Synergistic Effects of Suberonitrile-LiBOB Binary Additives on the Electrochemical Performance of High-Voltage LiCoO₂ Electrodes

Yajuan Ji, a Shiguang Li, a Guiming Zhong, a Zhongru Zhang, a Yixiao Li, a Matthew J. McDonald, a and Yong Yang b,c,d,e

a State Key Laboratory for Physical Chemistry of Solid Surfaces, and Department of Chemistry, College of Chemistry and Chemical Engineering, Xiamen University, Xiamen 361005, People’s Republic of China
b School of Energy Research, Xiamen University, Xiamen 361005, People’s Republic of China

Abstract: Suberonitrile (SUN) and lithium bis(oxalate)borate (LiBOB) were investigated as binary additives for Li-ion batteries that used LiCoO₂ as a cathode, cycled at high cutoff potentials and utilized LiPF₆-based electrolyte. Linear sweep voltammetry (LSV) results revealed that LiBOB oxidized prior to the decomposition of the reference electrolyte. By contrast, SUN has a higher oxidation potential, and in the electrolyte it provided better electrolyte stability at higher potentials. In the electrolyte with binary additives, the electrochemical performance of LiCoO₂ was enhanced significantly, and the initial coulombic efficiency increased to 94% compared with 90% in reference electrolyte. The cell also exhibited capacity retention of 62% after 500 cycles, a strong contrast with the 25% measured in reference electrolyte. Preliminary studies using electrochemical impedance spectra (EIS), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and X-ray photoelectron spectroscopy (XPS) analyses indicated that the combination of the two additives had a unique influence on the structure and composition of the cathode-electrolyte interface (CEI) on LiCoO₂. Ex situ X-ray diffraction (XRD) confirmed that structural change of the LiCoO₂ material was not the main reason causing poor cycling performance when charging to the 4.5 V cutoff potential.

Suberonitrile (SUN) and lithium bis(oxalate)borate (LiBOB) were investigated as binary additives for Li-ion batteries that used LiCoO₂ as a cathode, cycled at high cutoff potentials and utilized LiPF₆-based electrolyte. Linear sweep voltammetry (LSV) results revealed that LiBOB oxidized prior to the decomposition of the reference electrolyte. By contrast, SUN has a higher oxidation potential, and in the electrolyte it provided better electrolyte stability at higher potentials. In the electrolyte with binary additives, the electrochemical performance of LiCoO₂ was enhanced significantly, and the initial coulombic efficiency increased to 94% compared with 90% in reference electrolyte. The cell also exhibited capacity retention of 62% after 500 cycles, a strong contrast with the 25% measured in reference electrolyte. Preliminary studies using electrochemical impedance spectra (EIS), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and X-ray photoelectron spectroscopy (XPS) analyses indicated that the combination of the two additives had a unique influence on the structure and composition of the cathode-electrolyte interface (CEI) on LiCoO₂. Ex situ X-ray diffraction (XRD) confirmed that structural change of the LiCoO₂ material was not the main reason causing poor cycling performance when charging to the 4.5 V cutoff potential.

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counter and reference electrodes in a three-electrode system, using a Versa STAT MV Multichannel potentiostat/galvanostat (Princeton Applied Research, USA) at a scan rate of 1 mV/s.

**Electrochemical measurements.**—The LiCoO₂ (L800D) material was provided by Hunan Shanshan Advanced material Co., Ltd. (China). The electrochemical measurements were taken using CR2025 coin cells, assembled in an argon-filled glove box. The working electrodes were prepared by mixing 80 wt% active material with 10 wt% acetylene black and 10 wt% binder. The loading mass of active material was controlled at about 3 mg, and metal lithium was used as the counter electrode. Celgard 2300 served as physical separators. The volume/mass ratio of electrolyte vs. active materials is used as the counter electrode. The LiCoO₂ (L800D) material was provided by Hunan Shanshan Advanced material Co., Ltd. (China). The electrochemical measurements were performed on a Versa STAT MV Multichannel potentiostat/galvanostat in a frequency range of 10⁵–0.01 Hz and with an amplitude of 5 mV. The EIS data was collected at the charged state of 4.2 V.

