# Low Temperature Electrolytes Based on Linear Carboxylic Ester Co-solvents for $SiO_x$/graphite Composite Anode

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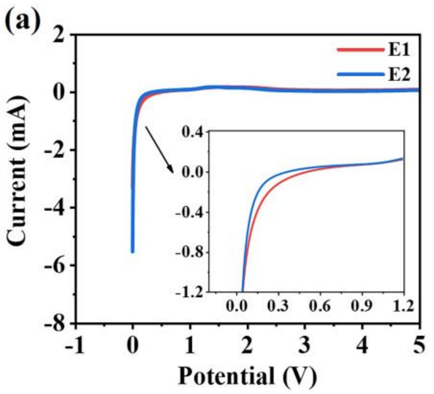


Figure S1. (a) Oxidation stability measured by LSV and (b) cyclic voltammograms of SiOC half cells with E1 and E2.

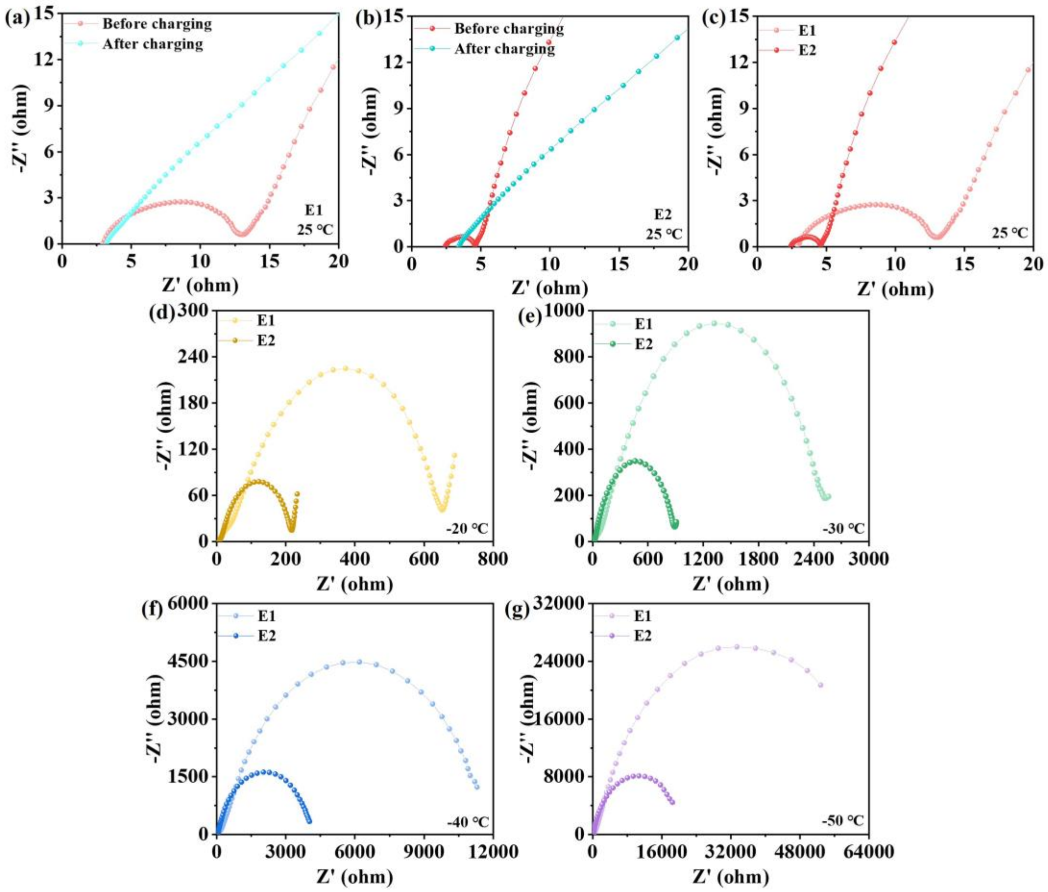


Figure S2. The EIS of SiOC half cells with (a) E1 and (b) E2 before/after charging at 25 ℃; and the EIS comparison of E1 and E2 system before charging (c) at 25 ℃, (d) at −20 ℃, (e) at −30 ℃, (f) at −40 ℃ and (g) at −50 ℃.

