JANUARY REPORT: PERFORMANCE-ENABLING SOYBEAN-DERIVED MATERIALS FOR NEXT-GENERATION SOLID-STATE LITHIUM-SULFUR BATTERIES

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The Kansas Soybean Commission (KSC) is currently supporting our project to develop performance-enabling soybean-derived materials as functionally graded materials (FGMs) for next-generation solid lithium-sulfur (Li-S) batteries. **Fig. 1** summarizes the generic procedure for battery electrodes utilizing large amounts of soy protein concentrate (SPC). For example, the battery anode include SPC (85%), Carbon Black (CB) (5%), and polyvinylidene fluoride (PVDF) (10%). Although interrupted by unexpected equipment shutdown and repairs in 2023, we managed to test the SPC-enriched lithium metal batteries. We utilized CCCV (constant current constant voltage) charging, a typical method of charging rechargeable batteries. Operation switches between CC charging, which charges with a constant current, and CV, which charges at a constant voltage, depending on the voltage of the rechargeable battery. Here are several cycling results tested at 0.1C, 0.5C and 1C rates for up to 2000 cycles. The open circuit voltage (OCV) was set at 2.99V for all tests. The test shows that the SPC-enriched lithium metal batteries show stable and long cyclic electrochemical performance, as shown in **Fig. 2**.

