

Effect of Design Parameter on the Performance of Lithium Ion Battery

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Abstract

The demand of alternative energy sources increasing because gasoline reserve in world is depleting day by day. Various alternative energy resources is being used to meet out the requirement of the human beings. Battery are also a kind of alternative energy source. Due to limitation of fuel reserves researchers have focused towards the lithium ion batteries to power automotive vehicles. Such as electric vehicle (EV), hybrid electric vehicle and plug-in hybrid electric vehicles. Apart from that lithium ion battery are being used in various small electronic portable devices. In this work we have simulated mathematical model for lithium ion battery to see the effect of kee parameter such as porosity of positive electrode, porosity of negative electrode and radius of solid particle in negative electrode and radius of solid particle in positive electrode. I have seen that increasing the particle radius and porosity in negative electrode greatly affect the charge and discharge behaviour of the battery apart from that effect of increasing particle radius and porosity of positive electrode has minute effect over the battery behaviour.

I. Introduction

The capacity or power to do work, such as the capacity to move an object (of a given mass) by the application of force. Everything what happened in the world is the expression of flow of energy from one form to other form. energy is a key input in economic growth. there is a close link between the availability of energy and future growth of a nation . However in a developing country like India greater the availability of energy more is its shortage.

A battery is defined as a combination of individual cells .In electricity , a battery is a device consisting of one or more electrochemical cell that convert stored chemical energy into electrical energy. A battery can also be thought of as black box into which electrical energy is put stored electro chemically and later recovered as electrical energy.

A lithium-ion battery consists of two electrodes with a separator in between. The total

thickness of the assembly is approximately 70-200 μm , depending on the type of application the cell is intended for. Battery cells are assembled by winding or stacking the layers of the electrodes and the separator into cylindrical or prismatic shapes. The electrode with the highest electrode potential is called the positive electrode. It usually consists of a transition metal material, which can host lithium ions. The other electrode is usually made of graphite and it is called the negative electrode. Both the electrodes and the separator are porous. An electrolyte fills up the pores to create electrolytic contact between the electrodes. The electrolyte is a lithium salt dissolved in a mixture of solvents, polymers or ionic liquids. The process is represented by the reactions below, where X represents the transition metal material in the positive electrode and C₆ the graphite in the negative electrode.

II. Objective

Effect of design parameter on the performance of lithium ion battery (1)Effect of varying particle radius of cathode and anode on battery capacity. (2) Effect of varying porosity or volume fraction on battery capacity.

III. Methodology

A schematic of a lithium ion battery is shown in fig 1. Generally, a lithium ion battery consists of the current collector, the positive electrode, the separator and the negative electrode. A lithiated organic solution fills the porous components and serves as the electrolyte. The material balance for the Li ions in an active solid material particle is governed by Fick's second law in spherical coordinates:

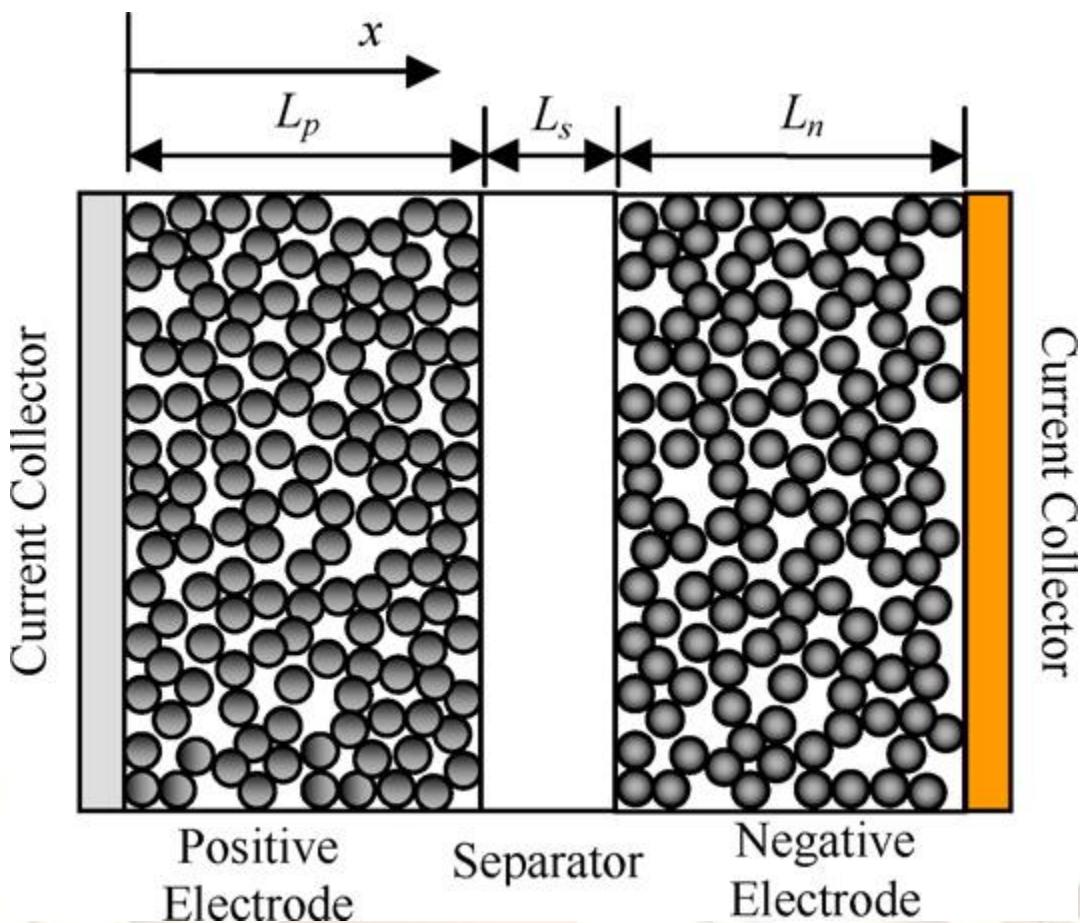


Figure 1: working model of lithium ion battery

Material balance in the electrolyte

$$\frac{\partial(c_e \varepsilon_e)}{\partial t} = \nabla \cdot (D_e^{\text{eff}} \nabla c_e) - \frac{i_e \nabla t_+^0}{F} + \frac{1-t_+^0}{F} a_s j \quad (1)$$

Ohm's law in the solid phase

$$\nabla \cdot (\sigma_s^{\text{eff}} \nabla \phi_s) - a_s j = 0 \quad (2)$$

Ohm's law in the electrolyte phase

$$\nabla \cdot (\kappa_e^{\text{eff}} \nabla \phi_e) + \nabla \left(\frac{2RT\kappa_e^{\text{eff}}}{F} (t_+^0 - 1) \left(1 + \frac{d \ln(f_{\pm})}{d \ln c_e} \right) \nabla \ln c_e \right) + a_s j = 0 \quad (3)$$

Where

$$j = j_{\text{int}} \quad (4)$$

Li-ion intercalation current density j_{int} is given by

Butler-Volmer kinetics

$$j_{\text{int}} = F K (c_e)^{\alpha_a} (c_{s,\text{max}} - c_s)^{\alpha_a} (c_s)^{\alpha_c} \times \left(\exp\left(\frac{\alpha_a F}{R T} \eta\right) - \exp\left(-\frac{\alpha_c F}{R T} \eta\right) \right) \quad (5)$$

Over-potential for intercalation reaction is given by

$$\eta = \phi_s - \phi_e - U_{\text{ref}} - j R_f \quad (6)$$

$R_f = 0$ For cathode

and anode

Diffusion of Li^+ into the anode particle is given by Fick's second law of diffusion

$$\frac{\partial c_s}{\partial t} = D_s \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial c_s}{\partial r} \right) \quad (8)$$

Where $i = p$ for the positive electrode and $i = n$ for the negative electrode.

By use of these equation we analysis the different parameter of lithium ion battery such that Effect of varying particle radius of cathode and anode on battery capacity. And effect of varying porosity or volume fraction on battery capacity by the comsol software.

