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# Current Status of Lithium-Ion Batteries, its Future Prospects and Challenges

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**Abstract:** As a power source, lithium-ion batteries dominate lightweight electronic products, penetrate the electric automobile mart, and are about to enter the electric energy storage service market. The triumph of Mercantile lithium-ion batteries in the 1990s was not attained suddenly but was the outcome of the painstaking study and contributions of many eminent Researchers and engineers. Subsequently, people made many attempts to further progress of the performance of lithium-ion batteries and made some notable improvement. To meet the increasing demand for energy storage, particularly from increasingly popular electric vehicles, intensified research is required to develop next generation. Li-ion batteries with dramatically improved performances, including improved specific energy and volumetric energy density, cyclability, charging rate, stability, and safety. There are still significant burdens in developing the next generation of lithium-ion batteries. In the future, new battery ideas need to be further progressed to improve on lithium-ion batteries. New battery concepts must be further developed to go beyond Li-ion batteries in the future. Brief discussion on popularly studied “beyond Li-ion” batteries is also provided. Compared with all previous refillable battery orders, the sales and profits of lithium-ion batteries have grown rapidly over the past 25 years. The present study focused on the introducing the basic concepts, highlighting the recent progress, and discussing the challenges regarding Li-ion batteries.

## Introduction

Li-ion batteries, as one of the maximum superior rechargeable batteries, are attracting a whole lot of interest within side the beyond few many years. Recently, lithium batteries are the main cellular strength reset for portable digital devices and widely used in mobile phones and computers. Li-ion batteries are taken into consideration the powerhouse for the non-public virtual digital revolution beginning from approximately a long time ago, kind of on the identical time while Li-ion batteries have been commercialized. As one may also have already observed from his/ her everyday life, the growing capability of cell electronics usually needs for higher Li-ion batteries. For example, to rate the mobileulartelecell Smartphone with growing functionalities much less often because the modern telecell Smartphone will enhance pleasant of one’s life. Another critical increasing marketplace for Li-ion batteries is electrical and hybrid vehicles, which require next-technology Li-ion batteries with now no longer simplest excessive energy, excessive capacity, excessive charging rate, lengthy life, however additionally dramatically progressed protection overall performance and high cost. Furthermore, Li-ion batteries may also be hired to buffer the intermittent and fluctuating inexperienced power deliver from renewable resources, which includes sun and wind, to clean the distinction among power deliver and demand. Even greater sun electricity generated at some point of the daytime may be saved in Li-ion batteries to deliver power at night-time while solar mild is not available. Large-scale Li-ion batteries for grid utility would require future batteries to be produced at low cost.

Li-ion batteries have an unmatchable aggregate of excessive strength and strength density, making it the generation of preference for transportable electronics, electricity tools, and hybrid/complete electric powered vehicles. If electric powered vehicles (EVs) update the bulk of fueling powered transportation, Li-ion batteries will notably lessen greenhouse fuel line emissions. The excessive power performance of Li- ion batteries may permit their use in diverse electric powered grid applications, inclusive of enhancing the fine of power harvested from wind, sun, and geo-thermal and different renewable reasserts, hence contributing to their greater huge use and constructing a power-sustainable resources. Therefore Li-ion batteries are of intense interest from both industry and government funding agencies, and research in this field has abounded in the recent years.

**Methodology**

The study adopted a content analysis method to reveal the present status and its prospectsof Lithium-Ion Battery. The data had been incorporated and administered by illustrating relevant contents derived from academic research articles, government databases, newspapers, magazines, original documentaries, and research reports. Both exclusion and inclusion criteria were followed to adjust with the overall objective of the study.

**Early Lithium-Ion Batteries**

Sony was clearly the first to manufacture and sell lithium-ion batteries, several previous studies were prelude to the 1991 product. The concept of a battery wherein the lithium ion moved reversibly among the nice and poor electrodes become first formulated with the aid of using Armand within side the overdue 1970s, the use of intercalation substances of various potentials for the two electrodes and is frequently referred to as a rocking chair battery due to the go with the drift of lithium ions again and ahead among the two electrodes. The concept changed into speedy taken up through Lazzari and Scrosati and applied with a lithiated tungsten dioxide electrode and a titanium disulfide electrode. The potential range was only 0.8 to 2.1 volts and the electrodes both featured high molecular weights, but the important principle was established as the cell cycled for over 60 cycles although the charge voltage was limited to about 2.2 V and discharge to about 1.6 V.