**Material characterization.**—X-ray diffraction (XRD) patterns were collected on a Panalytical X-pert diffractometer (PANalytical, Netherlands). Scanning electron microscopy (SEM) images were taken on a S-4800 (HITACHI, Japan) microscope, operating at 15 kV. Transmission electron microscopy (TEM) and high resolution transmission electron microscopy (HRTEM) analysis were performed on a Tecnai F30 (Philip-PEL, Netherlands) apparatus, operating at 300 kV. For the preparation of TEM samples, acetone was used as a dispersing agent. Samples were in acetone and ultrasonically treated for ten minutes to make sure most of the adhesive (PVdF) was removed. Two drops of the solution were then placed on standard pieces for ten minutes to make sure most of the adhesive (PVdF) was removed. Two drops of the solution were then placed on standard pieces of copper mesh, dried, then brought to the TEM equipment. The cells were disassembled and stored in a dry glove box under argon, but the cathodes were exposed to air for a short time when they were transferred into the XPS vacuum chamber. X-ray photoelectron spectroscopy (XPS) measurements were taken with a Quantum 2000 ESCA spectrometer (Physical Electronics, USA) with monochromatic Al Kα 1486.6 eV radiation, operating at 23.2 W and in a vacuum of < 10⁻⁸ Torr. Depth analysis was performed by Ar⁺ ion beam sputtering to 3 nm. Our etching process can be described as follows. Ar ion sputtering was performed with a beam size of 2 mm × 2 mm and an energy of 4 keV, sputtering for 11 seconds. The universal contamination of the C-H bond at 284.8 eV was used as a reference for the final adjustment of the energy scale in the spectra.

**Results and Discussion**

To evaluate the oxidation potential of the electrolytes, LSV experiments were performed with a three-electrode cell. As shown in Fig. 1, the electrolyte with LiBOB has an irreversible oxidation peak at 4.5 V vs. Li⁺/Li before the oxidation of the electrolyte at 5.6 V. This is mainly due to BOB⁻ anion oxidation, which is known to be less stable compared to carbonate solvents and PF₆⁻. In comparison, the electrolyte with SUN has a higher electrochemical stability in agreement with what was previously reported by this group and Abu-Lebdeh’s group. When considering the electrolyte with binary additives, it is clear that SUN can improve the stability of the electrolyte system against oxidative decomposition, which is useful in a high-voltage cathode intercalation device. Presumably, this unique anodic stability of the electrolyte with binary additives is due to the formation of an effective protective film on the working electrode surface.

Fig. 2 shows the voltage profiles and cycling performance of the half-cells. The half-cells exhibit voltage plateaus at ∼3.95 V, which are attributable to the Co₃O₄ charge/discharge redox couple. The

![Figure 1](image1.png)

**Figure 1.** Linear sweep voltammetry (LSV) scans of electrolyte with/without additive, using Pt as a working electrode and Li metal as both counter and reference electrodes. Scan rate: 1 mV/s⁻¹.

![Figure 2](image2.png)

**Figure 2.** Comparison of (a) the initial voltage profiles at 14 mAg⁻¹, (b) the cycling performance and coulombic efficiencies of LiCoO₂/Li half cells at 140 mAg⁻¹.
Table I. Initial charge-discharge capacity, irreversible capacity loss (ICL), and coulombic efficiency (CE) of LiCoO$_2$ in different electrolytes at 14 mAg$^{-1}$.

<table>
<thead>
<tr>
<th></th>
<th>Charge capacity (mAh.g$^{-1}$)</th>
<th>Discharge capacity (mAh.g$^{-1}$)</th>
<th>ICL (mAh.g$^{-1}$)</th>
<th>CE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD120</td>
<td>203.7</td>
<td>184.3</td>
<td>19.4</td>
<td>90.5%</td>
</tr>
<tr>
<td>LD120 + LiBOB</td>
<td>212.3</td>
<td>189.1</td>
<td>23.2</td>
<td>89.1%</td>
</tr>
<tr>
<td>LD120 + SUN</td>
<td>200.1</td>
<td>177.5</td>
<td>22.6</td>
<td>88.7%</td>
</tr>
<tr>
<td>LD120 + LiBOB + SUN</td>
<td>198.9</td>
<td>187.2</td>
<td>11.7</td>
<td>94.2%</td>
</tr>
</tbody>
</table>

