first reason is for environmental concerns. Although lithium ion batteries are called “green batteries,” the solvent is flammable, and toxic HF can be released when the batteries burn. Second, recycling the batteries is important for economic reasons. The materials used in lithium ion batteries are expensive; the cathode materials for most lithium ion batteries in laptop and cell phones are LiCoO_2 . Li and Co are not renewable materials and are relatively expensive; it only makes good common sense to recycle them. The third reason is for national security. Lithium reserves are mostly located in Chile, Bolivia, and Afghanistan. Although the United States is the leading consumer of lithium minerals and compounds and the leading producer of value-added lithium materials, reserves of lithium minerals in the United States are relatively poor. Having a lithium ion battery recycling program can reduce the reliance on foreign sources.

In a typical 18650 cell, the weight of LiCoO_2 is about 10 g. Using 2006 market

data, and assuming that the active material for a cathode is LiCoO_2 , this translates to 46 million kg of LiCoO_2 . The impact of not recycling lithium ion batteries is exacerbated when we consider the volumes involved. As we look into the near future, lithium ion batteries are gradually being used for larger applications, such as hybrid or electrical cars and grid systems. Researchers at Argonne National Laboratory have estimated that a battery capable of providing 100 miles of range for an electric vehicle would contain between 3.4 and 12.7 kg of lithium, depending on the specific lithium ion chemistry used and the battery range. A123 system has successfully made 2MW power lithium ion batteries, which have been used for the electrical grid and there are 82,000 cylindrical cells and 1.2 tonnes of cathode material. Thus the market for lithium is significant, as are the volumes of critical materials.

Although there is some research work on recycling lithium ion batteries,⁴⁻⁹ the work to date considers LiCoO_2 as the cathode material. In a recent review paper by Xu et al.,¹⁰ all the recycling methods consider LiCoO_2 as the cathode material. However, in the commercial world, the cathode material in lithium ion batteries includes LiCoO_2 , LiMn_2O_4 , $\text{LiNi}_{0.33}\text{Mn}_{0.33}\text{Co}_{0.33}\text{O}_2$, and LiFePO_4 . Thus the recycling methods that will be viable need to take this diversity into account.

At CR3 Professors Yan Wang and Diran Apelian are leading an effort to establish a lithium ion battery recycling research group within. Specifically, the WPI team is exploring innovative options that integrate chemical and electrochemical methods. Key pathways are:

- Develop proper procedures to disassemble lithium ion batteries
- Recycle lithium ion batteries by integrated chemical and electrochemical methods
- Synthesize active materials using recycled materials

The Center for Resource Recovery and Recycling envisions a future that values and increasingly strives to achieve materials sustainability. We are progressing toward a time when materials recovery and recycling are no longer an afterthought, but rather represent a critical consideration in the design and manufacture of materials and products. In the future, the efficiency of materials recovery from the waste stream will increase and recycled scrap will be the preferred input material for materials processes yielding both energy and cost saving.

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