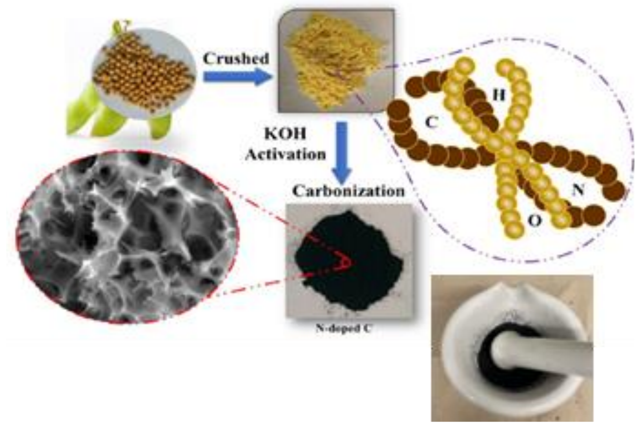


Fig. 1 Battery SPC preparation

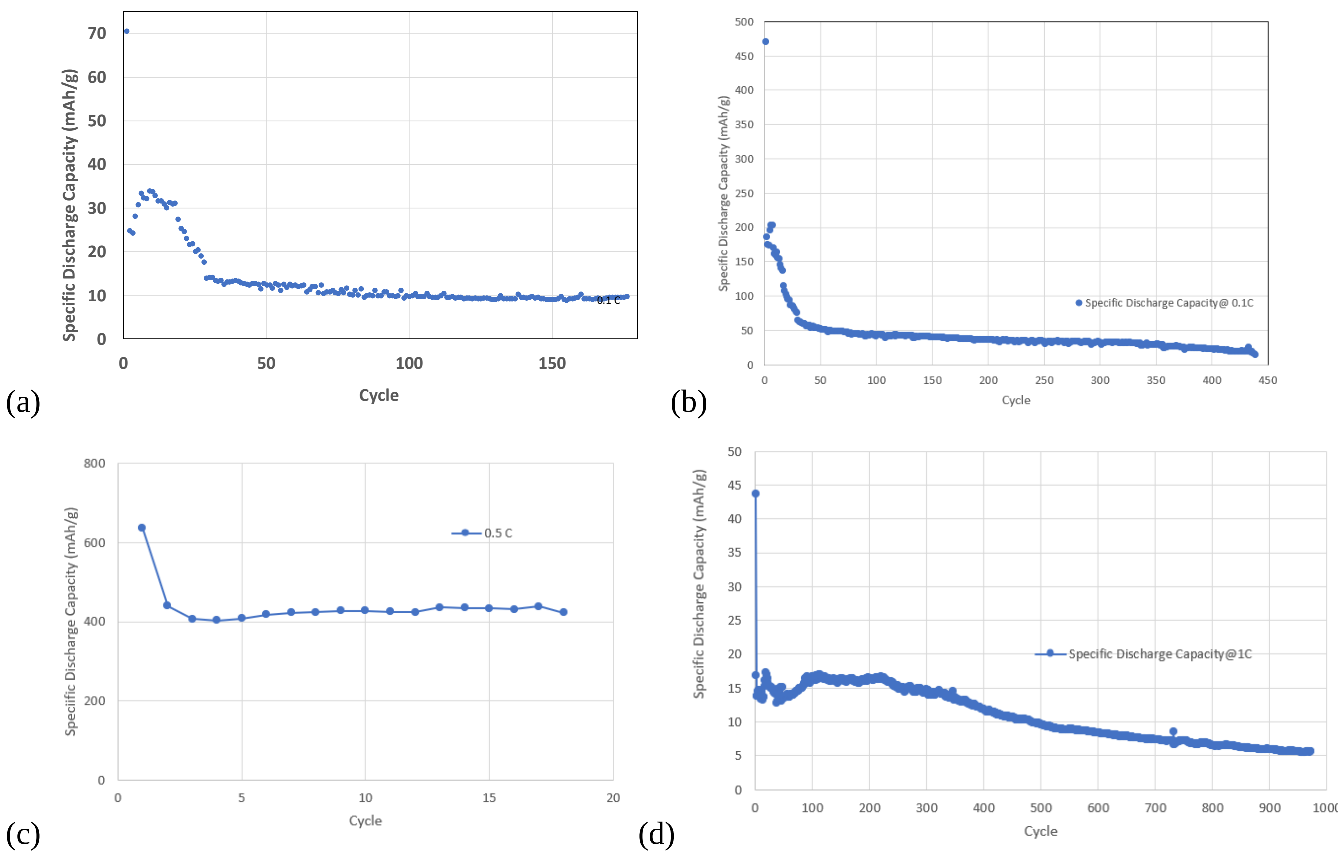


Fig. 2 Tests conducted @ (a) 0.1C for 175 cycles, (b) 0.1 C for 500 cycles (still running, max. capacity 469.8 mAh/g), (c) 0.5C for 2000 cycles (still running, max. capacity 635.34 mAh/g), and (d) 1C for 2000 cycles, (still running, max. capacity 43.75 mAh/g)

We also performed material characterization of the developed SPC-enriched batteries. Utilizing the Phenom ProX desktop Scanning Electron Microscope (SEM), **Fig 3.** shows the microstructures of SPC-enriched electrodes, and **Fig. 4** shows the Energy Dispersive Spectroscopy (EDS) tests of material compositions and elements weight concentrations.

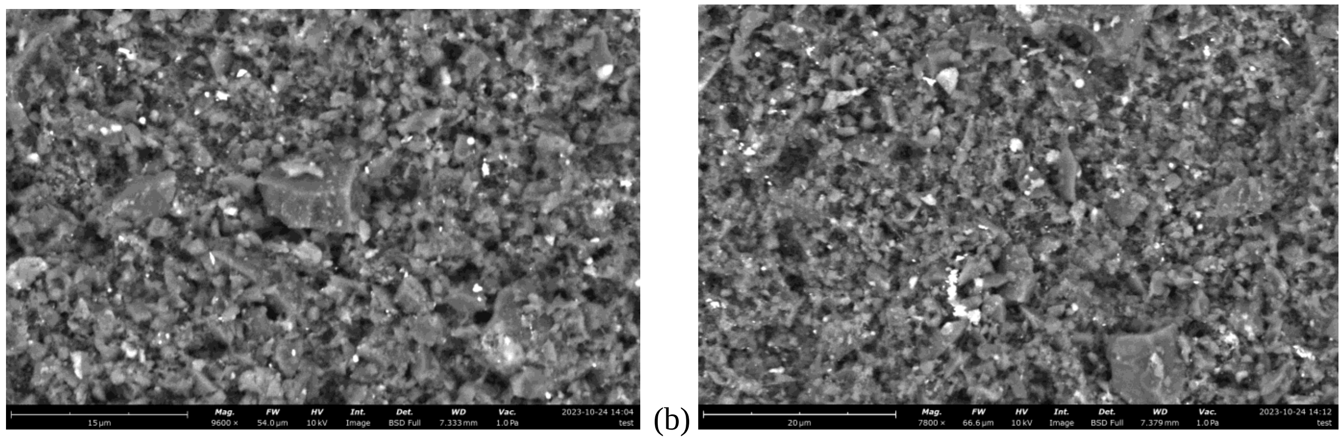
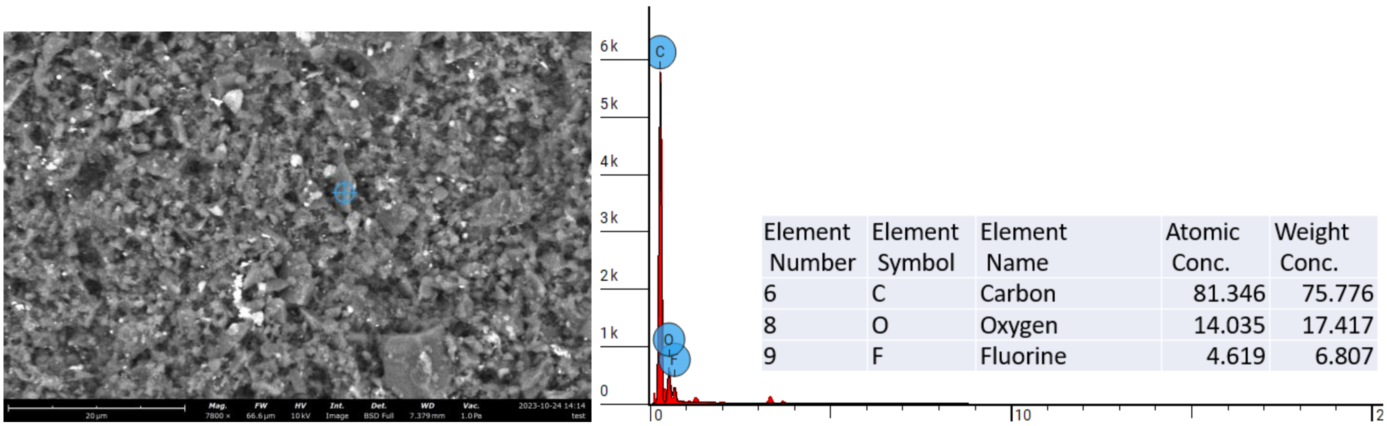


