institute imdea energy

EXCELENCIA MARÍA DE MAEZTU

EUROPEAN UNION STRUCTURAL FUNDS

Gel Polymer Electrolyte for Energy Storage System

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Ciurduc Diana Elena

Supervised by: Dr. Rebeca Marcilla

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Outline

- State of the art
- Objectives
- Methodology and Working Plan
- Results

Energy Storage Systems

- These interfaces contribute to the overall performance:
  - Capacity
  - Energy/power density
  - Cycle performance

- The desired electrolyte properties are determined by the working mechanism as well as the structure and type of the energy storage system.

- Refers to a liquid or solid solution that is able to conduct ions but not electrons.

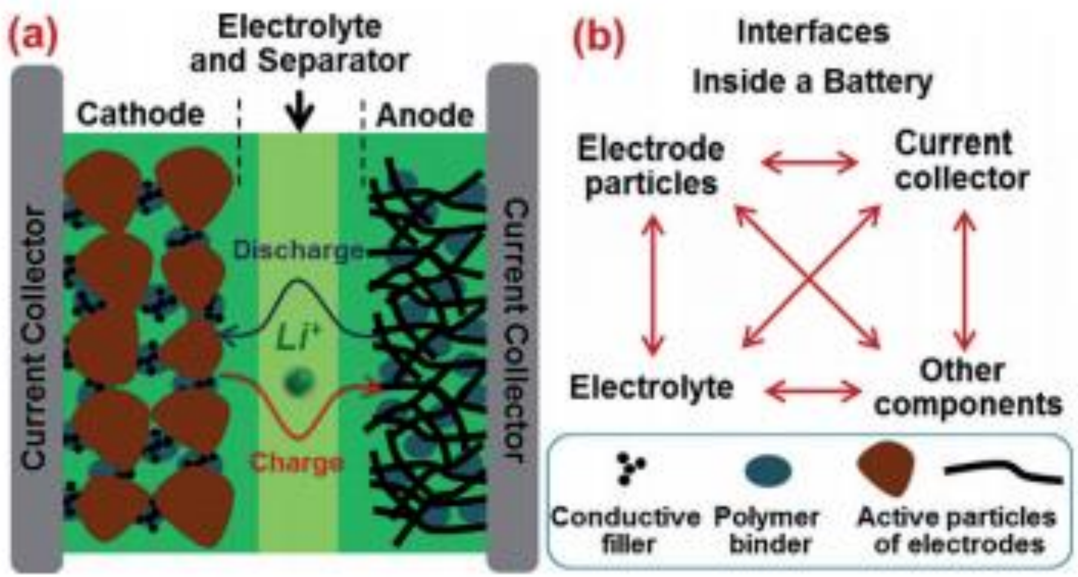


Figure 1. a) Illustration of the structures of a planar battery (e.g. a LIB) and b) interfaces inside the battery

Wang, Y. and Zhong, W.-H. (2015), Development of Electrolytes towards Achieving Safe and High-Performance Energy-Storage Devices: A Review. CHEMELECTROCHEM, 2: 22-36.

Liquid Electrolyte

- Advantages:
  - ✓ High ionic conductivity
  - ✓ Good/stable contact with electrodes

