Testing Production Methods of MXene-Sulfur Electrodes for Lithium-Sulfur Batteries

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SMART SUMMER MATERIALS RESEARCH @ TULANE

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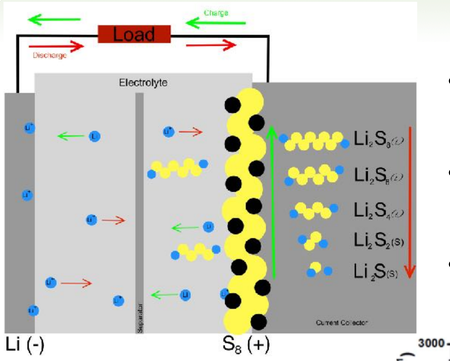
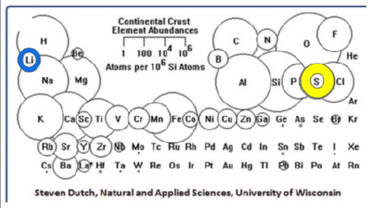
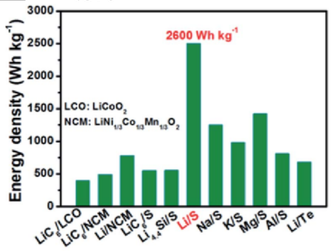
Lithium Batteries



- Li-ion battery has the current highest energy density
- Li-S battery has the potential to out perform them
- Li-S batteries operate as described on the left



Sulfur is abundant



Compares energy densities of batteries

Some Problems with Li-S Batteries?

- Sulfur is an insulator
- Some polysulfides dissolve in the electrolyte and migrate cross the separator, causing rapid capacity loss
  - called the shuttling effect

Our Research Goal

- Produce a scaleable MXene-S electrode with improved stability and capacity

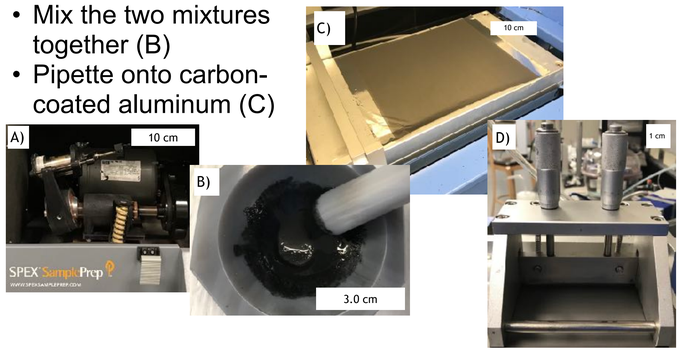
Production Methods

Method 1

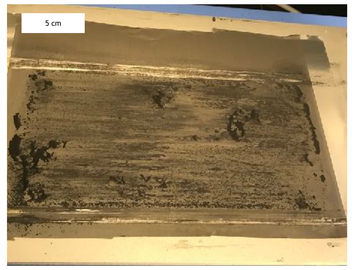
- High energy ball-mill (A) MXene and Sulfur
- Filter dry
- Mix MXene-Sulfur with Carbon Black
- Mix binder with solvent
- Mix the two mixtures together (B)
- Pipette onto carbon-coated aluminum (C)

Method 2

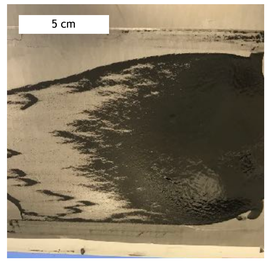
- High energy ball-mill MXene, Sulfur, and Carbon Black
- Add dissolved binder in solvent
- Shake
- Drop-cast using the doctor blade (D)



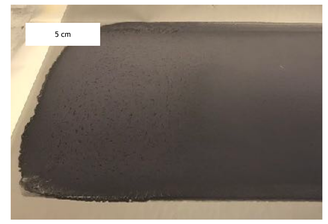
Results - Uniform Film



20% LiPAA Trial

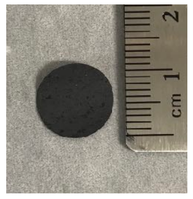


15% LiPAA Trial

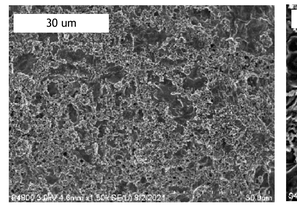


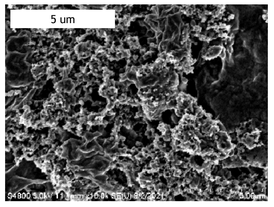
1:1 water to Ethanol Trial, 20% LiPAA

- Found the balance between binder and solvent
- Method 2 can mass produce many electrodes in only 4 hours, while pipette drop-casting must wait overnight for material to dry