Fig. 3 Microstructures of SPC-enriched electrodes (a) top view, (b) bottom view.



Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	81.346	75.776
8	O	Oxygen	14.035	17.417
9	F	Fluorine	4.619	6.807

Fig. 4 EDS tests of Material Composition of SPC-enriched electrodes

In addition to the proposed research collaborations with NASA Glenn Research Center (GRC), Black & Veatch (BV), and KU Center for Technology Commercialization (KUCTC), leveraged by this project and KSC support, we've developed new collaborations with NASA Ames Research Center, Department of Energy Argonne National Laboratory, Orange EV, Spirit AeroSystems, Sunflower Electric Power Corporation, and Meta Platform to achieve the proposed research goal and objectives. In the foreseeable future, at least one U.S. student will be financially supported and working on the project for at least 25 hours/week at a KU-approved rate of $20/hour. We will also have other 2-3 U.S. students partially participate in the project to help with, e.g., experiment setup modification and maintenance, material synthesis and characterization, presentation, and education outreach. In addition, we plan to perform more electrochemical performance analyses, such as Cyclic performance analysis and C-rate analysis. We also plan to analyze the impact of particle size, electrode thickness, and compositions on their electrochemical performance and performance degradation (shown in **Fig. 5**).

Thank you again for your support!

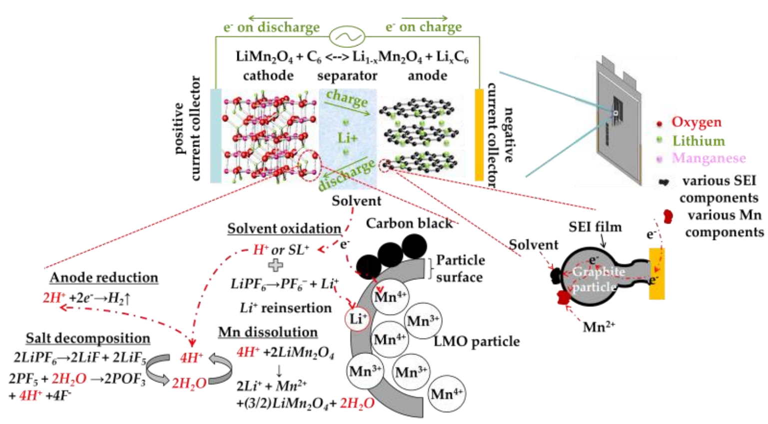


Fig. 5 Summary of Lithium Batteries Major Degradation