Replacing the Carbon Felt Heating Material in Ultrafast High-Temperature Sintering

Dhiya Srikanth, Amir Arefpour, Dr. Liangbing Hu

MARYLAND ENERGY INNOVATION INSTITUTE

THE DEPARTMENT of MATERIALS SCIENCE AND ENGINEERING

Abstract

Ultrafast High-Temperature Sintering (UHS) is a process used to sinter green pellets at incredibly high speeds using electrodes and carbon felt. Due to some drawbacks of the carbon felt, the researchers investigated UHS with another material other than carbon felt. Research was done to find another material with a sufficiently high resistance and melting point that could be used. Tungsten wire was chosen and the testing process was started. As of now, testing has not been concluded, but plans are in place to continue testing with tungsten wire, and then compare those results to the current method of sintering as well as tests with other wires.

Background

Battery research helps the advancement of renewable energy by creating dependability in the electrical grid, filling the gaps caused by the variable output of solar and wind. Lithium-ion batteries are widely used because they are rechargeable and can store more energy within a given physical space relative to other batteries. The battery industry is moving towards solid-state batteries (SSBs) compared to the widely-used conventional battery because SSBs are safer, have a higher energy density and can have a longer cycle life. Sintering is integral to the process of using ceramics for the solid electrolytes in these batteries. Sintering is the process of using heat and pressure to densify loose material into a solid piece, increasing properties like thermal and electrical conductivity, material strength and integrity. The current process of ultrafast high-temperature sintering has a few drawbacks, so researchers are looking into other materials to replace the carbon felt. One of the main drawbacks is the residue that the carbon felt leaves on the sintered pellets.

Figure 1. Pellet sintered with carbon felt on top of unsintered pellet

This pellet that has been sintered is on top of one that has not been sintered. After sintering, the pellet is noticeably smaller, which shows how much it has densified. It is also much darker, which is the result of the diffusion from the carbon felt.

Current Process of Sintering

The first step of the process is measuring out each of the oxide powders needed for the pellet and ball-mill them for 12 hours to reduce their particle size.

→ Calcination is the next step in the process. The powder is put into an oven and heated slowly over several hours in order to remove all moisture.

→ A die mold is used to condense the powder into pellets that can be used for sintering. This process only compresses the pellets axially.

→ After the pellets are formed, they are isostatically pressed so they are densified from all sides. This further strengthens the pellets and keeps them from breaking while sintering.

→ The sintering process starts with placing the pellet between two pieces of carbon felt in a vacuum chamber. Voltage is applied for a few seconds in differing amounts. Pressure is then released in the chamber and the pellet is removed.

→ To check how well the sintering worked, the density of the pellets is tested. An SEM is also used on the sintered pellets to see how dense they are and see how well combined the different elements are.

Table 1. Resistivity and Melting Point of Possible Materials.

Material	Resistivity (Ωm)	Melting Point (°C)
Carbon	6.00×10^{-5}	3600
Tungsten	$\mathbf{5.60 \times 10^{-8}}$	**3422**
Titanium	4.20×10^{-7}	1670
Nickel	6.99×10^{-8}	1455
Stainless Steel	6.90×10^{-7}	1230-1530
Tantalum	1.25×10^{-7}	3017
Nichrome	1.04×10^{-6}	1400
Platinum	1.06×10^{-7}	1769
Constantan	4.90×10^{-7}	1210

