

Hydrothermal Synthesis and Electrochemical Properties of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ Cathode Material for Lithium Ion Batteries

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The aim of this work was to perform hydrothermal synthesis and study the electrochemical properties of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ ($0 \leq x \leq 0.15$) cathode material for lithium ion batteries. XRD, FE-SEM, and ICP-OES studies revealed that highly crystalline phases and stoichiometric compositions of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ were successfully synthesized. The electrochemical characteristics of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ compositions reveal that they have excellent capacity retention and rate capability. In particular, $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$, which presented outstandingly rate capacity (217 mAh g^{-1} and 167 mAh g^{-1} at 0.1 C and 10 C rate, respectively) at 27 °C. Study the stability and capacity retention of compositions at high potential in the wide voltage range from 2.7 to 4.5 V at 60 °C showed the initial discharge capacities of compositions $x = 0.00, 0.01, 0.05, 0.1$ and 0.15 for the first 20 cycles at 0.2 C reached 98%, 97%, 95%, 94% and 97%, respectively, and for subsequent 100 cycles at a rate of 0.5 C reached 81%, 79%, 73%, 80% and 93%, respectively. Results showed that $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ had excellent capacity retention during 100 cycles at 0.5 C, indicating that 10% doping of Mg was significantly appropriate to enhance cycling stability for the Ni-containing layered cathode at the high cut-off voltage and high temperature. A comparison between the electrochemical performance of $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ and various reported cathode materials for lithium ion batteries indicated the better or comparable performance of $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$.

Keywords: $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$; Cathode Material; Lithium Ion Batteries; Hydrothermal method; Capacity retention; Cycling stability

1. INTRODUCTION

The use of advanced rechargeable lithium-ion batteries for energy storage in consumer electronics and electric vehicles has resulted in an exponential increase in demand for the fabrication of environmentally friendly, low-cost, high-performance lithium-ion batteries in order to improve power density, life time, and safety [1-3]. Because of its combined characteristics of high compacted density, outstanding cyclability, high energy density, great cycle life, and reliability, LiCoO_2 has

recently gained substantial interest as a possible substitute for energy storage devices [4-6]. Other appealing cathodic materials include Ni-rich $\text{LiNi}_x\text{Co}_{1-x}\text{O}_2$ compositions, which have superior safety and capacity and are more available [7-10]. However, there are certain disadvantages to $\text{LiNi}_x\text{Co}_{1-x}\text{O}_2$ compositions that affect their electrochemical performance [11-13]. It has been observed that only half of the intercalated lithium can be recovered, causing phase changes in $\text{LiNi}_x\text{Co}_{1-x}\text{O}_2$ and lowering the intercalation process' stability and reversibility [14, 15]. Furthermore, long-term cycling causes structural degeneration in these cathodes [16, 17]. Furthermore, because Co is the most expensive and rare element, replacing it with a less expensive element as a strategy for improving the stability and electrochemical characteristics of $\text{LiNi}_x\text{Co}_{1-x}\text{O}_2$ in battery research is crucial. As a result, a variety of $\text{LiNi}_x\text{Co}_{1-x}\text{O}_2$ compositions have been produced and analyzed via cationic substitution and surface doping [18-20].

Mn, Al, Zr, Fe, Cr, Ti, Ce, Cu, B, Zn, Mg and Na are the most widely doped elements in $\text{LiNi}_x\text{Co}_{1-x}\text{O}_2$ compositions [21-26]. Among them, doping sustainable and environmentally friendly Mg elements has been shown to be an efficient strategy to improve the energy and power density of Ni-containing layered cathodes [21, 27-29]. However, optimizing the magnesium concentration as well as researching high temperature and high voltage conditions are critical. The chemical and structural properties of Ni-rich layered oxide cathodes frequently undergo drastic changes in morphological and crystallographic features during high temperature aging at high potential, limiting the use of lithium-ion batteries in portable electronic devices, as well as electric and hybrid electric vehicles [30-33]. Thus, there is a high demand for lithium-ion batteries thermal, chemical, and structural stability that is critical in practical applications for cycling performance. Therefore, this study was conducted on the hydrothermal synthesis and electrochemical properties of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ ($0 \leq x \leq 0.15$) cathode material for lithium ion batteries.

