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3D model electrodes: Cathode-liquid electrolyte interphase engineering for lithium-ion batteries

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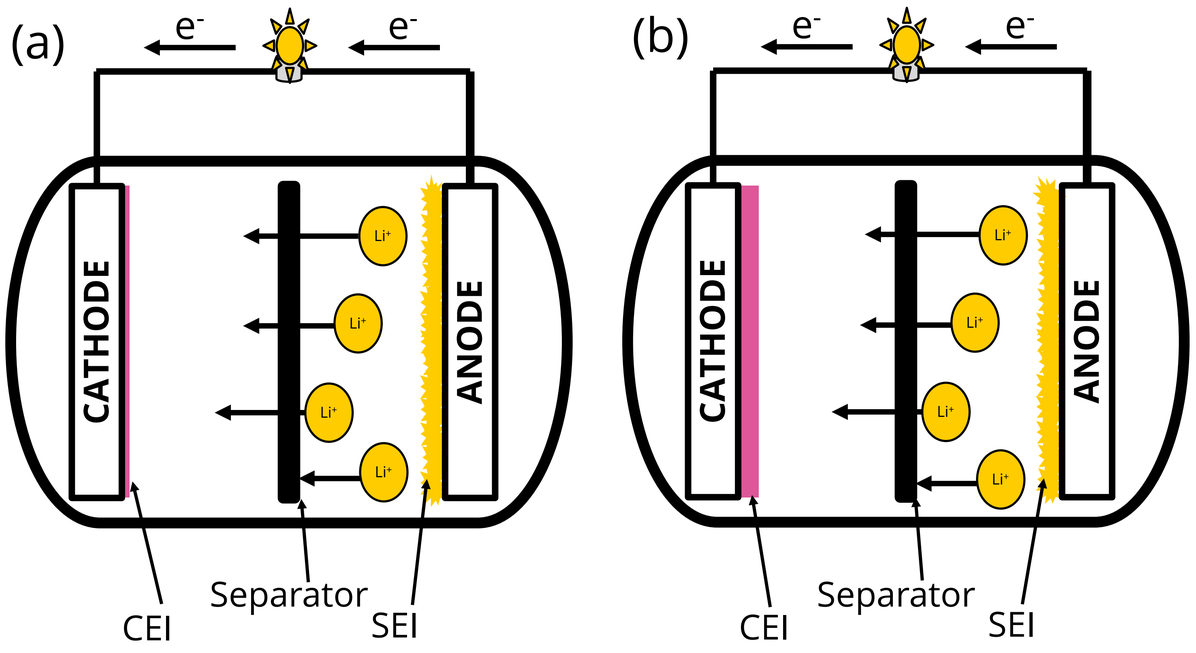
Abstract:

Lithium-ion batteries suffer from Solid-electrolyte Interface (SEI) formation (on the anode), resulting in problems like lithium plating, capacity loss, and lithium consumption. A similar process is also observed at the electrode surface, which is known as the cathode-electrolyte interface (CEI). This research project will help identify the cause of CEI formation. As part of our research project, we will use surface coating methods such as ALD, PLD, and MLD to coat Ni-rich cathode materials.

Introduction:

Lithium-ion batteries are high-power and high-energy storage devices. Theoretically, all lithium can be extracted from $LiCoO2$[1,2]. The discharge capacity of the cell increases when the cutoff potential is increased beyond 4.3V, when all the lithium from the cathode structure can be extracted. But cycling above 4.3V CEI is developed on the cathode surface. This causes cracking of the cathode active materials (CAM), HF evolution, metal ion dissolution, and oxygen loss[3].
Initially it was believed that no interface was formed on the surface of the cathode. However, recent research has shown that a CEI is developed on the surface of the cathode, of varying thickness[4,5]. This CEI development is unstable and causes capacity loss. The following section discusses existing methods for resolving this issue.