- Drawbacks:
  - ✗ Safety issues

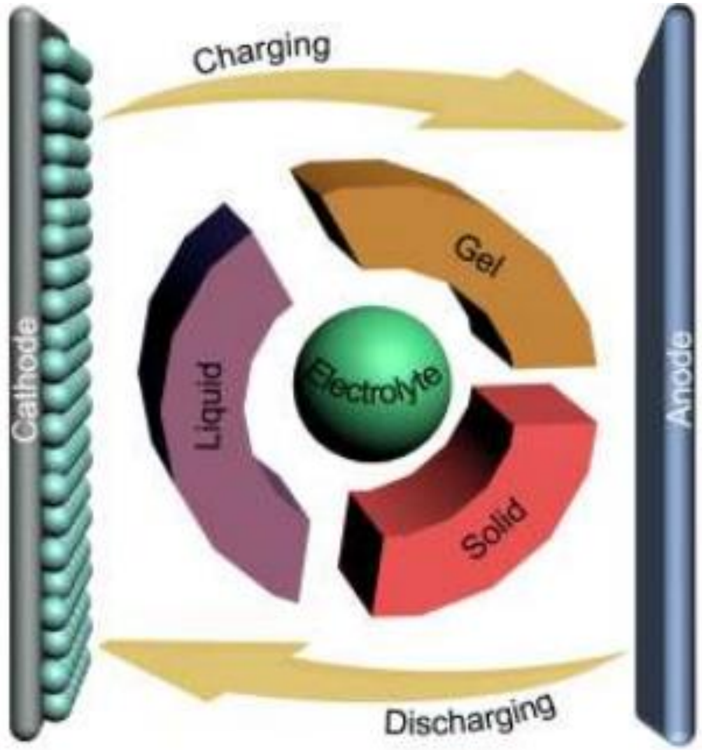
1. Organic Liquid Electrolyte
2. Aqueous Liquid Electrolyte
3. Ionic Liquid Electrolyte

Solid Electrolyte

- Advantages:
  - ✓ Safety
  - ✓ Mechanical properties
  - ✓ Flexibility
  - ✓ Avoid the dendrites

- Drawbacks:
  - ✗ Low ionic conductivity
  - ✗ Poor interfacial properties

1. Solid Polymer Electrolyte
2. Inorganic Solid Electrolyte

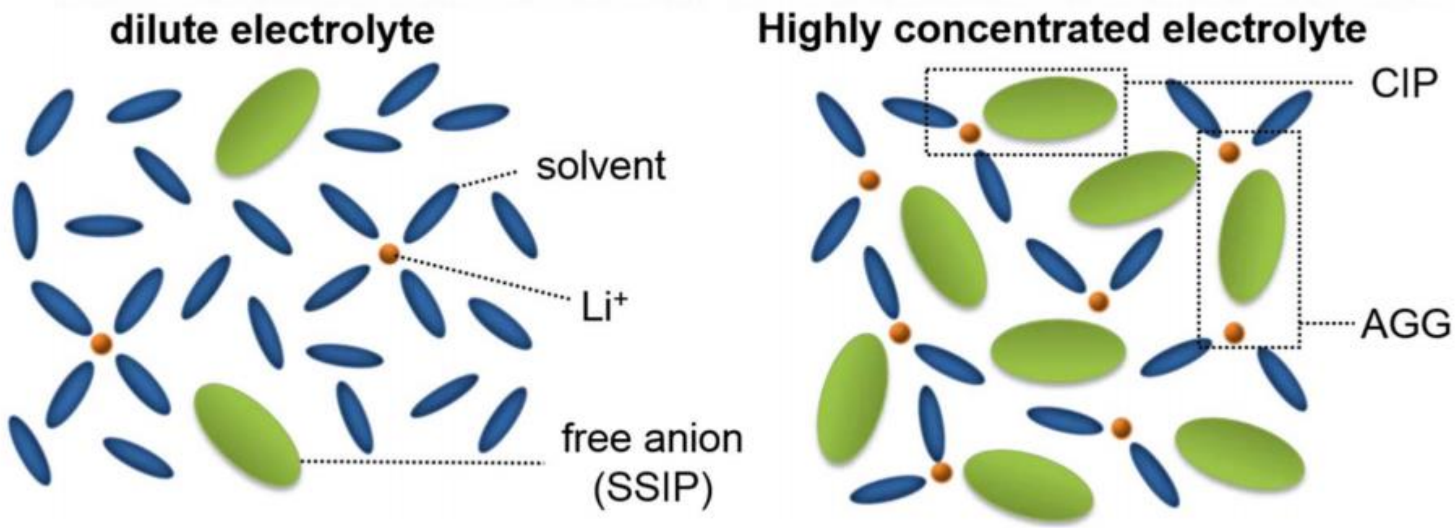


Gel Electrolyte

- Advantages :
  - ✓ High conductivity
  - ✓ Risk of leakage is reduced
  - ✓ Good interfacial properties