2. EXPERIMENTAL

2.1. Synthesis of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$

According to [29, 34], a hydrothermal reaction was used to synthesize $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$. The $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ (99%, Shanghai Jarred Industrial Co., Ltd., China) and $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ (99%, Shanghai Jarred Industrial Co., Ltd., China) were ultrasonically mixed with a mixture of LiOH (99%, Shanghai Jarred Industrial Co., Ltd., China) and 1.5 g/l l-ascorbic acid (99%, Shanghai Jarred Industrial Co., Ltd., China). The molar ratio of the Li:Mg:Co was 3:1:1. After the formation of a white gel in the beaker, the obtained gel was put in a 150 mL Teflon-lined stainless steel autoclave that was sealed and subjected to hydrothermal treatment at 250 °C for 24 hours. The resulting precipitates were sintered at 400 °C for 4 hours under an O_2 atmosphere. Finally, the products were collected, filtered, and dried in a vacuum oven at 70 °C for 2.5 hours.

2.2. Characterization

The molarity of all the metallic elements in solutions was tested by inductive coupled plasma optical emission spectrometry (ICP-OES; Perkin Elmer Optical Emission Spectrometer, Optima 8000, USA). An X-ray diffractometer (XRD; Bruker D8 advanced AXS GmbH, Karlsruhe, Germany) and using field emission scanning electron microscopy (FE-SEM; Hitachi Company Model S-4160, China) were used to study the crystal structures and morphology of the synthesized compositions.

2.3. Electrochemical analyses

The electrochemical properties of the synthesized compositions were evaluated using a 2032 coin-type cell which contained a positive cathode and a lithium metal negative electrode. The electrodes were separated by a microporous polypropylene film (Celgard 2400, Hoechst-Celanese Co., North Carolina, USA). The cathode was made up of 85 weight percent prepared compositions powder, 8 weight percent acetylene black (99.5%, Shandong Gelon Lib Co., Ltd., China), and 7 weight percent polyvinylidene fluoride (PVDF; 99.5%, Shandong Gelon Lib Co., Ltd., China) binder. The well-blended slurry was spread on aluminum foil, dried at 80 °C for 30 minutes, and then heated at 150 °C in a vacuum oven for 120 minutes. For preparation of the electrolyte, 1 M LiPF₆ (Dongguan Gelon Lib Co., Ltd., China) was added into the mixture with an equal volume ratio of Ethyl Methyl Carbonate (EMC; 99%, Itrade Chemical (Jiangsu) Co., Ltd., China), of dimethyl carbonate (DMC; ≥99%, Sigma-Aldrich) and ethylene carbonate (EC; 99%, Sigma-Aldrich).

3. RESULTS AND DISCUSSION

3.1. Study the structural properties

In Figure 1, XRD patterns of LiNi_{0.8}Co_{0.2-x}Mg_xO₂ samples are depicted. The diffraction patterns correspond to the LiNiO₂ pattern (JCPDS Card No. 98-003-4550) [35-37]. It can be observed that there are well-defined, sharp and strong peaks indicating that these compounds are generally well crystallized. There are diffraction peaks at 38.54° and 46.91° which confirm the presence of the R3m space group in all samples (JCPDS Card No. 740919) [38, 39]. The explicit splitting of (108)/(110) and (006)/(012) peaks demonstrated the highly ordered layer structure of all samples, and the enlargement of (003)/(104) peak intensity ratio is closely related to the low degree of Ni²⁺/Li⁺ cation mixing in LiNi_{0.8}Co_{0.2-x}Mg_xO₂ samples, implying Ni-rich layered cathode materials [40, 41].

FE-SEM images of LiNi_{0.8}Co_{0.2-x}Mg_xO₂ (0 ≤ x ≤ 0.15) samples are shown in Figure 2. There is no discernible variation between the particle sizes of the samples.

