Nanoporous Metals for Onboard Hydrogen Generation and Li-Ion Battery Applications

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Introduction

My time in the 3DAFSN lab has been spent working on two projects with the aim of contributing to the effort on energy research.

- *Onboard* generation of hydrogen from **bulk nanoporous aluminum** that can be used to feed **hydrogen fuel cells** and power cars.
- Study of the **volume expansions** in Li-ion battery anodes using **nanoporous silver** (NP-Ag) as a model anode material. The primary research goal is to use transmission electron microscopy (TEM) to image the pore expansion in NP-Ag anodes in real-time during charging and discharging.

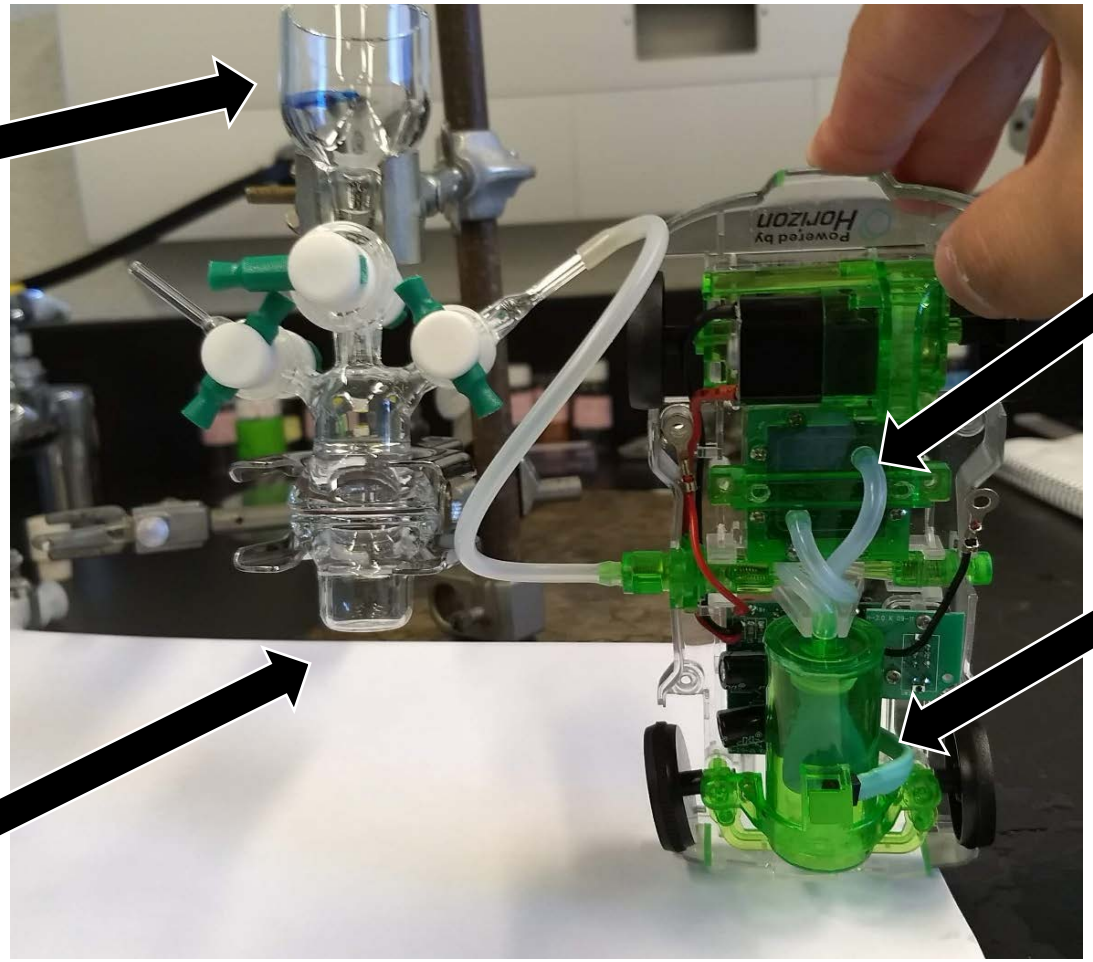
Onboard generation of hydrogen

Step 1: Hydrogen from Aluminum and Water

Reaction: $2Al(s) + 6H_2O(l) \rightarrow 2Al(OH)_3(s) + 3H_2(g)$

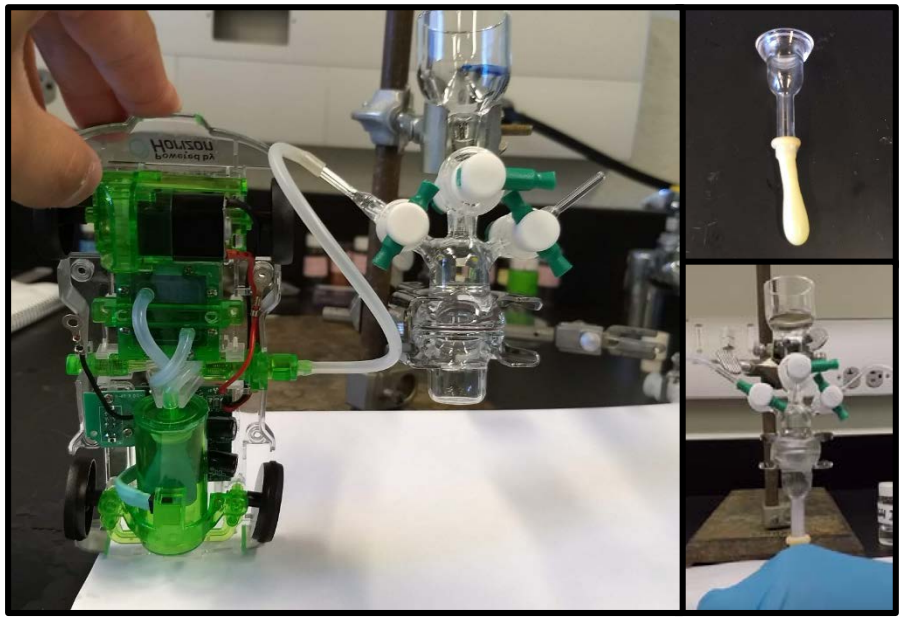
Step 2: Creating a Airtight Reaction Vessel

Initial Attempt for Reaction Vessel



Want “Onboard Hydrogen Generation” instead

- After various attempts, we ended up using a vial wrapped in Teflon tape, Parafilm, and electrical tape.