First charge capacity increases from 204 to 212 mAh g$^{-1}$ when the cell is cycled in the LD120 with LiBOB as additive, indicating that LiBOB itself decomposes at high potentials. The coulombic efficiency is slightly lower than that of the LD120 alone. When SUN is used as an additive, the decomposition of the electrolyte at high potentials could be effectively suppressed, but with SUN alone, both discharge capacity and coulombic efficiency are noticeably reduced. The reason for this behavior will be discussed later. However, when electrolyte is tested with both LiBOB and SUN, there is a distinctly reduced irreversible capacity loss and improved initial coulombic efficiency, as summarized in Table I. A comparison of the cycling performances shows that with just the LiBOB additive, the capacity fades extremely rapidly. This was possibly due to the LiBOB salt severely decomposing at high voltages and causing a series of side reactions that reduced the coulombic efficiency and specific capacity during prolonged cycling, as shown in Fig. 2b. In the LD120 + SUN cell, the charge capacity and discharge capacity are slightly less than the reference cell, however, using SUN plus LiBOB as binary additives significantly enhances the electrochemical stability of the LiCoO$_2$ material: the capacity retention ratio reaches 62.3% after 500 cycles compared with the 25.5% for the LD120 sample, the 9.6% for the LD120 + LiBOB sample and the 53.7% for the LD120 + SUN sample. These results suggest a remarkable stabilization effect from the presence of SUN as a co-additive with LiBOB in EC-DMC/LiPF$_6$ solutions.

The cycling stability of LiCoO$_2$ cathodes were tested at a current density of 140 mAg$^{-1}$ for 500 cycles of the four electrolytes. Representative voltage profiles are shown in Fig. 3. A gradual decrease can be seen in the average discharge voltage along with obvious polarization, upon cycling in reference electrolyte and LiBOB as sole additive electrolyte systems. It is clear that in the LD120 + SUN and LD120 + LiBOB + SUN samples, the electrochemical stability of the materials is obviously enhanced and the polarization of cells is substantially reduced. The midpoint voltage (MPV) is an important parameter for evaluating cathode materials as contenders for high energy density lithium ion batteries. As described in Fig. 4, with an increase in cycle number, the MPVs of discharge shows an analogous trend as cycling performance. At the 500th cycle, the MPVs of discharge for the cathode material cycled in electrolyte samples LD120, LD120 + LiBOB, LD120 + SUN, and LD120 + LiBOB + SUN are 3.48 V, 3.30 V, 3.88 V, and 3.86 V, respectively. In the LD120 and LD120 + LiBOB electrolytes, a continuous MPVs decay is recorded upon cycling. However, the rate of decay changes more moderately in the SUN-containing solutions. This result confirmed that a more stable electrode/electrolyte interface was built using the SUN additive.

The discharge capacity of the LiCoO$_2$ material can be divided into the contribution of two parts: a) 3.9–4.5 V and b) 3–3.9 V, based on the calculation of discharge curves as shown in Fig. 5. In the 3.9–4.5 V region, without using SUN the delivered capacities drop sharply for...
the first 150 cycles and then flatten out, which is in strong agreement with the cycling performance in these electrolytes. However, the rate of decline of capacity decreases significantly when using SUN as an additive, especially in the LiBOB and SUN binary additive system. As for delivered capacities below 3.9 V, the cathode materials show steady performance except for the cells with LD120 + LiBOB, indicating that the structure of the electrodes exhibit instability upon cycling in this system. However, the structural stability of the material is improved by adding SUN, especially in the high voltage range, an observation bolstered by XRD measurements.

To examine the relationship between CEI film and the structural stability of LiCoO₂, changes in the crystal structure of the LiCoO₂ composite electrodes were examined by ex situ XRD. As discussed in previous publications, 34,35 when x > 0.5, the structure of Li1-xCoO2 gradually but irreversibly changes from the hexagonal phase to the monoclinic phase. These structural changes upon cycling are demonstrated in Fig. 6. The characteristic diffraction lines of the pristine LiCoO₂ can be indexed to the O3 layered structure with a R3m space group as the major phase. After undergoing 500 cycles in different electrolyte systems, the (003) peak shows an obvious change, while the change of the other peaks were negligible. This implies that the O3 phase coexisted with a new monoclinic layered phase, which is evident from the fact that the (003)hex diffraction line located at 18.9 (2θ) splits into two peaks, with the lower angle peak assignable to (001)mon.35 However, the two peak percentages exhibit different behavior in different electrolyte systems. The monoclinic becomes the dominant phase in the LD120 + LiBOB electrolyte, but by contrast, in the reference and SUN-containing electrolyte systems, the hexagonal and monoclinic phases show an almost equal percentage, even though these systems have conspicuous differences in electrochemical stability. This fact confirmed that the poor cycling performance of LiCoO₂ should not be attributed to structural instability, but rather the key factor responsible for the poor capacity retention of LiCoO₂ cycled to 4.5 V is the lack of an effective CEI film layer. This phenomenon is in good agreement with the results reported by J. R. Dahn et al.36

