



The Study of Large Scale Printing Electrode Material VO_x on Substrates for Energy Storage

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Abstract

This research sets out to develop a methodology of scaling up a electrode printing process using V₂O₅, and therefore, developing an pouch cell battery with a large loading of active material. We were able to synthesis vanadium oxides with a rod like morphology. Successful printing was achieved using a commercial V₂O₅ on multiple substrates. Printing the synthesized VO_x was more complicated and needs further study on adhesion of materials on substrates. Next steps have been identified to increase the success of future research.

Background

Energy consumption and production is shifting away from fossil fuels towards renewable energy source. This shift has positive consequences for the environment and humanity. However, renewable energy resources are dependent on time, weather, season, and location which often makes them intermittently available in contrast to energy consumption that is relatively constant (3). This dynamic presents an opportunity to improve how renewable energy is utilized. Therefore, energy storage technology such as batteries is needed and promising opportunities exist.

Batteries are currently an effective energy storage and conversion mechanisms

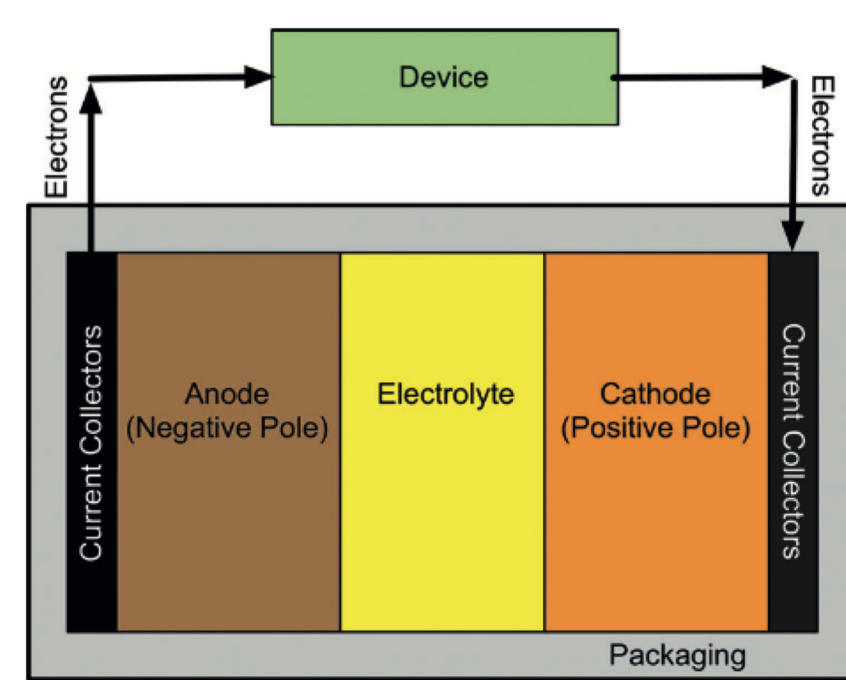
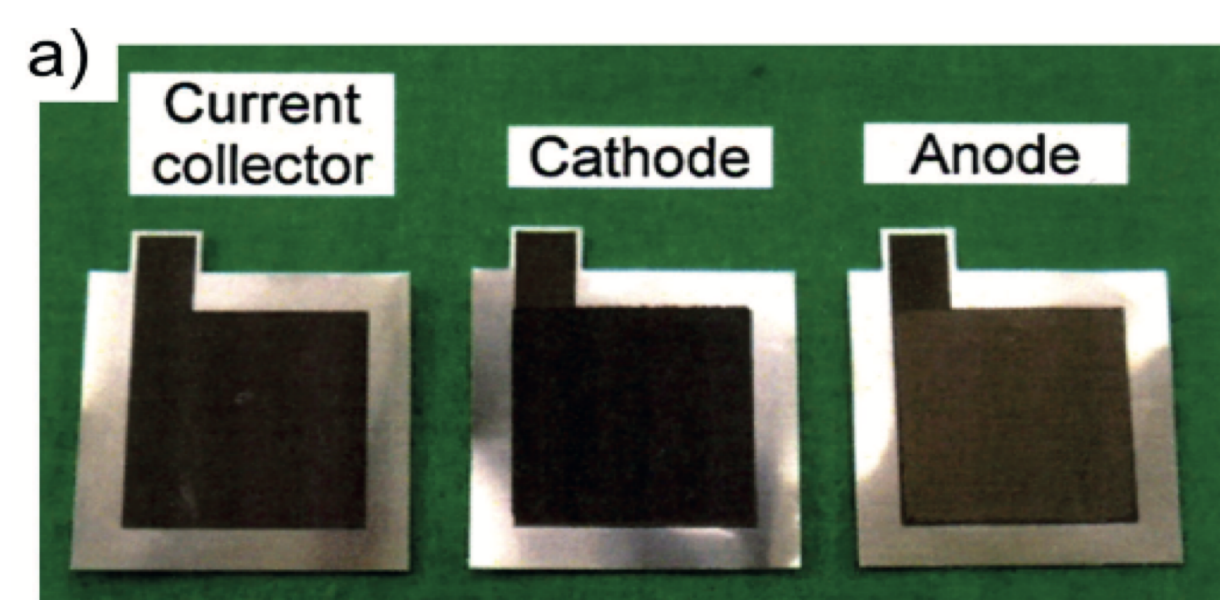
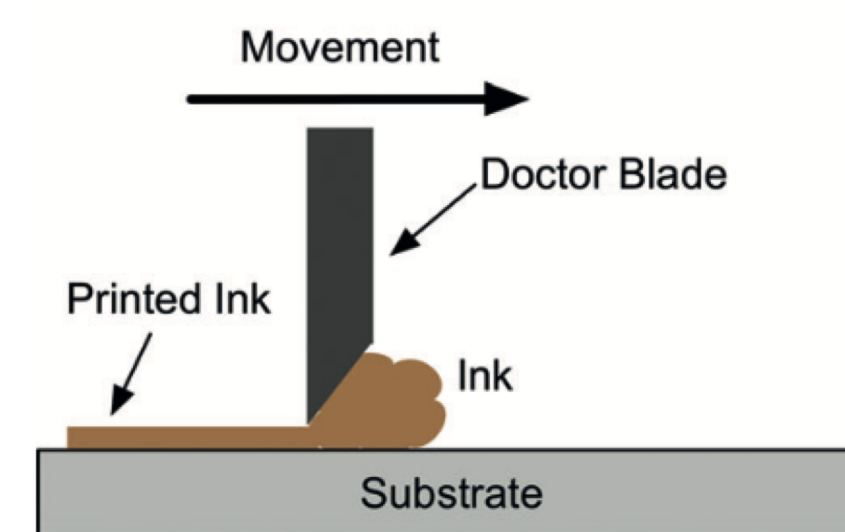


