Created in COMSOL Multiphysics 6.1

Electrode Utilization in a Large Format Lithium-Ion Battery Pouch Cell

Introduction

Large lithium-ion batteries are widely employed in electric vehicles and for stationary energy storage applications. In the (stacked) pouch battery cell design, all current exits the cell on the cell “tabs”, and as the cell size and power increases, the voltage gradients in the highly conductive metal foil current collectors may come into play, resulting in a non-uniform current distribution and electrode utilization in the cell.

A non-uniform utilization results in sub-optimal use of the battery electrodes and may also result in non-uniform and accelerated electrode aging.

This tutorial models the current distribution and electrode utilization in a large format lithium-ion battery pouch cell, and how it depends on the cell current.

The model is in 3D. Note that all plots are scaled 100 times in the z direction due to the high aspect ratio of the geometric features.

Model Definition

Figure 1 shows the model geometry. The geometry defines one foil-to-foil unit cell, stacking 5 layers in the z direction:

- Negative metal current collector foil: 10 µm, Cu (due to symmetry, half of this thickness is used in the model geometry)
- Negative electrode: 60 µm, graphite
- Separator: 30 µm
- Positive electrode: 60 µm, LMO
- Positive metal current collector foil: 10 µm, Al (due to symmetry, half of this thickness is used in the model geometry)
- The electrolyte is LiPF6 in 3:7 EC:EMC
- Symmetry is assumed along the center of the cell

The positive and negative current terminals are located opposite to each other (but may easily be placed on the same side by altering the Geometry node in the model).

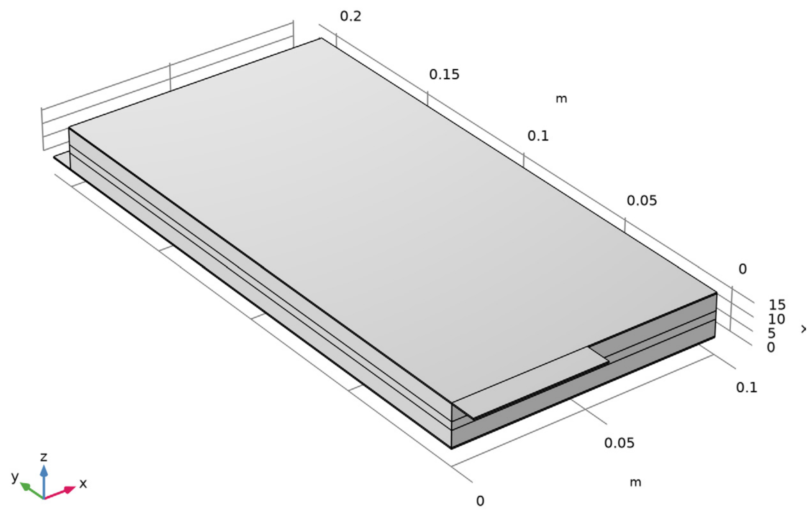


Figure 1: Model geometry, scaled 100 times in the z direction.

The Lithium-Ion Battery interface is used to set up the physics, using Material data from the Battery Material Library.

The Particle Intercalation subnodes to the Porous Electrode nodes model the solid lithium concentration in an additional particle dimension (extra dimension). The model hence defines a fully coupled “pseudo-4D” model.

The battery is charged from 20% to 80% cell state-of-charge (SOC). The Initial Cell Charge Distribution node is used to set the initial cell state-of-charge.

An Electrode Ground boundary condition is used on the negative tab whereas an Electrode Current boundary condition defines the cell current exiting the cell on the positive tab.

A Parametric Sweep is used to solve for two different charge rates (1C and 4C).

Results and Discussion

Figure 2 and Figure 3 show the potential distribution in the negative and positive metal foils (current collector and tab), respectively, at the beginning of the 4C charge. The potential variation is about 6 mV in the negative current collector and 10 mV in the positive current collector at a 4C charge current.

For a 1C charge current the corresponding potential variation is below 2 mV (results not shown here).

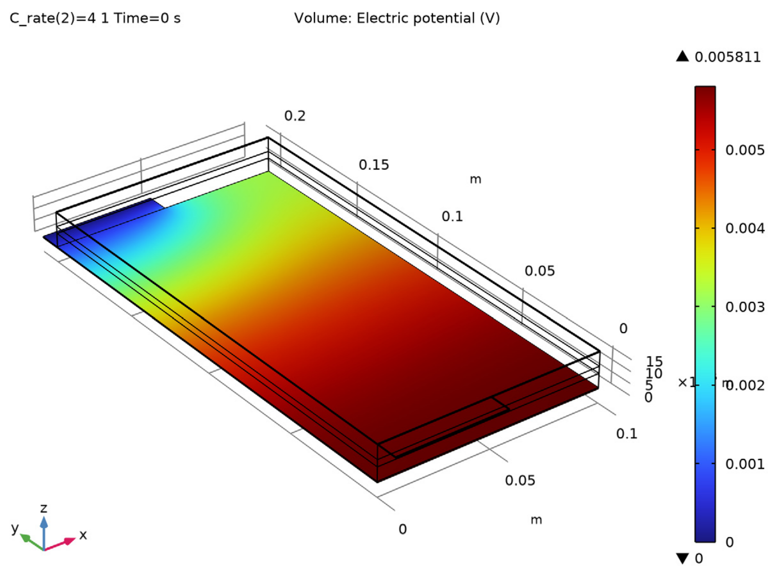


Figure 2: Potential distribution in the negative metal foil (current collector and tab) at the beginning of the 4C charge.

