Solvent-Free Electrode Manufacturing for Low Cost/Fast Charging Batteries

By Yan Wang (P.I.), Yangtao Liu, Ruihan Zhang
Worcester Polytechnic Institute

Overview

Timeline
- Project start date: Nov. 19, 2019
- Project end date: Nov. 18, 2022
- Percent complete: 40%

Barriers
- Barriers addressed
  - Charging time
  - Cost
  - Energy density

Budget
- Total project funding: $2,426,552
  - DOE share: $1,213,276
  - Contractor share: $1,213,276
- Funding received in FY 2020: $360,332

Partners
- Interactions/ collaborations:
  - Texas A&M University, Missouri University of Science and Technology, Rice University, Microvast
- Project lead: WPI

Relevance and Project Objectives

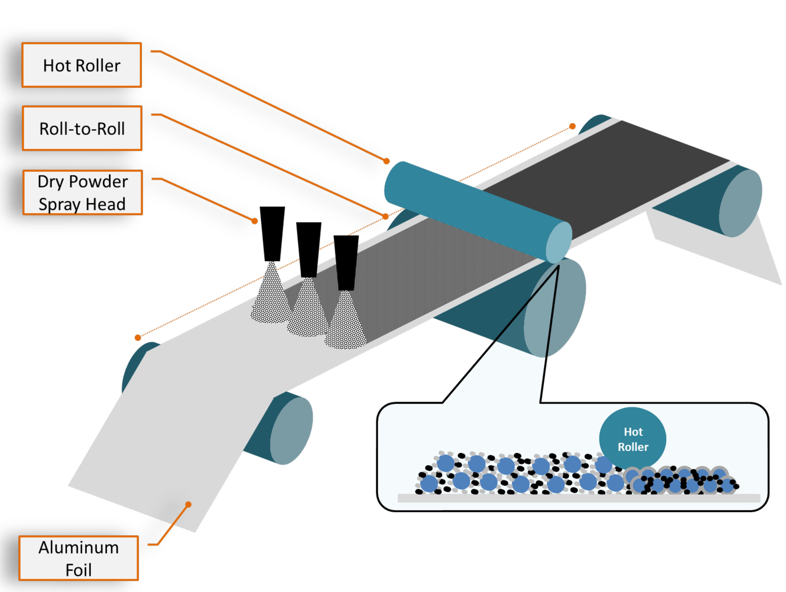
The project's **objective** is to develop low cost batteries capable of fast charging for EV applications according to the USABC targets.

In order to achieve the goal, the team will further develop solvent-free manufacturing method for **hetero-structured** electrodes in order to achieve fast charging capable and low cost batteries.

Milestones

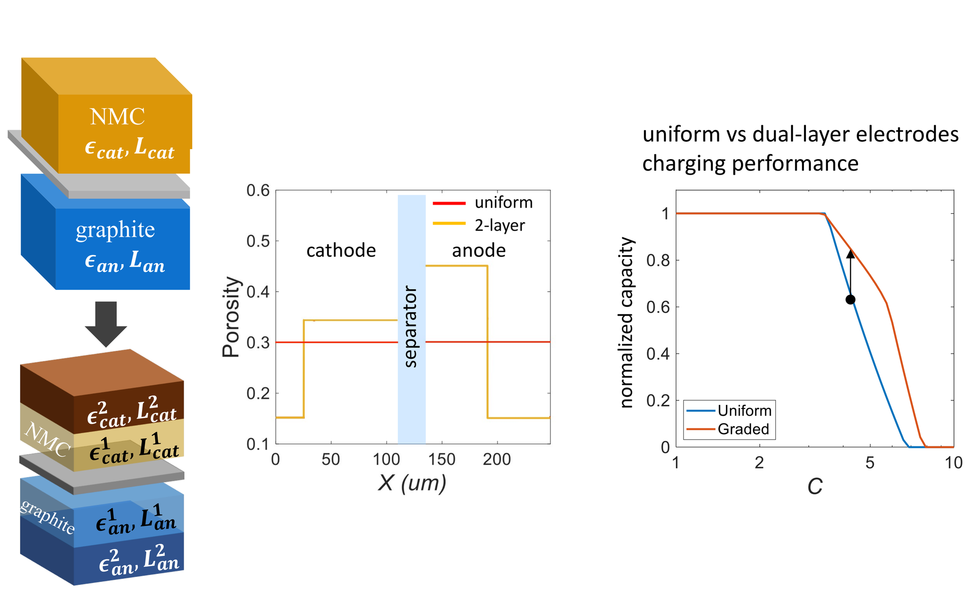
Time	Description
October, 2020	Successfully fabricate pouch size electrodes
October, 2020	Successfully fabricate 2 layered electrodes
December, 2020	Solvent free electrodes show better rate performance in coin cells
April, 2021	Single layer pouch cells with solvent free electrodes show better rate performance

