Effects of Upper Cutoff Potential on LaPO4-Coated and Uncoated Li[Ni0.42Mn0.42Co0.16]O2/Graphite Pouch Cells

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Lithium-ion (Li-ion) cells are currently used in phones, laptop computers and, more recently, electric vehicles (EV). Electrolyte additives can have a dramatic effect on the cycling performance and calendar life of Li-ion cells. In addition to achieving longer lifetimes and better capacity retention, it is important to increase the voltage range of Li-ion cells which will increase their energy density. In order to reduce the cost of batteries for EV and grid energy storage applications, the use of NMC instead of LiCoO2 (LCO) as a positive electrode material is advantageous due to the reduced amount of cobalt, an expensive component, in NMC. NMC/graphite cells do not normally function well when charged to high potential (>4.3 V), however, appropriate electrolyte additives have been investigated for use in cells operating at high voltage.1–2

Although vinylene carbonate (VC) is one of the most widely used electrolyte additives, it is less effective when used in cells cycling to high voltage3 or at elevated temperatures.4 The superiority of prop-1-ene-1,3-sultone (PES) over VC in NMC/graphite cells has been demonstrated by Xia et al.5 and Nelson et al.6 Ternary combinations of electrolyte additives are superior to PES alone, particularly when used with a surfactant-containing additive (either methylene bis(morpholino)ethane sulfoxylate [MBMSO] or 1,3,2-dioxathiolane-2,2-dioxide [DTD]) and tris-(trimethyl-silyl) phosphite (TTSPi).7,8 These ternary additive mixtures improved the cycling performance and safety of Li[Ni0.43Mn0.3Co0.2]O2 (NMC111)/graphite cells while reducing the impedance and parasitic reactions at the positive electrode when compared to VC alone in the electrolyte.7 They also improved capacity retention, decreased impedance growth and improved the tolerance of Li[Ni0.42Mn0.42Co0.16]O2/NMC442/graphite cells to high potential.7

Although the effectiveness of these ternary additive mixtures has been shown to withstand continuous cycling up to 4.4 and 4.5 V,1–2 it is important to study and understand the performance of these additives when used in cells undergoing experiments representative of “real-life” Li-ion cell use. Nelson et al.7 studied the effect of ternary combinations of PES, MMDS or DTD and TTSPi (all added at 1 or 2% by weight to control electrolyte) on the impedance and cycling performance of NMC442 cells up to 4.4 and 4.5 V.3 Cells containing the ternary mixture with MMDS showed very low impedance and excellent capacity retention when cycled continuously up to 4.5 V.3 These cells, however, exhibited severe capacity fade and large impedance growth when subjected to a 24 hour hold at 4.4 V every cycle.3 When MMDS was replaced with DTD, cells undergoing cycling with a hold at high voltage had significantly improved capacity retention and very little impedance growth.1 Therefore, in this work, only one electrolyte was selected for study which contained 2% PES + 2% DTD + 2% TTSPi since it has been shown to have excellent performance in NMC442 cells even in experiments with extended exposure to high voltages. Studying the effect of extended periods of time at high voltage on the cycling performance and impedance growth of cells is imperative since practical applications of Li-ion cells often leave the cells at high voltage for extended periods of time after charging.

In addition to utilizing electrolyte additives to improve cell performance at high potential, coatings on the electrode active materials have been investigated. Coatings can act as an “artificial SEI”, ideally limiting the amount and reducing the rate of parasitic reactions.8 Coatings can also increase the electrolyte oxidation stability at high potential and decrease transition metal dissolution.8,9 Coatings can provide a barrier between the active material and the electrolyte, and can also scavenge reactive species from the electrolyte. AlF3 was investigated as a positive electrode coating and was found to improve the capacity retention of LCO cells up to 4.54 V10 and reduce the reactivity of NMC positive electrodes and decrease transition metal dissolution.11