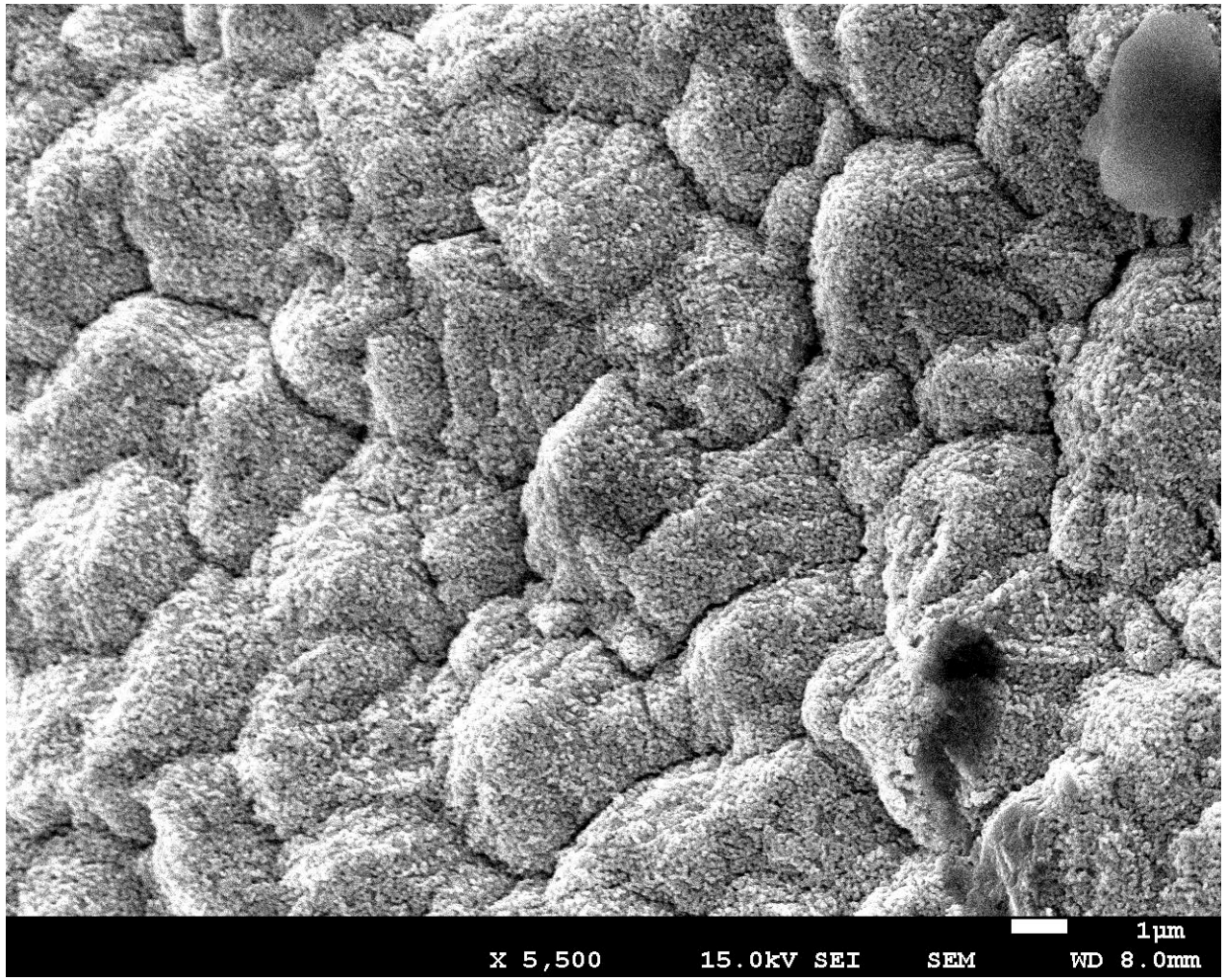
Video of Hydrogen Powered Toy Car

Further Steps

Hydrogen Generation Project

Make a system that retains pressure and can run without the addition of the argon balloon

Development of Nanoporous Silver



Preliminary signs for Nanoporosity

Al and Ag are deposited in layers and annealed to make an Al-Ag alloy.