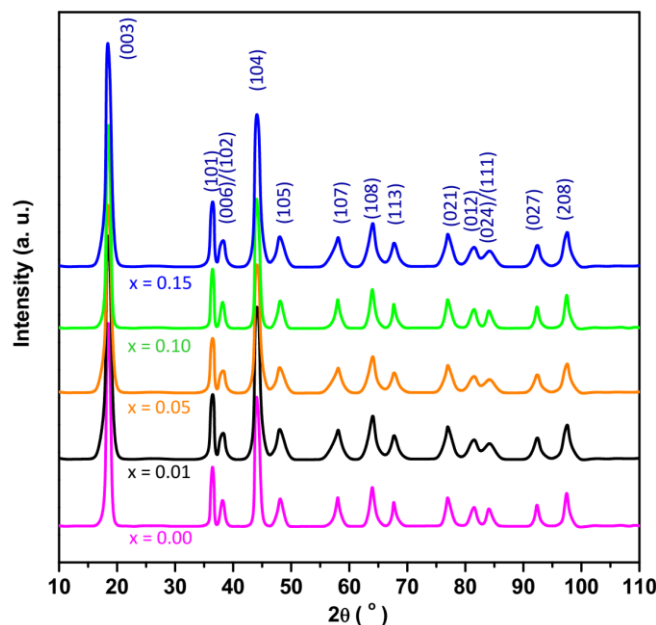


Figure 1. XRD patterns of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ samples ($0 \leq x \leq 0.15$).

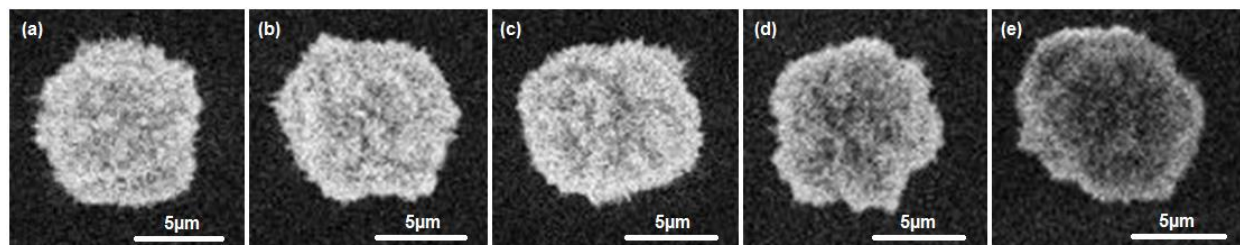


Figure 2. FE-SEM images of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ samples; (a) $x = 0.00$, (b) $x = 0.01$, (c) $x = 0.05$, (d) $x = 0.10$ and (e) $x = 0.15$.

Table 1. The findings of the ICP-OES analysis for $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ samples.

x	$\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$	Li	Ni	Co	Mg
0.00	$\text{LiNi}_{0.8}\text{Co}_{0.2}\text{O}_2$	1.000	0.802	0.198	0.000
0.01	$\text{LiNi}_{0.8}\text{Co}_{0.19}\text{Mg}_{0.01}\text{O}_2$	1.008	0.790	0.193	0.009
0.05	$\text{LiNi}_{0.8}\text{Co}_{0.15}\text{Mg}_{0.05}\text{O}_2$	1.003	0.782	0.148	0.049
0.10	$\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$	1.004	0.799	0.099	0.098
0.15	$\text{LiNi}_{0.8}\text{Co}_{0.05}\text{Mg}_{0.15}\text{O}_2$	1.001	0.802	0.049	0.148

The production of well crystalline, dense, and regular particles with a spherical morphology and an average diameter of 10 μm may be seen in FE-SEM images of samples. The mixed Co-Mg compound produces a more block morphology. The findings of the ICP-OES analysis for $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ samples are presented in Table 1 which indicate to the chemical composition of elements in

LiNi_{0.8}Co_{0.2-x}Mg_xO₂ samples is very close to the stoichiometric value, without any detectable contamination. These results indicate the ability to successfully synthesize stoichiometric compositions of the LiNi_{0.8}Co_{0.2-x}Mg_xO₂.