EIS measurements were also carried out to probe the effects of SUN and LiBOB additives on the cycling performance of cells and to understand the electrochemical processes occurring in the electrode/electrolyte interface in these lithium-ion batteries. As shown in Fig. 7, a typical EIS of the Li-ion cells is composed of two partial semicircles and a straight-sloped line at the low frequency end. Such an EIS pattern can be fitted by an equivalent circuit, as shown in the inset of Fig. 8. The model reflects the Li⁺ intercalation/de-intercalation process: R1 is bulk resistance of the cell, which reflects diffusion of Li⁺ in solution, Li⁺ migration through the solid/electrolyte interface (SEI) film is attributed to the high-frequency semicircle (RSEI), charge transfer through the electrode/electrolyte interface is related to the medium-frequency semicircle (RCT), and the low-frequency tail is due to the Li⁺ diffusion process in the solid phase of the electrode. The R_SEI and R_CT values are calculated after fitting the experimental data with an appropriate equivalent circuit as previously proposed by...
Aurbach et al.\textsuperscript{37} The fitted curves are demonstrated as lines in Fig. 8a and 8b.

In Fig. 8a, surface film resistance presents an obvious difference upon the addition of SUN and LiBOB. Electrolyte containing LiBOB has the \( R_{\text{SEI}} \) value increasing substantially more than that of other electrolytes in the initial cycles, confirming that the LiBOB salt decomposes and participates in the formation of CEI film. As cycling continues, the CEI film shows instability and \( R_{\text{SEI}} \) values are reduced rapidly both in the LD120 and the LiBOB additive systems until 100 cycles are completed. However, SUN could optimize the CEI component to form a relatively stable film, and could also help suppress the further decomposition of LiBOB, which can be confirmed by XPS data.

Fig. 8b presents the variation in \( R_{\text{CT}} \) values of electrodes. The results showed that the \( R_{\text{CT}} \) values of the electrodes increase rapidly with cycling in the LD120 and LiBOB-containing electrolyte systems, even to over 800 ohms after 300 cycles. In contrast, in systems with the SUN additive, smaller \( R_{\text{CT}} \) values are exhibited along with slower increases in charge-transfer impedance. The \( R_{\text{CT}} \) value begins at 5 ohms after one cycle, increases slowly, and reaches only 488 ohms at the 300\textsuperscript{th} cycle. Remarkably, when using SUN and LiBOB as binary additives, the \( R_{\text{CT}} \) value was 58 ohms in the second cycle, increases

Figure 7. EIS spectra of LiCoO\(_2\) electrodes in electrolyte with/without additive. The inset shows a magnification of the high-frequency semicircle.

Figure 8. The fitted results of EIS spectra from cells cycled in different electrolyte systems, (a) \( R_{\text{SEI}} \) and (b) \( R_{\text{CT}} \). The inset in Fig. 8a describes the equivalent circuit.
By contrast, the film became relatively stable when SUN was added, evidenced by the appearance of sharp edges on the LiCoO₂ particles. However, in the LD120 electrolyte, with results displayed in Figs. 9d and 9e, causes the cathode material surface to become only slightly less stable. This demonstrated that SUN participated in the cathode surface film formation, which stabilized the electrode/electrolyte interface and benefited charge transfer while reducing the cell polarization. The data was consistent with the results of the cycling performance tests. Taken together, these suggest that the presence of SUN in solution led to a slightly lower specific capacity but also to excellent capacity retention, lower MPV changes and interface impedance upon cycling. However, further measurements were conducted in order to identify additional, more subtle effects related to the presence of SUN with LiBOB as binary additives in solutions.