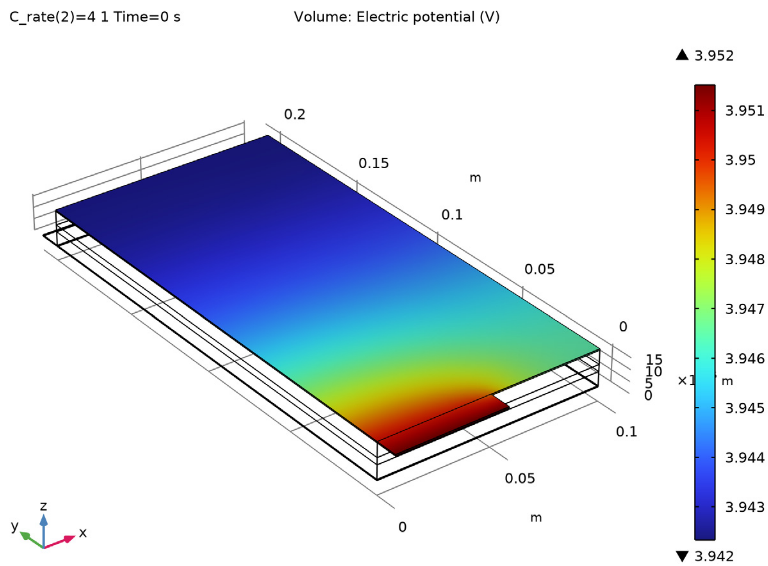


Figure 3: Potential distribution in the positive metal foil (current collector and tab) at the beginning of the 4C charge.

Figure 4 and Figure 5 show the current distribution for a cross section in the middle of the separator at the beginning and end of the 4C charge, respectively. This provides a measure of the instantaneous electrode utilization. The current distribution varies about 6% in the separator plane over time. For 1C, the variation is generally smaller (results not shown here). Initially, the separator current density is higher close to the tabs whereas toward the end of the charge, the current density is higher in the central parts of the cell.

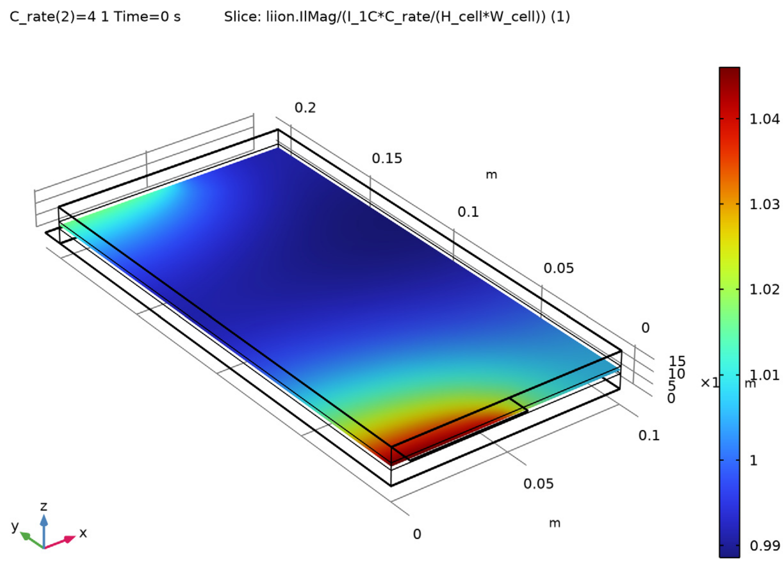


Figure 4: Current distribution in the middle of the separator at the beginning of the 4C charge.

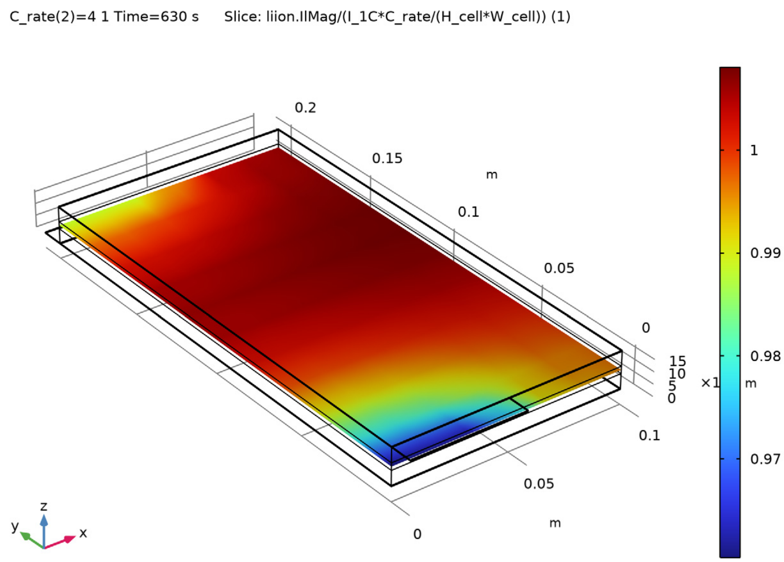


Figure 5: Current distribution in the middle of the separator at the end of the 4C charge.