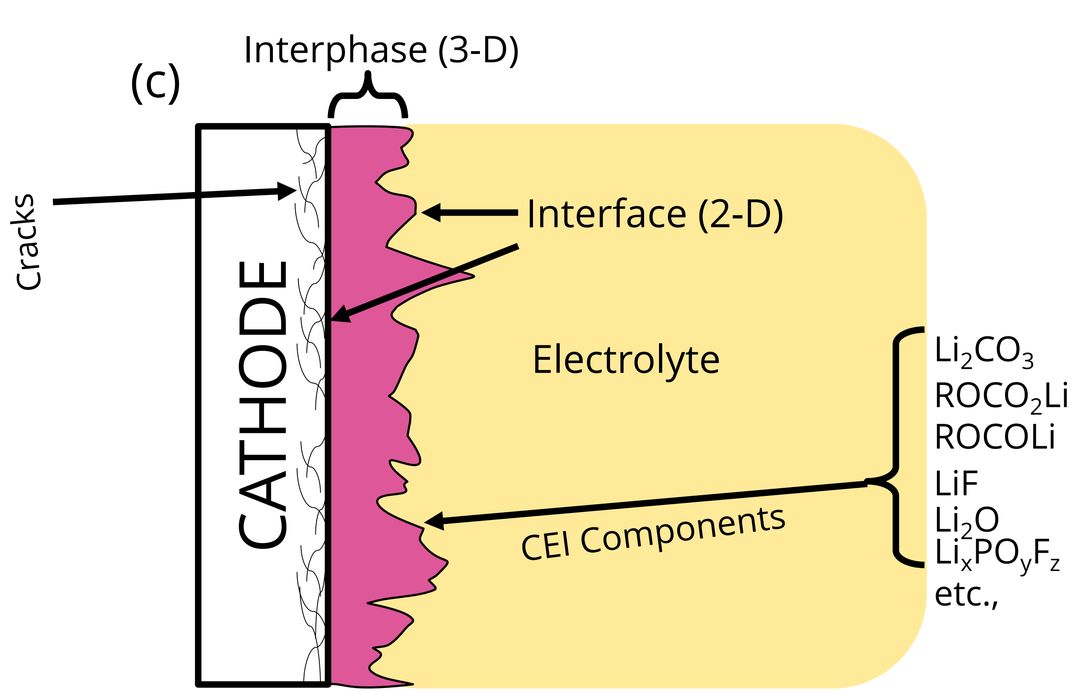


Fig. 1 Schematic representation of Cathode-Electrolyte– Interphase and Interface (a) under 4.3V, (b) above 4.3V, and (c) close-up of CEI

Approach:

For a robust CEI which stabilizes the cathode and helps with long cycle life we can:

1) Develop a stable and robust CEI using fluoride or boron based complex polymer compounds that can be coated on the surface of the electrode
2) Coating electrode surface or cathode material with metal oxides, carbon or phosphates, with understanding their effect on cycling stability, and capacity retention
3) Doping the cathode material into the structure
4) Electrolyte engineering to develop a robust CEI

Conclusions:

Research will be done using different materials for surface coating technique for lithium-ion (Ni-rich) cathodes. The aim of this research project is to fully understand the cause of CEI and using surface coating or doping methods to develop a robust CEI.

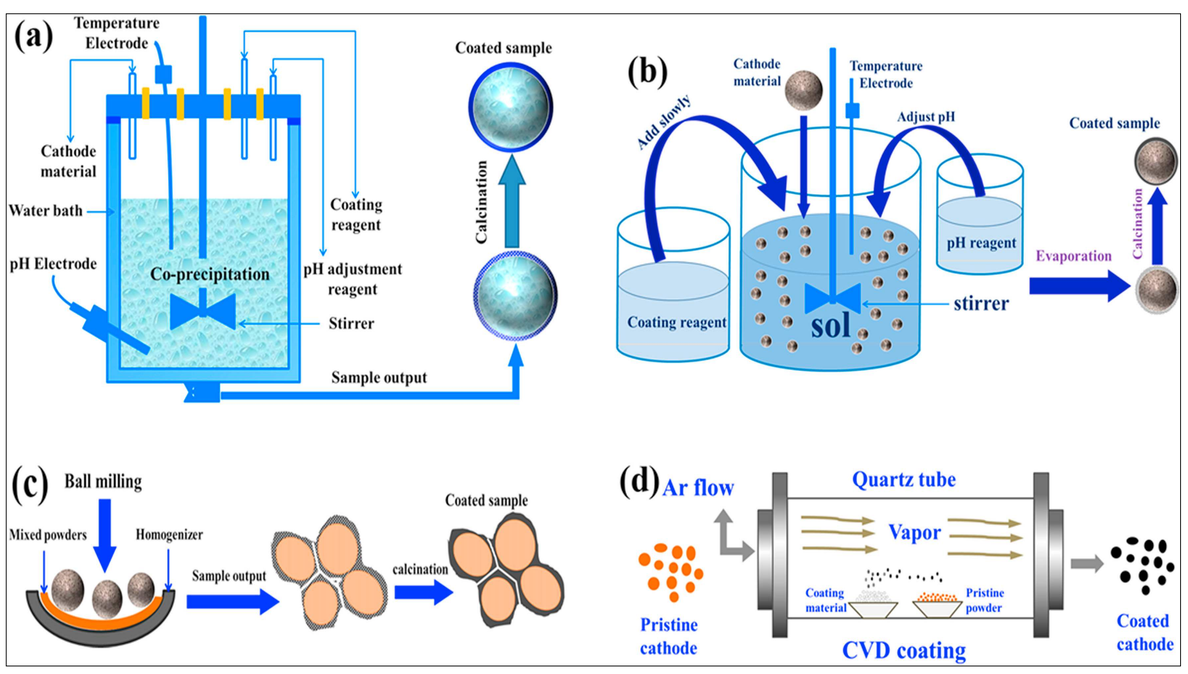


Fig. 2 Schematic diagram for the Coating process of (a) Co-precipitation, (b) Sol-gel, (c) Dry coating, and (d) Chemical Vapor deposition [5]