3.2. Study the electrochemical properties

The electrochemical performances of prepared LiNi_{0.8}Co_{0.2-x}Mg_xO₂ ($0 \leq x \leq 0.15$) were investigated under a working voltage from 2.7 to 4.5 V at 27 °C. Figures 3a and 3b display the first charge/discharge profiles at the 0.1C rate and cycling performances of LiNi_{0.8}Co_{0.2-x}Mg_xO₂, respectively. As depicted in Figures 3a, the first cycle discharge capacity increased from 165.1 mAh g⁻¹ ($x = 0.0$; LiNi_{0.8}Co_{0.2}O₂) to 217 mAh g⁻¹ ($x = 0.1$; LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂) with increasing the Mg content up to $x = 0.1$, because Mg doping can suppress electrode-electrolyte side reactions by reducing the content of active Ni⁴⁺ on the surface, and exert a pillaring effect on enhancing the cycling performance of Ni-containing layered cathode [21, 42]. The Coulombic efficiencies at 1st cycles are ~ 94% implying great reversibility for all compositions of LiNi_{0.8}Co_{0.2-x}Mg_xO₂. However, for more Mg content ($x = 0.15$; LiNi_{0.8}Co_{0.05}Mg_{0.15}O₂) the first cycle discharge capacity decreased to 202.3 mAh g⁻¹ which is attributed to the powerful columbic interactions between Mg²⁺ and the intercalating cathode materials [27, 43]. Furthermore, these interactions eventually result in slow solid-state diffusion of Mg²⁺, resulting in poor ionic conductivity in transition metal oxide-based materials [44-46]. Thus, it is illustrated that a large polarization for Mg²⁺ during charge/discharge and redox reactions, and poor intercalation of Mg²⁺ into the host materials [47]. From Figure 3a, the shoulder is observed in the charge-discharge curve of LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂ which is correlated with the phase transition of hexagonal to hexagonal (H₂ to H₃) for Ni-containing layered compounds [48, 49].

The cycling test was conducted at a rate of 0.2 C for the first 20 cycles followed by a rate of 0.5 C for the subsequent 100 cycles. As observed from Figure 3b, the capacity retention is improved as Mg content increases from $x = 0.0$ to $x = 0.1$ because Mg substitutions help to eliminate particle cracking and improve the chemical and structural stability, hence improving charge-discharge capacity retention [50-52]. Liu et al. [28] suggested that this phenomenon is associated with the charging process where the Ni²⁺ in the Li slab can be oxidized to Ni^{3+/4+} that it induces a local collapse of the layered structure and impedes more Li⁺ deintercalation from the structure. The doped Mg can support the layered structure and inhibit the collapse of the structure and inhibit Ni migration. This is useful to facilitate more Li⁺ deintercalation and provides high capacity. For more content of Mg ($x = 0.15$; LiNi_{0.8}Co_{0.05}Mg_{0.15}O₂), more Mg substitutions in Co sites shows the decrease in capacity retention which related to important Co role in redox reaction, because the low-spin Co^{3+/4+} band overlaps with the 2p band of O²⁻, and electron transfer from O²⁻ to Co^{3+/4+} can be carried out and reduce oxidized transition metal ions, thus releasing O₂ into battery cells [53-55]. All compositions of LiNi_{0.8}Co_{0.2-x}Mg_xO₂ exhibit excellent capacity retention for the first 20 cycles at a rate of 0.2 C. As seen for the first 20 cycles, it attains more than 96% for compositions $x = 0.00, 0.01$ and 0.05 , and it achieves ~98% for the compositions $x = 0.1$ and 0.15 . For subsequent 100 cycles a rate of 0.5 C, the capacity retention for compositions $x = 0.00, 0.01$ and 0.05 is decreased to ~89%, 88% and 86%, respectively, and the

capacity retention of composition $x = 0.1$ is decreased to $\sim 89\%$, but it decreased to $\sim 82\%$ for composition $x = 0.15$ because of the presence of a larger amount of stable Mg^{2+} which might counteract the volume shrinking/swelling during the Li^+ reversible extraction/insertion process [56-59]. Therefore, the Ni-rich composition $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ exhibits great cycling stability, and the optimized ratio of Ni to Co and Mg is found to be 0.8% in $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$.

