Development of Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$ and LiMn$_{0.8}$Fe$_{0.2}$PO$_4$ Thin Film Electrodes for Next Generation Li-ion Batteries

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Abstract

LiMn$_{1-x}$Fe$_{x}$PO$_4$ and Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$ thin film were selected to investigate the thin film electrode material. The low electronic conductivity and Li$^+$ diffusivity of LiMnPO$_4$ severely limits its electrochemical activity room for maneuver, especially under high current density. On the other hand, Li(Ni$_{0.5}$Mn$_{0.2}$Co$_{0.3}$)O$_2$ can exhibit a promising electrochemical performance among currently cathode materials. However, the Ni/Li mixing and growth of preferred orientation seriously affect the capacity and rate capability. To overcome these drawbacks, DC/RF magnetron sputtering approach will be incorporated. Through intrinsic modification of LiMnPO$_4$ cathode with Fe and C, a better electrochemical performance could be demonstrated in half lithium-ion battery. For layered type material, the Li(Ni$_{0.5}$Mn$_{0.2}$Co$_{0.3}$)O$_2$ is deposited on various buffer layer substrate by reactive magnetron sputtering using single NMC target in an argon/oxygen atmosphere. It is expected that the development of LiMn$_{0.8}$Fe$_{0.2}$PO$_4$ and Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$ would exhibit a great potential to meet the demand of next-generation high power Li-ion battery.

Introduction to Thin Film Battery

<table>
<thead>
<tr>
<th>Advantage for Thin Film Batteries (TFBs)</th>
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<tr>
<td>✓ High energy density</td>
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<tr>
<td>✓ High safety</td>
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<td>✓ Long cyclability</td>
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<tr>
<td>✓ Fast charge/discharge</td>
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<td>✓ High power density</td>
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Characteristic of Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$ Thin Film

SEM images of NMC Thin Film under Various Temperature (a) 400°C, (b) 500°C, (c) 600°C, and (d) 700°C

Electrochemical performance of Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$

(a) Cycling tests for 200 cycles of various electrodes under the same rate of 0.5C
(b,c) Capacities of all samples subject to charge–discharge under different charging rates

The best Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$ quality can be grown at 700°C

Different Epitaxial Layer

(a) XRD pattern of High Quality (003) Oriented LiNi$_{0.5}$Mn$_{0.3}$Co$_{0.2}$O$_2$ Thin Film
(b) Cycling tests for 200 cycles of various electrodes under the same rate of 0.5C

The high quality (003) oriented Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$ thin film were prepared via different epitaxial layer.

The Experimental Process of LiMn$_{0.8}$Fe$_{0.2}$PO$_4$

SEM images of LMFP Thin Film under Different Power (a) 150W (b) 300W

The images show two different compositions of LiMn$_{0.8}$Fe$_{0.2}$PO$_4$, namely LMFP/C-50/150 and LMFP/C-50/300.

Electrochemical performance of LiMn$_{0.8}$Fe$_{0.2}$PO$_4$

(a) The first cycles of cyclic voltammetry for all specimens from 3V to 4.5V versus Li/Li$^+$ at 0.2 mV$^{-1}$ scan rate.
(b,c) Capacities of all samples subject to charge–discharge under different charging rates

The results indicate that the LiMn$_{0.8}$Fe$_{0.2}$PO$_4$ has poor conductivity, which should be further improved by adding more carbon to alleviate the polarization.

Conclusions

LiMn$_{0.8}$Fe$_{0.2}$PO$_4$ and Li(Ni$_{0.5}$Mn$_{0.3}$Co$_{0.2}$)O$_2$ thin film have been successfully fabricated by the co-sputtering system.

The epitaxial layer effectively enhanced the capacity during charge–discharge, and maintained a better cycling stability under high current rate.

Acknowledgement

The authors would like to acknowledge the financial support from Ministry of Science and Technology, Taiwan, under Contact No. MOST-107-2911-I-007-509-. 