To get a measure of the utilization over the charge period, General Projection operators are used to integrate the amount of lithium along the electrode depth (the z direction). Dividing the projected change of lithium by the average for the whole electrode gives a measure of the relative utilization (capacity thruput). Figure 6 and Figure 7 show the relative utilization over the whole charge period for the 1C and 4C charges, respectively for the positive electrode. The utilization varies around 2.5% for the 4C charge and 1% for the 1C charge. The cycle-averaged utilization is lower than the instantaneous utilization shown in Figure 4 and Figure 5.

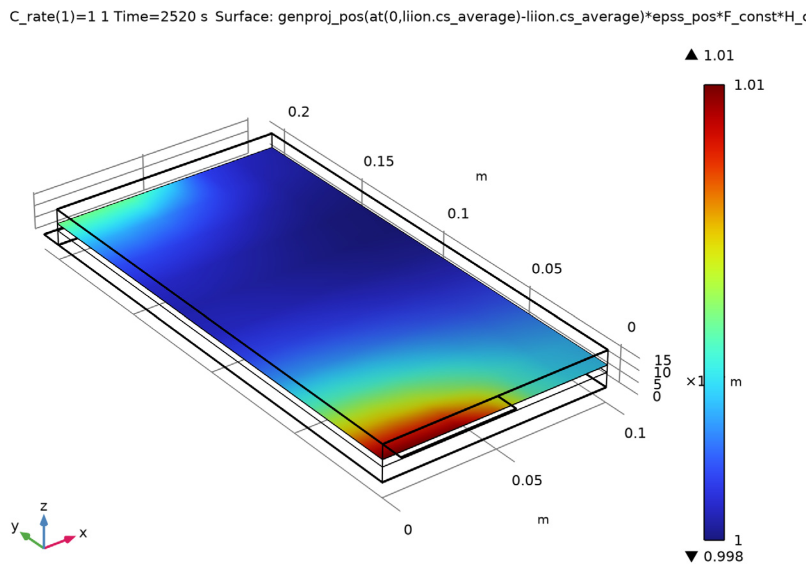


Figure 6: Relative electrode utilization during the 1C charge.

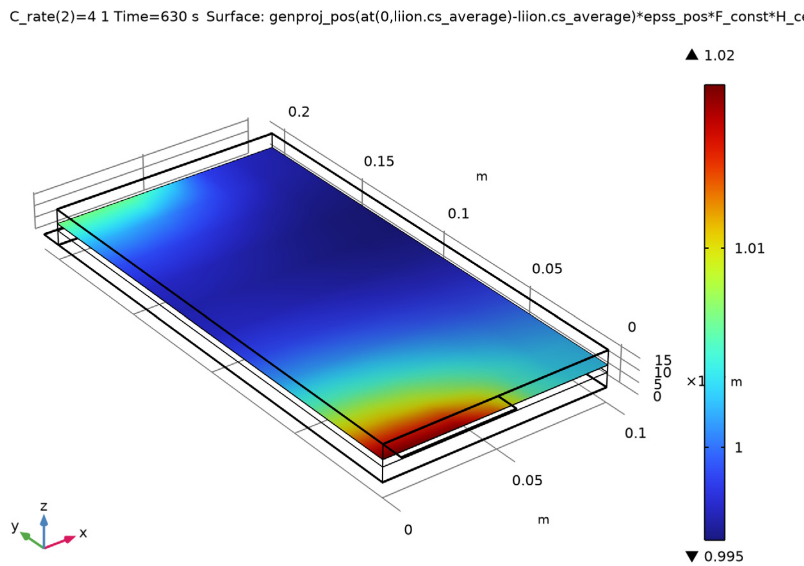


Figure 7: Relative electrode utilization during the 4C charge.

The tutorial demonstrates that the local electrode utilization along the metal foil (current collector and tab) changes over the course of a charge cycle. For this configuration, utilization is fairly uniform during a 1C charge, but a higher charge of 4C results in a slightly non-uniform utilization.

Application Library path: `Battery_Design_Module/Batteries,_Lithium-Ion/pouch_cell_utilization`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.
2 In the **Select Physics** tree, select **Electrochemistry>Batteries>Lithium-Ion Battery (liion)**.
3 Click **Add**.
4 Click **Study**.
5 In the **Select Study** tree, select **Preset Studies for Selected Physics Interfaces> Time Dependent with Initialization**.
6 Click **Done**.

GLOBAL DEFINITIONS

Parameters 1

Import the parameter file.