Song et al. found that a coating of LaPO4 on Li[Ni0.5Mn0.3Co0.2]O2 was effective at reducing transition metal dissolution and could therefore improve cycling stability.12 Mohan and Kalaigian found that cells with LiMn2O4 coated with LaPO4 had excellent cycling and structural stability up to 4.5 V and high reversible capacity at elevated temperatures.13 Xia et al. demonstrated that LaPO4-coated NMC442 active material improved the performance of cells without electrolyte additives.14 Figure 1 shows the discharge capacity as a function of cycle number for NMC442/graphite cells with and without a LaPO4 coating on the positive electrode active material during cycling between 2.8 and 4.5 V at 40 °C and C/2.5.14 Coated cells containing electrolyte without additives exhibited improved capacity retention compared to cells without a coating. However, Xia et al. also showed that when state-of-the-art electrolyte additives were included in the cells, both coated and uncoated cells had dramatically improved and almost equal performance. Xia et al. concluded that the state-of-the-art additives had a more dramatic effect on cell performance than the coatings did.

Studying the effect of active material coatings in the presence of state-of-the-art additives in Li-ion cells tested to high potential is essential to understand the potential benefit of positive electrode coatings. This work compares coated and uncoated NMC442/graphite cells with upper cutoff potentials selected from 4.4, 4.425, 4.45, 4.475 or 4.5 V to examine the impact of the upper cutoff potential on performance. The electrochemical impedance spectra are analyzed...
using a transmission line model to determine how the charge transfer impedance and the impedance of the electronic/ionic path change with cycle number as a function of the upper cutoff potential selected.

**Experimental**

Machine made 180 mAh NMC442/graphite wound pouch cells with a 3 wt% LaPO4 coating on the NMC442 active material (referred to as coated cells) and 240 mAh NMC442/graphite wound pouch cells (referred to as uncoated cells), both balanced for 4.7 V operation, were obtained dry (no electrolyte added) from LiFUN Technologies (Zhuzhou City, China). The coated cells have a thinner positive electrode than the uncoated cells and therefore have smaller capacity. The NMC442 was prepared by Umicore Co. and the LaPO4 coating was applied by 3M Co. to the active material before the pouch cells were manufactured without electrolyte and vacuum sealed in a dry room in China by LiFUN Technologies. After cells were heated to 80 °C for 14 hours under vacuum to remove any residual water and moved into an argon-filled glove box, the pouch cells were filled with 0.85 g of 1 M LiPF6 in ethylene carbonate (EC): ethylmethyl carbonate (EMC) (3:7) in a ratio of 3:7 by weight with 2% by weight each of PES (Lianchuang Medicinal Chemistry Co., 98.20%), DTD (Aldrich, 98%) and TTSPi (TCI America, >95%). This additive combination will be referred to as PES222. Figure 2 shows the chemical structures of the additives used in this work. Cells were vacuum sealed after electrolyte filling using a compact vacuum sealer (MTI Corp.).

All cells did a formation cycle at 40 ± 0.1 °C, consisting of a 24 hour hold at 1.5 V to ensure adequate electrolyte wetting followed by a C/20 charge to 3.5 V. After this step, cells were transferred into an argon-filled glove box, cut open just below the heat seal to release generated gas and then vacuum sealed again. After degassing, the cells were charged to 4.5 V at C/20 followed by a C/20 discharge to 3.8 V. The temperature boxes used for the measurements presented in this work are stable to ±0.1 °C and are within one degree centigrade of the set temperature.