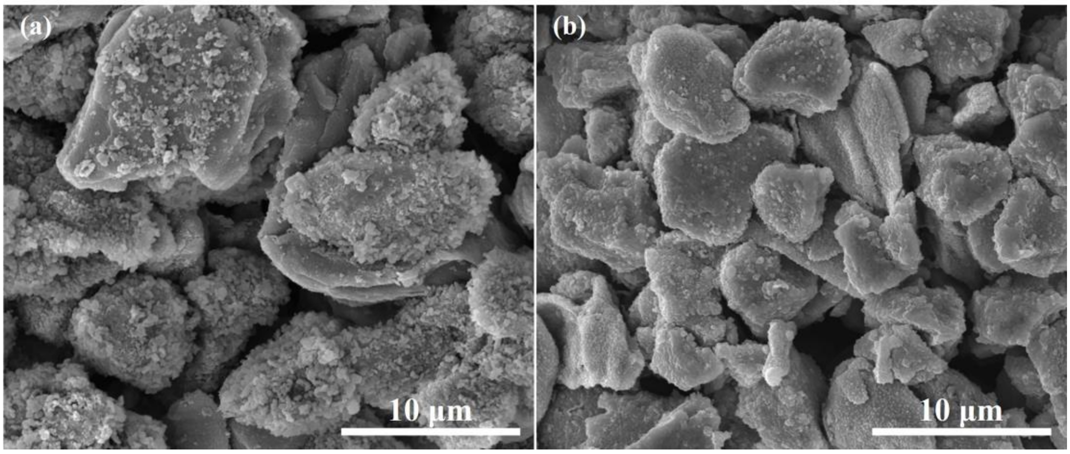


Figure S3. The SEM images of electrodes with (a) E1 and (b) E2 after finishing all tests at low temperatures.

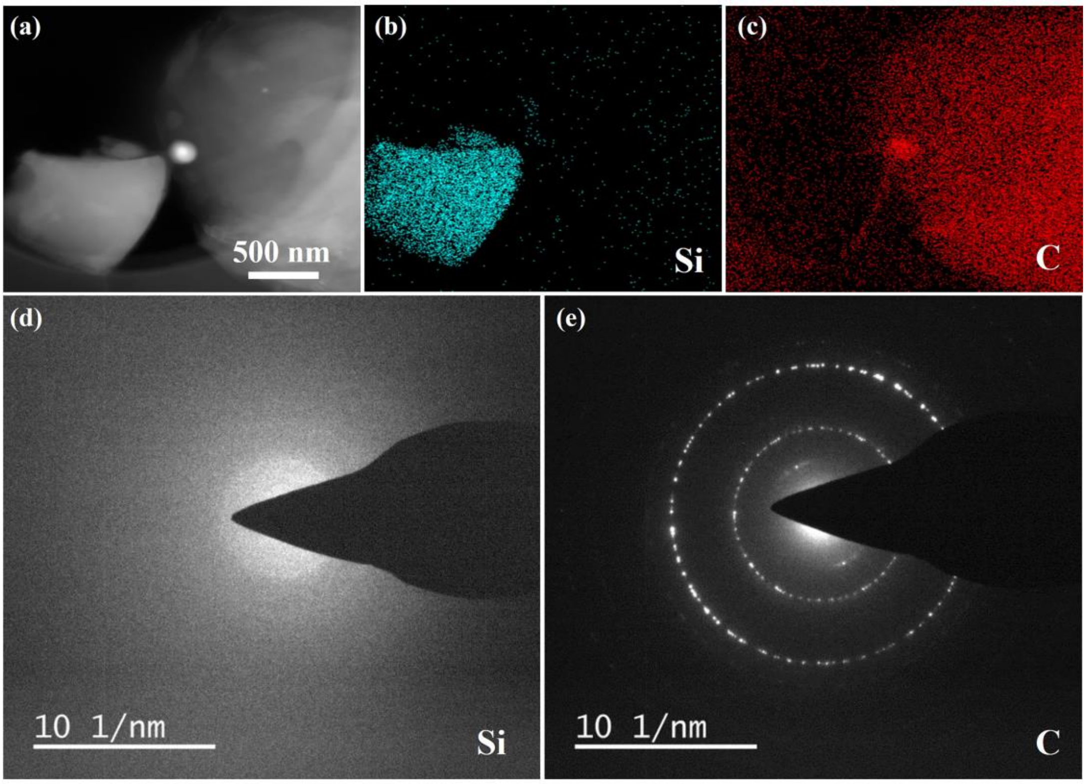


Figure S4. (a) The dark-field TEM images of the pristine electrode; and the homologous elemental mapping of the (b) Si element and (c) C element; and the corresponding SAED pattern of (d) Si and (e) C.