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.
2 In the **Settings** window for **Parameters**, locate the **Parameters** section.
3 Click **Load from File**.
4 Browse to the model's Application Libraries folder and double-click the file `pouch_cell_utilization_parameters.txt`.

GEOMETRY 1

Set up the model geometry using the following steps.

Work Plane 1 (wp1)

In the **Geometry** toolbar, click **Work Plane**.

Work Plane 1 (wp1)>Plane Geometry

In the **Model Builder** window, click **Plane Geometry**.

Work Plane 1 (wp1)>Rectangle 1 (r1)

1 In the **Work Plane** toolbar, click **Rectangle**.
2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.
3 In the **Width** text field, type `W_cell`.
4 In the **Height** text field, type `H_cell`.

Extrude 1 (ext1)

1 In the **Model Builder** window, right-click **Geometry 1** and choose **Extrude**.
2 In the **Settings** window for **Extrude**, locate the **Distances** section.

3 In the table, enter the following settings:

Distances (m)
L_neg_cc/2
L_neg_cc/2+L_neg
L_neg_cc/2+L_neg+L_sep
L_neg_cc/2+L_neg+L_sep+L_pos
L_neg_cc/2+L_neg+L_sep+L_pos+L_pos_cc/2

Block 1 (blk1)

1 In the **Geometry** toolbar, click **Block**.

2 In the **Settings** window for **Block**, locate the **Size and Shape** section.

3 In the **Width** text field, type `W_tab`.

4 In the **Depth** text field, type `H_tab`.

5 In the **Height** text field, type `L_neg_cc/2`.

6 Locate the **Position** section. In the **y** text field, type `H_cell`.

7 Click **Build Selected**.

8 Click the **Zoom Extents** button in the **Graphics** toolbar.

Block 2 (blk2)

1 In the **Geometry** toolbar, click **Block**.

2 In the **Settings** window for **Block**, locate the **Size and Shape** section.

3 In the **Width** text field, type `W_tab`.

4 In the **Depth** text field, type `H_tab`.

5 In the **Height** text field, type `L_neg_cc/2`.

6 Locate the **Position** section. In the **y** text field, type `-H_tab`.

7 In the **z** text field, type `L_neg_cc/2+L_neg+L_sep+L_pos`.

8 Click **Build Selected**.

Form Union (fin)

In the **Geometry** toolbar, click **Build All**.

DEFINITIONS

Scale the geometry in the *z* direction to make it easier to see the different layers in the model geometry.

View 1

In the **Model Builder** window, expand the **Component 1 (comp1)>Definitions** node.

Camera

1 In the **Model Builder** window, expand the **View 1** node, then click **Camera**.

2 In the **Settings** window for **Camera**, locate the **Camera** section.

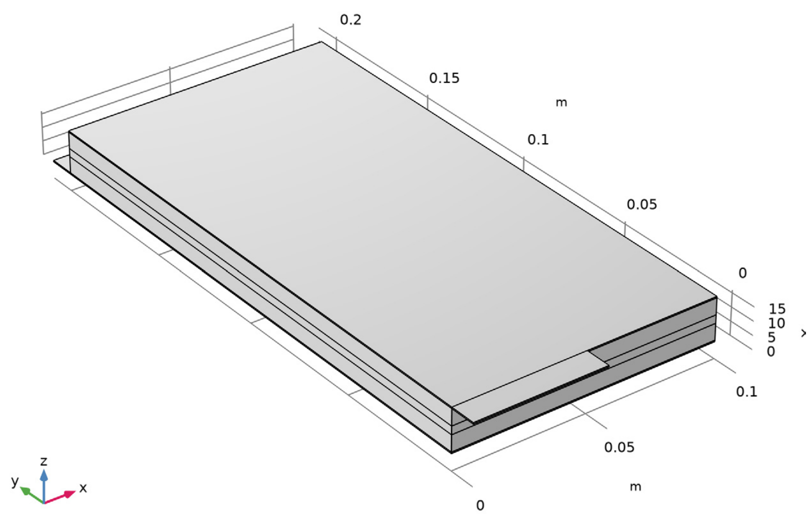
3 From the **View scale** list, choose **Manual**.

4 In the **z scale** text field, type `100`.

5 Click **Update**.

6 Click the **Zoom Extents** button in the **Graphics** toolbar.

The finalized geometry should now look like as follows.



Positive Tab

Create named selections of the different battery domains for ease of selection later in the model.

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, type `Positive Tab` in the **Label** text field.

3 Select Domain 1 only.

Positive Current Collector

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, type `Positive Current Collector` in the **Label** text field.

3 Select Domain 6 only.

Positive Electrode

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domain 5 only.

3 In the **Settings** window for **Explicit**, type `Positive Electrode` in the **Label** text field.

Negative Tab

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domain 7 only.

3 In the **Settings** window for **Explicit**, type `Negative Tab` in the **Label** text field.

Negative Current Collector

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domain 2 only.

3 In the **Settings** window for **Explicit**, type `Negative Current Collector` in the **Label** text field.

Negative Electrode

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domain 3 only.