A seminal discovery through the best sufficient laboratory turned into the volume of the own circle of relatives of lithiated transition metallic oxides of the $NaFeO_2$ shape to reversibly deintercalate and reintercalate lithium ions at distinctly excessive potentials (however voltage became confined to save you electrolyte oxidation). Nickel and cobalt in addition to combos of those with Mn, Al, Fe, etc. had been all discovered to have this capacity and the later adoption of this patented material ($LiCoO_2$) shaped the energetic fine material of Sony's lithium ion battery. Slightly later, J. C. Hunter of the Eveready Laboratories observed a brand new shape of $MnO_2$, targeted because the λ design, with a spinal shape, and organized from $LiMn_2O_4$ (additionally a spinel shape), that would be reversibly decreased and oxidized in a no aqueous electrolyte at a excessive ability much like that of $LiCoO_2$ with a comparable holding power. This material was also later selected for a number of higher rate batteries for commercial applications.

The discovery of appropriate bad electrode substances became fairly greater complex than the advantageous electrode substances. Early works on graphite and carbonaceous substances had proven that lithium ions may be intercalated, the system turned into complex via way of means of the co intercalation of solvent molecules, throughout which solvent discount and disruption of the carbon shape evolved. Early work on graphite electrodes, which includes the early patent by Basu of Bell Laboratories, or Yazami of University of Grenoble, did now no longer take this component under consideration and were unsuccessful to use as practical batteries. An important finding by Fong, Von Sacken and Dahn, showed that petroleum coke was much better than graphite for resistance to solvent co-intercalation and reduction, while addition of ethylene carbonate to PC greatly improved the resistance on both graphite and petroleum coke.

**Present Status of Li-Ion Batteries**

A Li-ion battery is built with the aid of using related fundamental Li-ion cells in parallel (to increase current), in series (to increase voltage) or mixed configurations. Multiple battery cells may be incorporated right into a module. For example, the eighty-five kWh battery percent in a standard Tesla automobile consists of 7104 cells. Typically, a primary Li-ion cells includes a cathode (positive electrode) and an anode (negative electrode) which might be contacted through an electrolyte containing lithium ions. The electrodes are isolated from every different through a separator, usually micro porous polymer membrane, which lets in the alternate of lithium ions among the two electrodes however now no longer electrons. In addition to liquid electrolyte, polymer, gel, and ceramic electrolyte have additionally been explored for programs in Li-ion batteries. The fundamental layout of Li-ion cells nowadays remains similar to the ones cells Sony commercialized many years back, even though diverse varieties of electrode materials, electrolyte, and separators had been uncovered.

The industrial cells are usually assembled in discharged state. The discharged cathode substances (e.g., LiCoO2, LiFePO4) and anode substances (e.g., carbon) are strong in ecosystem and may be without difficulty treated in business practices. Yoshiro made a great contribution to the industrial manufacturing of Li-ion batteries through the use of discharged electrode substances in full cells for the first time. During charging procedure, the two electrodes are related externally to an external electric supply. The electrons are forced to be released at the cathode and move externally to the anode. Simultaneously the lithium ions flow with inside the identical direction, however internally, from cathode to anode through the electrolyte.Progresses in Li-Ion Batteries Since the commercialization of Li-ion batteries by Sony, Li-ion batteries have been attracting much attention world widely. The global production of Li-ion batteries continuously increase in the past two decades, especially with popularity of personal mobile electronics devices.