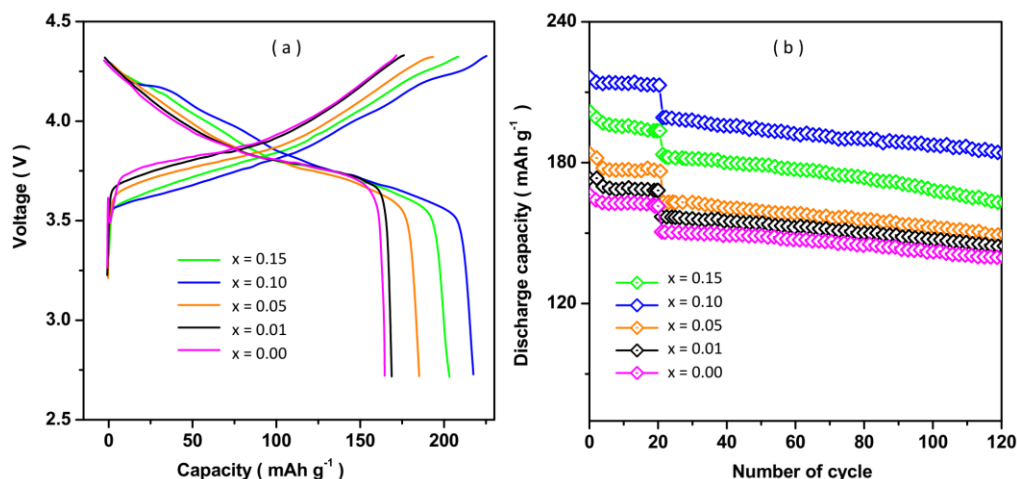


Figure 3. Electrochemical performance of the prepared $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ ($0 \leq x \leq 0.15$) cathodes under a working voltage from 2.7 to 4.5 V at 27°C . (a) Initial charge-discharge profiles at a rate of 0.1 C, (b) capacity retention profiles at a rate of 0.2 C for the first 20 cycles followed by a rate of 0.5 C for subsequent 100 cycles (21 to 120 cycles).

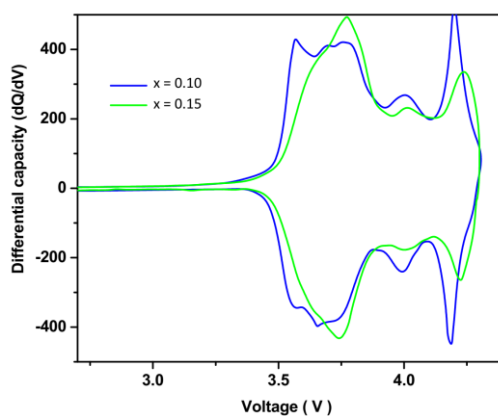


Figure 4. The profiles of differential capacity (dQ/dV) versus the operating voltage of both of $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ and $\text{LiNi}_{0.8}\text{Co}_{0.05}\text{Mg}_{0.15}\text{O}_2$.

The profiles of differential capacity (dQ/dV) versus the operating voltage of both $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ and $\text{LiNi}_{0.8}\text{Co}_{0.05}\text{Mg}_{0.15}\text{O}_2$ are presented in Figure 4. As seen in the profile of $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$, there is a well-defined redox peak at ~ 4.2 V attributed to the H_2 to H_3 phase transition [60-62], while with increasing Mg content in $\text{LiNi}_{0.8}\text{Co}_{0.05}\text{Mg}_{0.15}\text{O}_2$, the corresponding peak has approximately disappeared. It has been reported that the rapid volume contraction during the structural transformation from H_2 to H_3 mostly affects the capacity fading of the Ni-rich layered oxide

cathodes [63-66].

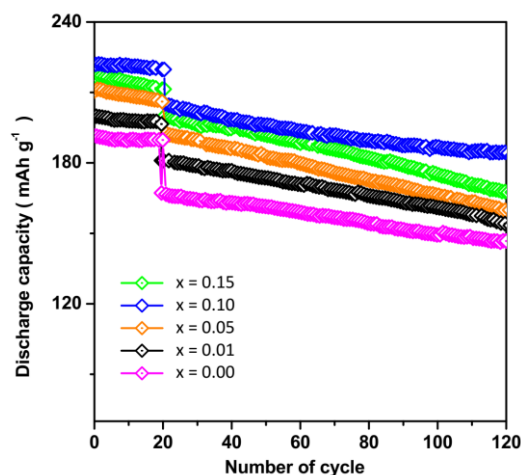


Figure 5. Capacity retention profiles of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ ($0 \leq x \leq 0.15$) composition at a rate of 0.2 C for the first 20 cycles followed by a rate of 0.5 C for subsequent 100 cycles (21 to 120 cycles) at high potential in the wide voltage range from 2.7 to 4.5 V at 60 °C.