3 In the **Settings** window for **Explicit**, type `Negative Electrode` in the **Label** text field.

Separator

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domain 4 only.

3 In the **Settings** window for **Explicit**, type `Separator` in the **Label** text field.

Negative Tab End

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, type `Negative Tab End` in the **Label** text field.

3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Boundary**.

4 Click **Paste Selection**.

5 In the **Paste Selection** dialog box, type 29 in the **Selection** text field.

6 Click **OK**.

Positive Tab End

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 Click **Paste Selection**.

5 In the **Paste Selection** dialog box, type 2 in the **Selection** text field.

6 Click **OK**.

7 In the **Settings** window for **Explicit**, type `Positive Tab End` in the **Label** text field.

Negative Current Collector and Tab

1 In the **Definitions** toolbar, click **Union**.

2 In the **Settings** window for **Union**, locate the **Input Entities** section.

3 Under **Selections to add**, click **Add**.

4 In the **Add** dialog box, in the **Selections to add** list, choose **Negative Tab** and **Negative Current Collector**.

5 Click **OK**.

6 In the **Settings** window for **Union**, type `Negative Current Collector and Tab` in the **Label** text field.

Positive Current Collector and Tab

1 In the **Definitions** toolbar, click **Union**.

2 In the **Settings** window for **Union**, locate the **Input Entities** section.

3 Under **Selections to add**, click **Add**.

4 In the **Add** dialog box, in the **Selections to add** list, choose **Positive Tab** and **Positive Current Collector**.

5 Click **OK**.

6 In the **Settings** window for **Union**, type `Positive Current Collector and Tab` in the **Label** text field.

Metal Foil Domains

1 In the **Definitions** toolbar, click **Union**.

2 In the **Settings** window for **Union**, locate the **Input Entities** section.

3 Under **Selections to add**, click **Add**.

4 In the **Add** dialog box, in the **Selections to add** list, choose **Negative Current Collector and Tab** and **Positive Current Collector and Tab**.

5 Click **OK**.

6 In the **Settings** window for **Union**, type `Metal Foil Domains` in the **Label** text field.

Cell Voltage

1 In the **Definitions** toolbar, click **Probes** and choose **Global Variable Probe**.

2 In the **Settings** window for **Global Variable Probe**, type `Cell Voltage` in the **Label** text field.

3 Locate the **Expression** section. In the **Expression** text field, type `liion.phis0_ec1`.

4 In the **Table and plot unit** field, type `V`.

5 Select the **Description** check box. In the associated text field, type `Cell Voltage`.

General Projection - Negative

Now add General Projection operators that will be used to integrate the amount of lithium along the electrode depth (the z direction).

1 In the **Definitions** toolbar, click **Nonlocal Couplings** and choose **General Projection**.

2 In the **Settings** window for **General Projection**, type `General Projection - Negative` in the **Label** text field.

3 In the **Operator name** text field, type `genproj_neg`.

4 Locate the **Source Selection** section. From the **Selection** list, choose **Negative Electrode**.

General Projection - Positive

1 Right-click **General Projection - Negative** and choose **Duplicate**.

2 In the **Settings** window for **General Projection**, type `General Projection - Positive` in the **Label** text field.

3 In the **Operator name** text field, type `genproj_pos`.

4 Locate the **Source Selection** section. From the **Selection** list, choose **Positive Electrode**.

MATERIALS

Add Copper and Aluminum from the built-in materials.

ADD MATERIAL

1 In the **Home** toolbar, click **Add Material** to open the **Add Material** window.

2 Go to the **Add Material** window.

3 In the tree, select **Built-in>Aluminum** and **Built-in>Copper**.

4 Click **Add to Component** in the window toolbar.

ADD MATERIAL

Use the Battery Material Library to set up the material properties for the electrolyte and electrode materials in the pouch cell.

1 Go to the **Add Material** window.

2 In the tree, select **Battery>Electrodes>Graphite, LixC6 MCMB (Negative, Li-ion Battery)** and **Battery>Electrodes>LMO, LiMn2O4 Spinel (Positive, Li-ion Battery)**.

3 Click **Add to Component** in the window toolbar.

4 In the tree, select **Battery>Electrolytes>LiPF6 in 3:7 EC:EMC (Liquid, Li-ion Battery)**.

5 Click **Add to Component** in the window toolbar.

6 In the **Home** toolbar, click **Add Material** to close the **Add Material** window.

MATERIALS

Aluminum (mat1)

Assign the materials to the corresponding battery domains.

1 In the **Model Builder** window, click **Aluminum (mat1)**.

2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.

3 From the **Selection** list, choose **Positive Current Collector and Tab**.

Copper (mat2)

1 In the **Model Builder** window, click **Copper (mat2)**.

2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.

3 From the **Selection** list, choose **Negative Current Collector and Tab**.

Graphite, LixC6 MCMB (Negative, Li-ion Battery) (mat3)

1 In the **Model Builder** window, click **Graphite, LixC6 MCMB (Negative, Li-ion Battery) (mat3)**.

2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.

