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Lithium ion battery production

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A B S T R A C T

Recently, new materials and chemistry for lithium ion batteries have been developed. There is a great emphasis on electrification in the transport sector replacing part of motor powered engines with battery powered applications. There are plans both to increase energy efficiency and to reduce the overall need for consumption of non-renewable liquid fuels. Even more significant applications are dependent on energy storage. Materials needed for battery applications require specially made high quality products.

Diminishing amounts of easily minable metal ores increase the consumption of separation and purification energy and chemicals. The metals are likely to be increasingly difficult to process. Iron, manganese, lead, zinc, lithium, aluminium, and nickel are still relatively abundant but many metals like cobalt and rare earths are becoming limited resources more rapidly.

The global capacity of industrial-scale production of larger lithium ion battery cells may become a limiting factor in the near future if plans for even partial electrification of vehicles or energy storage visions are realized. The energy capacity needed is huge and one has to be reminded that in terms of cars for example production of 100 MWh equals the need of 3000 full-electric cars. Consequently annual production capacity of 10^6 cars requires 100 factories each with a 300 MWh capacity. Present day lithium ion batteries have limitations but significant improvements have been achieved recently [1–8]. The main challenges of lithium ion batteries are related to material deterioration, operating temperatures, energy and power output, and lifetime. Increased lifetime combined with a higher recycling rate of battery materials is essential for a sustainable battery industry.

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1. Introduction

Metals and metal products play important role in our industrial development. Sustainable use of the earth's resources in metal products production, end use, and recycling of metals has to be taken into account. Lithium ion batteries have developed rapidly and different types of chemistry have successfully been introduced. Common applications are power sources for cell phones, laptops, and other portable devices. Development is currently going on in larger applications such as energy storage, partly or fully powered electric vehicles, industrial vehicles, lifts, cranes, harbour machines, mining vehicles, boats, and submarines. Production of cells and battery management system electronics scaling from the individual cell to large modular solutions are ramping up globally. These new applications demand huge amounts of specially made products (copper and aluminium metal foils, electrolyte, lithium metal oxide, separator polymers, binders, graphite, conductive additives, cover bags, tabs, and production hardware). Over the long term, diminishing amounts of easily minable metal ores sites influence material availability. Iron, manganese, lithium, and nickel are still relatively abundant but metals like cobalt, and rare earths are becoming limited resources in coming decades.

The driving force behind this growing interest in Li-ion batteries is both the desire to increase energy efficiency and to reduce consumption of hydrocarbon-based fuels. The deployment of battery systems and the battery industry are expected to grow rapidly over the next 2 to 3 years.

The main challenges of Li-ion battery technology are related to chemistry, material deterioration, lifetime, operating temperatures, energy and power output, and, scaling up, long term material supply for some, and overall costs. Cost targets for Li-ion batteries are ambitious, only a couple of hundred dollars per kWh, while currently the price is closer to $1000 per kWh. In the near future, the price is expected to decrease only modestly due to more challenging chemistry and safety requirements of the electric vehicle (EV) industry.

Batteries are specific in their uses and one type does not fit all purposes. Challenges appear, for example, when individual cells are combined into in larger battery systems. In larger combinations, cooling is required to avoid hot spots and deterioration of lifetime due to overheating. Thermal control is also necessary for safety reasons.

Advanced Li-ion battery systems include electronic control known as the battery management systems (BMS) which is crucial when operating electric vehicles (EV), and hybrid electric vehicles

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Abbreviations

LFP	Lithium iron phosphate
NCA	Lithium nickel cobalt aluminium oxide
LCO	Lithium cobalt oxide
NCM	Lithium nickel cobalt manganese oxide
LMO	Lithium manganese oxide
SOC	State of charge

(HEV). BMS also prevents battery overcharging and deep discharging of the battery.

2. Lithium ion batteries

Batteries are devices that convert stored chemical energy into electricity within a closed system. Electrochemical conversion occurs at two electrodes, *viz.*, cathode and anode. The nature of the reaction is dependent on the chemistry of the electrodes. The power of the battery is more determined directly by the area of the electrodes in contact with the electrode while the energy content is depends more on mass and volume of the active material. In a rechargeable battery (secondary battery), if the external load is replaced with power supply the direction of electrons (and lithium ions) are reversed, and the battery is charged. Lithium ions (Li^+) move from anode to cathode during discharge and from cathode to anode in charging. Electrons move in the external circuit into the same direction as Li-ions. The anode (negative electrode) is usually graphite or lithium titanate. The cathode (positive electrode) is typically lithium metal oxide [1–6].

Lead acid, nickel-metal hydride, and lithium ion batteries are the most common rechargeable batteries. Lead acid battery technology is well proven and is more than a century old. However the lead acid battery shows low gravimetric and volumetric energy density.

Nickel-metal hydride batteries provide reliable cyclability and are commonly used in hybrid vehicles. Their downside is a relatively low energy density and low cycle life and relatively high self-discharge rate up to 10% per month. That makes lithium ion systems an attractive alternative. Figure 2 shows crudely volumetric and gravimetric energy densities for some common batteries.

Lithium ion cells provide a cell configuration that operates at over twice the potential of lead acid or NiMH cells. The reactivity of lithium has been problematic and the low cycle life has been a problem especially under high current densities. However, modern lithium based electrodes provide much better power density and cycle life, and as a result lithium ion cells are being considered for use in larger applications like vehicles.

FIGURE 1. Rechargeable lithium ion battery cell (above) and cell frame, module, and larger system (below). The module and system include BMS and temperature control.

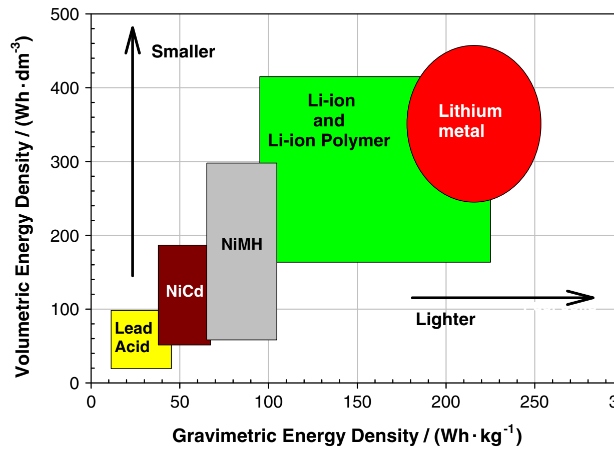

FIGURE 2. Plot of volumetric energy density against gravimetric energy density for common batteries [8].

Battery electrodes provide electron conductivity outside, they store chemical energy, and generate electrical energy by releasing of stored energy.

All these functions should be completed isothermally, and with as little mechanical or chemical strain as possible. New novel lithium cathode materials are continuously developed in universities and company research laboratories to improve battery performance, lifetime, thermal tolerance, power performance, energy density and charge rate, as well as to obtain desired size, thickness, and flexibility.

3. Chemistry

Lithium cobalt oxide, $LiCoO_2$, is the oldest type of lithium-ion batteries. It has been produced since 1991 (Sony). Many other structures developed since which include $LiCo_{1/3}Ni_{1/3}Mn_{1/3}O_2$ (NCM), $LiMn_2O_4$ (LMO), $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ (NCA), and $LiFePO_4$ (LFP). Figure 3 shows an overview of lithium iron phosphate

FIGURE 3. Overview of one of LFP electrode coating lines in European Batteries plant at Varkaus, Finland. The annual capacity of the plant is 100 MWh [9].

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