Antimony (Sb) Nanocomposites for Applications on Lithium-Ion Batteries

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Abstract

An approach on working with Antimony (Sb) as anode materials on lithium-ion batteries has been to achieve pure synthesized Sb; by fabricating Antimony (III) acetate precursor fibers through forcespinning and calcination under air. Various temperatures were chosen in order to produce short fibers to analyze its phase changes and showcase how the performance can be affected. These fibers are eventually used to produce slurry solutions that are needed to construct Sb-based anodes. This study highlights the recent progress in improving and understanding the electrochemical performance of Antimony at different compound ratios. As work is being continued, it may confirm that Antimony is a valued anode material in the field of Lithium and Sodium-ion batteries.

Introduction

Identifying alternative materials for next generation batteries is being researched extensively at this time. This is due to the overgrowing demand of using batteries on various applications for electric vehicles, electronic devices, and energy storage systems. Currently many different types of materials are being researched due to the lack of abundancy of materials and cost. Antimony (Sb) has been considered as a promising anode material for both lithium-ion batteries and sodium-ion batteries because it can store both types of ions and display a high theoretical capacity of 660 $mAhg^{-1}$. Which is presently double than commonly used graphite anodes. However, working with Sb has its fair share of setbacks. A key issue is that during lithiation of Sb-based batteries it encounters large volume expansion causing severe degradation known as pulverization. This action breaks the electrode material into small pieces accelerating corrosion by the electrolyte and leads to capacity fading. This is shown in the first charge-discharge cycle in LIB's, representing a significant loss in the reversible capacity (irreversible capacity) due to the formation of the Solid-Electrolyte Interface (SEI) layer. Therefore, developing efficient Sb-based nanostructures are in demand.

Methodology

The approach on fabricating the anode consists of preparing antimony (III) acetate precursor solutions. That is producing two control precursor solutions and two modified precursor solutions. Control solutions were prepared at 12% PAN/DMF 50% Sb at different heat treatments of 500°C, and 700°C. The other two were 10% PVP/Ethanol 50%Sb at 700°C and 12% PAN/PMMA 60%Sb at 700°C. All solutions were magnetically stirred for at least 48 hours until a homogeneous solution was achieved. Once mixed properly; solutions were ready to be forcespinned at the Cyclone forcespinning system L-1000M. Syringes were used to transfer 2mL of the given solution into the center nozzle of the spinneret. Half-inch 20G regular bevel needles were inserted at the ends of the spinneret where the solution would be extruded. An rpm was applied to each solution to which led the best quantity of fibers at a humidity below 60%. Every collected fiber mat was dried for 24 hours in ____oven. Once dried for the desired time, the collected fiber mats were calcined with the absence of air at 500°C and 700°C in order to remove volatile substances. Based on the amount collected after calcination, slurry solutions were prepared at an 8:1:1 ratio consisting of the active material, carbon black and polyacrylonitrile (PAN). All slurry solutions were magnetically stirred for at least 48 hours until mixed homogeneously. Afterwards slurry solutions were spread onto copper foil at a thickness of 25 mm and left to dry at 60°C in the ____ oven for 24 hours. After that each slurry mat was cut into anodes and used to assemble the battery inside the glovebox under an argon environment.