Models of Sintering Pellets

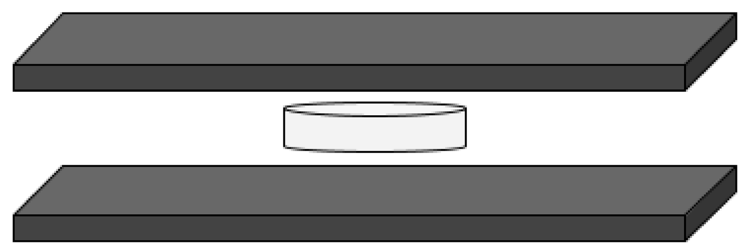

Figure 2. Current method of sintering with carbon felt

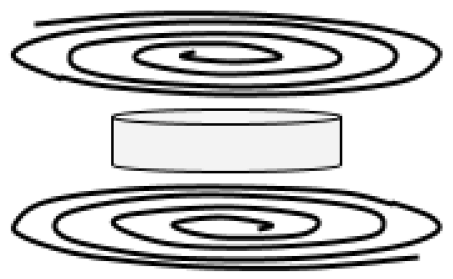

Figure 3. Possible method of sintering with wire

Tests Done on Tungsten Wire

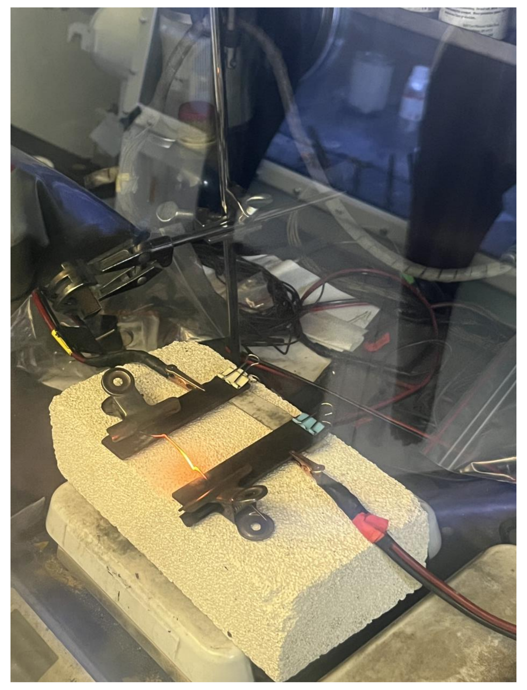

Figure 4. Test for tungsten wire in glove box

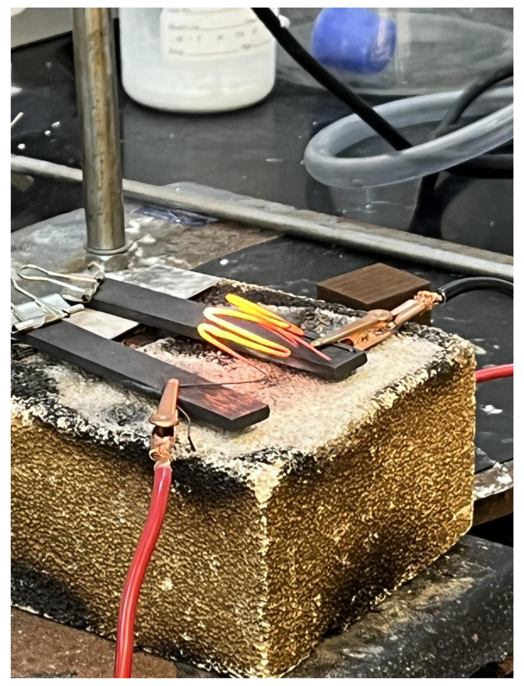

Figure 5. Test for tungsten wire in open air

Future Work

The experiments in this study have not yet been completed but in the future this project will continue. Firstly, the tests will be finished using the tungsten wire to see if it is feasible to use. If it is, it will be used to sinter pellets. If the process of sintering is successful with the tungsten wire, this process will be repeated with other types of wire like titanium or nickel. Then, the properties of the pellets sintered with each type of wire will be compared to each other and compared to those sintered with carbon felt. These tests will see which process densified the pellets the most and had the fewest drawbacks.

Acknowledgements

We would like to acknowledge the financial support of NSF Grant DMR2149982, REU/RET Site: Summer Research Experiences in Renewable and Sustainable Energy Technology (ReSET) and the Maryland Energy Innovation Institute (MEI2) and University of Maryland Department of Materials Science and Engineering. In addition, we would like to acknowledge the guidance and support of Shufeng Liu on this project.

References

Wang, C., Ping, W., Bai, Q., Cui, H., Hensleigh, R., Wang, R., Brozena, A. H., Xu, Z., Dai, J., Pei, Y., Zheng, C., Pastel, G., Gao, J., Wang, X., Wang, H., Zhao, J.-C., Yang, B., Zheng, X. (Rayne), Luo, J., … Hu, L. (2020). A general method to synthesize and sinter bulk ceramics in seconds. Science, 368(6490), 521–526. https://doi.org/10.1126/science.aaz7681

Zhang, Z., Shao, Y., Lotsch, B., Hu, Y.-S., Li, H., Janek, J., Nazar, L. F., Nan, C.-W., Maier, J., Armand, M., & Chen, L. (2018). New Horizons for Inorganic Solid State Ion Conductors. *Energy & Environmental Science*, *11*(8), 1945–1976. https://doi.org/10.1039/c8ee01053f

Janek, J., & Zeier, W. G. (2016). A solid future for battery development. *Nature Energy*, *1*(9). https://doi.org/10.1038/nenergy.2016.141