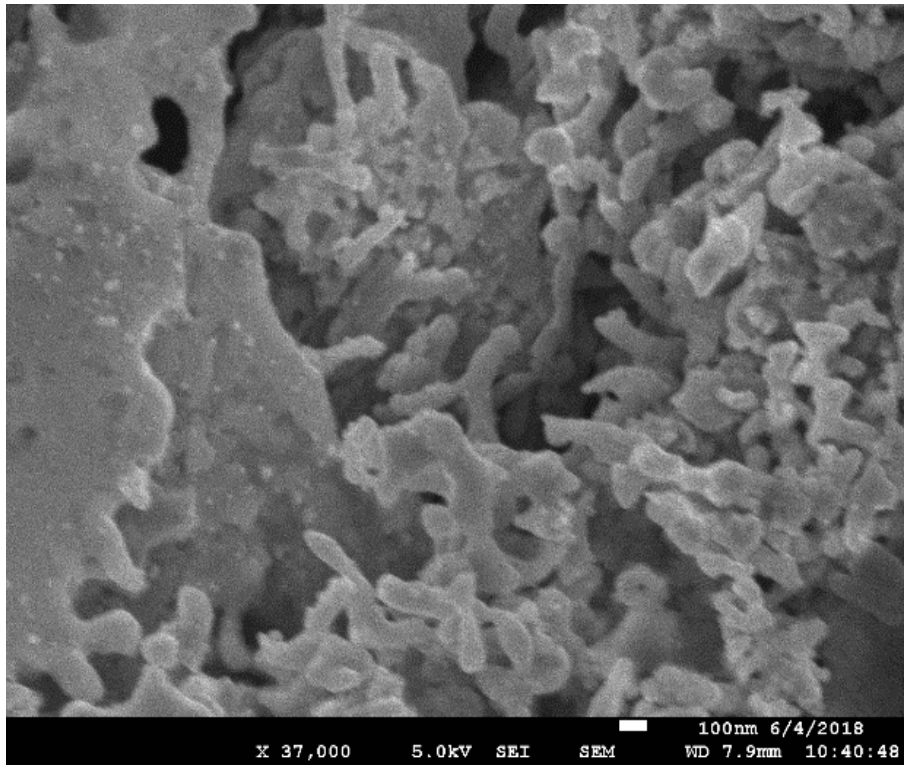
This is dealloyed in 0.1 M HCl to remove aluminum from the alloy, and leave only silver, with **structural nanopores**, where the aluminum was.

To tell if sample is nanoporous, we look for these signs:

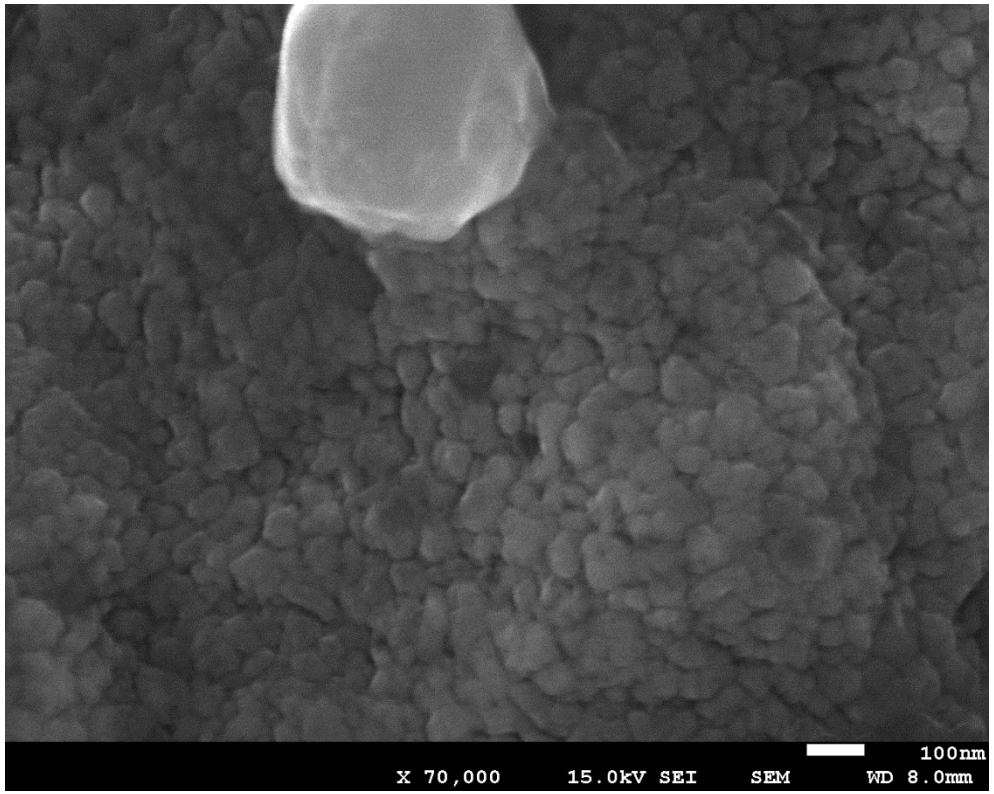
- EDXS ratio of **85:15 Al:Ag**
- **Bubbles** during dealloying (when submerged in HCl)
- Turns **black** when dealloying

