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Recent Development and Scope of Transition Metal Oxide Based Cathode Material - A Review

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ABSTRACT

In the recent years number of research groups have concentrated on cathode material of LIBs. The batteries are promissible power source which can be used in portable electronic devices, electric vehicles and to store the energy from the natural sources. The capacity of LIBs varies with material to material. Nowadays most used LIBs cathodes are based on transition metal oxides. In these review, we describe the different types of cathode material for LIBs as well as their working efficiency.

I. INTRODUCTION

Nowadays, the world is facing the problems of energy crises, such as limited source fossil fuel and pollution by CO_2 emission another serious issue in point of view of environment. To overcome these issues, we are shifting towards the efficient in use of renewable energy sources, such as solar energy, wind energy and other renewable energy sources. But renewable energy sources are depends on whether, so it is need to develop the energy storage device which can be used to store the energy generated from renewable sources, in the portable electronics devices, electric vehicle with high energy density and energy conversion efficiency with the less self-loss and higher safety. Development of energy storage devices is in focus of number of research groups.

Among the various energy storage system, Lithium ion battery are considered among the best choice due to their high operating voltage, high energy density, power density, good cycle rate and relatively good safety[1]. However the current Lithium ion batteries (LIBs) have already reached their practical limits. Therefor a new class of material for cathode for lithium ion batteries needs to be developed with higher specific capacity, high operating voltage, high power density, good cycle rate, high thermal stability, higher safety and low cost.

II. EARLY DEVELOPMENT IN CATHODE MATERIAL

The idea of reversibility was first proposed by Armand in the 1970, using the intercalation materials of different potential for two electrodes [2]. Then Nazzari and Scrosati developed a lithiated tungsten dioxide electrode and Titanium disulfide electrode [3] as cyclable cell up to 60 cycles although with limited charge voltage 2.2 V and discharge haunted 1.6 V. Goodenough laboratory [4] discover the family of lithiated transition metal oxide of $NaFeO_2$ structure of rechargeable lithium ion battery with relatively high potential. Transition metal Nickel and Cobalt with mixture of Mn, Al, Fe, etc. were formed the active positive material of Sony's lithium ion battery.

Slightly later J. C. Hunter of everyday laboratory covered a new form of MnO_2 with spinel structure and prepared from $LiMn_2O_4$ that could be reversibly charge and discharge in no aqueous electrolyte at high potential, similar to that of $LiCoO_2$ with a similar capacity which is used in commercial application.

III. NEW GENERATION OF CATHODE FOR Li-ION BATTERIES

The commonly used Lithium ion batteries include graphite anode and cathode from $LiCoO_2$, $LiMnO_3$ and $LiMn_2O_4$. In the present day, material for the cathode includes $LiCoO_2$, $LiMn_2O_4$ and most developing material $LiNi_xMn_yCo_{1-x-y}O_2$. Among the cathode material layered oxides provides high energy density. Moreover Manganese oxides are more intensively explored high energy density, low toxicity and safety, which shows promising electrochemical properties during cycles [5-13]. $LiMnO_3$ combined with $LiMO_2$ (where, M- Transition metals) [14-16] offers higher energy density than the conventional layered oxide electrodes.

The improper selection of the metal oxide reduces the capacity [17-21] so that the capacity can be improved by selecting appropriate transition metal in $LiMO_2$ (where, M- Transition metals) structure.

The various compounds substituted with nickel such as $Li[Li_{0.2}Ni_{0.2}Mn_{0.6}]O_2$ ($0.5Li_2MnO_3{\cdot}0.5LiNi_{0.5}Mn_{0.5}O_2$) and substituted with both nickel and cobalt: $Li[Li_{0.2}Mn_{0.54}Ni_{0.13}Co_{0.13}]O_2$, ($0.5Li_2MnO_3{\cdot}0.5LiNi_{0.33}Mn_{0.33}Co_{0.33}O_2$) or $Ni[Li_{0.05}Ni_{0.31}Co_{0.31}Mn_{0.31}]O_2$ ($0.1Li_2MnO_3{\cdot}0.9LiMn_{0.26}Ni_{0.37}Co_{0.37}O_2$) have been studied by many authors [22-24]. In which Ni and Co addition are used for providing cycling stability with the high capacity. Moreover, the use of the cobalt helps in reducing the electrode polarization [25].

