Technologies and Materials for Next Generation Rechargeable Batteries

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Rechargeable batteries have been extensively investigated during last several decades according to the development of electronic devices, natural (renewable) energy systems, and electric vehicles. By the way, until 2050, the production of carbon dioxide should be reduced to less than 20% of the present production level. In order to achieve this target, the utilization of natural energy and electric vehicles become very important. The rechargeable batteries used in energy storage and electric vehicle applications have already high energy density and high power density. However, there is still a strong demand to increase the energy density of rechargeable batteries to realize the energy storage devices with smaller size and the electric vehicles with longer mileage. In order to realize higher energy density, an improvement of lithium ion battery has been carried out and new battery systems have been also developed. The improvement of lithium ion batteries has been conducted by using new anode and cathode materials, such as Si based materials, Li-rich cathode materials, high voltage cathode materials and so on. Simultaneously, new battery technologies have been also developed in order to increase energy density of batteries. For example, a thicker electrode and highly dense electrode have been applied to lithium ion batteries. In addition, new electrolyte systems have been proposed for high voltage lithium ion batteries. As new category for cathode materials, transition metal oxide materials which can utilize O^{2-} ion redox during Li^+ insertion and extraction have been proposed as higher discharge capacity cathode. Thus, the improvement of lithium ion batteries has progressed based on both new material chemistry and new battery technologies. However, the energy density of lithium ion batteries may be less than 800 Wh L^{-1} (400 Wh kg^{-1}). The rechargeable batteries with more than 500 Wh kg^{-1} may not be realized by using lithium ion battery technology. Therefore, new electrochemical systems should be utilized for the next generation rechargeable batteries. The battery with Li metal anode and insertion cathode for lithium ion battery is the most promising technology at this moment. Both liquid and solid electrolytes can be applied to the Li metal battery. The Li metal batteries will be constructed in near future. Li-sulfur and Li-air batteries are also new possible technologies for rechargeable batteries. The multi-valent cations, Mg^{2+} , Al^{3+} and Ca^{2+} may be applied to new battery systems. In order to realize these new battery systems, some problems in materials and battery technologies should be solved. Then, new battery systems will be able to be constructed with a real high energy density. The energy density of battery should be discussed based on a prototype cell with a relatively large capacity. In national projects in Japan, new technologies and new materials have been extensively researched to solve key issues for realization of the next generation batteries. A lot of excellent researches have been already done in the projects. Through the development of battery technologies, carbon dioxide production rate will be diminished in the future society.

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