Diagram of cell components for battery device (4).

When discharging, electrons flow from the anode to the cathode through an external load and cations (e.g. Li- and Na-ions) flow from anode to cathode with an opposite in internal battery. When the battery is recharged, the energy source and the flow of electrons and cations are reversed.

Blade coating is a commonly used printing technique for depositing battery slurries in large-scale manufacturing. The technique uses a blade to spread slurry, and the vertical distance separating the blade and the substrate controls the thickness of the wet ink (4).



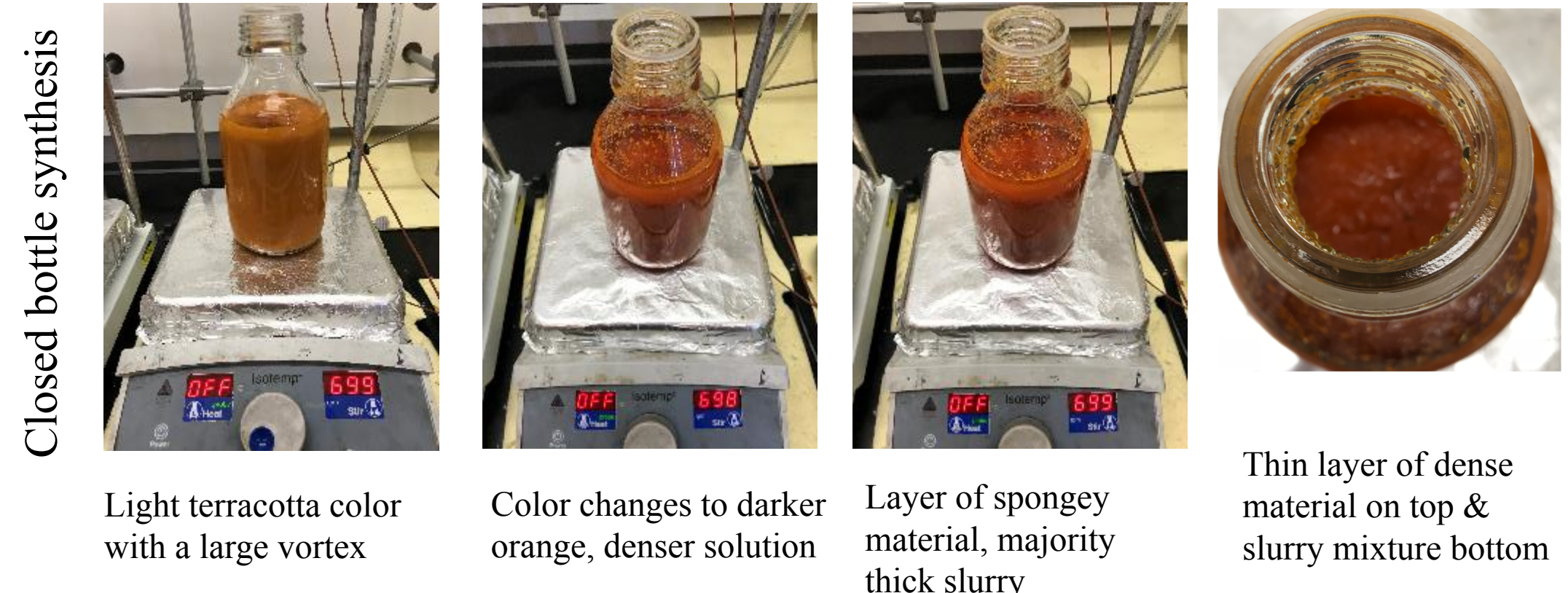
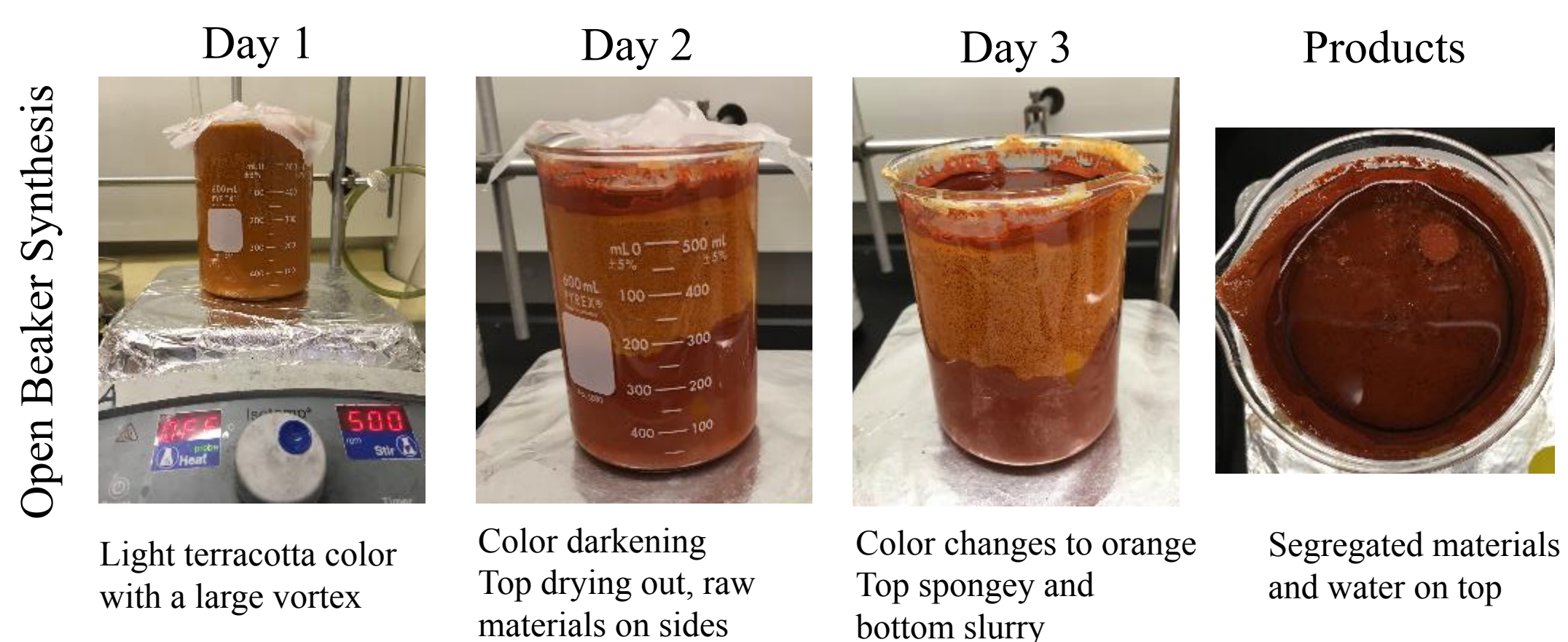
a) Photograph of the current collector (left), positive (middle), and negative (right) electrode screen printed on an Al-laminated pouch. b) Photograph of the li-ion battery formed by screen printing the anode, cathode, and gel electrolyte on evaporated current collectors (4).

