Faculty and Postdoc, Science and Engineering.

SiO_2 Coated Li-rich Layered Oxides-$Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ for efficient energy storage applications

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Introduction

Abstract

- The lithium rich layered oxide (LLO) $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ was synthesized using sol-gel technique.
- $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ displays poor cyclic stability and poor capacity retention hence SiO_2 coating is done to improve electrochemical performance.
- XRD, SEM and TEM analysis confirms the formation of phase pure materials and presence of SiO_2 layer.
- There is an improvement in electrochemical performance with SiO_2 coating due to prevention of direct cathode material and electrolyte.

$Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$

- High operating voltage and high reversible capacity are necessary for batteries with high energy density and power density..
- $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ displays a very good reversible discharge capacity of ~250mAhg^{-1} and operates at very high voltages.
- Drawbacks for this cathode material include rapid capacity fading and voltage fade during successive cycling due to unstable structure and oxygen loss.

Why Li-ion batteries

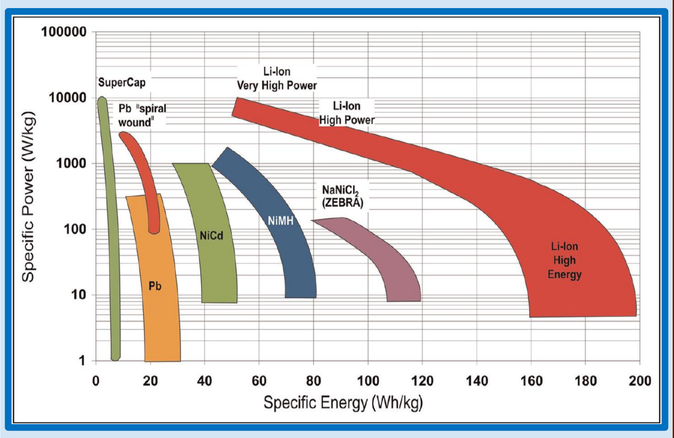
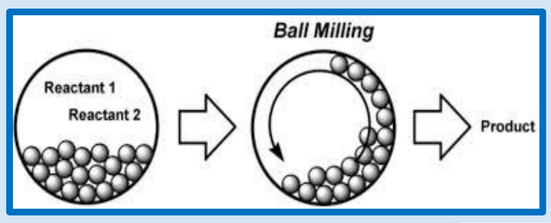


Fig. 1. Energy vs. power density of different types of batteries.

Budde-Meiwes, Heide & Drillkens, Julia & Lunz, Benedikt & Muennix, Jens & Lehner, Susanne & Kowal, Julia & Sauer, Dirk. (2013). Journal of Automobile Engineering. 227. 761-776. 10.1177/0954407013485567.

SiO_2 Coating

- SiO_2 coating prevents the direct contact of cathode material with the electrolyte, thus preventing side reactions.



SiO_2 + $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ → Ball milling (300rpm, 24h) → Heat treatment (900°C, 12hrs, Air)

Fig. 2. SiO_2 coating using ball milling technique.