![Figure 2](image.png)

**Figure 2.** The chemical structures of the additives used in this work.

After formation, these cells were placed in a 40 ± 0.1 °C temperature box connected to a system capable of electrochemical impedance spectroscopy (EIS) measurements coupled with cycling capabilities. The system is discussed in detail by Nelson et al. Cells underwent charge-hold-discharge cycling as shown in Figure 3. The time axis is simply provided as a scale, not as the specific time cycles occurred in the experimental method. Cells were cycled between 2.8 V and an upper cutoff voltage of 4.4, 4.425, 4.45, 4.475 or 4.5 V. All cells underwent two cycles between 2.8 V and the upper cutoff voltage at C/5 followed by three cycles between 2.8 V and the upper cutoff voltage with a C/5 charge and C/2.5 discharge. All five cycles included a 24 hour hold at the top of charge. The five cycles were followed by an “FRA cycle” consisting of a charge and discharge at C/20 between 2.8 V and the upper cutoff voltage while the FRA measured the cell impedance every 0.1 V between 3.6 and 4.4 or 4.5 V from 40 mHz to 100 kHz. After the FRA cycle, the cells were cycled again for 5 cycles and the protocol was repeated. Cells were removed after 80 or 84 cycles or approximately 2250 hours.

![Figure 3](image.png)

**Figure 3.** The method used in the experiments reported here, with upper cutoff potentials ranging from 4.4 to 4.5 V. The red shaded region represents the voltage range in which the FRA was used to take EIS measurements every 0.1 V.

Gas evolution measurements employing Archimedes principle were done on all cells before and after formation and after cycling. This was done by weighing the cells in nanopure water with \( \rho = 0.998 \text{ g/mL} \) (20 °C), such that the change in mass, \( \Delta m \), is a direct measure of the volume, \( \Delta V \), of gas produced during formation or cycling as described by \( \Delta V = -\Delta m/\rho \). This procedure is discussed in depth by Aiken et al.

Following all cycling experiments, selected pouch cells were dismantled and the electrodes were used to assemble positive and negative symmetric coin cells in order to determine the source of impedance growth. The symmetric coin cells consist of either two positive electrodes or two negative electrodes punched from the original pouch cell with a polypropylene blown microfiber separator (BMF available from 3M Co. 0.275 mm thickness, 3.2 mg/cm²) and...
control electrolyte (no additives). The size of the punched electrodes was 1.36 cm². Once assembled, EIS measurements were taken at $10 \pm 0.1$ °C from 10 mHz to 100 kHz using ten points per decade. The cell potentials were approximately 0.0 V because these were symmetric cells.

Results and Discussion

Figures 5a and 5b show the discharge capacity versus cycle number of the 180 mAh coated and 240 mAh uncoated cells, respectively. Each cell has two distinct curves displaying the difference in capacity between the two C/5 and the three C/2.5 discharge segments. The cycles at C/5 had higher capacity than the cycles at C/2.5. Figure 5a shows that coated cells had severe discharge capacity fade at high rate after only 20 cycles when cycled above 4.425 V. At the end of testing, coated cells cycled above 4.425 V had severe capacity fade at both the C/5 and C/2.5 cycles. Uncoated cells, however, exhibit very small capacity fade for cells cycled up to 4.45 V during all cycles. As shown in Figure 5b, the uncoated cell cycled to 4.5 V began to exhibit severe capacity fade after 30 cycles for C/2.5 cycling and after 45 cycles for C/5 cycling, and the cell cycled to 4.475 V began to exhibit severe capacity fade after 35 cycles for C/2.5 cycling and after 60 cycles for C/5 cycling. Uncoated cells had significantly better capacity retention than coated cells, and very small capacity fade in cells up to 4.45 V, unlike the coated cells.

Once the cells were removed from testing after 80 cycles with the FRA measurements, the cells were cycled at C/50 and 40°C to determine what capacity remained during low rate cycling. For the uncoated cells cycled at 4.4 V, 4.45 V and 4.5 V, the measured C/50 discharge capacities were 245, 240, and 213 mAh, which correspond to 100%, 100%, and 89% of their first cycle discharge capacity respectively. This suggests that the majority of the capacity loss in Figure 5 shown by the uncoated cell cycling to 4.5 V is a result of impedance growth, not a result of Li inventory loss. To further explore this, Figure 6 shows positive and negative reference voltage-capacity curves used for differential voltage analysis and the resulting calculated Li-ion cell voltage-capacity curves, which agree well with the measured full cell curves, for the uncoated cells with upper cutoff voltages of 4.4 V (panel a), 4.45 V (panel b), and 4.5 V (panel c). Figures 6a, 6b and 6c show that the relative slippage between positive and negative electrodes is virtually unchanged as a function of upper cutoff-potential proving that Li-inventory loss in growth of the negative electrode SEI is not occurring to a significant extent. Therefore, it is most likely that the capacity loss shown in Figure 5 is a result of impedance growth.