Approach: Solvent Free Manufacturing



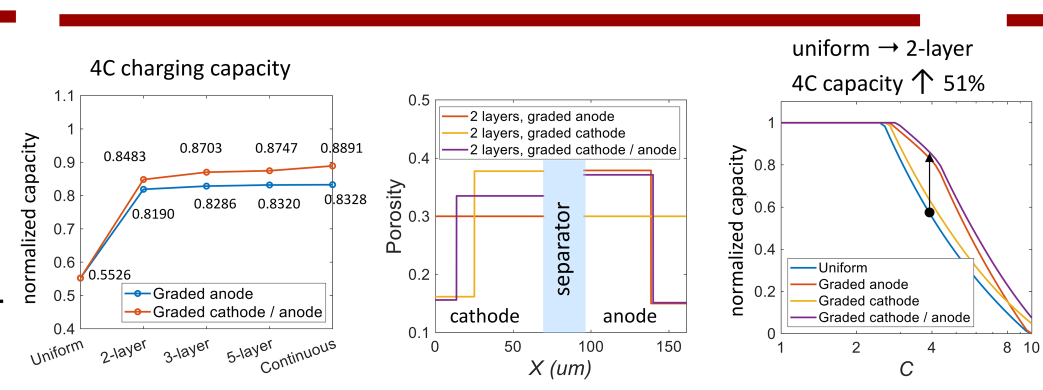
	Current technology	Our proposed technology
Material mixing	Wet mixing with solvent	Dry mixing without solvent
Coating	Slurry casting	Dry printing
Dry	Dry step needs	No drying
Solvent recovery	Organic solvent needs to be recovered	No recovery step
Electrode	Uniform porosity electrode	Porosity graded electrode (proposed work)

Technical Accomplishment-Modeling



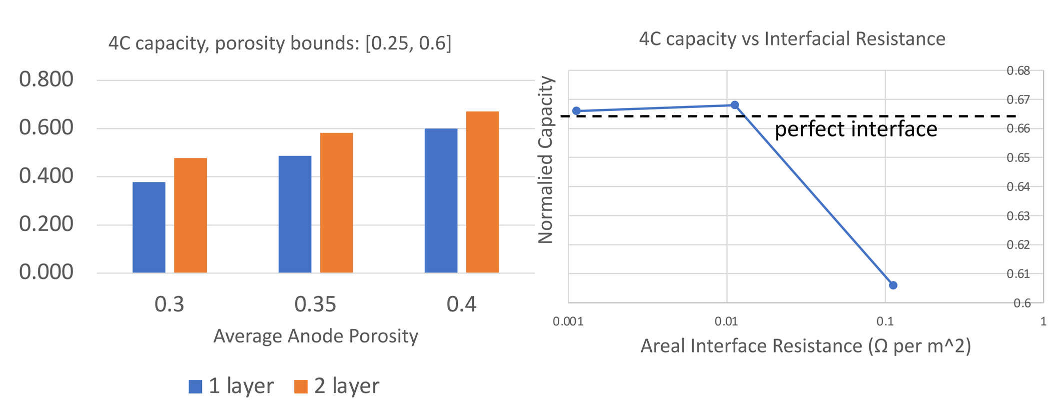
- Battery cell simulation predicts that the charging rate capability is improved by dual- or multi-layer electrode structure with spatially varied porosity.
- Higher porosity near separator + lower porosity near current collector
  ➔ more uniform reaction across electrodes ➔ longer charging