Experimental Procedure

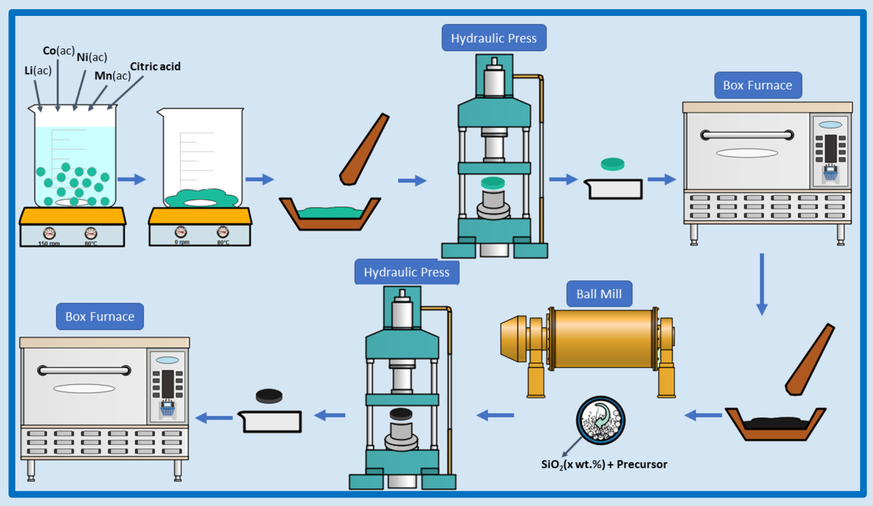


Fig. 3 Schematic diagram for synthesis of $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ and SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$

Synthesis of $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$

Li(ac.) + Mn(ac.) + Co(ac.) + Ni(ac.)

↓ Add in 100ml DI water, Stir @ 80°C

Add Citric Acid (Chelating Agent)

↓ Stir until dried @ 80°C

Gel formation

↓ After complete drying, grind to powder for heat treatment

Heat treatment (450°C, 6h, Air; 900°C, 12h, Air)

Results & Discussion

XRD, SEM & TEM

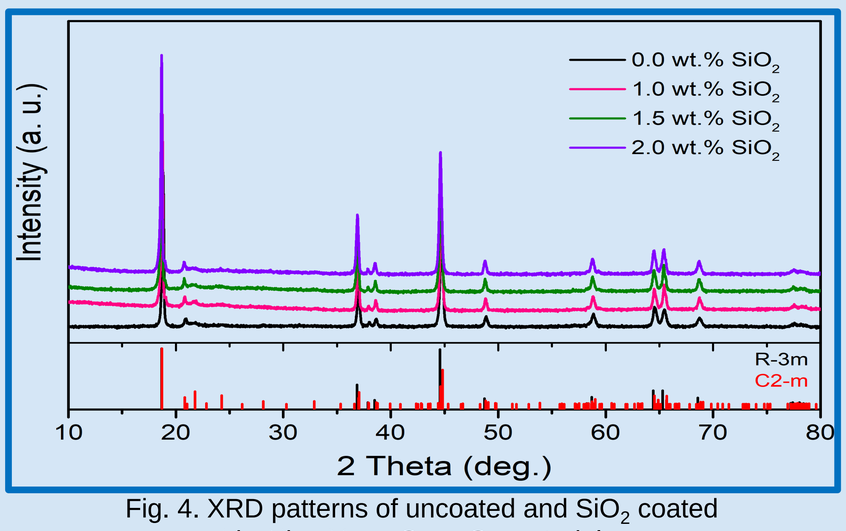


Fig. 4. XRD patterns of uncoated and SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ materials.

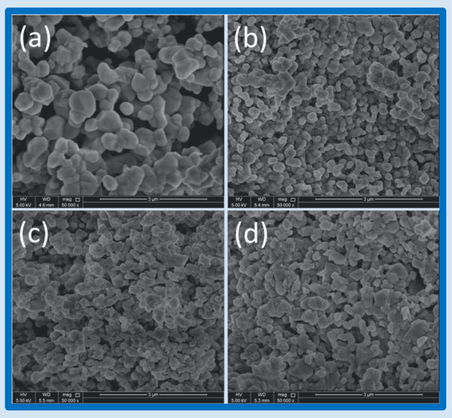


Fig. 5. Shows the SEM Images of the uncoated (a) and SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ (b-d).

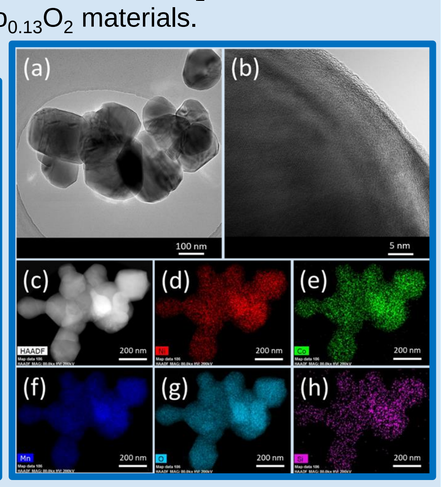


Fig. 6. Shows the TEM Images of the particle (a-b) and elemental mapping (c-h) for 1.5wt%. SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$.