Figure 7 shows the raw impedance spectra collected by the FRA at all voltages during cycles 26, 50, and 74 for the coated (top panels) and
uncoated (bottom panels) cells cycled with an upper cutoff potential of 4.4 V. Note the different x and y axis scales for the coated and uncoated cells. The long tail that occurs at low values of the real component of impedance (at high frequencies) is due to the inductive contribution from the FRA equipment. In all panels, the width of the spectra grows with increasing potential from 3.7 V. With an upper cutoff of 4.4 V, the coated cell had very small impedance at cycles 26 and 50, but grew significantly by cycle 74, particularly at high potential. By contrast, the uncoated cell showed very little change in impedance spectra with cycle number. Both the coated and uncoated cells exhibited an overall shift in the high frequency real component of the impedance spectra with cycle number, which indicates an increase in the electrolyte resistance or electrode resistance with cycle number.

Figure 8 shows the raw impedance spectra collected by the FRA for all voltages during cycles 26, 50, and 74 for the coated (top panels) and uncoated (bottom panels) cells cycled with an upper cutoff of 4.475 V. Note the different y axis scale for the coated and uncoated cells. In all panels, the width of the spectra grows with increasing voltage from 3.7 V. The coated cell exhibited significant impedance growth with both cycle number and voltage. At high potentials and large cycle numbers, the spectra for the coated cell are incomplete – the FRA does not scan down to low enough frequency to capture the entire spectra. The uncoated cell exhibited impedance growth, albeit much less than that shown by the coated cell. At high potential and large cycle number, the uncoated cell exhibited two peaks in the impedance spectra. This is most likely due to a change in either the positive or negative electrode when repeatedly subjected to high potential. Both the coated and uncoated cell at 4.475 V show an increase in electrolyte or electrode resistance with increasing cycle number as evidenced by the shift of the point where the high frequency part of the spectrum crosses the real axis.

In order to distinguish the contributions from the positive and negative electrode to the impedance growth, the coated and uncoated pouch cells charged to upper cutoff potentials of 4.4 V and 4.45 V were dismantled and assembled into positive and negative symmetric cells after 80 cycles. Figure 9 summarizes the EIS data for the symmetric cells. Figure 9a shows the impedance spectra of the positive electrode symmetric cells made from the coated pouch cells. Figure 9b shows the impedance spectra of the positive electrode symmetric cells made from the uncoated pouch cells and the inset shows a
Figure 7. The raw impedance spectra as measured by the FRA for the coated cell at (a) cycle 26, (b) cycle 50 and, (c) cycle 74 and for the uncoated cell at (d) cycle 26, (e) cycle 50, and (c) cycle 74, both with an upper cutoff of 4.4 V.

Figure 8. The raw impedance spectra as measured by the FRA for the coated cell at (a) cycle 26, (b) cycle 50 and, (c) cycle 74 and for the uncoated cell at (d) cycle 26, (e) cycle 50, and (c) cycle 74, both with an upper cutoff of 4.475 V.
Figure 9. The impedance spectra measured at 10.0 ± 0.1°C for the a) coated positive symmetric cell, b) uncoated positive symmetric cell, c) coated negative symmetric cell and d) uncoated negative symmetric cell made from the respective pouch cells charge to 4.4 V and 4.45 V.