- Drawbacks:
  - ✗ Poor mechanical properties

Super - Concentrated Electrolyte



- Advantages :
  - ✓ Al anti-corrosion
  - ✓ Passivation of graphite and Al
  - ✓ Supression of dendrites
  - ✓ High reductive-oxidative potential
  - ✓ High level of safety
    - Non flammability
    - Reducing the volatility of the solvent
- Drawbacks:
  - ✗ Low ionic conductivity
  - ✗ High viscosity
  - ✗ Lithium salt are expensive

J. Zheng, J. A. Lochala, A. Kwok, Z. D. Deng, and J. Xiao, “Research Progress towards Understanding the Unique Interfaces between Concentrated Electrolytes and Electrodes for Energy Storage Applications,” *Adv. Sci.*, vol. 4, no. 8, 2017.

- Formulation of gel-type polymer electrolytes:
  - PVdf-HFP in combination with a super-concentrated electrolyte
  - PEG400 (molecular crowding)
  - LiPAA in combination with salt

- Adequate electrochemical properties
  - High ionic conductivity at RT (≈ 10^{-3} S cm^{-1})
  - Wide electrochemical stability window
    - up to 5V in organic gel electrolyte
    - up to 2 V in aqueous gel electrolyte
  - Suitable Li^+ or Zn^{2+} transport number

- Structure and behavior analysis of the different formulated gels
  - Raman spectroscopy
  - Thermal behaviour (DSC and TGA)

- Use of the developed gels in different types of batteries
  - Metalic Lithium → organic gel
  - Metalic Zinc → aqueous gel

Summary of the Experiments

Electrolyte preparation

Physico-chemical characterization

- *Electrolyte uptake of PVDF-HFP membranes*
- *Rheology of liquid electrolyte (LE)*
- *Raman spectroscopy of LE and GPE*
- *Thermal properties of the gel polymer electrolyte (GPE)*

Electrochemical characterization

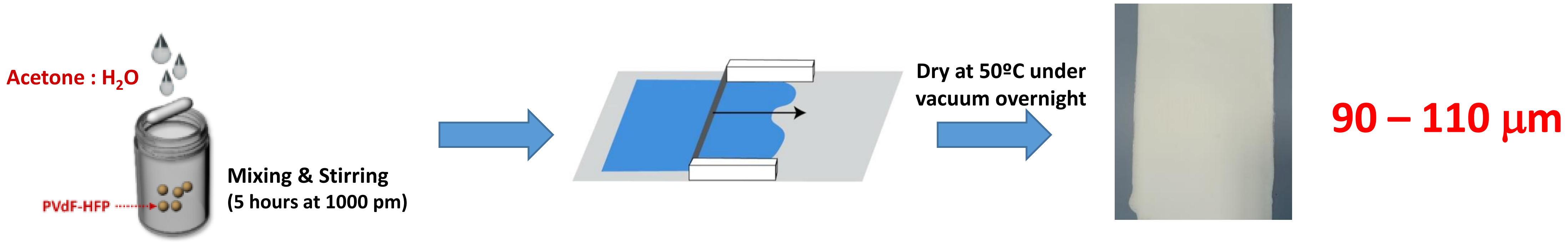
- ***Ionic conductivity (σ) of LE and GPE***
- *Lithium transference number (t_{Li}^{+}) of GPE*
- ***Electrochemical stability window (ESW) of GPE***
- ***Corrosion of aluminum current collector***
- *Li Plating/Stripping in Li/Li and Cu/Li*