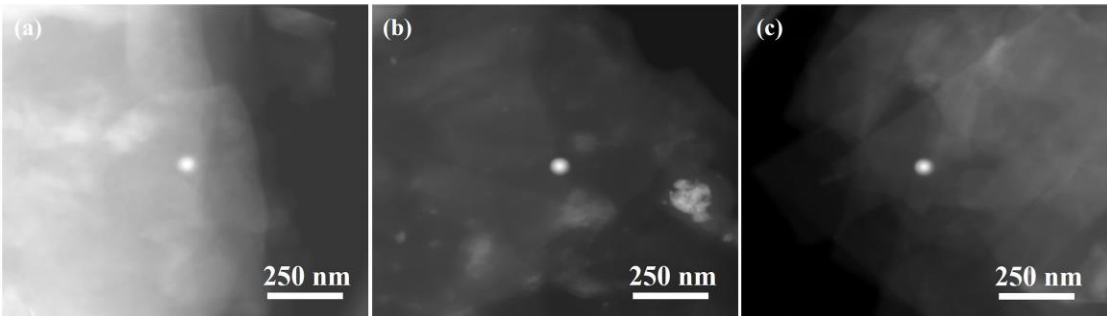


Figure S5. The dark-field TEM images of graphite of (a) the pristine electrode and electrodes with (b) E1 and (c) E2 after finishing all tests at low temperatures

Table S1. Relative component concentrations form XPS spectra for C1s for pristine and cycled SiOC electrodes.

| | Pristine | E1 | E2 |
|---|---|---|---|
| Graphite | 10.78 | 0.00 | 0.00 |
| C-C/C-H | 35.08 | 11.40 | 10.40 |
| C-O | 39.33 | 20.23 | 16.69 |
| $CO_3^{2-}$ | 0.00 | 1.58 | 2.14 |
| C-F | 0.00 | 1.59 | 1.13 |

Table S2. Relative component concentrations form XPS spectra for F1s for pristine and cycled SiOC electrodes.

| | Pristine | E1 | E2 |
|---|---|---|---|
| LiF | 0.00 | **15.66** | **18.98** |
| C-F | 0.00 | 6.02 | 6.27 |

Table S3. Relative component concentrations form XPS spectra for Si2p for pristine and cycled SiOC electrodes.

| | Pristine | E1 | E2 |
|---|---|---|---|
| $SiO_2$ | 0.56 | 0.00 | 0.00 |
| Si | 0.10 | 0.00 | 0.00 |
| $Li_xSiO_y$ | 0.00 | 0.21 | 0.24 |

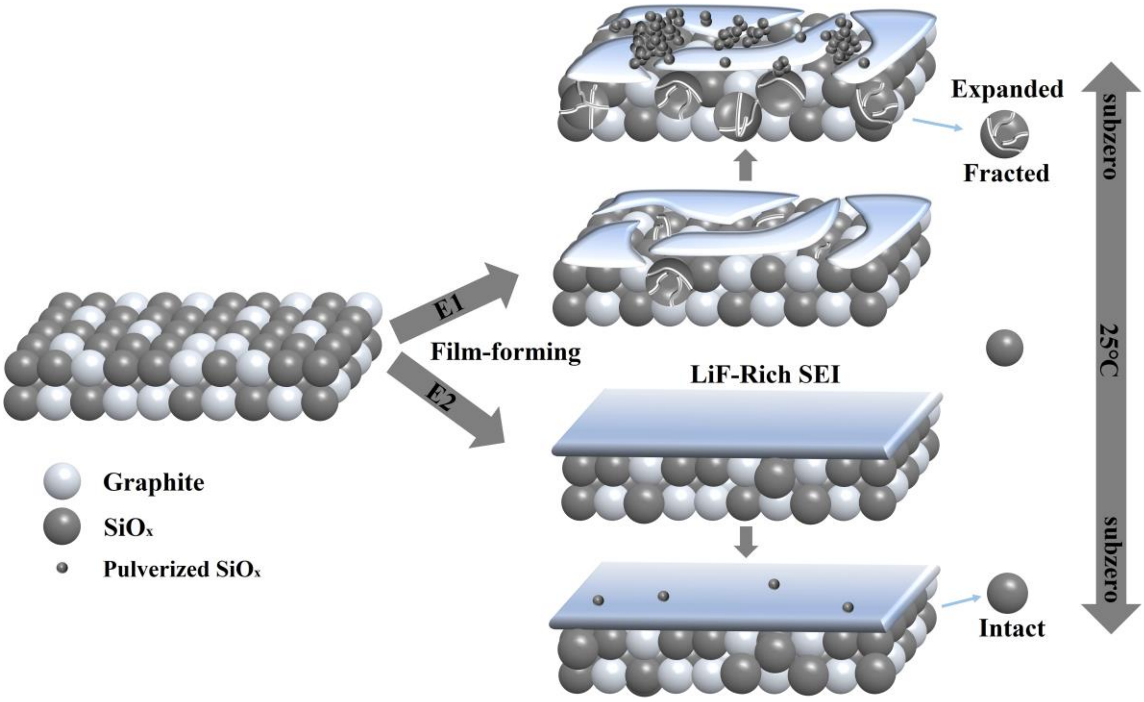


Figure S6. Schematic illustration of SEI forming process of SiOC electrode at 25 °C and variation of electrode surface with different SEI at subzero temperature.