Modeling



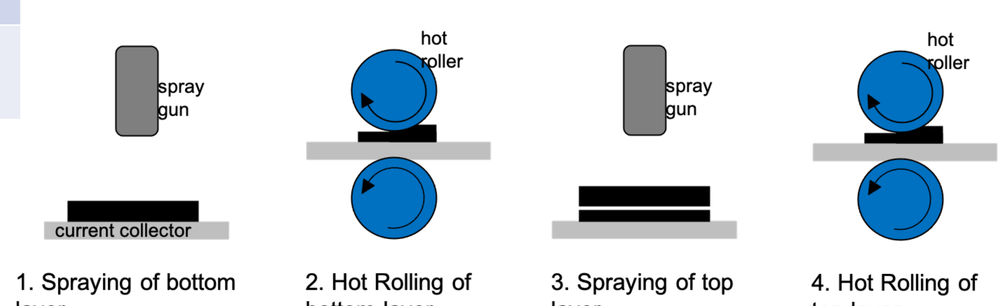
- New analytical model (Wang & Tang, Cell Reports Physical Science 2020 1, 100192) optimizes dual- or multi-layer electrodes (porosity & thickness of each layer) for NMC/graphite cells with $10^5\times$ speedup over standard P2D simulation.
- 2-layer electrode is the practical best design; multi-layer configurations only exhibit modest improvement.
- Grading porosity in graphite anode benefits fast charging the most due to the larger tortuosity in anode than cathode
  ➔ Adopted cell design: uniform NMC cathode + 2-layer Graphite anode

Modeling



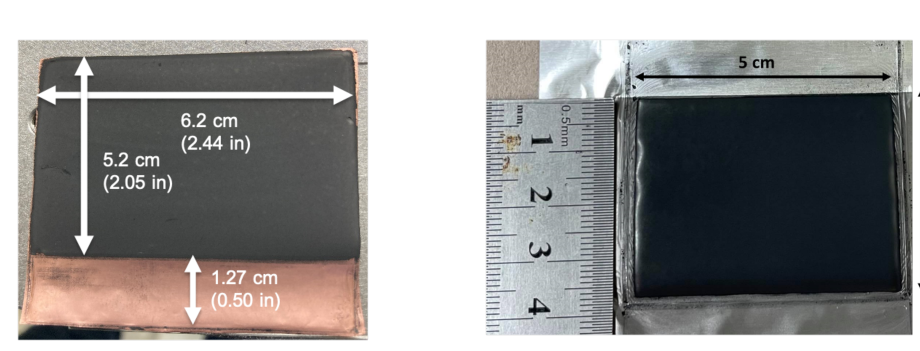
- Dry-printing fabrication tests reveal manufacturing constraints on the electrode design:
  Accessible porosity range: 0.25 – 0.45 (cathode), 0.25 – 0.6 (anode)
  Interfacial resistance between anode layers
  Electrode optimization re-performed with constraints
- Subject to the porosity limit, uniform NMC (35% porosity) + 2-layer graphite delivers 27% higher 4C capacity than a uniform NMC/graphite cell.
- Interfacial resistance should be kept below 0.01 Ω m^{-2} to minimize negative impact on charging performance.