Fig. 9 displays SEM images taken from the LiCoO₂ electrodes after 500 cycles in different electrolytes. Compared to the initial morphology of the electrode (Fig. 9a), the cycled material in all electrolytes have obviously changed. For the reference electrolyte, as shown in Fig. 9b, the particles are locally covered by a thin layer of surface film, which may contribute to electrolyte oxidation decomposition at high potentials, but the film layer structure is rough and loose. By contrast, in the LD120 + LiBOB electrolyte (Fig. 9c), there is almost no film on the surface. Adding SUN to the electrolyte, with results displayed in Figs. 9d and 9e, causes the cathode material surface to be completely covered by a smooth, dense layer. Consistent with the EIS data, this data showed that the surface film derived from the carbonate electrolyte and LiBOB salt was not electrochemically stable, and could be dissolved or decomposed during prolonged cycling as evidenced by the appearance of sharp edges on the LiCoO₂ particles. By contrast, the film became relatively stable when SUN was added.

Fig. 10 displays TEM images from pristine LiCoO₂ electrode along with 500th cycled LiCoO₂ electrode in different electrolyte samples. The TEM image of pristine LiCoO₂ cathode (Fig. 10a) shows evidence of a good crystallinity and a smooth surface at the edge of the grains. The inset figure is the associated selected-area electron diffraction (SAED) pattern. The SAED pattern taken from the particle can be indexed to the [018] zone axis of the single-crystal LiCoO₂ structure. In comparison, after long cycling in LD120 + LiBOB (Fig. 10c), the LiCoO₂ particles have been corroded and converted to a disordered lattice structure, as the insert SAED pattern shows. In addition, a film has obviously changed. For the reference electrolyte, as shown in Fig. 9b, the particles are locally covered by a thin layer of surface film, which may contribute to electrolyte oxidation decomposition at high potentials, but the film layer structure is rough and loose. By contrast, in the LD120 + LiBOB electrolyte (Fig. 9c), there is almost no film on the surface. Adding SUN to the electrolyte, with results displayed in Figs. 9d and 9e, causes the cathode material surface to be completely covered by a smooth, dense layer. Consistent with the EIS data, this data showed that the surface film derived from the carbonate electrolyte and LiBOB salt was not electrochemically stable, and could be dissolved or decomposed during prolonged cycling as evidenced by the appearance of sharp edges on the LiCoO₂ particles. By contrast, the film became relatively stable when SUN was added.

The DMC solutions were replaced after 12 hours to make sure any residual electrolyte was totally removed. At that point, to further analyze the composition and structure of the CEI layer formed on the surface of the LiCoO₂ material, XPS measurements were carried out on the cathode material in LiCoO₂/Li cells undergoing 500 cycles with/without LiBOB and SUN additives. The C1s, O1s, F1s, P2p, N1s and B1s XPS spectra of the electrode surfaces extracted from cells are depicted in Fig. 11. For the pristine electrode, the C 1s spectrum contains several peaks, with a conductive carbon peak at 284.8 eV and the poly(vinylidene) fluoride (PVdF) binder (-CF₂-, 290.9 eV) assignable to F 1s (688 eV). The O 1s peak appearing at 530 eV is assigned to the Co-O bond. After cycling, these peak intensities are substantially attenuated compared with those of the pristine cathodes, which is indicative of surface film growth on the electrode surface.

In the sample cycled without additives, the surface film composition consists of a large amount of Li₂CO₃ (531.5 eV) and ROCO₂Li (533.3 eV). The F 1s spectra and P 2p spectra show that there exists LiF and decomposition of the LiPF₆. This phenomenon confirmed that the carbonate solvents and LiPF₆ were seriously decomposed during cycling. With the LiBOB sample, a pronounced B 1s spectrum peak at 191.5 eV appears at the CEI layer, which was attributable to the decomposition product of LiBOB and consistent with the opened rings of BO₂⁻, which precipitated on the cathode material surface. However, there is also a visible peak assignable to PVdF and carbon, confirming that the film showed serious instability and further decomposed on the Co-based cathode material, leading to the impedance of Li⁺ ion motion and unfavorable cycling performance. Examination...
ing the SUN samples shows that the amount of LiF and Li$_2$CO$_3$ increases distinctively. These inorganic components benefited the stabilization of the CEI layer, while a large amount of LiF would increase the impedance of the film. From Fig. 11, a mass of N can also be seen to exist in the CEI layer, indicating that the presence of SUN modifies the SEI layer formation reaction. It was found that when SUN was added with LiBOB, the cell cycling performance was significantly enhanced and the surface film resistance increased at the slowest rate. This phenomenon showed that SUN and LiBOB were incorporated into the CEI film: SUN could modify the compounds making up the CEI, suppressing the charged-state Co ions from catalyzing the further decomposition of carbonyl-rich boron-bearing compounds.