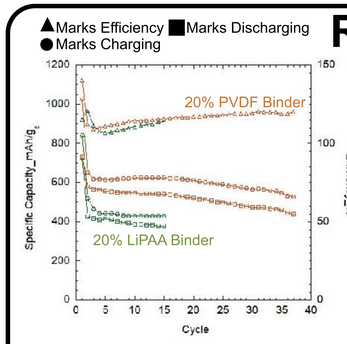
MXene-S Electrode



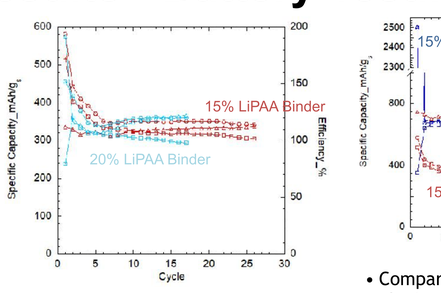


- SEM images on the show the even distribution of particles throughout the electrode

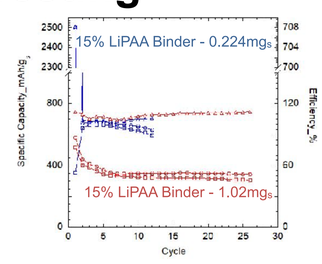
Results - Battery Testing



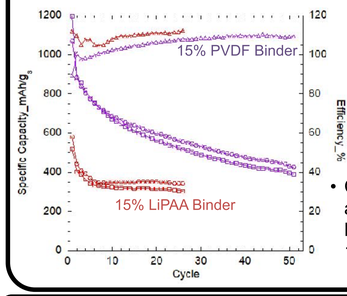
- Compared LiPAA and PVDF using Method 1, under a 100mA/g$_s$ current



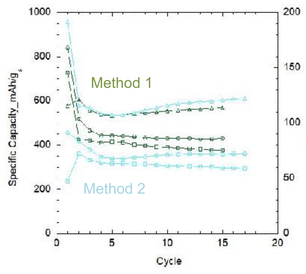
- Compared different percentages of LiPAA using Method 2, under a 100mA/g$_s$ current



- Compared identical method 2 electrodes, but with different sulfur loading (amount of sulfur in a certain area)

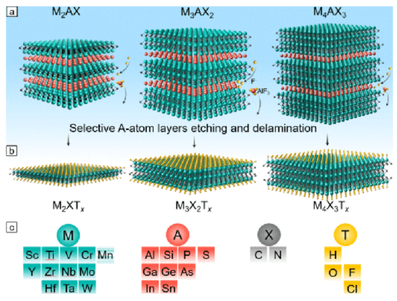


- Compared LiPAA and PVDF using Method 2, under a 100mA/g$_s$ current



- Compared Method 1 and 2, using 20 LiPAA, under a 100mA/g$_s$ current

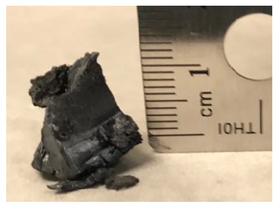
What are MXenes?



- 2D metal carbide material with high elastic modulus and high electrical conductivity
- Made from MAX, a 3D metal carbide
- 2D property formed through HF treatment
- Delaminate MXene with TMAOH
- Filter to eliminate disolved ions

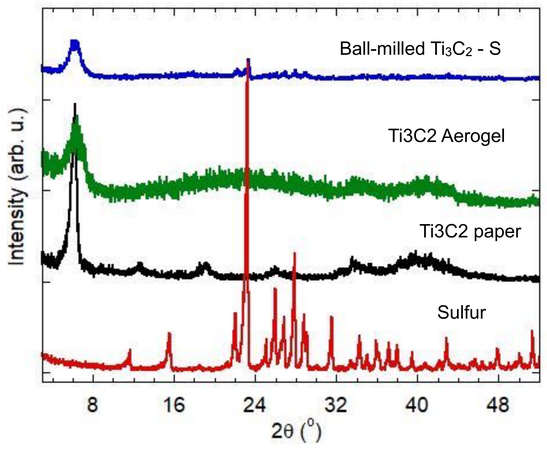
MXene Aerogel

- Formed by freeze drying water dispersed MXene
- Has a higher specific surface area
  - 200 m^2/g compared to 10 m^2/g for multilayer MXene
- Ti_3C_2 MXene was used in the project



Ti_3C_2 Aerogel Piece

Results - Structural Change



- XRD shows the change in crystal structure of our MXene-S material as it is processed into an electrode

Conclusions

- Method 2 is a scaleable method to produce electrodes
- The Method 1 outperformed Method 2 in terms of capacity, but stability is still unknown
- The low areal loaded 15% LiPAA produced the highest specific capacity

Future Work

- Replace Ti_3C_2 with Ti_2CN to better bind polysulfide
- Continue testing performance of doctor blade electrodes to see overall lifespan performance

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