Cell assembly and electrochemical testing

- ***LFP // GPE211 // Li***
- ***NMC111 // GPE211 // Li***

Electrolyte Preparation

1. Membrane Preparation

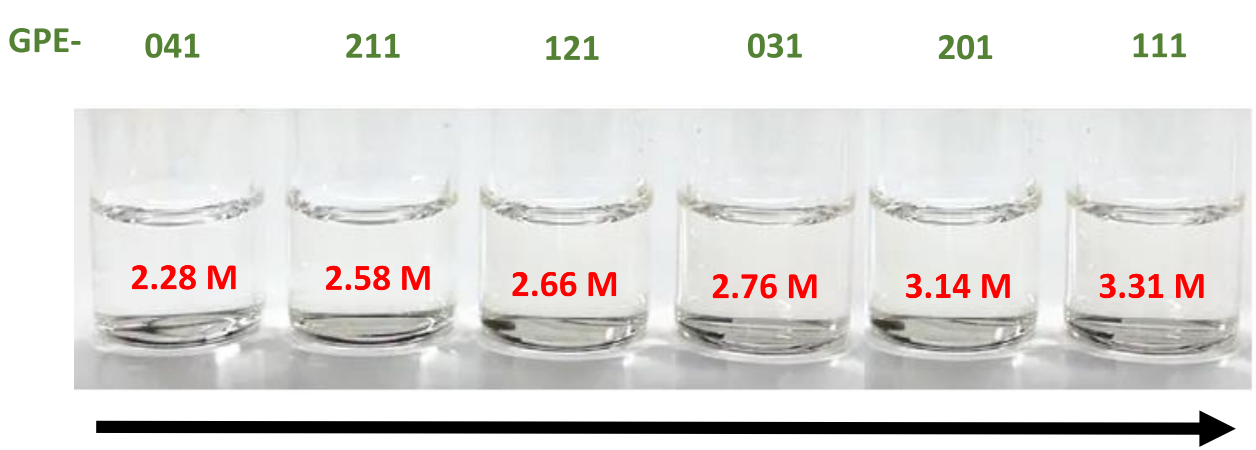


(a) Mixing Step