These additives were used to deactivate the “catalytic” center atoms on the cathode surface in order to remain inert with respect to the bulk electrolyte. All of these conclusions are in good agreement with the previous results and are consistent with the final testing described below.

![Figure 10. TEM images of (a) pristine and cycled LiCoO$_2$ electrodes in (b) LD120, (c) LD120 + LiBOB, (d) LD120 + SUN and (e) LD120 + LiBOB + SUN electrolyte systems.](image)

![Figure 11. XPS spectra of pristine LiCoO$_2$ electrode and electrodes cycled in electrolyte with/without additive for 500 cycles.](image)
To further understand the mechanism of CEI formation in the electrolytes with LiBOB and SUN, the surfaces of electrodes were etched to obtain an approximately 3 nm depth profile of the CEI, revealing the inner parts of the CEI to the XPS beam. The “inner CEI” products, which were formed in contact with the cathode surface, could be distinguished from “outer CEI” products, which were farther away from the cathode surface. The data can be seen in Fig. 12. As expected, the data shows that the CEI is heterogeneous and the respective CEI products vary in species and quantity across the width of the CEI. Compared with the O 1s and P 2p spectra, the components of ROCO2Li, LiP0F6, and LiPF6 in the outer CEI are larger in amount than those of the inner CEI. Only very small amounts of nitrogen can be found in the inner CEI after the 2nd cycle compared to after the 500th cycle. The quantity of nitrogen can be ordered as outer CEI-500th > inner CEI-500th > CEI-2nd. The mass of boron existing in the CEI layer could be ordered as CEI-2nd > CEI-500th, suggesting that the oxidation of BOB− anions was also involved in the CEI formation process during the initial cycling, which agrees well with the LSV results. However, the depth profile data also suggested a larger amount of Li2CO3 and LiF close to the cathode surface. It was well known that Li2CO3 is a better passivating agent than either ROLi or ROCO2Li, due to its lower solubility in electrolyte and better conductive performance with Li+ ions. The borate produced from the decomposition of LiBOB had a strong electron-withdrawing ligand character, and it captured F− from LiF. It thus improved the dissolvability of the LiF in the CEI film and avoided generating a large amount of LiF, resulting in a more stable interfacial impedance. In addition, the decomposition of BOB− and reference electrolyte together with a small amount of LiF were the main products involved in the CEI formation. Consequently, SUN would stabilize the production of BOB− via decomposition by generating LiF, which prevented Co4+ from directly contacting BOB−. It was additionally possible that there existed a strong interaction between SUN and borate groups, based on the chelation with the electron deficient center (boron) and electron rich center (CN), thus stabilizing the decomposition of BOB−. The presence of SUN modified the CEI layer formation reaction components, with the use of SUN and LiBOB as binary additive combining the advantages of the two components and producing stable CEI with moderate thickness and stiffness. The working mechanism producing the synergistic effects of the binary additive systems of SUN and LiBOB in CEI formation requires more data and evidence to fully understand, with further experiments to be carried out in future work. Useful characterization methods include the application of advanced spectroscopic techniques such as high-resolution solid state nuclear magnetic resonance (NMR), Raman, soft X-ray absorption spectroscopy and so on.

Conclusions

SUN and LiBOB have been demonstrated to be a useful binary additive for improving the electrochemical performance of LiCoO2 when cycling at high cutoff potentials in LiPF6-based electrolyte. The cell also exhibited capacity retention of 62% after 500 cycles, a strong contrast with the 25% measured in reference electrolyte. In this work, the components of the electrolyte were found to have a major influence on the composition and structure of CEI films, which strongly impact battery performance in areas such as cycling performance, coulombic efficiency, and safety. LiBOB traditionally does not work well with Co-based materials, and the use of SUN as an additive tends to form too large an amount of LiF to make a thick surface film. However, the combination of SUN and LiBOB as a binary additive was found to have a synergistic effect that stabilized the film, greatly suppressing the otherwise dramatic increases in interface impedance and significantly enhancing the cycling performance of the LiCoO2 material. This work also suggests that the interfacial reaction is the main factor that affects the LiCoO2 material’s electrochemical stability when charged to a 4.5 V high cutoff potential, not the structural stability. Continuing research on this system promises to provide a thorough understanding of the interface reactions on the surface of LiCoO2 cathodes as well as a controlled modification of them, greatly beneficial steps toward the development of high-potential electrolyte systems.

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