3 From the **Selection** list, choose **Negative Electrode**.

LMO, LiMn2O4 Spinel (Positive, Li-ion Battery) (mat4)

1 In the **Model Builder** window, click **LMO, LiMn2O4 Spinel (Positive, Li-ion Battery) (mat4)**.

2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.

3 From the **Selection** list, choose **Positive Electrode**.

LiPF6 in 3:7 EC:EMC (Liquid, Li-ion Battery) (mat5)

1 In the **Model Builder** window, click **LiPF6 in 3:7 EC:EMC (Liquid, Li-ion Battery) (mat5)**.
2 In the **Settings** window for **Material**, locate the **Geometric Entity Selection** section.
3 From the **Selection** list, choose **Separator**.

LITHIUM-ION BATTERY (LIION)

Start by adding the separator domain to the battery.

Separator 1

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Lithium-Ion Battery (liion)** and choose **Separator**.
2 In the **Settings** window for **Separator**, locate the **Domain Selection** section.
3 From the **Selection** list, choose **Separator**.

Now set up the physics in the porous electrodes and current collectors.

Porous Electrode - Negative

1 In the **Physics** toolbar, click **Domains** and choose **Porous Electrode**.
2 In the **Settings** window for **Porous Electrode**, type `Porous Electrode - Negative` in the **Label** text field.
3 Locate the **Domain Selection** section. From the **Selection** list, choose **Negative Electrode**.
4 Locate the **Electrolyte Properties** section. From the **Electrolyte material** list, choose **LiPF6 in 3:7 EC:EMC (Liquid, Li-ion Battery) (mat5)**.
5 Locate the **Porous Matrix Properties** section. In the ε_s text field, type `epss_neg`.
6 In the ε_l text field, type `1-epss_neg`.

Particle Intercalation 1

1 In the **Model Builder** window, click **Particle Intercalation 1**.
2 In the **Settings** window for **Particle Intercalation**, locate the **Particle Transport Properties** section.
3 In the r_p text field, type `rp_neg`.

Porous Electrode Reaction 1

1 In the **Model Builder** window, click **Porous Electrode Reaction 1**.
2 In the **Settings** window for **Porous Electrode Reaction**, locate the **Electrode Kinetics** section.
3 In the $i_{0,\mathrm{ref}}(T)$ text field, type `i0ref_neg`.

Porous Electrode - Positive

1 In the **Physics** toolbar, click **Domains** and choose **Porous Electrode**.

2 In the **Settings** window for **Porous Electrode**, type `Porous Electrode - Positive` in the **Label** text field.

3 Locate the **Domain Selection** section. From the **Selection** list, choose **Positive Electrode**.

4 Locate the **Electrolyte Properties** section. From the **Electrolyte material** list, choose **LiPF6 in 3:7 EC:EMC (Liquid, Li-ion Battery) (mat5)**.

5 Locate the **Porous Matrix Properties** section. In the ε_s text field, type `epss_pos`.

6 In the ε_l text field, type `1-epss_pos`.

Particle Intercalation 1

1 In the **Model Builder** window, click **Particle Intercalation 1**.

2 In the **Settings** window for **Particle Intercalation**, locate the **Particle Transport Properties** section.

3 In the r_p text field, type `rp_pos`.

Porous Electrode Reaction 1

1 In the **Model Builder** window, click **Porous Electrode Reaction 1**.

2 In the **Settings** window for **Porous Electrode Reaction**, locate the **Electrode Kinetics** section.

3 In the $i_{0,\mathrm{ref}}(T)$ text field, type `i0ref_pos`.

Electrode 1

1 In the **Physics** toolbar, click **Domains** and choose **Electrode**.

2 In the **Settings** window for **Electrode**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **Metal Foil Domains**.

Electric Ground 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Electric Ground**.

2 In the **Settings** window for **Electric Ground**, locate the **Boundary Selection** section.

3 From the **Selection** list, choose **Negative Tab End**.

Electrode Current 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Electrode Current**.

2 In the **Settings** window for **Electrode Current**, locate the **Boundary Selection** section.

3 From the **Selection** list, choose **Positive Tab End**.

4 Locate the **Electrode Current** section. In the $I_{s,\mathrm{total}}$ text field, type `I_1C*C_rate`.

5 In the $\phi_{s,bnd,init}$ text field, type `4[V]`.

Initial Cell Charge Distribution 1

1 In the **Physics** toolbar, click **Global** and choose **Initial Cell Charge Distribution**.

2 In the **Settings** window for **Initial Cell Charge Distribution**, locate the **Battery Cell Parameters** section.

3 From the **Initial battery cell setting** list, choose **Initial cell state-of-charge**.

4 In the $SOC_{cell,0}$ text field, type `SOC_start`.

5 In the $Q_{cell,0}$ text field, type `Q_cell`.

Negative Electrode Selection 1

1 In the **Model Builder** window, expand the **Initial Cell Charge Distribution 1** node, then click **Negative Electrode Selection 1**.

2 In the **Settings** window for **Negative Electrode Selection**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **Negative Electrode**.