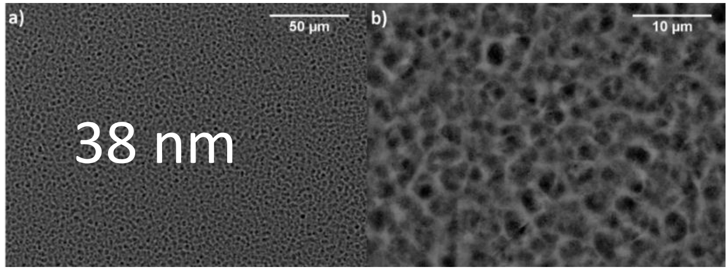
(b) Doctor Blade Technique

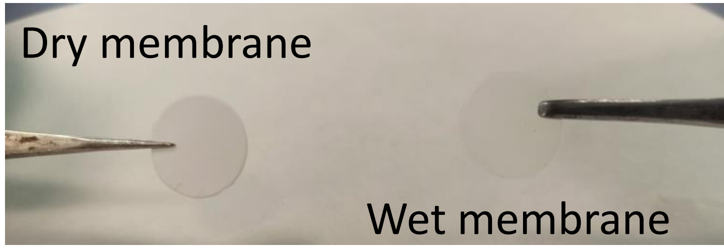
(c) Store in the Glove Box

2. Preparation of Concentrated Electrolyte (DMC : FEC : LiTFSI)



1 M LiTFSI in DMC



