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Research Article

Power Generation through Lithium-ion Batteries

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ABSTRACT

Electric power is the key energy source in a current and future society, which supports the life of ease and the world's socioeconomic system. As symbolized by the recent rapid growth in the use of compact portable telephones, computers and other electronic devices, it is also evident that batteries have become an essential part of our electricity-dependent day and age. Li-ion batteries are one of the most successes of modern electrochemistry. These batteries, which became a commercial reality about a decade ago, are conquering the markets with increasingly wider applications. Li-ion battery systems have a very limited performance at elevated temperatures and their cycle life is also limited, due to surface phenomena on both electrodes that increase their impedance upon cycling. Li-ion batteries are light weight as compared to the other rechargeable batteries of the same weight. They have a very high energy density hence lot of energy can be stored in it and this is due to the fact that electrodes of lithium ion batteries are made of lightweight lithium and carbon and lithium is highly reactive element. A current trend in technology is towards the deployment of autonomous microdevices, microsensors and batteries are likely to be either the sole power source or a component in a hybrid power source for these new electronics systems. The safety features of commercially produced Li-ion batteries are not sufficient for large size applications. Among the areas where 3-D structures offer promising opportunities are photonic crystals for optical devices and components, optical data storage, magnetic data storage, chemical and biochemical sensors, 3-D lithographic microfabrication and 3-D self-assembled structures. Lithium transition metal oxides such as $LiCoO_2$, $LiNiO_2$, and $LiMn_2O_4$ have received significant attention due to their industrial applications especially in rechargeable lithium-ion batteries.

Keywords: Lithium ion batteries, $LiCoO_2$, $LiMn_2O_4$, Microbatteries and Advantages.

1. INTRODUCTION

The development of new technology for generating electricity has become an important issue in recent years. Solar energy, wind power, hydropower, geothermal energy and other energy sources have become particularly important. Power storage technology is also important for storing generated electrical energy that is not yet required. Energy and environment are the two most challenging issues faced by our society. With the production of oil predicted to decline and the number of vehicles and their pollution impact to increase globally, a safe, low-cost, high efficiency and environmentally friendly alternative power sources have become a most urgent need. Solar energy, H_2 energy, fuel cells and batteries are attracting considerable interest as alternative power sources. Specifically, batteries are portable and easily replaced, commonly used in household and industrial applications such as energy storage and management[1]. Among various existing batteries, lithium batteries have raised the most interest and have a high priority on the development of energy projects in many countries because of their high energy density, long cycle life, cost-effective, long lasting and abuse-tolerant properties[2, 3].

Lithium-ion batteries are particularly useful for portable devices including mobile phones, notebooks and vehicles. The safety and efficiency of lithium-ion batteries must be examined. The electrolyte, separator, anode and cathode in a lithium battery influence its safety[4]. During rapid charging and discharging, chemical and electrochemical reactions precede in the lithium ion cells and the lithium separates out on the electrodes in the battery. Overcharging lithium-ion cells can cause thermal runaway and possibly an explosion[5]. A three-dimensional transient electro-thermal model that is based on a finite volume method has been used to model the thermal behavior of lithium-ion (Li-ion) polymer cells. Overcharging lithium-ion batteries can generate and unsafe voltage. Traditionally, a drill is utilized to put a thermocouple in the center of the positive electrode side of such a battery to measure its interior temperature[6]. Portable energy storage is used in mobile phones, notebooks and electric cars. Accordingly, safety is an important issue in lithium-ion battery research. The formation of lithium dendrites and the high reactivity of metallic lithium with organic solvents can be hazardous[7]. Unwanted reactions among the battery components and the electrolyte that are activated by unforeseen local overheating or short circuits can rapidly increase the temperature of the battery and eventually trigger a fire or explosion. Heat generation and thermal management are crucial the safe operation of lithium-ion cells. Explosive accidents and fire-related incidents that involve Li-ion batteries are still frequently recorded; however, most incidents appear to involve overcharging or overheating[8-10].