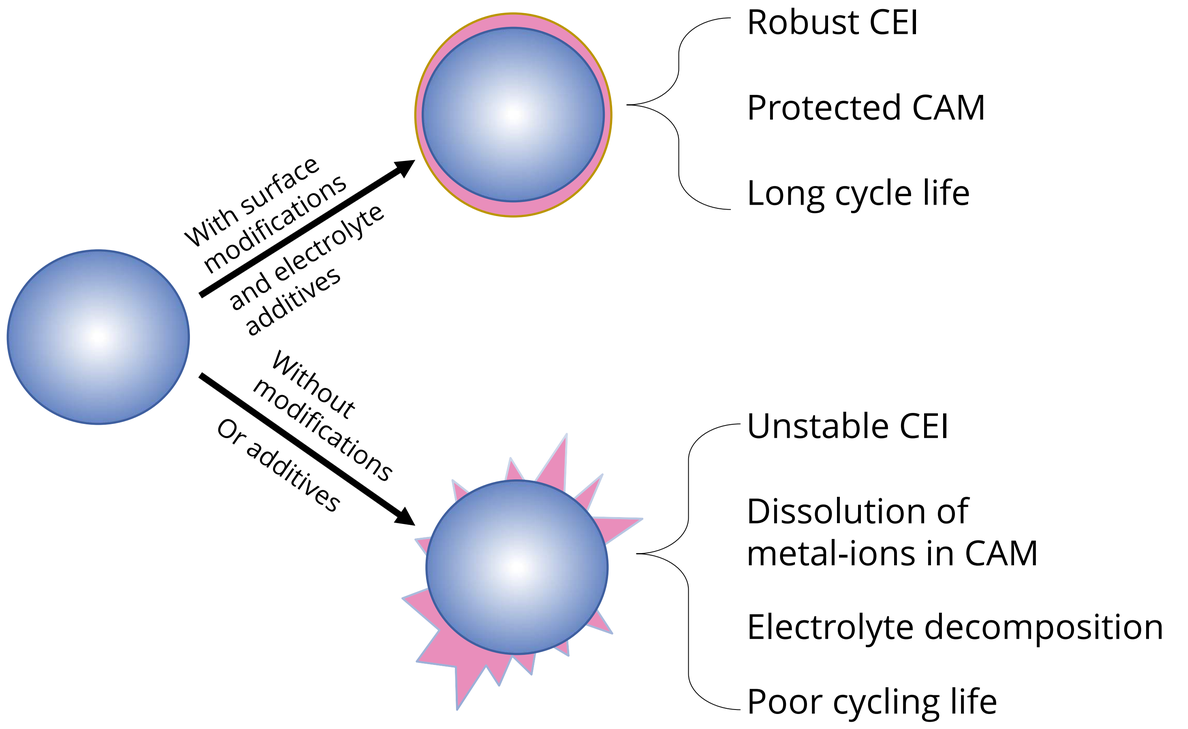


Fig. 3 Schematic diagram showing our approach to counter unstable CEI, and help with long battery life

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BatteryNL DUTCH BATTERY MATERIALS

References:

[1] *An Overview on the Advances of LiCoO2 Cathodes for Lithium-Ion Batteries, Advanced Energy Materials 11(2)*, Wiley 2021, 1614-6832, *10.1002/aenm.202000982*
[2] K. Mizushima, P.C. Jones, P.J. Wiseman, J.B. Goodenough, *Li_xCoO_2 (0<x<-1): A new cathode material for batteries of high energy density, Materials Research Bulletin*, Volume 15, Issue 6, 1980, Pages 783-789
[3] Xu, J. *Critical Review on cathode–electrolyte Interphase Toward High-Voltage Cathodes for Li-Ion Batteries. Nano-Micro Lett.* **14**, 166 (2022).
[4] *Face to Face at the Cathode Electrolyte Interphase: From Interface Features to Interphase Formation and Dynamics, Advanced Materials Interfaces* 9(8) Wiley 2022, 2196-7350
[5] Daxian Zuo, Guanglei Tian, Xiang Li, Da Chen, Kangying Shu, *Recent progress in surface coating of cathode materials for lithium-ion secondary batteries, Journal of Alloys and Compounds*, Volume 706, 2017, Pages 24-40
[6] *Improving $LiNi_xCo_yMn_{1-x-y}O_2$ cathode electrolyte interface under high voltage in lithium-ion batteries, Nano Select* 1(1):111-134, Wiley 2020, 2688-4011