In this manner the external electricity are electrochemically stored with inside the battery with inside the shape of chemical power with inside the anode and cathode substances with one of kind chemical potentials. The contrary happens at some point of discharging manner: electrons flow from anode to the cathode through the external load to do the work and Li ions move from anode to the cathode in the electrolyte. This is likewise recognized as “shuttle chair” mechanism, wherein the Li-ions shuttle goes back and forth among the anode and cathodes in the course of fee and discharge cycles. Progresses in Li-Ion Batteries Since the commercialization of Li-ion batteries through Sony, Li-ion batteries had been attracting a lot interest global widely. The international manufacturing of Li-ion batteries constantly boom with inside the beyond a long time, in particular with reputation of private cellular electronics devices, such as mobile phones and personal computers, and electric vehicles.

Composite alloys, Si, Sn-primarily based materials and 3d-metallic oxides substances have rather better capacities than graphite. However, they suffer from severe volume expansion during the process of lithiation, which causes the fracture of original structure upon lithium extraction, leading to bad electrical contact between particles and current collectors and poor cycling performance. Li metal has the problem of dendrite formation and is not always secure as anode, which defined the failed commercialization of the Exxon’s lithium-ion batteries withinside the 70s. Given the high capacity of Li metal as anode, it should still be worthy for further exploration and research should focus on depressing the dendrite formation issues.

**Future of Lithium-Ion Battery**

Lithium-Ion Battery is international a far used battery which has a sufficient of possibility to be improved. To boom strength density Li-ion batteries, it is far suitable to discover electrode couples

with each high-specific capacities and high operating cell voltage. There are a huge range of anode applicants that might dramatically grow the capacities, in particularly, with highly attractive Si-and Sn-primarily based anodes. It remains difficult to put together Si nonmaterial on a huge scale with low cost.Sn- based anodes suffer from the issue of poor cycling performance due to pulverization.
The future low-cost cathode materials could be Mn-and/ or Fe-based. Therefore, one of the feasible destiny anodes might be Si-Sn-primarily based composites. In comparison to that of anode candidates, the cell capacity is confined with the aid of using the low capability of cathode candidates. The current cathode material of $LiCoO_2$ is highly priced and highly toxic.The more and more famous $LiFePO_4$ has a low ability. The facilely prepared Ni-Co- Mn- based cathodes developed by Argonne National Laboratory are highly attractive, especially from industrial perspective. However, the precise potential remains taken into consideration moderate, and each Co and Ni are costly and poisonous. Future cathode material must attempt to keep away from using both Co or Ni, or different poisonous elements, from environmental views. Additionally, the ideal cathode should be able to reversibly insert/extract multiple electrons per 3d metal. The destiny low-fee cathode substances can be Mn-and/ or Fe-primarily based totally. The problem of intrinsically low conductivity must be creatively addressed, maximum possibly through nanotechnology and nano composites.

Therefore, LCA is an important tool for the development of truly “green” Li-ion batteries in the future, which can contribute to future sustainability. Another important area that should attract deserved attention is techno-economic analysis (TEA) of Li-ion batteries. TEA will help to determine whether a new Li-ion battery system developed is technically and economically feasible for large-scale production. The combination of LCA and TEA studies will help to develop next-generation Li-ion batteries achieving optimized social, environmental and economic impacts.

Intuitive search for new electrolytes that are compatible with both the anode and cathode interfaces is needed if we are to increase the operating voltage. Organic solvents with compatible lithium salts that can offer a wider electrochemical stability window and support a higher operating voltage need to be developed. Solid electrolytes that support a wider electrochemical stability window are being intensively pursued, but the huge charge-transfer resistance at the solid−solid interface between the electrolyte and electrode and the mechanical stability and cost-effective, large-scale manufacturability of solid electrolytes pose problems. Some examples of solid electrolytes pursued are based on garnet, LISICON, NASICON, sulfide, and poly (ethylene oxide) (PEO). Development of new liquid or solid electrolytes with desired characteristics will enable the utilization of the high-voltage (>4.3 V) cathodes mentioned above and could also offer better safety.