New stoichiometric Li-rich layered oxides ($xLi_2MnO_3{\cdot}(1-x)LiMn_{0.5}Ni_{0.25}Co_{0.25}O_2$ or $Li[Li_yMn_{1-y-2z}Ni_zCo_z]O_2$) were proposed as high-energy density cathode materials for Li-ion batteries. The analysis of the charge-discharge tests shows that $Li[Li_{0.2}Mn_{0.6}Ni_{0.1}Co_{0.1}]\ O_2$ electrode delivers nearly 350 mAh·g−1 for the first discharge process and 250mAh·g−1 for following cycles. The investigation of the kinetics of the electrode reactions by means of CV and EIS methods confirmed that $Li[Li_{0.2}Mn_{0.6}Ni_{0.1}Co_{0.1}]O_2$ exhibits highest lithium diffusion coefficients, what with obtained electrochemical cycling tests suggest optimal chemical composition of this material ensuring high energy density along with long-term endurance [26].

Lithium-rich layer oxide, $Li_{1.2}Ni_{0.16}Mn_{0.56}Co_{0.08}O_2$ (NMC), is a potential cathode candidate for high-energy density batteries. The synthesis of Cr-doped lithium-rich phases $Li_{1.2}Ni_{0.16}Mn_{0.56}Co_{0.08-x}Cr_xO_2$ (where x=0.00, 0.01, and 0.02) (NMC-Cr) by the sol-gel technique. The Cr-doped materials exhibit much better cycling stability with 100% capacity retention versus 44% for the undoped sample after 50 cycles [27].a

New generation Li-insertion cathode materials includes,

1. $LiMn_{1.5}Ni_{0.5}O_4$ spinel.
2. Layered integral materials comprising Li_2MnO_3 and $LiMO_2$.
3. $LiMPO_4$ olivines, M ¼ Mn, Mn and Fe, Co.

The spinel structure (3D solid-state diffusion options for Li ions) ensures high rate capability. Hence, it is possible to develop high voltage Li-ion cells, based on this cathode material with graphite anodes. It should be noted that during the last decade, considerable experience with this material has been acquired by a number of research groups throughout the world [1]. The safety features of this material are similar to those lithiated transition metal oxides (Li_xMO_2).

Another important novel material for advanced Li-ion batteries is the integrated layered–layered cathode materials, which were developed recently at the Argonne National Laboratory in the United States [28]. It is possible to synthesize composite materials of the stoichiometry, $[Li_2MnO_3]x$ [LiMO2]y and other possible combinations of transition metal cations.

The three composite structures of $[Li_2MnO_3]x$ $[LiMn_{1/3}Ni_{1/3}Co_{1/3}O_2]y$, is Having the optimal composition is around Li_2MnO_3—$LiMn_{1/3}Ni_{1/3}Co_{1/3}O_2$. Intensive studies of these materials are underway, to a much higher capacity and energy density, compared to the first generation of these battery systems. These new cathode materials exhibit the surface chemistry typical of all kinds of Li_xMO_y cathode materials.

IV. CONCLUSION

The rigorous study is going on Li-ion batteries cathode material. There are many challenges for developing cathode material for Lithium ion batteries regarding to new materials that can bring these batteries to high density, high charge-discharge rate, higher safety and that can open for fully EV. There are much more scope to develop the better combination of Li2MnO3 and LiMO2. LiFePO4 is suggested as super cathode in terms of the rate of capability, high capacity, low price, and high thermal stability, nevertheless LiFePO4 can be replaced by other better material.

With the high performance of batteries safety is most important. So, it is need to develop materials with high performance with high safety, so that we can move towards the use green energy.

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