Figure 1. LIBs Assembly

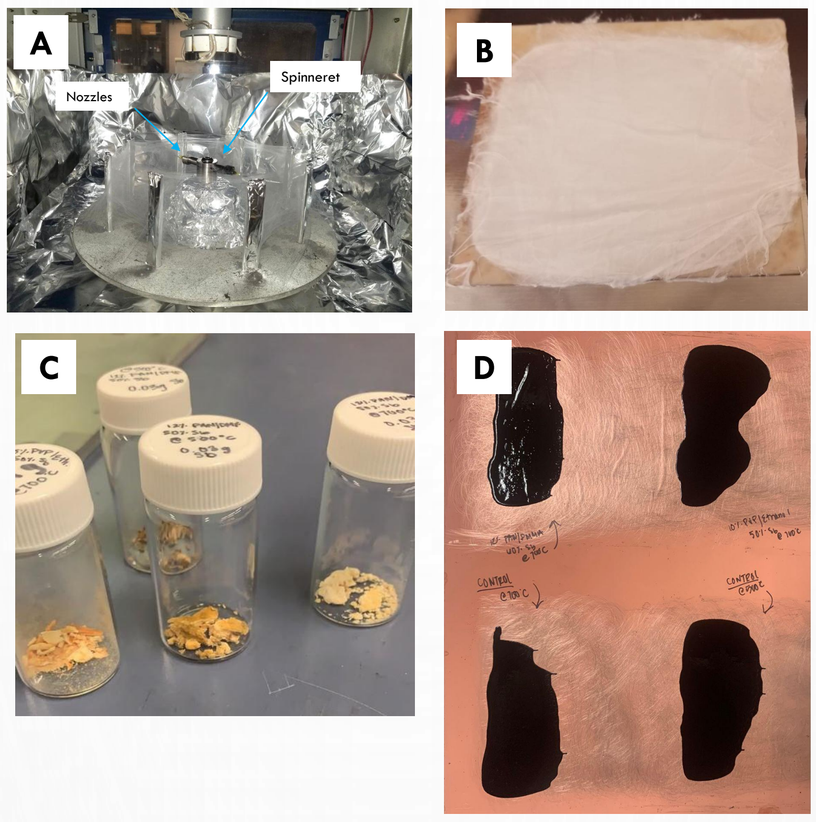

Figure 3. (A) Actual view of forcespinning, (B) Antimony based fiber mat, (C) Calcinated fibers (D) Slurry mats on copper foil