Increasing the Charge-Storage Capacity. In the absence of a practically viable solution at present to increase the cathode operating voltage, much attention is being paid toward increasing the charge-storage capacities of both the anode and cathode. In this endeavor, anodes and cathodes that undergo a conversion reaction with lithium rather than an insertion reaction have drawn much attention in recent years. While the capacity of insertion-reaction electrodes is limited by the number of crystallographic sites available for reversible insertion/extraction of lithium, the conversion-reaction electrodes do not have such limitations. They display up to an order of magnitude higher capacities.
Focusing on High-Nickel Layered Oxides. With the challenges encountered with Lithium-rich $Li_{1+x}(Ni_{1-y-z}Mn_yCo_z)_{1-x}O_2$ cathodes, much attention is currently being directed toward increasing the capacity by increasing the Ni content in layered $LiNi_{1-y-z}Mn_yCo_zO_2$. The high-nickel cathodes are emerging as a near-term future technology. As discussed in the previous section, the characteristics of Ni are between those of Co and Mn in almost all the necessary aspects

(chemical stability, structural stability, conductivity, cost, and toxicity). More importantly, $Ni^{3+}$ can be fully oxidized to $Ni^{4+}$ without the loss of oxygen from the lattice, unlike in the case of $Co^{3+}$. Therefore, $LiNiO_2$ is a better preferred layered oxide cathode. Consequently, if it is possible to improve the Li-ion battery it will be more useful.

**Challenges in Li-Ion Batteries**

Although Li-ion batteries are enormously successful commercially, there are nevertheless major disadvantages.

01. The value of Li-ion batteries based on per unit of energy stored ($/kWh) continues to be very excessive, even though the rate changed into lowering during the last decades. The Li-ion battery packs for electric powered motors could price about $600/kWh, and it's miles expected that the price might be decreased to about $200/kWh with the aid of using 2020. In contrast, the common retail price of electricity to clients is about 0.1 $/kWh in 2014 in line with the U.S. Energy Information Administration.
02. The performances of Li-ion batteries degrade at excessive temperature.
03. At the same time, it can now no longer be secure if hastily charged at low temperature. Therefore, protective circuits are usually used keep away from overcharge and thermal runaway. However, the protecting circuits should upload weight burdens and reduce electricity density of the complete batteries.
04. Another disadvantage is the possible venting and fire when crushed, which requires critical safety enhancement.
05. Recently, an awful lot of attempt is shifted to polyanionic components, along with $LiFePO_4$ and $LiMnPO_4$. The main requirements for cathode materials are high free energy of reaction with lithium, incorporating large quantities of lithium and insoluble in electrolytes. Although various promising electrode materials have been proposed, the slow lithium-ion diffusivity, poor electronic conductivity and high cost are limiting their practical applications. Objects in the promising Tesla Model S cars highlight the importance of battery safety. Therefore, active research is continuing in all aspects of batteries, from anode, cathode, separator, electrolyte, safety, thermal control, packaging, to cell construction and battery management. The electrode materials selected are critical to the performances of Li-ion batteries, as they generally determine cell voltage, capacity, and cyclability. There are a number of potential alternative electrode materials to replace carbon-based anodes and $LiCoO_2$-based cathodes.

**Challenges for $LiNiO_2$**

First, it's far very hard to maintain all Ni as $Ni^{3+}$ throughout the synthesis manner at better temperatures (>700 °C), so the lifestyles of a part of Ni as $Ni^{2+}$ outcomes in a volatilization of a part of lithium and formation of a lithium-poor $Li_{1-x}Ni_{1+x}O_2$. This implies a warning ailment among Li and Ni and the presence of Ni with inside the lithium layer can obstruct the charge capability.

Second, $LiNiO_2$ undergoes a chain of section transitions at some point of the rate−discharge procedure, mainly at deep rate related to the removal of a sizeable quantity of lithium from the lattice. This, again, can cause degradation in rate capability.

Third, $Ni^{4+}$ is enormously oxidizing and reacts aggressively with the natural electrolytes utilized in lithium-ion cells. The response outcomes within side the formation of a thick SEI layer, which, again degrades the price capability, will increase the impedance, and consumes energetic lithium.

Fourth, the chemical instability of the oxidized $Ni^{4+}$ outcomes in a change of the layered oxide to a rock s alt $Li_xNi_{1-x}O$ section on the surface of $LiNiO_2$.