Manufacturing



- Avoid very low porosity on the bottom layer
- Low porosity leads to "flat" surface which weaken the interfacial bonding

Manufacturing

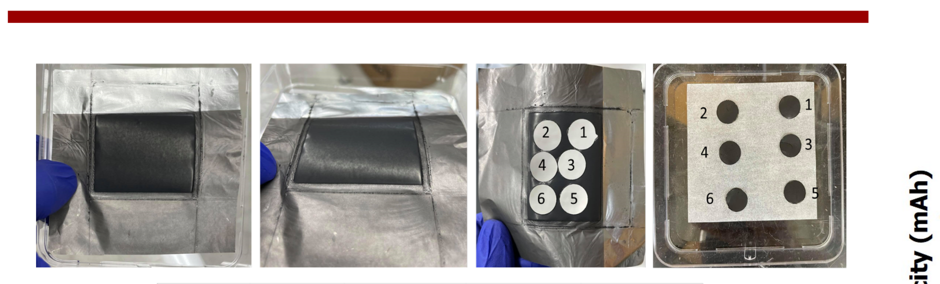


PVDF loading: 0.05-0.06 mg/cm2
Loading: ~10 mg/cm2
Porosity: ~35 %
Hot rolling temperature: ~ 100 deg C at final rolling step

PVDF loading: N/A
Loading: ~20.0 mg/cm2
Porosity: ~35 %
Current collector: Carbon coated Al

- Both anode and cathode for single layer pouch cells are successfully fabricated
- The loading and porosity meet the target

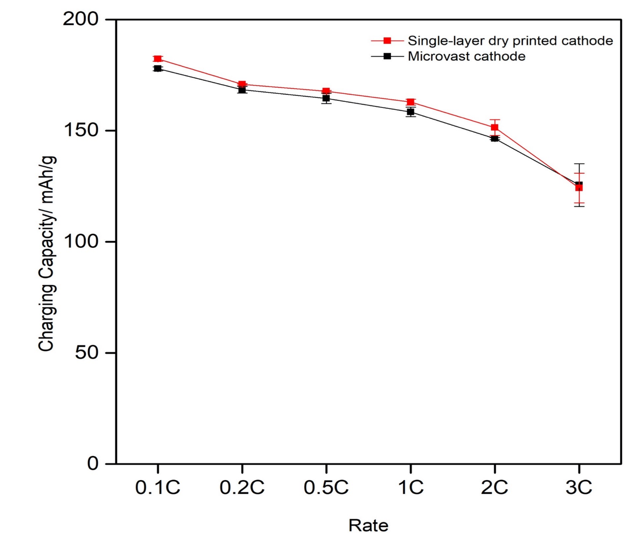
Manufacturing



Electrode no.	Mass gm	Thickness um	Loading mg/cm2	Porosity %
1	32.8	96	19.95	37.9
2	32.1	92	19.4	36.4
3	31.7	94	19.15	38.9
4	32.6	96	19.8	38.4
5	32.4	96	19.65	38.9
6	32.0	94	19.35	38.2

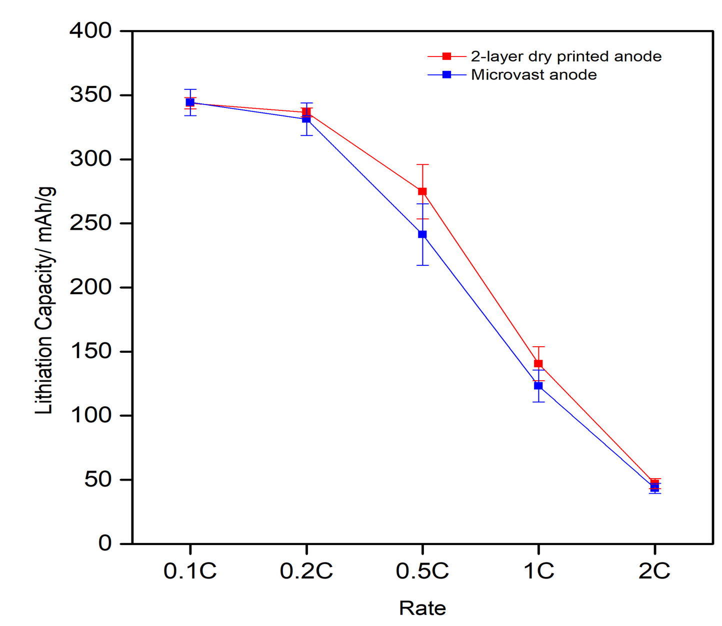
- Consistently show <5% loading variation and good adhesion with the current collector