Positive Electrode Selection 1

1 In the **Model Builder** window, click **Positive Electrode Selection 1**.

2 In the **Settings** window for **Positive Electrode Selection**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **Positive Electrode**.

Set up the mesh for the model. Use a mapped mesh on boundary and swept mesh for rest of the geometry.

MESH 1

Mapped 1

1 In the **Mesh** toolbar, click **Boundary** and choose **Mapped**.

2 Select Boundary 20 only.

Swept 1

1 In the **Mesh** toolbar, click **Swept**.

2 In the **Settings** window for **Swept**, locate the **Domain Selection** section.

3 Click to clear the **Activate Selection** toggle button.

Distribution 1

1 Right-click **Swept 1** and choose **Distribution**.

2 In the **Settings** window for **Distribution**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **Negative Electrode**.

4 Locate the **Distribution** section. From the **Distribution type** list, choose **Predefined**.

5 In the **Number of elements** text field, type 15.

6 In the **Element ratio** text field, type 3.

Distribution 2

1 In the **Model Builder** window, right-click **Swept 1** and choose **Distribution**.

2 In the **Settings** window for **Distribution**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **Separator**.

4 Locate the **Distribution** section. In the **Number of elements** text field, type 4.

Distribution 3

1 Right-click **Swept 1** and choose **Distribution**.

2 In the **Settings** window for **Distribution**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **Positive Electrode**.

4 Locate the **Distribution** section. From the **Distribution type** list, choose **Predefined**.

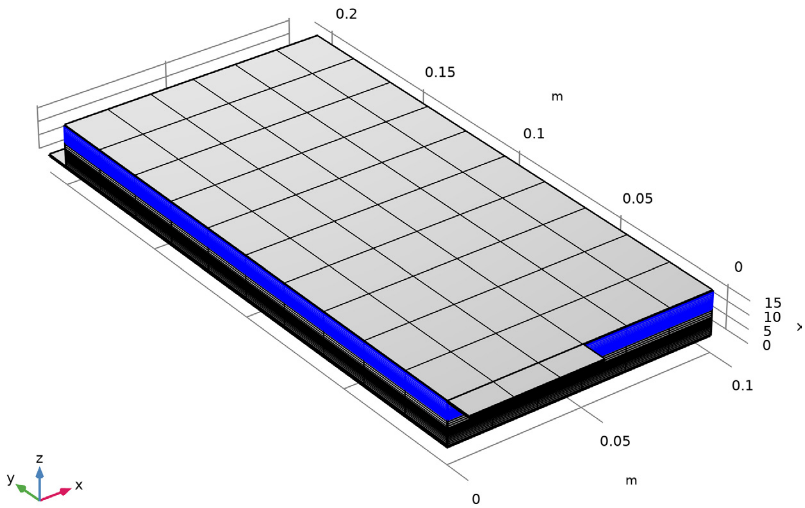
5 In the **Number of elements** text field, type 15.

6 In the **Element ratio** text field, type 3.

7 Select the **Reverse direction** check box.

8 Click **Build All**.

The finalized mesh should now look as follows.



STUDY 1

Parametric Sweep

1 In the **Study** toolbar, click **Parametric Sweep**.

2 In the **Settings** window for **Parametric Sweep**, locate the **Study Settings** section.

3 Click **Add**.

4 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
C_rate (C-rate during simulation)	1 4	1

Step 2: Time Dependent

1 In the **Model Builder** window, click **Step 2: Time Dependent**.

2 In the **Settings** window for **Time Dependent**, locate the **Study Settings** section.

3 In the **Output times** text field, type `range(0,sim_time/2,sim_time)`.

4 In the **Study** toolbar, click **Compute**.

RESULTS

Global 1

In the **Model Builder** window, expand the **Results>Boundary Electrode Potential with Respect to Ground (liion)** node.

Global 1

1. In the **Model Builder** window, expand the **Results>Average Electrode State-of-Charge (liion)** node, then click **Results>Boundary Electrode Potential with Respect to Ground (liion)>Global 1**.
2. In the **Settings** window for **Global**, locate the **x-Axis Data** section.
3. From the **Axis source data** list, choose **Time**.
4. In the **Boundary Electrode Potential with Respect to Ground (liion)** toolbar, click **Plot**.

Global 1

1. In the **Model Builder** window, under **Results>Average Electrode State-of-Charge (liion)** click **Global 1**.
2. In the **Settings** window for **Global**, locate the **x-Axis Data** section.
3. From the **Axis source data** list, choose **Time**.
4. In the **Average Electrode State-of-Charge (liion)** toolbar, click **Plot**.

Potential in Negative Current Collector and Tab

The following steps create the plot of the potential at the negative current collector and tab.

1. In the **Home** toolbar, click **Add Plot Group** and choose **3D Plot Group**.
2. In the **Settings** window for **3D Plot Group**, type `Potential in Negative Current Collector and Tab` in the **Label** text field.
3. Locate the **Data** section. From the **Dataset** list, choose **Study 1/Parametric Solutions 1 (sol3)**.
4. From the **Time (s)** list, choose **0**.
5. Locate the **Color Legend** section. Select the **Show maximum and minimum values** check box.
6. Click to expand the **Number Format** section. Select the **Manual color legend settings** check box.
7. In the **Precision** text field, type `4`.