Because of those challenges, $LiNiO_2$ become in large part is ignored as a possible cathode for decades. The push to boom the energy density, the ability to gain better capability as $Ni^{3+}$ can be oxidized all of the manner to $Ni^{4+}$, and the unsolvable hassle of the voltage decay related to the lithium-rich layered oxides have reinvigorated the interest in high-nickel-content oxides during the past couple of years.

**Conclusion**

Thelithium-ion era is primarily based on insertion-response cathodes and anodes will preserve for the foreseeable future, regardless of their constrained electricity density dictated through the wide variety of Crystallographicsites to be had in addition to the structural and chemical instabilities at deep charge. Much attempt has been made towards conversion-reaction anodes and cathodes as they provide as much as an order of value better capability than insertion-response electrodes, however their realistic viability is met with demanding circumstances. Renewed interest in employing lithium metal as an anode and replacing liquid electrolytes with a solid electrolyte has emerged recently as they can offer safer cells with higher operating voltages and charge-storage capacity, but only time will reveal their practical viability. With the challenges encountered with the alternatives (conversion-reaction electrodes, lithium metal, and solid electrolytes), a feasible near-term strategy is to focus on high-nickel layered oxide cathodes, liquid electrolytes compatible with and forming stable SEI on both graphite anode and high-Ni cathodes, innovations in cell engineering to fabricate thicker electrodes and reduce inactive components, and novel system integration to realize safer, long life, affordable systems.Twenty five years ago, the lithium ion battery made its debut into the marketplace area due to revolutionary work through Asahi Kasei and improvement and advertising via way of means of the Sony Corporation. The cognizance of lithium-ion batteries passed off hastily and has persevered to show notable development in potential, energy, and power and price reduction. Safety stays a robust situation for the industry, however trends in separator technology have stepped forward the outlook for safer batteries. With current development in new materials, the lithium-ion battery will keep enhancing in all its properties with a success implementation of latest battery standards in active substances, inert substances and cell designs.

**References**

[1]. Deng, D., M. G. Kim, J. Y. Lee, and J. Cho. 2009. Green energy storage materials: Nanostructured $TiO_2$ and Sn-based anodes for lithium-ion batteries. Energ. Environ. Sci. 2:818–837.

[2]. Yoshino, A. 2012. The Birth of the Lithium-Ion Battery. Angew. Chem. Int. Edit. 51:5798–5800.

[3]. Tarascon, J. M., and M. Armand. 2001. Issues and challenges facing rechargeable lithium batteries. Nature 414:359–367.

[4]. Whittingham, M. S. 1976. Electrical Energy Storage and Intercalation Chemistry. Science 192:1126–1127.

[5]. Besenhard, J. O., and G. Eichinger. 1976. High energy density lithium cells: Part I. Electrolytes and anodes. J. Electroanal. Chem. Interfacial Electrochem. 68:1–18.

[6]. Eichinger, G., and J. O. Besenhard. 1976. High energy density lithium cells: Part II. Cathodes and complete cells. J. Electroanal. Chem. Interfacial Electrochem.

[7]. Mizushima, K., P. C. Jones, P. J. Wiseman, and J. B. Goodenough. 1981. $Li_xCoO_2$ ($0<x\leq1$): A new cathode material for batteries of high energy density. Solid State Ionics 3–4:171–174.

[8]. Thackeray, M. M., W. I. F. David, P. G. Bruce, and J. B. Goodenough. 1983. Lithium insertion into manganese spinels. Mater. Res. Bull. 18:461–472.

[9]. Yazami, R., and P. Touzain. 1983. A reversible graphite-lithium negative electrode for electrochemical generators. J. Power Sources 9:365–371.

[10]. Basu, S., C. Zeller, P. J. Flanders, C. D. Fuerst, W. D. Johnson, and J. E. Fischer. 1979. Synthesis and properties of lithium-graphite intercalation compounds. Mat. Sci. Eng. 38:275–283.

[11]. Chan, C. K., H. Peng, G. Liu, K. McIlwrath, X. F. Zhang, R. A. Huggins, et al. 2008. High-performance lithium battery anodes using silicon nanowires. Nat. Nanotechnol. 3:31–35.