Properties



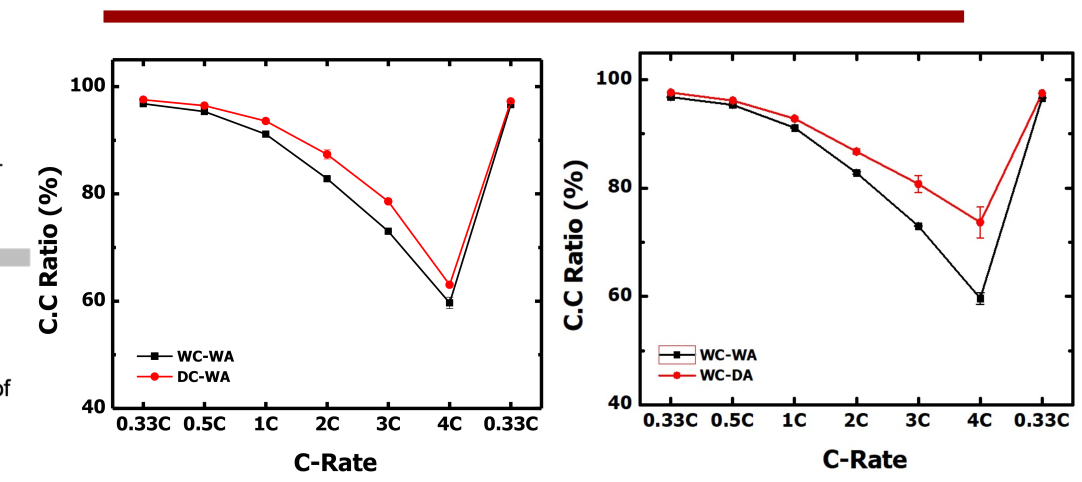
- Dry printed cathode has higher rate performance than the Microvast slurry casted cathode.
- The 3C performance is similar is due to the lithium metal anode

Properties



- Dry printed anode has higher rate performance than the Microvast slurry casted anode.
- The 2C performance is similar is due to the lithium metal counter electrode.

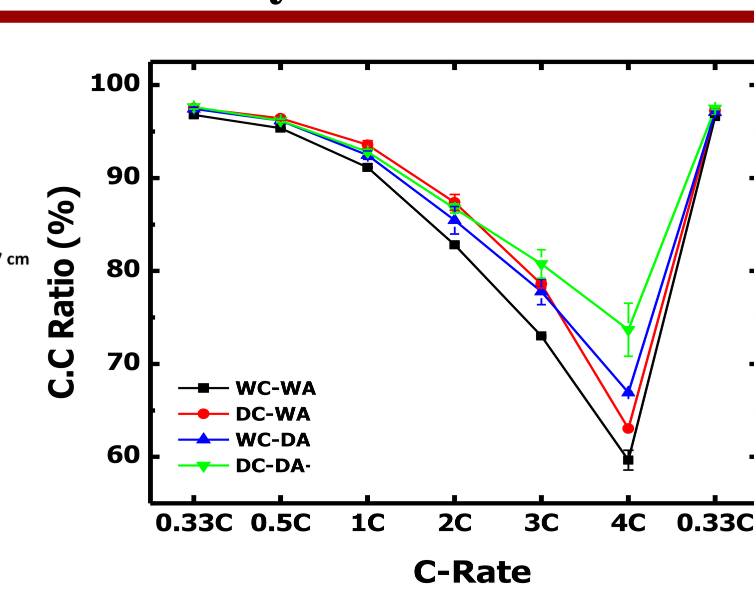
Properties



- Rate Test: Various C-rates charge, CV 15min cut-off, 0.33C discharge, 2.7 V to 4.3V
- Single layer pouch cells with dry anode and dry cathode has better rate performance