IV. Result and discussion

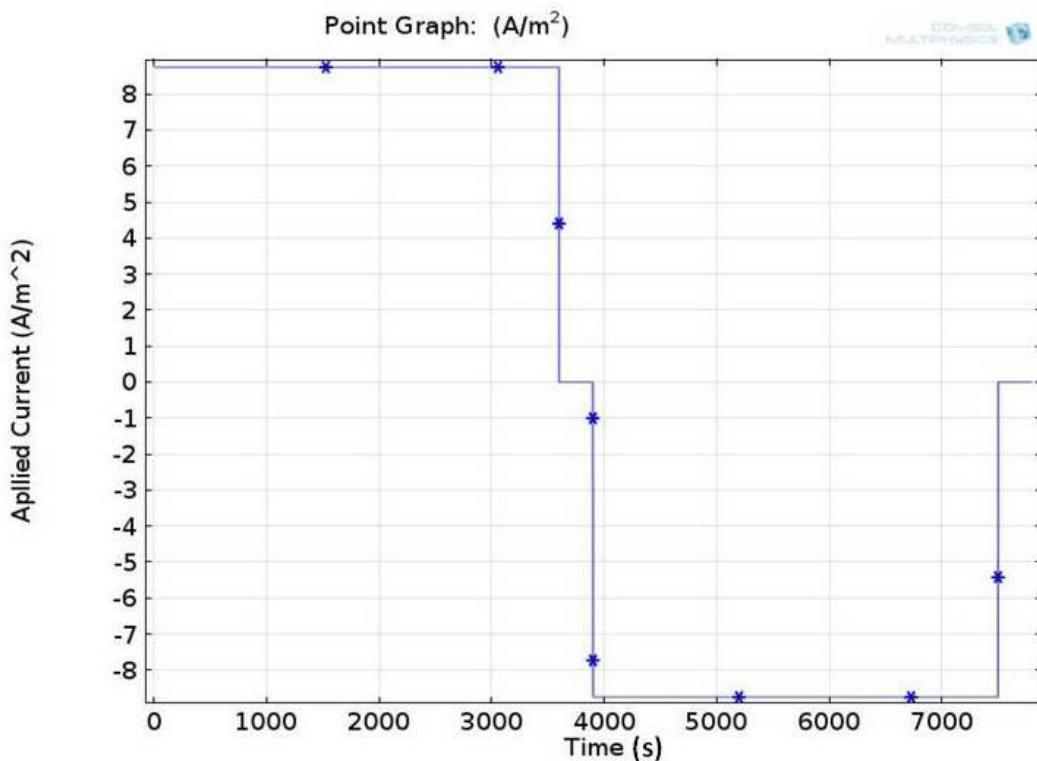


figure 2: Applied current density during discharge and charge (A/m^2)

Fig 2 shows the applied current density during discharge and charge of the battery . $8.75 A/m^2$ is applied for 3600 second to discharge the battery subsequently the battery is kept at zero current for

3000 seconds and charge upto3600 second the again kept at zero current for 300 second