[12]. Bates, J. B., N. J. Dudney, B. Neudecker, A. Ueda, and C. D. Evans. 2000. Thin-film lithium and lithium-ion batteries. Solid State Ionics 135:33–45.

[13]. Li, H., X. J. Huang, L. Q. Chen, Z. G. Wu, and Y. Liang. 1999. A high capacity nano-Si composite anode material for lithium rechargeable batteries. Electrochem. Solid State Lett. 2:547–549.

[14]. Xing, W. B., A. M. Wilson, G. Zank, and J. R. Dahn. 1997. Pyrolysed pitch-polysilane blends for use as anode materials in lithium ion batteries. Solid State Ionics 93:239–244.

[15]. Xing, W. B., A. M. Wilson, K. Eguchi, G. Zank, and J. R. Dahn. 1997. Pyrolyzed polysiloxanes for use as anode materials in lithium-ion batteries. J. Electrochem. Soc. 144:2410–2416.

[16]. Wilson, A. M., G. Zank, K. Eguchi, W. Xing, and J. R. Dahn. 1997. Pyrolysed silicon-containing polymers as high capacity anodes for lithium-ion batteries. J. Power Sources 68:195–200.

[17]. Xue, J. S., K. Myrtle, and J. R. Dahn. 1995. An epoxy-silane approach to prepare anode materials for rechargeable lithium ion batteries. J. Electrochem. Soc. 142:2927–2935.

[18]. Deng, D., and J. Y. Lee. 2010. Direct fabrication of double-rough chestnut-like multifunctional Sn@C composites on copper foil: lotus effect and lithium ion storage properties. J. Mater. Chem. 20:8045–8049.

[19]. Deng, D., and J. Y. Lee. 2009. Reversible Storage of Lithium in a Rambutan-Like Tin-Carbon Electrode. Angew. Chem. Int. Ed. 48:1660–1663.

[20]. Lou, X. W., D. Deng, J. Y. Lee, and L. A. Archer. 2008. Preparation of SnO2/Carbon Composite Hollow Spheres and Their Lithium Storage Properties. Chem. Mater. 20:6562–6566.

[21]. Deng, D., and J. Y. Lee. 2008. Hollow core-shell mesospheres of crystalline SnO2 nanoparticle aggregatesforhigh capacity Li+ ion storage. Chem. Mater. 20:1841–1846.

[22]. Zhu, J., K. S. Ng, and D. Deng. 2014. Hollow Cocoon-Like Hematite Mesoparticles of Nanoparticle Aggregates: Structural Evolution and Superior Performances in Lithium Ion Batteries. ACS Appl. Mat. Interfac. 6:2996–3001.

[23]. Deng, D., and J. Y. Lee. 2014. Meso-oblate Spheroids of Thermal-Stabile Linker-Free Aggregates with Size-Tunable Subunits for Reversible Lithium Storage. ACS Appl. Mat. Interfac. 6:1173–1179.

[24]. Kang, B., and G. Ceder. 2009. Battery materials for ultrafast charging and discharging. Nature 458:190–193.

[25]. Arico, A. S., P. Bruce, B. Scrosati, J. M. Tarascon, and W. Van Schalkwijk. 2005. Nanostructured materials for advanced energy conversion and storage devices.Nat. Mater. 4:366–377.

[26]. Winter, M., J. O. Besenhard, M. E. Spahr, and P. Novak. 1998. Insertion electrode materials for rechargeable lithium batteries. Adv. Mater. 10:725–763.

[27]. Poizot, P., S. Laruelle, S. Grugeon, L. Dupont, and J. M. Tarascon. 2000. Nano-sized transition-metaloxides as negative-electrode materials for lithium-ion batteries.

[28]. Nature 407:496–499.