close-up view of the spectra. Similarly to the spectra shown in Figures 7 and 8, the uncoated symmetric cells have much smaller impedance than the symmetric cells made from the coated electrodes. Figures 9a and 9b show that the upper cutoff potential had a dramatic effect on the impedance from the positive electrode. Figures 9c and 9d show the impedance spectra of the negative electrode symmetric cells made from the coated and uncoated pouch cells, respectively. The contribution to impedance from the negative electrode does not depend on the upper cutoff potential, and is also unaffected by the use of a LaPO₄ coating on the positive electrode. Figure 9 clearly shows that the impedance growth exhibited by cells charged to potentials above 4.4 V is dominated by contributions from the positive electrode and positive electrode SEI, which are heavily dependent on the upper cutoff potential.

In order to interpret the changes to the impedance spectra shown in Figures 7 and 8, a transmission line model of the positive electrode was used as shown in Figure 10a. In Figure 10a, the current collector is at the left and the separator is at the right. The circuit elements Rₑ, Rᵢ, Rₛ and C represent the resistance of the electronic path from particle to particle, the resistance of the ionic path from particle to particle, the charge transfer resistance at each particle surface and the double layer capacitance at the particle surfaces. The impedance of the circuit was solved analytically and also using LTSpice. Both solutions gave identical results. The blue curves in Figure 10b show how the impedance spectrum changes if Rₛ is increased sequentially from 0.2 to 3.0 Ω while Rₑ, Rᵢ and C are held fixed. It is worth noting that the same effect as shown by the red curves could be obtained by fixing Rₛ and increasing Rₑ. Figure 10b shows that increasing Rₑ causes the semicircle diameter to increase while increasing Rₛ causes the high frequency intercept, and the whole impedance spectrum, to shift to the right. Figure 10c combines the effects of increases in Rₑ and Rᵢ to approximately mimic the changes observed in the impedance spectra shown in Figures 8d, 8e and 8f for data collected at 3.8 V. The purpose of Figure 10 is to demonstrate that changes in the charge transfer resistance are primarily responsible for the changes in the impedance spectra in Figures 7 and 8, although both Rₑ and Rᵢ could increase somewhat. A recent paper by Metzger et al. suggests that oxidation of carbon black, leading to reduction of electronic conductivity of the positive electrode, is an important factor for cells exposed to high potentials. The data in Figures 7, 8 and 10 suggest that at potentials of 4.5 V and lower in these NMC442/graphite cells with PES₂₂₂ electrolyte additive, decreases in electronic conductivity of the electrode are of minor impact compared to the increases in the charge transfer resistance.

Figure 11 shows the charge transfer resistance, Rₑ, as a function of potential for the cells described by Figures 7 and 8. Only data for every other FRA cycle is shown for clarity. It is important to be clear that Rₑ is a function of potential for the cells described by Figures 7 and 8. Only data for every other FRA cycle is shown for clarity. It is important to be clear that Rₑ is a combination of the charge transfer resistances from both the positive and negative electrodes as well as the resistance due to the motion of the ions through the SEI layers at both the positive and negative electrodes. Rₑ for one electrode, is approximately equivalent to Rₛ in Figure 9a. The value of Rₑ plotted in Figure 11 was taken to be the
Figure 10. a) A transmission line model of the positive electrode used to interpret impedance spectra with the current collector at the left and the separator at the right. b) A Nyquist plot showing how the impedance spectrum changes if Rs is increased sequentially from 0.2 to 3.0 Ω at fixed values of Re, Ri and C (blue curves) and how the impedance spectrum changes if Re is increased sequentially from 0.25 to 0.3 Ω while Rs, Ri and C are held fixed (red curves). c) A Nyquist plot showing the effects of increases in both Rs and Re to approximate the changes observed in the impedance spectra shown in Figures 8d, 8e and 8f for data collected at 3.8 V.

