DEVELOPING SUSTAINABLE SYNTHETIC ROUTES TO LITHIUM-ION BATTERY CATHODES

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INTRODUCTION

The increasing demand for energy and the threat from Global Warming make electrical energy storage a worldwide priority. Rechargeable batteries are modular and scalable and as such can meet the demands of a wide range of applications, like electric vehicles. While concerns about the sustainability and cost of lithium-based batteries has encouraged the development of battery chemistries relying on more abundant elements, the lithium-ion technology still dominates the market.

NMC-type cathodes have replaced lithium cobalt oxide in electric vehicle batteries, owing to their higher energy density and lower cost and toxicity due to the reduced cobalt content. Yet, the synthesis of these materials is commonly achieved via a solid-state route which generally involves two high-temperature (~1000°C) calcination steps of about 15 hours each.

Microwave (MW) synthesis is an emerging technique to replace the conventional solid-state route. What makes MW optimal is its homogeneous heating ability, compared to the conventional surface-to-core heating. This significantly decreases the time it takes for synthesis from 30 hours to 15 minutes. This also reduces energy consumption from 6 kW/h to 0.25 kW/h. These different heating processes are expected to result in different microstructures and therefore properties of the battery materials of interest to this project.

OBJECTIVE

The objective of this research study was to determine whether differences in synthesis methods (solid-state vs. microwave) will have an effect on NMC-type cathode in rechargeable batteries. The purpose of this is to identify cheaper ways of synthesizing the active electrode material, which makes up ~70 wt.% of the electrode.

MATERIALS AND METHODS

1. Masses of Li₂CO₃, MnO₂, Ni acetate, and Co oxalate were weighed.
2. The reagents were ground in mortar and pestle for 20 minutes.
3. The compound was pressed into a 6mm pellet with 1.2 tons of pressure.
4. The compound was placed heated in a microwave for 10-20 minutes.
5. The material was ground with carbon and binder inside and Argon glove box to create a cathode.
6. A coin cell battery was assembled using the cathode made.
7. The active battery cell was connected to a potentiostat to be cycled at a range of 1 V to 4.2 V for two weeks.
8. The X-ray Diffraction and cycling data of solid-state and microwave methods were compared.

CHARACTERIZATION TECHNIQUES

- X-Ray Diffraction (XRD)
  - Gives information on structure and composition of the material
- Atomic Emission Spectroscopy (ICP-AES)
  - Quantifies material composition more precisely
- Nuclear Magnetic Resonance (NMR)
  - Shows accurate material structure
- Battery Cycler
  - Determines electrochemical properties of material

KEY COMPONENTS

CONCLUSION

From the preliminary XRD data, it can be concluded that microwave synthesis can yield the same product as solid-state synthesis. If battery performance also deliver similar results, a significant amount of energy and time can be saved in the synthesis of battery cathodes for electric vehicles, and possibly beyond, using microwave techniques.

FUTURE WORK

To attain a more extensive understanding of the differences between solid-state and microwave synthesis and their effects on cathode-making, other characterization techniques must be conducted. As mentioned, ICP-AES and NMR will be the next steps. Furthermore, Scanning Electron Microscopy (SEM) must be used to test particle size.

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Figure 1: Test Model X

Figure 2: Schematic Cell Diagram Picture by Raphaële Clément

Figure 3: Surface to Core Homogeneous Heating

Figure 4: Tube Furnace

Figure 5: Microwave

Figure 6: Coin cell

Figure 7: Microscope

Figure 8: X-ray Diffraction Machine

Figure 9: Coin cell battery

Figure 10: Three coin cell batteries being cycled

Figure 11: X-ray Diffraction Results

Figure 12: Microwave Synthesis XRD Result

Figure 13: Tube Furnace

Figure 14: Atomic Emission Spectroscopy Machine

Figure 15: Nuclear Magnetic Resonance Spectroscopy Machine

Figure 16: X-ray Diffraction Results

Figure 17: X-ray Diffraction Results

Figure 18: X-ray Diffraction Results

Figure 19: X-ray Diffraction Results

Figure 20: X-ray Diffraction Results

Figure 21: X-ray Diffraction Results