		Before Dealloying		After Dealloying	
Copper Foil Thickness	Magnification	Al	Ag	Al	Ag
A: 100 nm	no zoom	94.83	5.17	69.3	30.75
	zoom	n/a	n/a	64.2	35.82
B: 190 nm	55x	98.41	1.59	17.5	82.52
	1000x	n/a	n/a	46.4	53.64
	1000x	n/a	n/a	47.5	52.48
C: 250 nm	55x	44.62	55.38	32.4	67.56
	1000x	48.1	51.9	33.1	66.88
	1000x	45.98	54.02	30.9	69.06
D: 250 nm	55x	**65.86**	**34.14**	-4.46	104.46
	1000x	**75.71**	**24.29**	8.81	91.19
	1000x	**64.98**	**35.02**	74.5	25.51
Glass	55x	n/a	n/a	n/a	n/a
	1000x	43.04	56.96	n/a	n/a
	1000x	42.68	57.32	n/a	n/a

SEM Testing on the Annealed Samples



What we WANT, but didn't SEE



What we do SEE

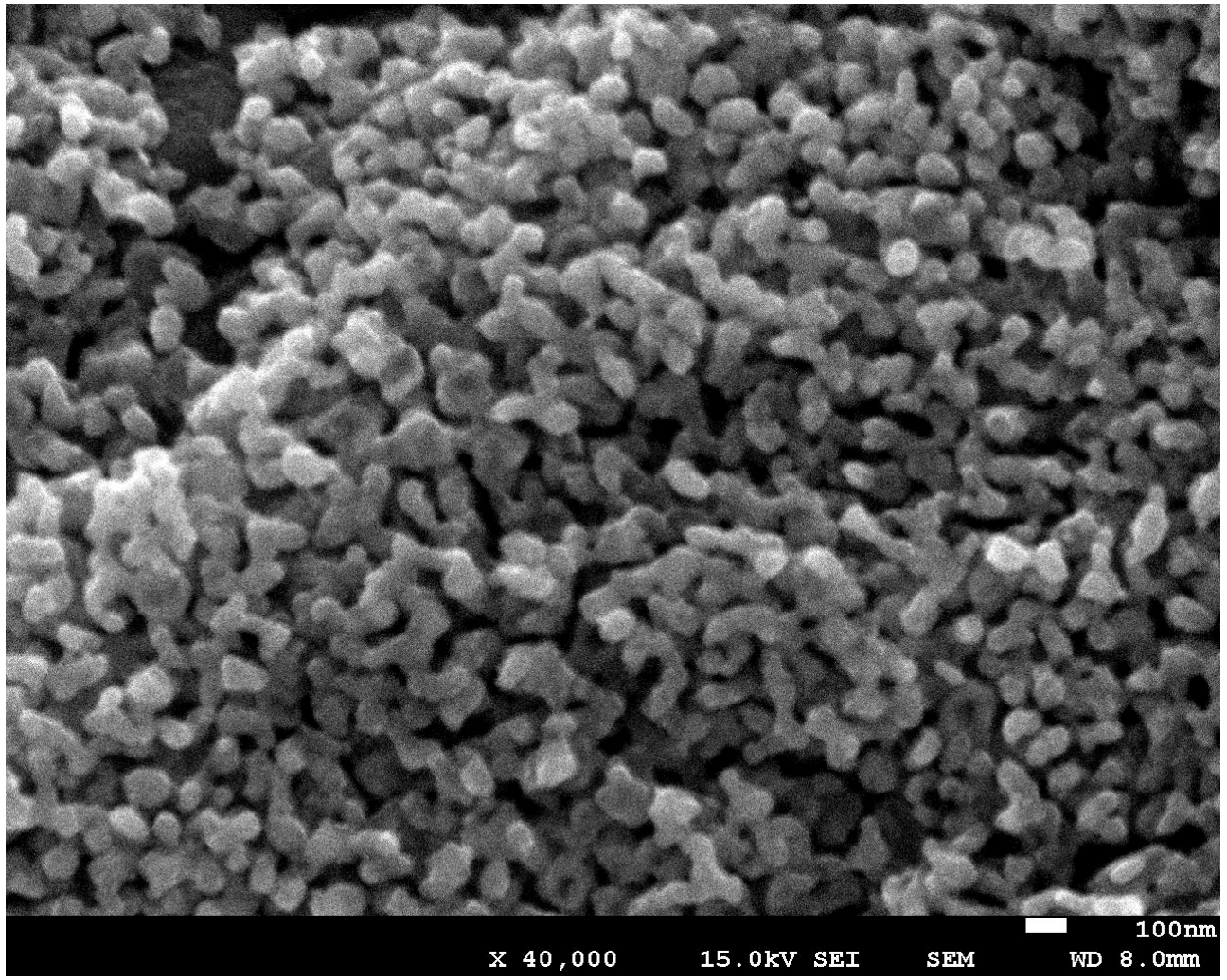
Annealing was the Problem