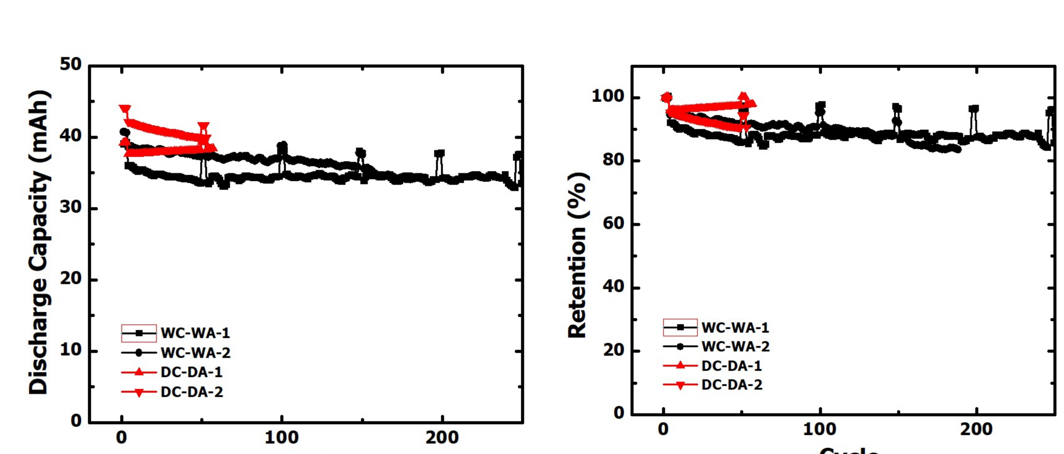
WC: wet cathode, WA: wet anode, DC: dry cathode, DA: wet anode

Rate Performance-Single Layer Pouch Cells



- Rate Test: Various C-rates charge, CV 15min cut-off, 0.33C discharge, 2.7 V to 4.3V
- Single layer pouch cells with dry anode and dry cathode has better rate performance

Cycle Life-Single Layer Pouch Cells



- Singler layer pouch cells with solvent free electrodes show comparable cycle life with slurry casted electrodes

Responses to Previous Year Reviewers' Comments

N/A

Collaboration and Partners

Solvent free electrode manufacturing

One of the Co-PIs moved from Missouri University of Science and Technology to Texas A&M University in summer 2020.

Modeling to guide the electrode design

Cell fabrication and testing

Remaining Challenges and Barriers

- Fabricate solvent free electrodes with higher loading
- Fabricate and scale up double sided electrodes with the dimension of 100mm*115mm
- Double sides electrodes show 4C charge capability with single layer pouch cells
- 5Ah cells with solvent free electrodes show 4C charge capability

Proposed Future Work

- Test more single layer pouch cells to determine the repeatability
- Fabricate single layer pouch cells for deliverables
- Deliver single layer pouch cells to Argonne National Laboratory by the end of June, 2021
- Test single layer pouch cells at Argonne National Laboratory and Microvast
- Model and design the electrodes for 4C charge capability

Summary

- Successfully fabricated both solvent free anode and cathode
- Successfully fabricate 2 layer electrodes
- Solve the bonding and uniformity issues for solvent free electrodes
- Consistently show solvent free anodes and cathodes have better rate performance in both half cells and full cells (coin cells)
- Demonstrate higher rate performance of single layer pouch cells with solvent free anode and cathode compared to single layer pouch cells with wet electrodes
- Achieve >80% capacity retention at 3C (Our initial target) in single layer pouch cells with solvent free anode and cathode

2021 DOE Annual Merit Review