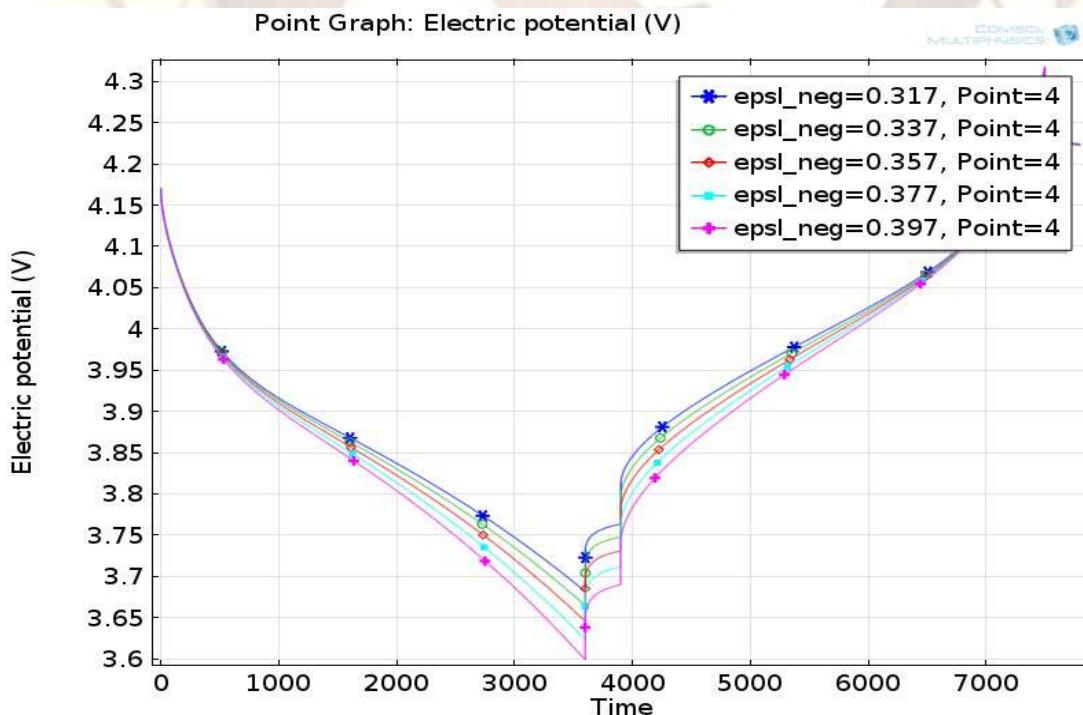


Figure 3: Variation of cell potential for various porosity of negative electrode during discharge and charge

Fig 3 shows variation of cell potential during discharge and charge for different porosity of the negative electrode. During discharge 8.75 A/m^2 current for 3600 seconds is applied so that cell potential decreases and during rest period all the gradients relaxes, then potential increases upto a certain value After that battery charges for 3600 seconds with 8.75 A/m^2 so that cell potential increases then cell is kept at open circuit condition

for 300 seconds. Fig10 shows that increasing the porosity of negative electrode decreases the cell potential i.e. capacity. Capacity decreases due to decrease in primary active material with increasing porosity of the negative electron.

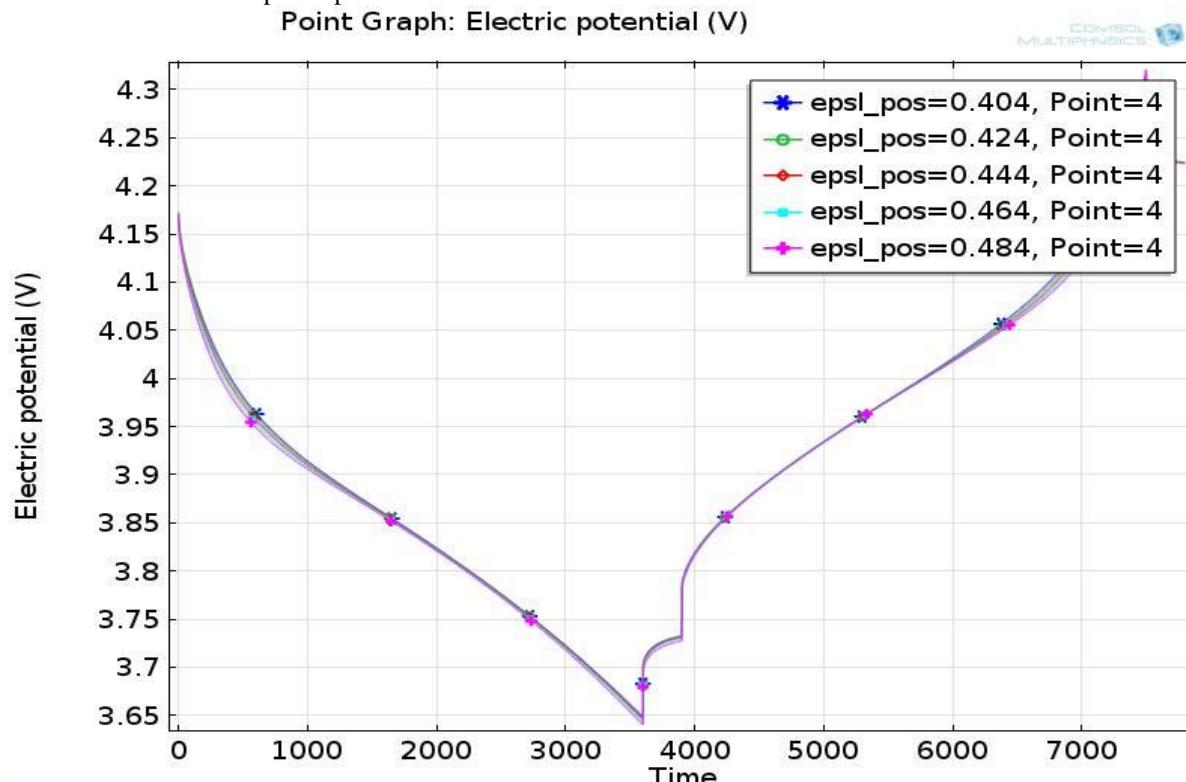


Figure 4: Variation of cell potential for various porosity of positive electrode during discharge and charge