Figure 5 illustrates the results of the study on the stability and capacity retention profiles of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ ($0 \leq x \leq 0.15$) composition at a rate of 0.2 C for the first 20 cycles followed by a rate of 0.5 C for subsequent 100 cycles at high potential in the wide voltage range from 2.7 to 4.5 V at 60 °C. It appears that the initial capacities are enhanced because of more lithium deintercalation at high voltage (cut-off voltage as high as 4.5 V) [67]. The increase in capacity is more notable with increasing Mg content because Mg-doping is conducive to enhancing the cycling stability due to the fact that reduces the polarization and improves the kinetic properties via increasing the electronic conductivity at elevated temperatures [68, 69]. A comparison of capacity retention at 4.3 V at 27 °C (Figure 3b) and 4.5 V at 60 °C (Figure 5) reveals a faster degradation process for Ni-containing layered cathode at higher cut-off voltage and higher temperature, which may be related to thermal instability, electrolyte decomposition, and poor structural stability of cathode material at high voltage [70-72]. Figure 5 shows that the initial discharge capacities of compositions $x = 0.00, 0.01, 0.05, 0.1$ and 0.15 for the first 20 cycles at 0.2 C reach 98%, 97%, 95%, 94% and 97%, respectively, and for the subsequent 100 cycles at 0.5C reach 81%, 79%, 73%, 80% and 93%, respectively. Results show that $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ has excellent capacity retention during 100 cycles at 0.5 C, indicating that 10% doping of Mg is significantly appropriate to enhance cycling stability for the Ni-containing layered cathode at the high cut-off voltage and high temperature [73-75].

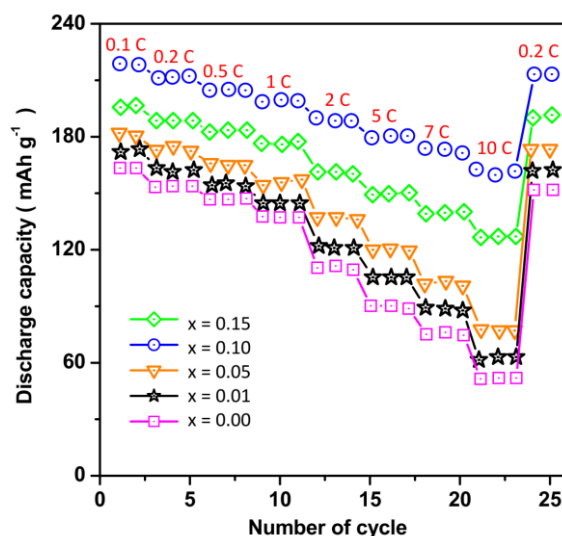


Figure 6. Rate capability of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ ($0 \leq x \leq 0.2$) compositions at a rate range from of 0.1 C to 10 C for 25 cycles in the wide voltage range from 2.7 to 4.3 V at 60 °C.

Table 2. Comparison between the electrochemical performance of $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ and various reported cathode materials for lithium ion batteries.

Composition	voltage range (V)	Discharge capacity (mAh g^{-1})	Capacity retention (%)	Ref.
$\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$	2.7–4.5	216 (0.2 C)	97% (20 cycles) at 0.2 C	This study
		200 (0.5 C)	93% (100 cycles) at 0.5 C	
$\text{LiNi}_{2/3}\text{Co}_{1/6}\text{Mn}_{1/6}\text{O}_2$	2.8–4.3	188.9 (0.2 C)	93.9% (50 cycles) at 0.5 C	[76]
		179.1 (0.5 C)		
NC-coated LiFePO_4	2–4.3	143 (10 C)	85% (30 cycles) at 0.5 C	[77]
N_2C -coated LiFePO_4	2–4.3	131 (10 C)	87% (30 cycles) at 0.5 C	[77]
N_3C -coated LiFePO_4	2–4.3	115 (10 C)	90% (30 cycles) at 0.5 C	[77]
$\text{LiNi}_{1/3}\text{Co}_{1/3}\text{Mn}_{1/3}\text{O}_2//\text{Zn}$	1.8–1.65	110 (5 C)	99% (40 cycles) at 0.5 C	[78]
$\text{LiNi}_{0.6}\text{Co}_{0.2}\text{Mn}_{0.2}\text{O}_2$	2.7–4.5	187.2 (0.2 C)	79.7% (100 cycles) at 0.2 C	[79]
$\text{Li}_{1.2}\text{Ni}_{0.13}\text{Co}_{0.13}\text{Mn}_{0.54}\text{O}_2$	2.0–4.8	258 (0.2 C)	69% (100 cycles) at 0.2 C	[80]
$\text{Li}_{1.2}\text{Ni}_{0.16}\text{Co}_{0.08}\text{Mn}_{0.56}\text{O}_2$	2.0–4.8	246 (0.2 C)	66% (100 cycles) at 0.2 C	[80]
$\text{Li}_{1.2}\text{Ni}_{0.20}\text{Co}_{0.08}\text{Mn}_{0.52}\text{O}_2$	2.0–4.8	235 (0.2 C)	73% (100 cycles) at 0.2 C	[80]
$\text{Li}_{1.2}\text{Ni}_{0.24}\text{Co}_{0.08}\text{Mn}_{0.48}\text{O}_2$	2.0–4.8	232 (0.2 C)	80% (100 cycles) at 0.2 C	[80]
$\text{Li}_{1.2}\text{Ni}_{0.32}\text{Co}_{0.04}\text{Mn}_{0.44}\text{O}_2$	2.0–4.8	225 (0.2 C)	85% (100 cycles) at 0.2 C	[80]
$\text{LiNi}_{0.65}\text{Co}_{0.25}\text{Mn}_{0.1}\text{O}_2$	2.5–4.5	130.5 (0.125 C)	96.9% (20 cycles) at 0.125 C	[81]