Figure 11. The combination of charge transfer resistance (both positive and negative electrodes) and resistance due to motion of ions through the SEI layers (both positive and negative electrodes), Rct, as a function of voltage measured every 12 cycles. The arrow in panel b) indicates the trend of the data with increasing cycle number, and applies to all panels. Figure 11 shows that uncoated cells cycled up to 4.45 V had virtually no increase in Rct, with potential or with cycle number. Uncoated cells up to 4.475 and 4.5 V, however, show an increase in Rct with cycle number. All LaPO₄-coated cells exhibited impedance growth with cycle number and with increasing potential. Although the coated cell cycled to 4.4 V has small impedance growth, Rct is five times larger than the uncoated cell cycled to the same potential. The LaPO₄-coated cell cycled up to 4.425 V has fifteen times larger impedance growth than the uncoated cell cycled to the same potential and the LaPO₄-coated cells cycled to 4.45 V and above exhibited extreme impedance growth.

Figure 12 shows the values of Rct (c and d) and the changes in Re (or Ri or a combination of Re and Ri) (a and b) extracted from the impedance spectra of LaPO₄-coated cells (red) and from uncoated cells (black) at 3.4 V (circles) and at 4.4 V (crosses) for cells cycled to 4.4 V (a, c) and to 4.475 V (b and d). Figure 12 shows that increases in Rct and Re are less than 0.1 Ω for uncoated cells charged to 4.4 V over 80 aggressive charge-hold-discharge cycles at 40°C. By contrast impedance increases occur in LaPO₄-coated cells after 40 cycles. Figures 12b and 12d show that both Rct and Re increase with cycle number for all cells charged to 4.475 V. However, the increases in Rct are about 5 to 10 times larger than the increases in Re. Again, it is worth noting that Rct is underestimated for the coated cells in Figure 12d because the full semicircle was not accessed at the lowest frequency measured (see Figures 8b and 8c).

Figures 13a and 13b show the volume of gas evolved in coated and uncoated cells, respectively, during each segment of formation and during the 84 charge-hold-discharge cycles coupled with the FRA. In general, the coated cell produced more gas during formation and during cycling than the uncoated cells. The initial volume of the cells
Figure 12. The values of $R_{ct}$ (c and d) and the changes in $R_e$ (or $R_i$ or a combination of $R_e$ and $R_i$) (a and b) extracted from the impedance spectra of LaPO$_4$-coated cells (red) and from uncoated cells (black) at 3.4 V (circles) and at 4.4 V (crosses) for cells cycled to 4.4 V (a, c) and to 4.475 V (b and d).

Figure 13. The volume of gas produced in (a) coated and (b) uncoated cells during both segments of formation and after the completion of 80 or 84 charge-hold-discharge cycles.

Conclusions

In our opinion, impedance growth, due to electrolyte oxidation, is the biggest obstacle to high-potential NMC/graphite Li-ion cells. The charge transfer resistance of the positive electrode increases much more (10x) than resistances associated with either the electronic path or the ionic path within the electrodes. Although positive electrode coatings may reduce the impedance of cells with control electrolyte, the work here shows that the use of state-of-the-art electrolyte additive combinations is effective at reducing impedance growth and improving capacity retention in uncoated cells. The impact of using state-of-the-art additives is thus more significant than the impact of using a LaPO$_4$ coating. The LaPO$_4$-coated cells used in this work demonstrated severe impedance growth and capacity fade when tested aggressively above 4.40 V. The uncoated cells performed well up to 4.45 V, where virtually no impedance growth or capacity fade was measured under the aggressive charge-hold-discharge test at 40°C, but the same cells failed when the upper cutoff was increased by only 25 mV to 4.475 V. This demonstrates the extreme sensitivity of the upper cutoff potential on cell lifetime and impedance growth. It is our opinion that the favorable passivating film on the positive electrode created by the PES222 additive set is itself oxidized and destroyed when the upper potential increases above 4.45 V (at 40°C) in the uncoated cells.