Fig 4 shows variation of cell potential during discharge and charge for different porosity of the positive electrode. During discharge 8.75 A/m^2 current for 3600 seconds is applied so that cell potential decreases and during rest period all the gradients relaxes, then potential increases up to a certain value After that battery charges for 3600 seconds with 8.75 A/m^2 so that cell potential increases then cell is kept at open circuit condition for 300 seconds. Fig13 shows that increasing the

porosity of positive electrode decreases the cell potential i.e. capacity. Capacity decreases due to decrease in primary active material with increasing porosity of the positive electron. But the graph shows small variation when we increases the porosity of positive electron as compared to porosity of negative electron

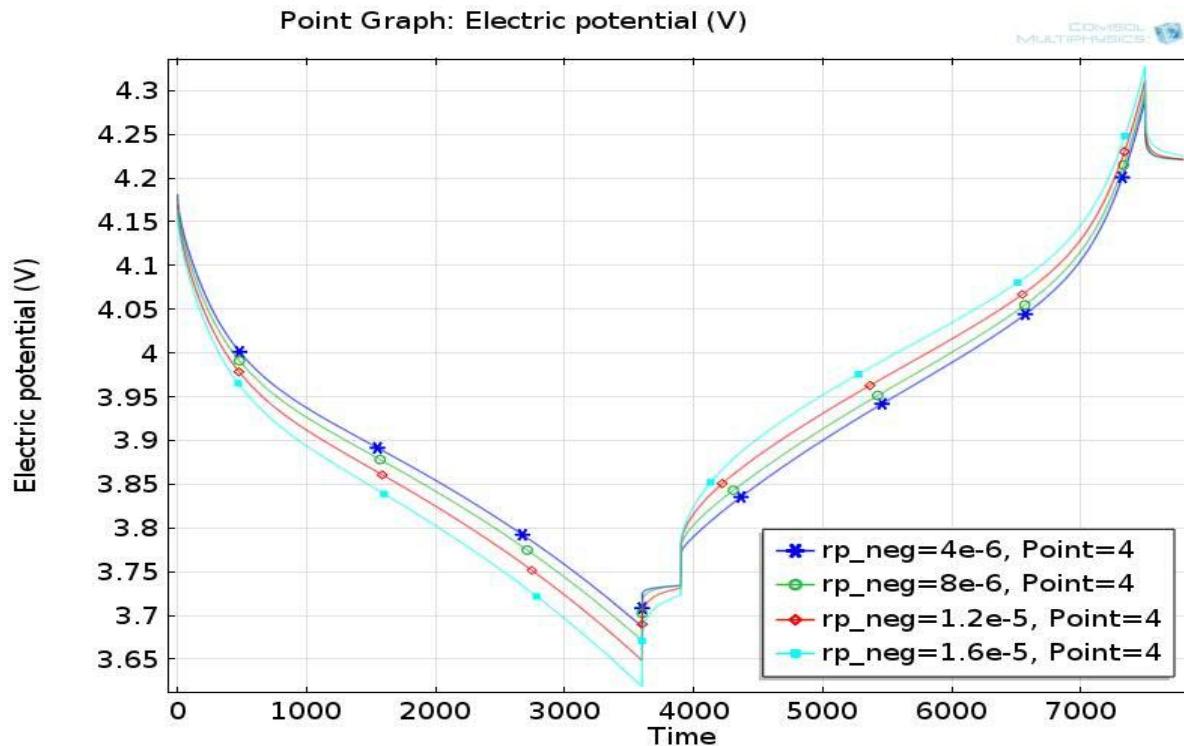


Figure 5: variation in cell potential for various particle radius in negative electrode during discharge and charge.

Fig 5 shows variation in cell potential for various particle radii in negative electrode during discharge and charge. If we increase the negative particle radius then the battery discharges up to lower potential because the rate of lithium diffusion inside the solid particle decelerated. This

deceleration of lithium inside the solid particle greatly affects the performance of the battery.