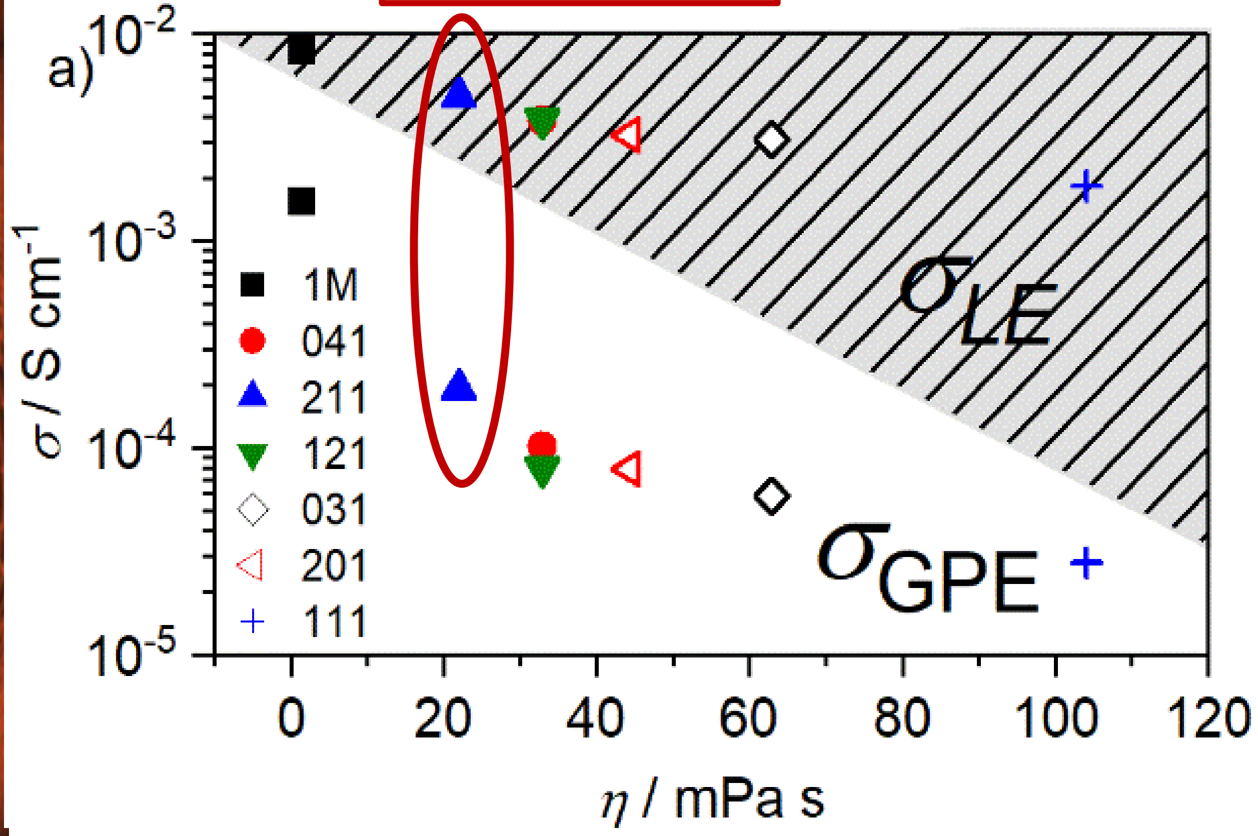


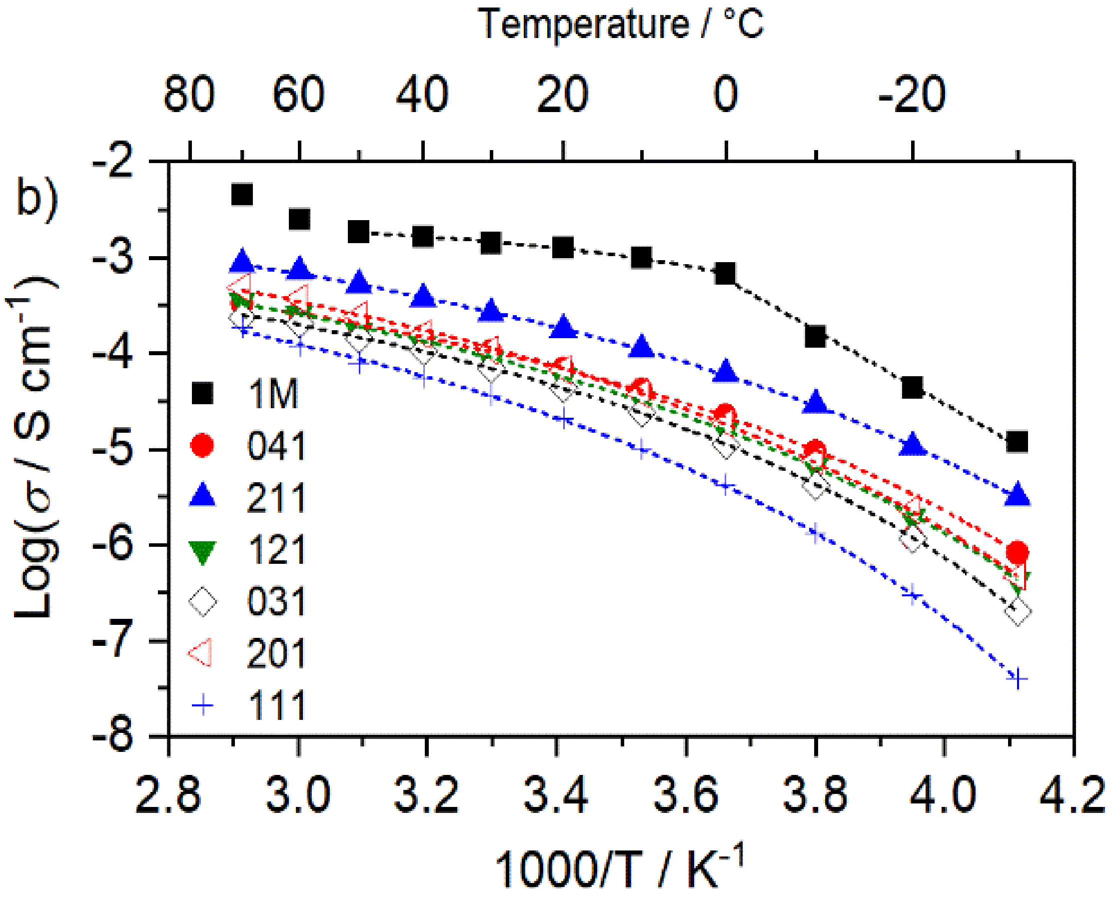
Ciurduc, D.E.; Boaretto, N.; Fernández-Blázquez, J.P.; Marcilla, R.; Journal of Power Sources, under revision.

Ionic Conductivity (σ)