The usefulness of automated impedance measurements coupled with cycling experiments has been demonstrated and, in addition, the importance of performing experiments representative of “real-life” Li-ion cell use. Results collected on high potential Li-ion cells during continuous high-rate charge-discharge cycling at 20°C are simply not representative of aggressive conditions that Li-ion cells can face.
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References

1. K. J. Nelson, G. L. d’Eon, A. T. B. Wright, L. Ma, J. Xia, and J. R. Dahn, J. Electrochem. Soc., 162, A1046 (2015).
2. L. Ma, J. Xia, and J. R. Dahn, J. Electrochem. Soc., 161, A2250 (2014).
3. J. Jeon, S.-W. Park, J.-J. Cho, S. Kang, Y.-K. Han, and H. Lee, J. Mater. Chem., 22, 21003 (2012).
4. H. M. Jung, S.-H. Park, J. Jeon, Y. Choi, S. Yoon, J.-J. Cho, S. Oh, S. Kang, Y.-K. Han, and H. Lee, J. Mater. Chem. A, 1, 11975 (2013).
5. J. Xia, L. Ma, C. P. Aiken, K. J. Nelson, L. P. Chen, and J. R. Dahn, J. Electrochem. Soc., 161, A1634 (2014).
6. K. J. Nelson, J. Xia, and J. R. Dahn, J. Electrochem. Soc., 161, A1884 (2014).
7. L. Ma, D. Y. Wang, L. E. Downie, J. Xia, K. J. Nelson, N. N. Sinha, and J. R. Dahn, J. Electrochem. Soc., 161, A1261 (2014).
8. K. Xu, Chem. Rev., 104, 4303 (2004).
9. C. Li, H. P. Zhang, L. J. Fu, H. Liu, Y. P. Wu, E. Rahm, R. Holze, and H. Q. Wu, Electrochim. Acta, 51, 3872 (2006).
10. Z. Chen, Y. Qin, K. Amine, and Y.-K. Sun, J. Mater. Chem., 20, 7606 (2010).
11. Y.-K. Sun, S.-W. Cho, S.-W. Lee, C. S. Yoon, and K. Amine, J. Electrochem. Soc., 154, A168 (2007).
12. H. G. Song, K.-S. Park, and Y. J. Park, Solid State Ionics, 225, 532 (2012).
13. P. Mohan and G. Paruthimal Kalaignan, Ceram. Int., 40, 1415 (2014).
14. J. Xia, Z. Lu, J. Camardese, and J. R. Dahn, submitted to J. Power Sources (2015).
15. C. P. Aiken, J. Xia, D. Y. Wang, D. A. Stevens, S. Trussler, and J. R. Dahn, J. Electrochem. Soc., 161, A1548 (2014).
16. R. Petibon, C. P. Aiken, N. N. Sinha, J. C. Burns, H. Ye, C. M. VanElzen, G. Jain, S. Trussler, and J. R. Dahn, J. Electrochem. Soc., 160, A117 (2012).
17. R. Petibon, N. N. Sinha, J. C. Burns, C. P. Aiken, H. Ye, C. M. VanElzen, G. Jain, S. Trussler, and J. R. Dahn, J. Power Sources, 251, 187 (2014).
18. H. M. Dahn, A. J. Smith, J. C. Burns, D. A. Stevens, and J. R. Dahn, J. Electrochem. Soc., 159, A1405 (2012).
19. R. de Levie, Electrochim. Acta, 8, 751 (1963).
20. N. Ogihara, S. Kawanishi, C. Okuda, Y. Ito, Y. Takeuchi, and Y. Ukyo, J. Electrochem. Soc., 159, A1034 (2012).
21. Linear Technology, (2011), http://www.linear.com/designtools/software/#LTspice.
22. M. Metzger, C. Marino, J. Sicklinger, D. Haering, and H. A. Gasteiger, J. Electrochem. Soc., 162, A1123 (2015).