2. LITHIUM ION BATTERIES

Improvements in the capacity of modern lithium (Li) batteries continue to be made possible by enhanced electronic conductivities and ionic diffusivities in anode and cathode materials. Fundamentally, such improvements present a materials science and manufacturing challenge: cathodes in these battery cells are normally comprised of metal oxides of relatively low electronic conductivity, and separator/electrolyte compositions must be tuned to readily admit ions, while simultaneously forming safe, impenetrable and electronically insulating barriers. The challenges faced by researchers in this field include the relatively low electrical and ionic conductivity values in cells, an unclear relationship between electrical conduction and ionic conductivity in cathode materials, constantly changing conduction properties in anode materials dependent upon phase transformations, and the inherent difficulty in identifying and measuring the microstructure and conductivity of the solid–electrolyte interphase (SEI) film. Li-ion batteries are light weight as compared to the other rechargeable batteries of the same weight. They have a very high energy density hence lot of energy can be stored in it and this is due to the fact that electrodes of lithium Ion batteries are made of lightweight lithium and carbon and lithium is highly reactive element. Batteries made by lead-acid which weighs 6 kilograms can store the same amount of energy which a 1 kilogram Li-ion battery can store. Charge lost by Li-ion batteries is as low as 5 percent per month as compared to NIMH batteries which has 20 percent charge loss per month. Li-ion batteries do not need to be discharged completely, i.e. they do not have any memory effect which some other batteries have. Hundreds of charge and discharge cycle can be handled by Li-ion batteries.

A current trend in technology is towards the deployment of autonomous microdevices and microsensors and batteries are likely to be either the sole power source or a component in a hybrid power source for these new electronics systems. Batteries are also less hazardous as they become smaller because issues such as runaway heating are minimized. Because batteries have a low heat signature and generate no noise, they cause little physical disruption to microelectronic systems. Another advantage of using micro batteries for micropower sources is the opportunity for direct integration into electronic components. One of the recent themes to emerge from several high technology areas is the prospect of exploiting three-dimensional (3-D) structures. Among the areas where 3-D structures offer promising opportunities are photonic crystals for optical devices and components, optical data storage, magnetic data storage, chemical and biochemical sensors, 3-D lithographic microfabrication and 3-D self-assembled structures[11].

3. CATHODE MATERIALS

Lithium rechargeable batteries are gaining more importance now days because of their capacity compared with conventional rechargeable systems and due to their wide potential use, ranging from portable devices to heavy electric vehicles. The use of transition metal oxides as intercalation cathodes has turned the lithium power sources into the current generation. Lithium transition metal oxides (LTMOs) such as $LiCoO_2$, $LiNiO_2$ and $LiMn_2O_4$ have received significant attention due to their industrial applications especially in rechargeable lithium-ion batteries. These materials are applied on the cathode side where Li is, respectively extracted and stored during the charge-discharge cycle of the battery. The $LiCoO_2$ is commonly used in the positive electrode of lithium rechargeable batteries, due to its high energy density, high specific capacity, high cycling stability and long shelf life whose operation is based on reversible insertion and removal of lithium ions to and from their positive and negative electrodes[12]. $LiCoO_2$ has the α-$NaFeO_2$ structure with the oxygen's in a cubic close-packed arrangement on complete removal of the lithium, the oxygen layers rearrange themselves to give hexagonal close packing of the oxygen in CoO_2. Between these composition limits several phases are formed with varying degrees of distortion of the ccp oxygen lattice. In the $LiMn_2O_4$ spinel structure (space-group: Fd3m), a ccp array of oxygen ions occupy the 32e position, Mn ions are located in the 16d site and Li in the 8a site. The Mn ions have an octahedral coordination to the oxygens, and the MnO_6 octahedra share edges in a three-dimensional host for the Li guest ions. The 8a tetrahedral site is situated furthest away from the 16d site of all the interstitial tetrahedra (8a, 8b and 48f) and octahedra (16c). Each of the 8a-tetrahedron faces is shared with an adjacent, vacant 16c site. This combination of structural features in the stoichiometric spinel compound constitutes a very stable structure[13].

4. CONCLUSIONS

Lithium-ion batteries are one of the most successes of modern electrochemistry. These batteries, which became a commercial reality about a decade ago, are conquering the markets with increasingly wider applications. Li-ion battery systems have a very limited performance at elevated temperatures and their cycle life is also limited, due to surface phenomena on both electrodes that increase their impedance upon cycling. They have a very high energy density hence lot of energy can be stored in it and this is due to the fact that electrodes of lithium ion batteries are made of lightweight lithium and carbon and lithium is highly reactive element. Lithium transition metal oxides such as $LiCoO_2$, $LiNiO_2$, and $LiMn_2O_4$ have received significant attention due to their industrial applications especially in rechargeable lithium-ion batteries.

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