GPE-211

SS/SS coin cells





25 ºC

σ ↓ μ ↑

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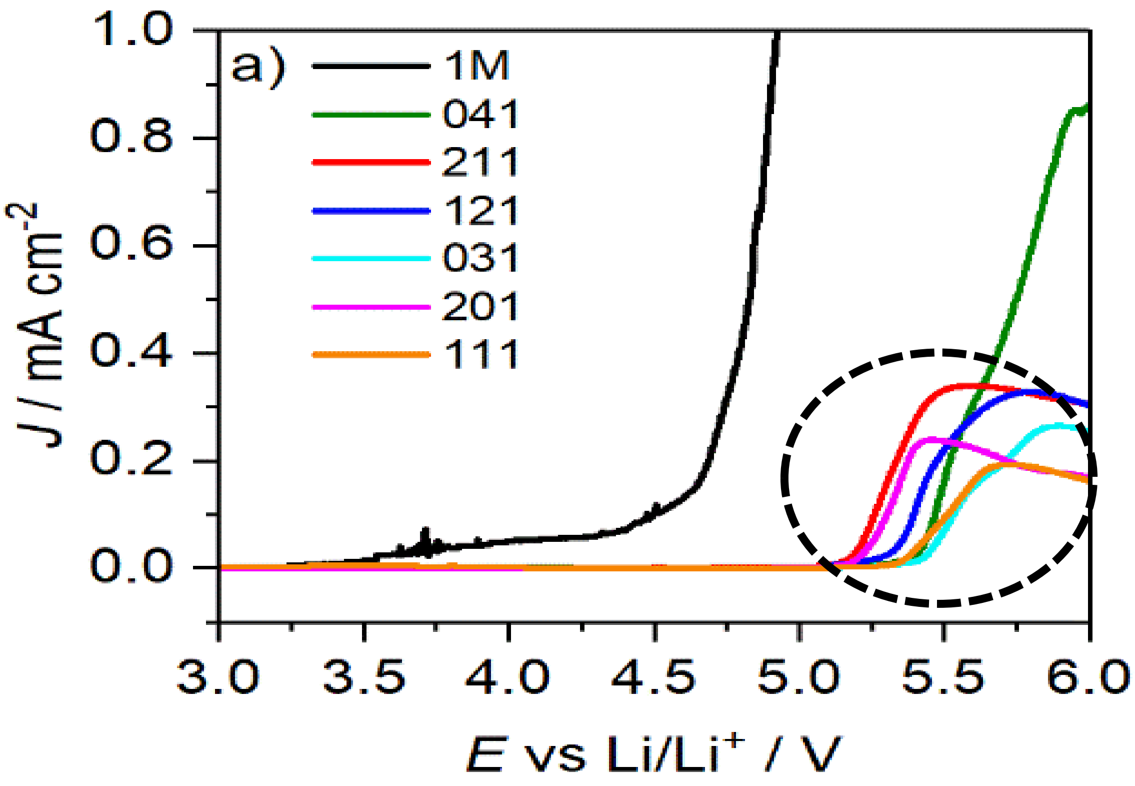
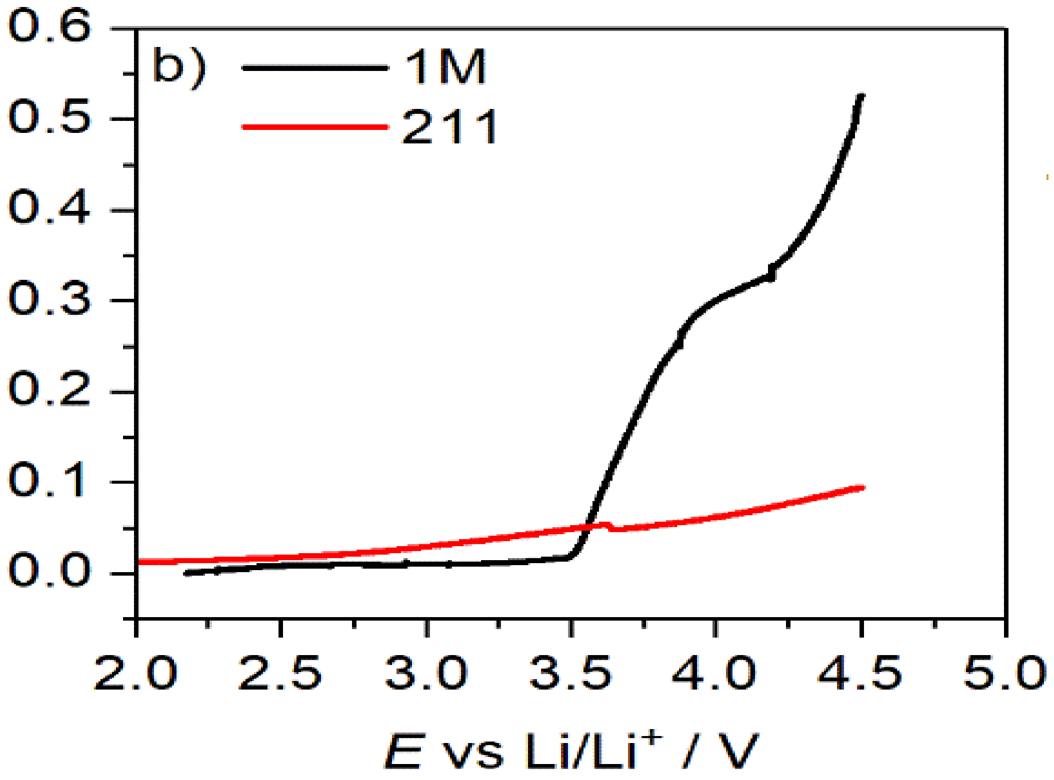
Electrochemical Stability