Volume 1

1 Right-click **Potential in Negative Current Collector and Tab** and choose **Volume**.
2 In the **Settings** window for **Volume**, locate the **Expression** section.
3 In the **Expression** text field, type `phis`.

Selection 1

1 Right-click **Volume 1** and choose **Selection**.
2 In the **Settings** window for **Selection**, locate the **Selection** section.
3 From the **Selection** list, choose **Negative Current Collector and Tab**.
4 In the **Potential in Negative Current Collector and Tab** toolbar, click **Plot**.
5 Click the **Zoom Extents** button in the **Graphics** toolbar.

Potential in Negative Current Collector and Tab

Duplicate the plot to get the potential at the positive current collector and tab.

Potential in Positive Current Collector and Tab

1 In the **Model Builder** window, right-click **Potential in Negative Current Collector and Tab** and choose **Duplicate**.
2 In the **Settings** window for **3D Plot Group**, type `Potential in Positive Current Collector and Tab` in the **Label** text field.
3 In the **Model Builder** window, expand the **Results>Potential in Positive Current Collector and Tab** node.

Selection 1

1 In the **Model Builder** window, expand the **Results>Potential in Positive Current Collector and Tab>Volume 1** node, then click **Selection 1**.
2 In the **Settings** window for **Selection**, locate the **Selection** section.
3 From the **Selection** list, choose **Positive Current Collector and Tab**.
4 In the **Potential in Positive Current Collector and Tab** toolbar, click **Plot**.
5 Click the **Zoom Extents** button in the **Graphics** toolbar.

Relative Current Density Across Separator

Plot the relative current density across the separator using a slice plot.

1 In the **Home** toolbar, click **Add Plot Group** and choose **3D Plot Group**.
2 In the **Settings** window for **3D Plot Group**, type `Relative Current Density Across Separator` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 1/ Parametric Solutions 1 (sol3)**.

4 From the **Time (s)** list, choose **0**.

Slice 1

1 Right-click **Relative Current Density Across Separator** and choose **Slice**.

2 In the **Settings** window for **Slice**, locate the **Expression** section.

3 In the **Expression** text field, type `liion.IlMag/(I_1C*C_rate/(H_cell*W_cell))`.

4 Locate the **Plane Data** section. From the **Plane** list, choose **XY-planes**.

5 From the **Entry method** list, choose **Coordinates**.

6 In the **Z-coordinates** text field, type `L_neg_cc/2+L_neg+L_sep/2`.

7 In the **Relative Current Density Across Separator** toolbar, click **Plot**.

8 Click the **Zoom Extents** button in the **Graphics** toolbar.

Relative Current Density Across Separator

1 In the **Model Builder** window, click **Relative Current Density Across Separator**.

2 In the **Settings** window for **3D Plot Group**, locate the **Data** section.

3 From the **Time (s)** list, choose **630**.

4 In the **Relative Current Density Across Separator** toolbar, click **Plot**.

Utilization (Relative Capacity Throughput)

1 In the **Home** toolbar, click **Add Plot Group** and choose **3D Plot Group**.

2 In the **Settings** window for **3D Plot Group**, type `Utilization (Relative Capacity Throughput)` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 1/ Parametric Solutions 1 (sol3)**.

4 From the **Parameter value (C_rate)** list, choose **1**.

5 Locate the **Color Legend** section. Select the **Show maximum and minimum values** check box.

Surface 1

1 Right-click **Utilization (Relative Capacity Throughput)** and choose **Surface**.

2 In the **Settings** window for **Surface**, locate the **Expression** section.

3 In the **Expression** text field, type `genproj_pos(at(0,liion.cs_average)-liion.cs_average)*epss_pos*F_const*H_cell*W_cell/(I_1C*C_rate*t)`.

Selection 1

1 Right-click **Surface 1** and choose **Selection**.

2 Select Boundary 16 only.

3 In the **Utilization (Relative Capacity Throughput)** toolbar, click **Plot**.

4 Click the **Zoom Extents** button in the **Graphics** toolbar.

Utilization (Relative Capacity Throughput)

1 In the **Model Builder** window, under **Results** click **Utilization (Relative Capacity Throughput)**.

2 In the **Settings** window for **3D Plot Group**, locate the **Data** section.

3 From the **Parameter value (C_rate)** list, choose **4**.

4 In the **Utilization (Relative Capacity Throughput)** toolbar, click **Plot**.

Battery Voltage Probe Plot

1 In the **Model Builder** window, under **Results** click **Probe Plot Group 8**.

2 In the **Settings** window for **1D Plot Group**, type `Battery Voltage Probe Plot` in the **Label** text field.

3 In the **Battery Voltage Probe Plot** toolbar, click **Plot**.

4 Click the **Zoom Extents** button in the **Graphics** toolbar.