Life-Cycle Assessment for Lithium-Ion Battery

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Abstract

This paper is generalized study on the life-cycle assessment of lithium-ion batteries. A special importance is given on constituent-material and the manufacturing of aforementioned battery. Particular interest is the prediction or estimation of the impact of materials recycling on battery production. Life cycle amassments are done because some of the materials come from comparatively less plentiful resources, therefore a discussion is presented on the recycling of these batteries and its potential impact on battery manufacturing life-cycle impacts. This study represents the early stage of lithium-ion battery life-cycle analysis, in which processes are characterized preparatory to detailed data. Due to the lack of data on battery-materials production, we estimate that the energy use and greenhouse gas emissions associated with battery manufacturing make up only a few percent of a plug-in hybrid vehicle's total life-cycle energy use. Further, the recycling of battery materials can potentially significantly reduce the manufacturing energy.

1. Introduction

Various concerns about energy crisis and climate change there is a need of innovations and a renewed interest in improving energy efficiency is taken into consideration. One of the ways that has been advanced to address these concerns is to electrify personal vehicles, home inverter batteries etc., By recent development initiatives on the part of both government and the auto industry, advanced batteries are seen as an important enabler for manufacturing and marketing electric-drive vehicles, whether they be battery electric vehicles or plug-in hybrid electric vehicles (PHEVs). The successful deployment of viable battery systems for electric-drive vehicles can reduce oil consumption and greenhouse gas (GHG) emissions, depending on how the electricity is produced. However, the battery technologies required to provide traction in vehicles with practical driving ranges between recharging's represent a significant departure in material composition and performance from the lead-acid batteries found in conventional vehicles. As a result of these differences, much has yet to be determined concerning the system-wide performance of electric-drive vehicles and the contribution that batteries make to it. Nonetheless, it is clear that batteries with high specific energies and cycle lives are key factors in successful penetration of electric-drive vehicles into the marketplace, and lithium-ion (Li-ion) batteries are considered by many as the best near-term technology [1].

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The market feasibility of electric-drive vehicles is multi-faced, including affordability, satisfaction, and performance. However, environmental performance of such vehicles is also very important, and is one of the primary reasons for their development in the first place. Owing to the concerns cited above, the two most germane components of environmental performance for vehicles are energy use and emissions, especially fossil-carbon emissions. Because the electric-drive vehicle product system is a departure from its conventional counterpart, there are trade-offs that need to be elucidated. Within any product system, the life-cycle assessments of batteries come from several life-cycle stages, including material production, battery production and use, and finally battery recycling. Unfortunately, much has yet to be learned about the life cycles of batteries, especially Li-ion batteries. For example, little information is available on the assessment with incurred in making lithium- constituent, like lithium cobalt dioxide, lithium nickel dioxide, lithium iron phosphate, lithium hexafluorophosphate, diethyl carbonate, and numerous others. In some cases, even process information is not at hand. This absence makes it very difficult to estimate production energy and emissions based on life-cycle information for similar materials.

This paper reviews what is known on the life-cycle assessments of lithium-ion batteries, particularly the active materials that have not been well considered up to now. Particular interest is the estimation of the impact of battery recycling on the

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production of these materials. While most of the discussion focuses on energy, other impacts are noted when they are significant [1].The potential impact of recycling on battery production life-cycle burdens is presented. Finally, recommendations for additional research needed to fill the information gaps on the life cycles of Li-ion batteries are discussed.