Li/SS coin cells



Li/Al coin cells



GPE-211

✓ Decrease in corrosion

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Cell Performance

LFP//Li Coin Cell

147 mAh g^{-1} at C/10

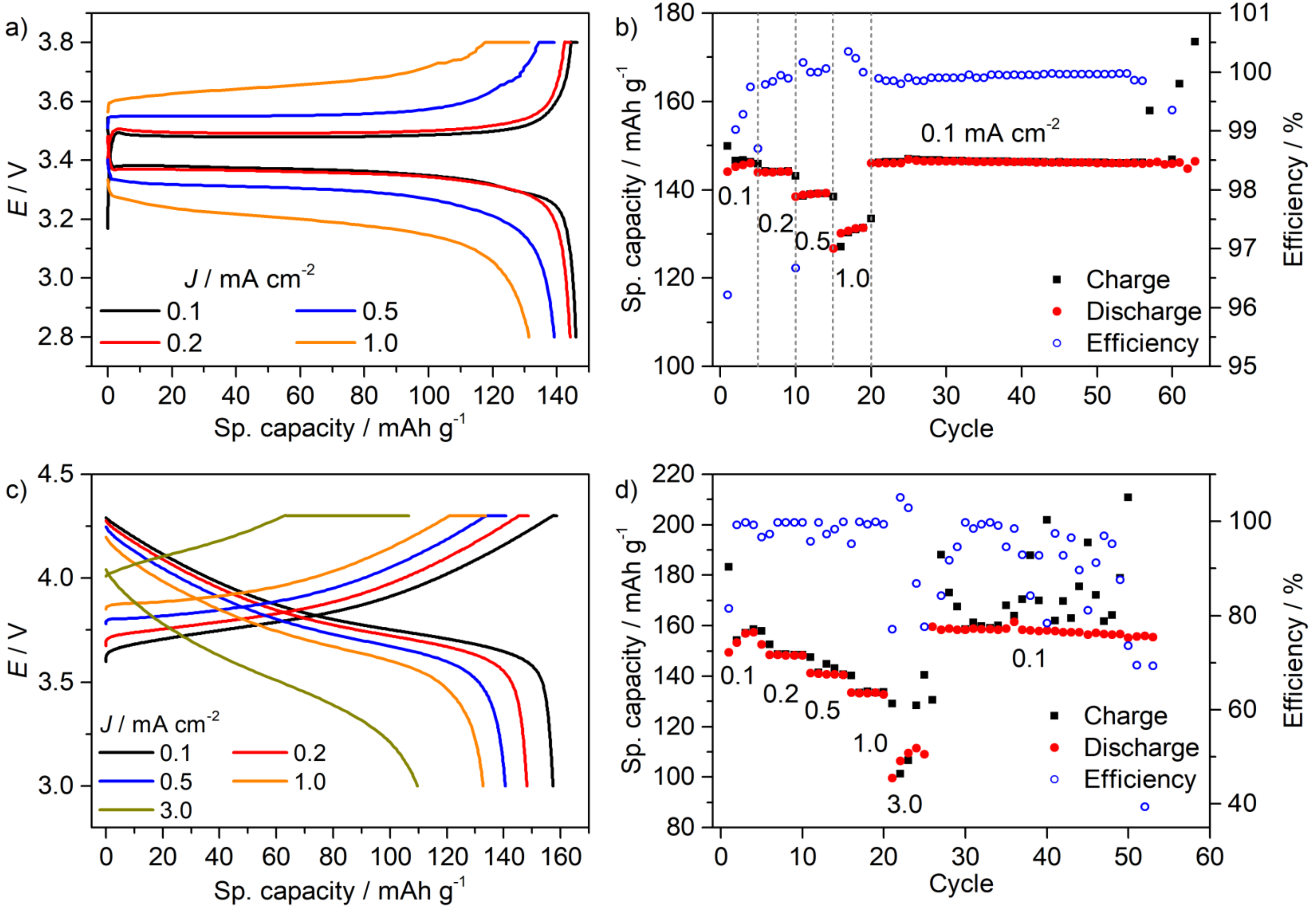
130 mAh g^{-1} at 1C

NMC111//Li Coin Cell

160 mAh g^{-1} at C/10

133 mAh g^{-1} at 1C

25 ºC



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