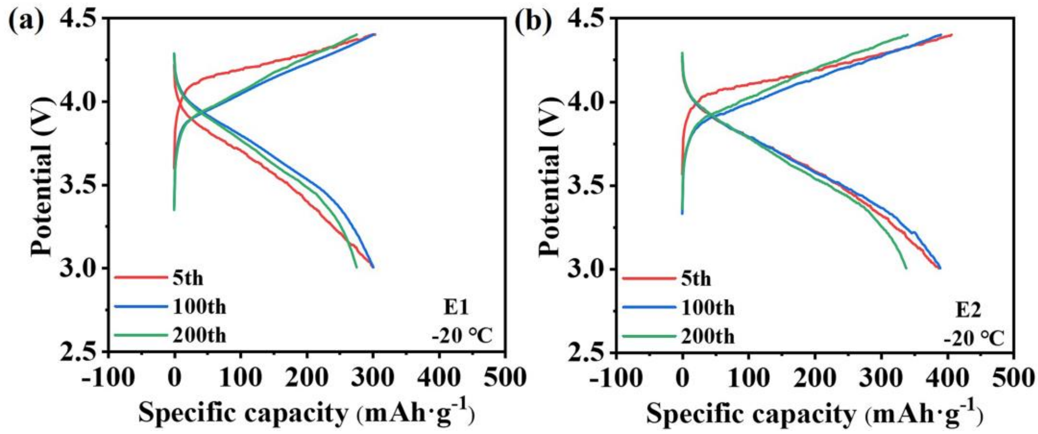


Figure S7. Charge-discharge curves of SiOC||LCO full cell with (a) E1 and (b) E2 of different cycles at −20 °C.

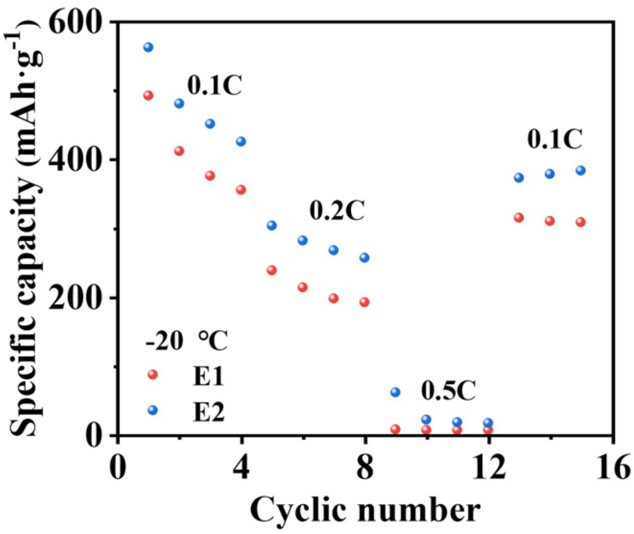


Figure S8. Rate performance of the SiOC||LCO full cell at −20 °C.

Table S4. Summary of progress on electrolyte for low temperature.

| Cathode‖anode | electrolyte | Temperature (℃) | Capacity retention (% of RT) | Rate | Ref |
|---|---|---|---|---|---|
| Graphite‖Li | 1.0 $LiPF_6$ EC-DEC (3:7) | –20 | 67% | C/20 | [1] |
| Graphite‖Li | 1.0 $LiPF_6$ EC-DMC (3:7) | –20 | 15% | C/20 | [1] |
| Graphite‖Li | 1.0 $LiPF_6$ EC-DMC-DMC (1:1:1) | –20 | 85% | C/20 | [1] |
| $LiCoO_2$‖Li | 1.0 $LiPF_6$ EC-DMC-EMC (1:1:1) | –20 | 91.8% | - | [2] |
| $LiCoO_2$‖Li | 1.0 $LiPF_6$ EC-DMC-EMC (1:1:1) | –40 | 12.86% | - | [2] |
| Graphite‖Li | 1.0 LiTFSI in ETFA-FEC（7：3） | –20 | 83.7% | 0.05C | [3] |
| $LiMn_2O_4$‖Graphite | 1.0 $LiPF_6$ in EC-EMC-DMC (1:1:1) | –40 | 8.44% | 0.1C | [4] |
| **$SiO_x$/Graphite‖Li** | **1.2 M $LiPF_6$ in DEC-EP-PC-EC-FEC (10:10:1:4:2)** | **–50** | **63.66%** | **0.1C** | **This work** |

**Supplementary references**


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