Battery manufacturing (Block Diagram)

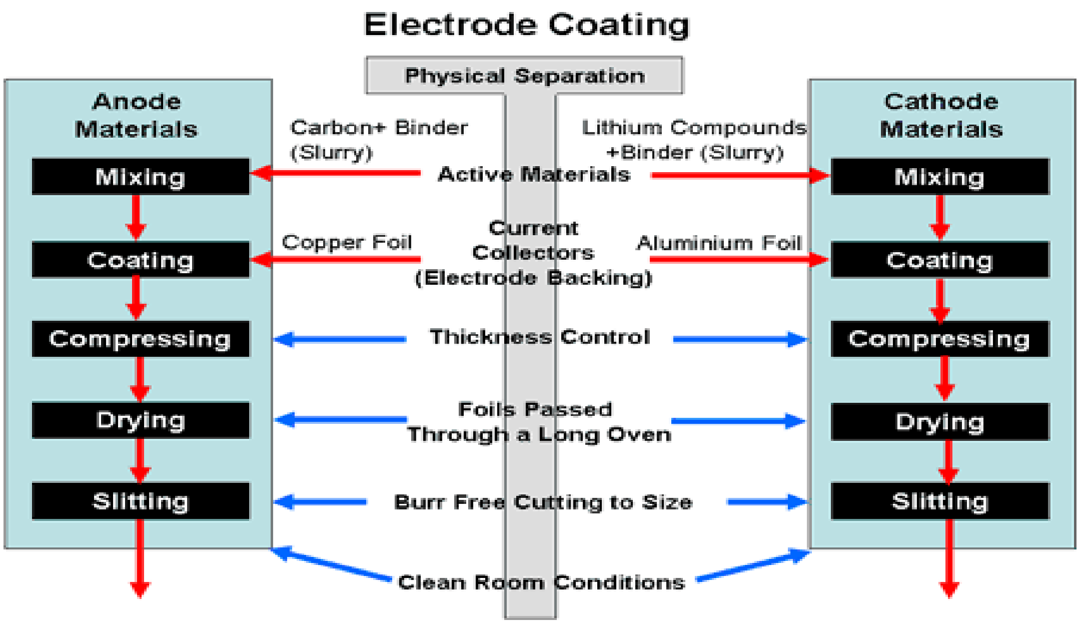

Fig: 1. Electrode coating of lithium ion battery

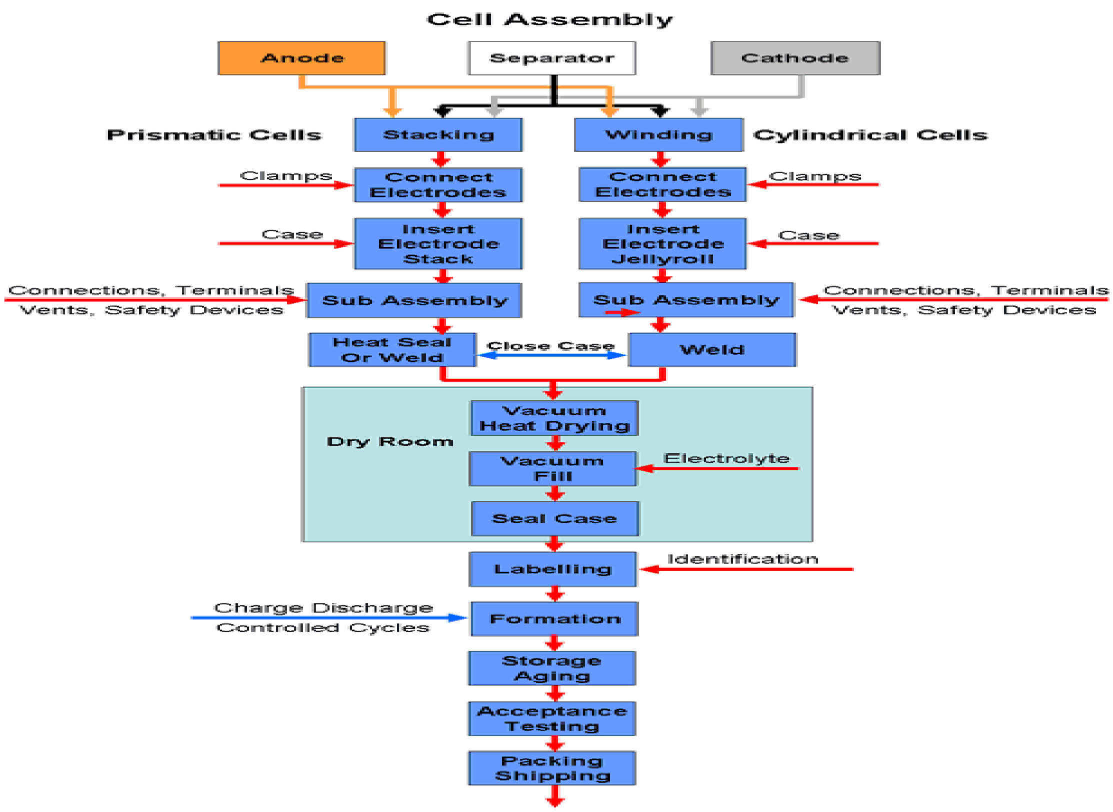

Fig: 2. Cell Assembly of a lithium ion battery

Materials in a Battery and Available Life-Cycle Information Table

Battery	**NCA-Graphite**	**LFP-Graphite**	**LMOSpinel)-Graphite**	**LMO(Spinel)-TiO**
Cathode	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	$LiFePo_4$	$LiMn_2O_4$	$LiMn_2O_4$
Anode	Graphite	Graphite	Graphite	
Battery mass (kg)	75.9	81.6	62.6	106.2
Material composition (mass%)				
Cathode active material	24.8%	22.2%	24.4%	28.3%
Anode active material	16.5%	15.3%	16.3%	18.9%
Electrode Elements				
Lithium (Li)	1.9%	1.1%	1.4%	2.8%
Nickel (Ni)	12.1%	0.0%	0.0%	0.0%
Cobalt (co)	2.3%	0.0%	0.0%	0.0%
Aluminum (Al)	0.3%	0.0%	0.0%	0.0%
Oxygen	8.3%	9.0%	12.4%	22.3%
Iron (Fe)	0.0%	7.8%	0.0%	0.0%
Phosphorus (P)	0.0%	4.4%	0.0%	0.0%
Manganese (Mn)	0.0%	0.0%	10.7%	12.4%
Titanium (Ti)	0.0%	0.0%	0.0%	0.0%
Graphite (C)	16.5%	15.3%	16.3%	0.0%
Carbon	2.4%	2.1%	2.3%	4.5%
Binder	3.8%	3.4%	3.7%	4.5%
Copper Parts	13.3%	13.8%	13.5%	4.5%
Aluminum parts	12.7%	13.3%	12.5%	2.6%
Aluminum Casing	8.9%	9.4%	9.2%	13.7%
Electrolyte solvent	11.7%	14.2%	11.8%	8.8%
Plastics	4.2%	4.6%	4.5%	3.6%
Steel	0.1%	0.1%	0.1%	0.1%
Thermal insulation	1.2%	1.3%	1.2%	1.2%
Electronic parts	0.3%	0.3%	0.4%	0.2%

Cleanliness is essential to prevent contamination and cells are normally manufactured in clean room conditions with controlled access to the assembly facilities often via air showers [2].

Apart from the production test equipment, a battery manufacturer should be expected to have a materials laboratory equipped to carry out a full analysis of the materials used in the production of the cells as well as to carry out failure analysis. The following list shows some of the major equipment used.

- Scanning electron microscope (SEM) for investigating the physical structure of the materials
- Mass spectrometer for analyzing the chemical content of the materials
- Calorimeters for checking the thermal properties of the materials and the cells
- Programmable charge/discharge cycle test equipment to exercise the cells and verify their lifetime
- Environmental chambers and vibration tables for investigating the performance of the cells under their expected operating conditions
- Mechanical stress testing equipment.