[29]. Winter, M., and R. J. Brodd. 2004. What are batteries, fuel cells, and supercapacitors? Chem.
[30]. Nam, K. T., D. W. Kim, P. J. Yoo, C. Y. Chiang, N. Meethong, P. T. Hammond, et al. 2006.
[31]. Virus-enabled synthesis and assembly of nanowires for lithium ion battery electrodes. Science
[32]. Yi, T. F., X. Y. Li, H. P. Liu, J. Shu, Y. R. Zhu, and R. S. Zhu. 2012. Recent developments in the doping and surface modification of LiFePO4 as cathode material for power lithium ion battery. Ionics
[33]. Xu, B., D. N. Qian, Z. Y. Wang, and Y. S. L. Meng. 2012. Recent progress in cathode materials research for advanced lithium ion batteries. Mat. Sci. Eng. R
[34]. Whittingham, M. S. 2012. History, Evolution, and Future Status of Energy Storage. Proc. IEEE
[35]. Wen, J. W., Y. Yu, and C. H. Chen. 2012. A Review on Lithium-Ion Batteries Safety Issues: Existing Problems and Possible Solutions. Mater Exp.
[36]. Qu, C. Q., Y. J. Wei, and T. Jiang. 2012. Research Progress in Li3V2(PO4)(3) as Polyanion-type Cathode Materials for Lithium-ion Batteries. J. Inorg. Mater
[37]. Oudenhoven, J. F. M., R. J. M. Vullers, and R. Schaijk. 2012. A review of the present situation and future developments of micro-batteries for wireless autonomous sensor systems. Int. J. Energ.
[38]. Du, N., H. Zhang, and D. R. Yang. 2012. One-dimensional hybrid nanostructures: synthesis via layer-by-layer assembly and applications. Nanoscale
[39]. de las Casas, C., and W. Z. Li. 2012. A review of application of carbon nanotubes for lithium ion battery anode material. J. Power Sources .
[40]. Chu, D. B., J. Li, X. M. Yuan, Z. L. Li, X. Wei, and Y. Wan. 2012. Tin-Based Alloy Anode Materials for Lithium Ion Batteries. Prog. Chem. 24:1466–1476.
[41]. Zhang, W. J. 2011. Structure and performance of LiFePO4 cathode materials: A review. J. Power Sources.
[42]. Marom, R., S. F. Amalraj, N. Leifer, D. Jacob, and D. Aurbach. 2011. A review of advanced and practical lithium battery materials. J. Mater. Chem.
[43]. Yi, T. F., Y. R. Zhu, X. D. Zhu, J. Shu, C. B. Yue, and A. N. Zhou. 2009. A review of recent developments in the surface modification of LiMn2O4 as cathode material of power lithium-ion battery.
[44]. Yi, T. F., C. B. Yue, Y. R. Zhu, R. S. Zhu, and X. G. Hu. 2009. A Review of Research on Cathode Materials for Power Lithium Ion Batteries. Rare Metal. Mat. Eng. 38:1687–1692.
[45]. Chung, S. Y., J. T. Bloking, and Y. M. Chiang. 2002. Electronically conductive phospho-olivines as lithium storage electrodes. Nat. Mater. 1:123–128.
[46]. Malik, R., D. Burch, M. Bazant, and G. Ceder. 2010. Particle Size Dependence of the Ionic Diffusivity. Nano Lett. 10:4123–4127.
[47]. Meethong, N., Y. H. Kao, S. A. Speakman, and Y. M. Chiang. 2009. Aliovalent Substitutions in Olivine Lithium Iron Phosphate and Impact on Structure and Properties. Adv. Funct. Mater.19:1060–1070.
[48]. Ma, J., B. H. Li, H. D. Du, C. J. Xu, and F. Y. Kang. 2011. Effects of tin doping on physicochemical and electrochemical performances of LiFe1-xSnxPO4/C (0 <= x <= 0.07) composite cathode materials. Electrochim. Acta 56:7385–7391.
[49]. Wang, D. Y., H. Li, S. Q. Shi, X. J. Huang, and L. Q. Chen. 2005. Improving the rate performance of LiFePO4 by Fe-site doping. Electrochim. Acta 50:2955–2958.
[50]. Zaghib, K., J. B. Goodenough, A. Mauger, and C. Julien. 2009. Unsupported claims of ultrafast charging of LiFePO4 Li-ion batteries. J. Power Sources 194:1021–1023.