Results and Discussion

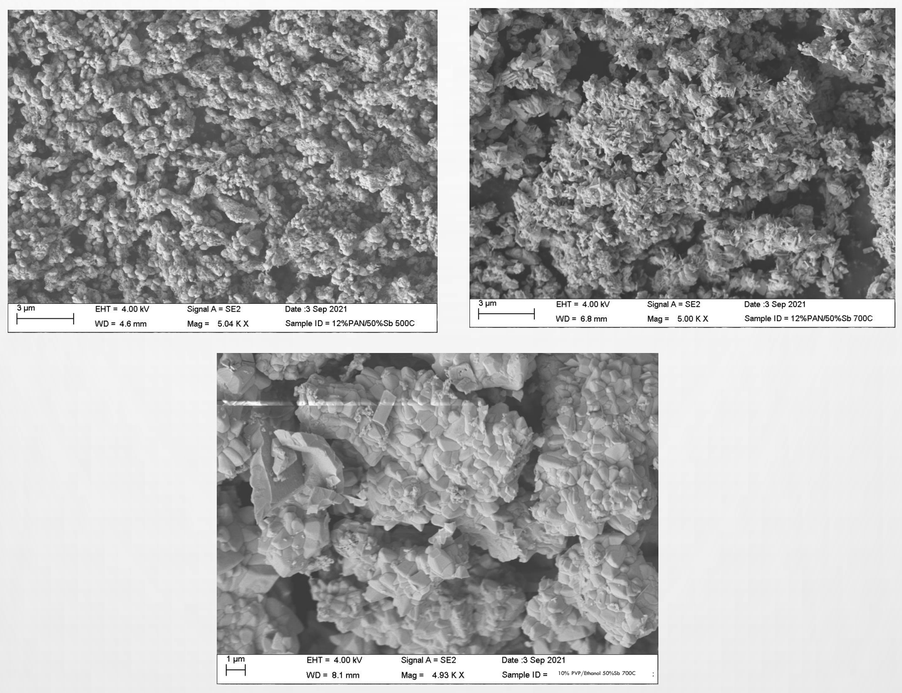

Figure 4. SEM images of calcinated fibers

Cyclic Voltammetry

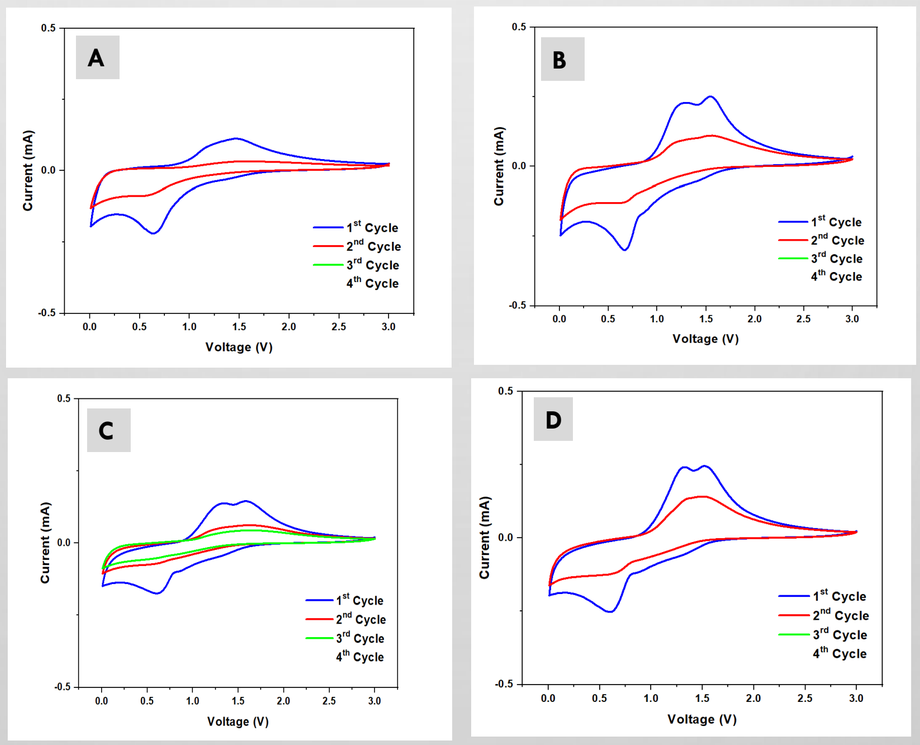

Figure 5. Charge/Discharge Profiles of: (A) 12% PAN/DMF 50% Sb @ 700C, (B) 10% PVP/Ethanol 50% Sb @ 700C, (C) 12% PAN/DMF 50%Sb @ 700, (D) 12% PAN/PMMA 60% Sb @ 700C

Based on the charge/discharge profiles, samples B and D worked best due to demonstrating higher peaks which is proportional to the concentration of the analyte (Sb) . Yet by the 2nd cycle it lowers experiencing irreversible process.

Impedance Performance

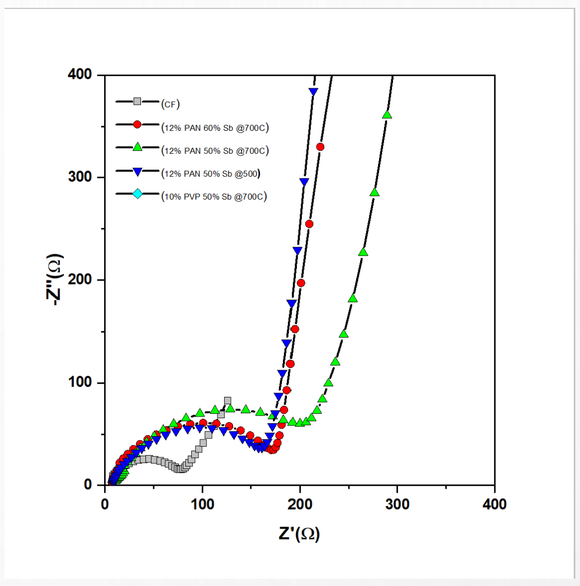

Figure 6. Impedance Characteristic Performance

Electrochemical Performance

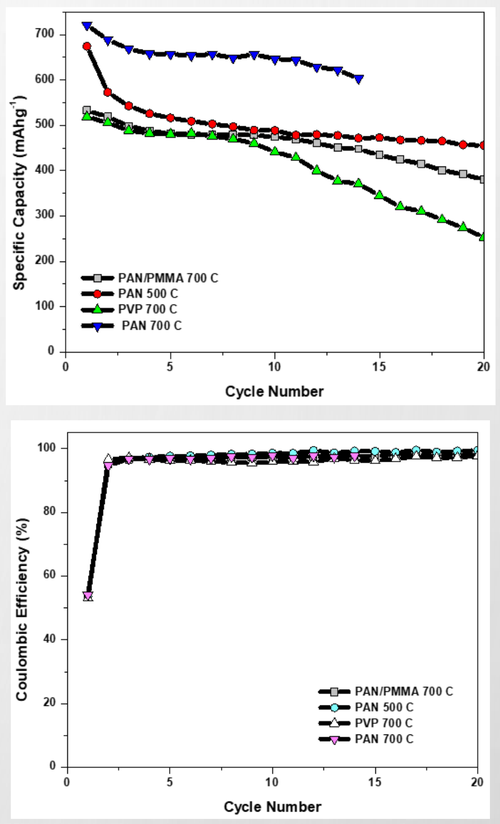

Figure 7. Cycle Performance

Conclusions and Future Work

Based on collected data, the prepared lithium-ion batteries showed signs of good stability reaching the theoretical capacity. Yet its life expectancy is not high, which is where improvement must be done to continue stability at long term. Future work would consist of increasing the percentage of active material in ratio to the polymer. Also eventually combine antimony with active/inactive carbon components to apply carbonaceous material as a buffer matrix for volume expansion. And investigate other ways to make anodes porous to support that expansion. If desired capacity and stability is reached with lithium-ion batteries; the following methodical approach will be applied to sodium-ion batteries since they are considered as the next promising energy storage.

Acknowledgments

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