2. System Boundries

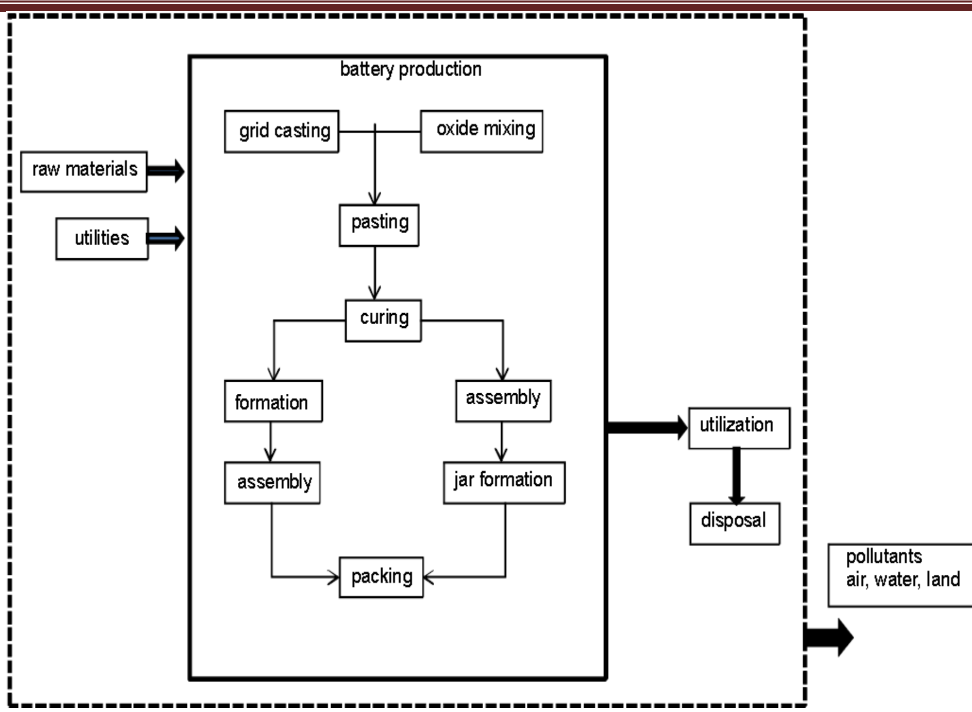

Fig: 3. System boundaries of the battery

3. Environmental impact study

Global warming and acidification were the most apparent forms of impact observed. The stage of obtaining raw materials had the most pronounced impact on the environment, followed by the stage of product use. Production had the least degree of impact, while management of waste batteries through recycling had a positive environmental impact. In the production phase, environmental impacts are dominated by formation (40%), grid casting (30%) and oxide mixing (5%). More than 90% of the environmental impact that occurred during battery use phase arose from charging the battery through burning fuel in the engine. The remaining 10% was from the use of distilled water and plastic bottles. Moreover the information on environmental impact derived from the LCA was incorporated with the principles of MET matrix to facilitate the analysis of other important environmental issues. These issues were analyzed and ways of improving the battery were proposed and separated according to the environ- mental issues that arose during the life cycle of the battery. The result of this study should be seen as environmental performance indication on how to even enhance the environmental friendliness of lead acid battery.

4. Improvements

Following are the various improvements and innovations techniques, which can be done in order to reduce the environmental impact.

1. Super capacitors
2. Change in ratio of lithium
3. Reducing the acid uses
4. Design for environment and innovative recycling process

References

[1] Linda Gaines, Johan Sullivan, Andrew Burnham, IliasBelharouak, LCA for Lithium-ion battery production and recycle, 2010, 90th Annual Meeting of TRB

[2] Kanchanapiya Premrudee, Utaka Jantima, Annanon Kittinan, Lecksiwilai Naruetep, Kitpakonsanti Kittiwan, Boonyananth Sudkla, LCA of lead acid battery case study of Thailand, 39, 10.5277/EPE130108

[3] Santha kumar Kannappan, Karthikeyan Kaliyappan, Rajesh Kumar Manian, Amaresh SamuthiraPandian, Hao Yang, Yun Sung Lee, Jae-hyung Jangand Wu Lu, Graphene based Super capacitors with Improved Specific Capacitance and Fast Charging Time at High Current Density

[4] Industrial Ecology And Sustainable Engineering by Author: Graedel T. E., Allenby B. R.

[5] http://en.wikipedia.org/wiki/Lithium-ion_battery.

[6]http://en.wikipedia.org/wiki/Life-cycle_assessment