High heat of annealing (550˚C) makes copper complexes

- Prevents the dealloying form occurring – NO NANOPOROUS STRUCTURES
- So we tried dealloying WITHOUT annealing

Promising Results

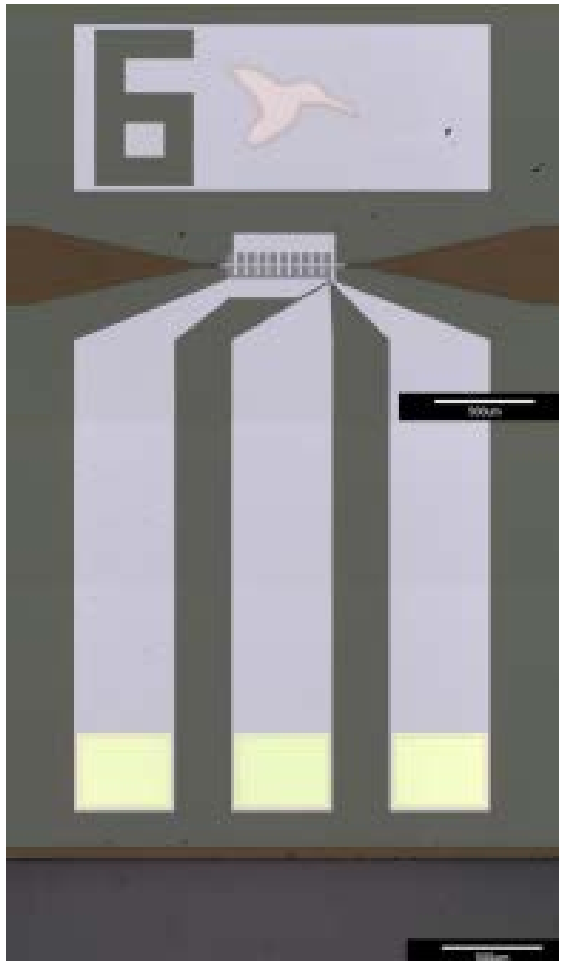
Type of Sample	Al	Ag
Dealloy GLASS	4.65	95.35
Dealloy Cu FOIL	18.20	81.80
No Dealloy Foil	76.28	23.72



Further Steps

NP-Ag Project

- These new NP-Ag samples will be tested in battery cells to collect the potentiometric data.
- Focused Ion Beam (FIB) will be used to transfer battery components to a microchip.
- The microchip battery will be imaged under TEM to observe the pore expansion



Special thanks to…

John Corsi

Timothy Lee

Sam Welborn

Dr. Eric Detsi

NSF PIRE #1545884