Galvanostatic Charge/Discharge, Rate Capability & Cycling

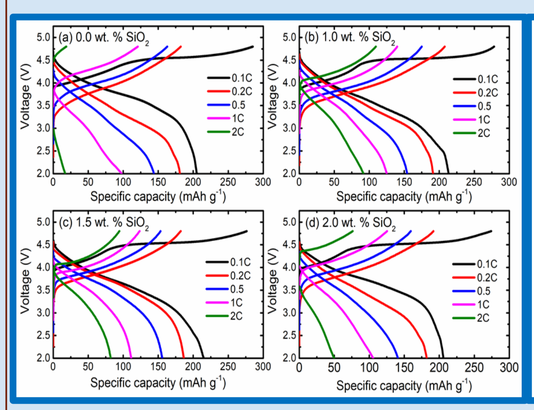


Fig. 8. Galvanostatic charge/discharge curves of uncoated and SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ materials.

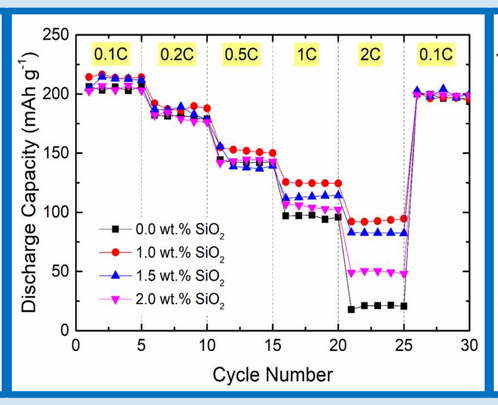


Fig. 9. Rate capability of uncoated and SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ materials.

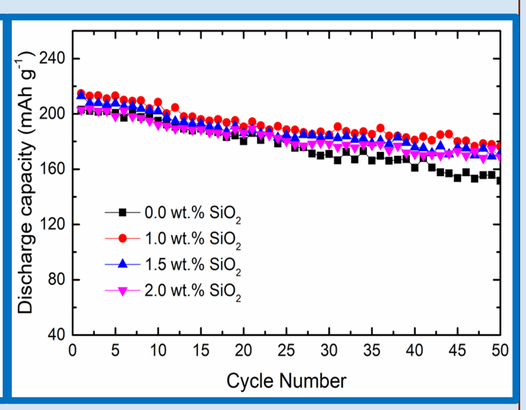


Fig. 10. Cycling behavior of uncoated and SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ materials at 0.1C for 50 cycles..

XPS Analysis

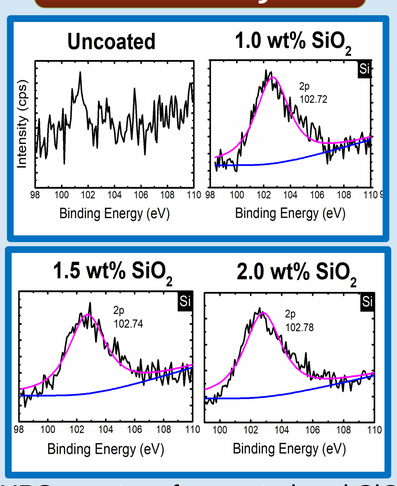


Fig. 7. Si XPS spectra of uncoated and SiO_2 coated $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ materials.

Conclusion

- Lithium rich layered oxide $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$ cathode material was synthesized and then coated with SiO_2 (1.0%, 1.5%, and 2.0%).
- XRD pattern confirms phase purity of the material and SEM/TEM and XPS analyses confirm nanometric sized particles and presence of SiO_2 layer on the particle surface.
- The SiO_2 coating improves the electrochemical performance of the cathode material by preventing the direct contact of cathode material and the electrolyte.
- However excessive coating thickness causes a decrease in electrochemical performance due to increase in interfacial resistance.

Acknowledgment

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