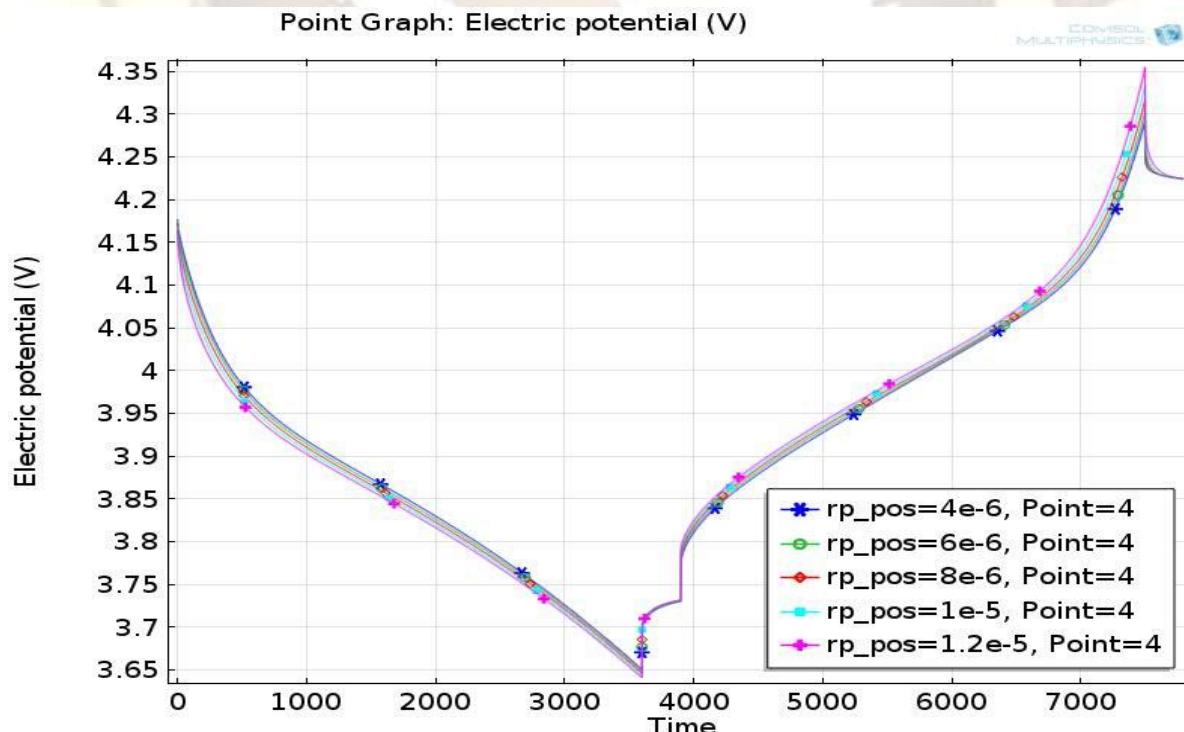


Figure 6: variation in cell potential for various particle radius in positive electrode during discharge and charge.

Fig 6 shows variation in cell potential for various particle radiiuses in positive electrode during discharge and charge. If we increase the positive particle radius then the battery discharges up to lower potential because the rate of lithium diffusion inside the solid particle decelerated. This deceleration of lithium inside the solid particle greatly affects the performance of the battery. But if we see the graph of battery capacity for positive and negative electrode then the variation for positive electrode radius shows small variation in battery performance.

V. Conclusion and future scope

VI. Conclusion

The result obtained by the plotting the graph between battery potential with time for discharging and charging are different. These graph shows the battery capacity variation more when we change the negative radius particle of lithium ion and or negative porosity . While the graph obtained by changing the positive electrode or positive porosity is less.

So these graph shows that if we increase the positive lithium ion radius or porosity then it performance does not vary more.

VII. Future scope

These result obtained by the plotting the graph between battery potential with respect to time by the comsol multyphysics software. Here the only two parameter that can vary lithium ion particle radius and porosity and keeping other thing constant . These result are obtained by software and need practical scope. I have done this by software if i acquire financial aid then I can validate these result experimentally. Using experimental setup we can also investigate the effect of varying electrode thickness, electrode and electrolyte material, conductivity additives and binders over the performance and behavior of lithium ion battery

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