Figure 6 depicts the rate capability of $\text{LiNi}_{0.8}\text{Co}_{0.2-x}\text{Mg}_x\text{O}_2$ ($0 \leq x \leq 0.15$) compositions at a rate range from of 0.1 C to 10 C for 25 cycles in the wide voltage range from 2.7 to 4.3 V at 60 °C. As seen, the rate capability of $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ is preferable than other compositions to the ones with appropriate incorporation of Mg content which is in agreement with the above results, and confirms the electrochemical performance of Ni-containing layered cathode [73, 82]. The discharge capacity of $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mg}_{0.1}\text{O}_2$ is 167 mAh g^{-1} at 10 C which concordances to 77% of the capacity at 0.1 C (217 mAh g^{-1}). In the event that the capacity of $\text{LiNi}_{0.8}\text{Co}_{0.05}\text{Mg}_{0.15}\text{O}_2$ at 10 C is 129 mAh g^{-1} that

concordances to 66% of that at 0.1 C (195 mAh g⁻¹).

In addition, after various rate cycles, the capacities of LiNi_{0.8}Co_{0.2-x}Mg_xO₂ (0 ≤ x ≤ 0.15) compositions recover to their initial levels when the current rate comes back to 0.1 C, demonstrating that there was no structural damage to the layer structure at high current and fast rates [83-85]. Table 2 shows the comparison between the electrochemical performance of LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂ and various reported cathode materials for lithium ion batteries which indicated to better or comparable performance of LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂.

4. CONCLUSION

This study was conducted on the hydrothermal synthesis and electrochemical properties of LiNi_{0.8}Co_{0.2-x}Mg_xO₂ (0 ≤ x ≤ 0.15) cathode material for lithium ion batteries. Study the structural properties indicated to successfully synthesize of highly crystalline phase and stoichiometric compositions of the LiNi_{0.8}Co_{0.2-x}Mg_xO₂. Study the electrochemical properties exhibited by LiNi_{0.8}Co_{0.2-x}Mg_xO₂ compositions showed great capacity retention and appropriate rate capability. Among them, LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂, presented excellent rate capacity of 217 mAh g⁻¹ and 167 mAh g⁻¹ at 0.1 C and 10 C rate, respectively at 27 °C. The stability and capacity retention of compositions at high potential in the wide voltage range from 2.7 to 4.5V at 60°C revealed that LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂ had excellent capacity retention during 100 cycles at 0.5 C, indicating that 10% Mg doping was significantly appropriate to improve cycling stability for the Ni-containing layered cathode in the high cut-off voltage and high temperature. Study the rate capability of LiNi_{0.8}Co_{0.2-x}Mg_xO₂ (0 ≤ x ≤ 0.15) compositions at a rate range from of 0.1 C to 10 C for 25 cycles in the wide voltage range from 2.7 to 4.3 V at 60 °C showed that the rate capability of LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂ was preferable than other compositions to the ones with appropriate incorporation Mg content. A comparison between the electrochemical performance of LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂ and various reported cathode materials for lithium ion batteries indicated the better or comparable performance of LiNi_{0.8}Co_{0.1}Mg_{0.1}O₂.

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