Synthesis/Characterizations of VO_x

VO_x Nanaobelt Synthesis

Produced by stirring commercial V₂O₅ in NaCl (2.0 M) aqueous solution

	Batch 1 (open beaker)	Batch 2 (open beaker)	Batch 3 (closed bottle)	Batch 4 (closed bottle)
Amount of materials	500 mL of NaCl and 33.3 g V ₂ O ₅	600 mL of NaCl and 40 g V ₂ O ₅	300 mL of NaCl and 20 g V ₂ O ₅	400 mL of NaCl and 26.67 g V ₂ O ₅
Isotemp™ Stirring speed	1000 rpm	500 rpm	700 rpm	700 rpm
Stirring entire time	No – stopped Day 2	No – sporadic Day 3	Yes – at bottom	Yes – at bottom
Amount of Final Product	32.81 g	34.95 g	24.1g	23.6g

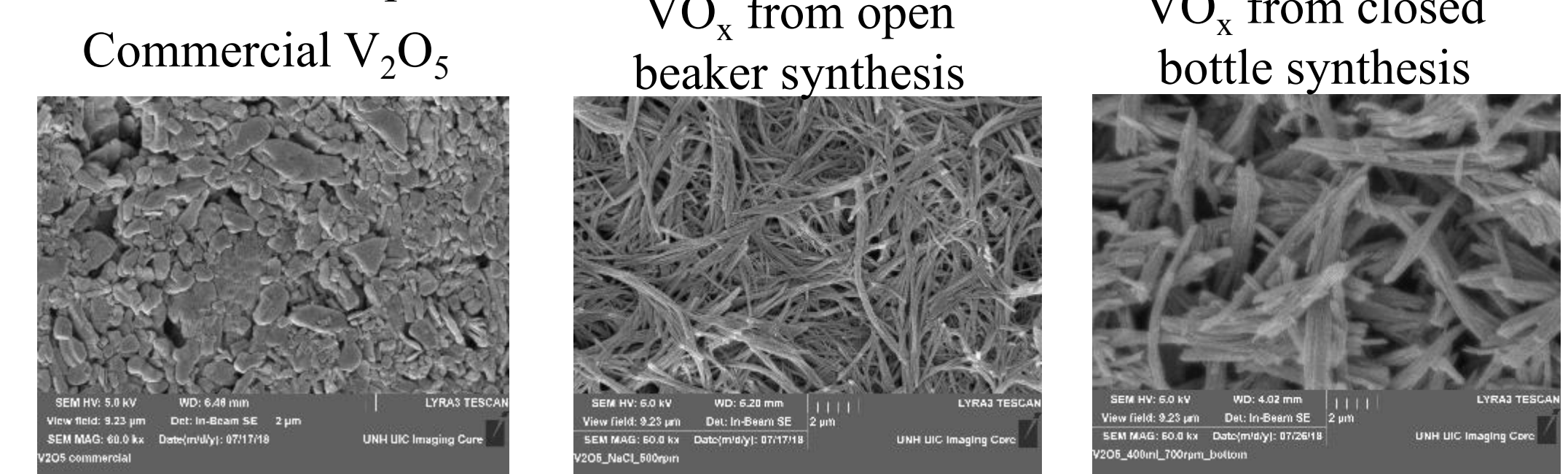


- Obtained products first washed 3x with De-Ionized (DI) H₂O and 1x with ethanol.
- Material dried for 3 days initially at 80° C for 12 hours in oven then under the fume hood.
- Grinded dried solids into VO_x powder.



Scanning Electron Microscope (SEM) Characterizations

- Commercial V₂O₅ materials has non-uniform flat pebbles.
- Synthesized VO_x materials has visible micro-sized rods morphology.
- VO_x sample obtained from open beaker synthesis revealed well-dispersive rods with a smaller sized pieces.



Printing Experiments and Results

Materials for Water-based Electrode Slurry

Active Powders	94.5%	1. Synthesized VO _x 2. Commercial V ₂ O ₅ 3. Commercial Mn ₃ O ₄
Binders	2.25%	Sodium carboxymethylcellulose (CMC)
	2.25%	Styrene-butadiene copolymer (SBR)
Additive	1%	Carbon Black (increase conductivity); Super P (future test)
DI H ₂ O	120% - 131%	The amount added depends on the material property and binder amount

SFM-7 Vacuum Mixer



MSK-AFA-III Automatic Thick Film Coater



Substrates used for printing

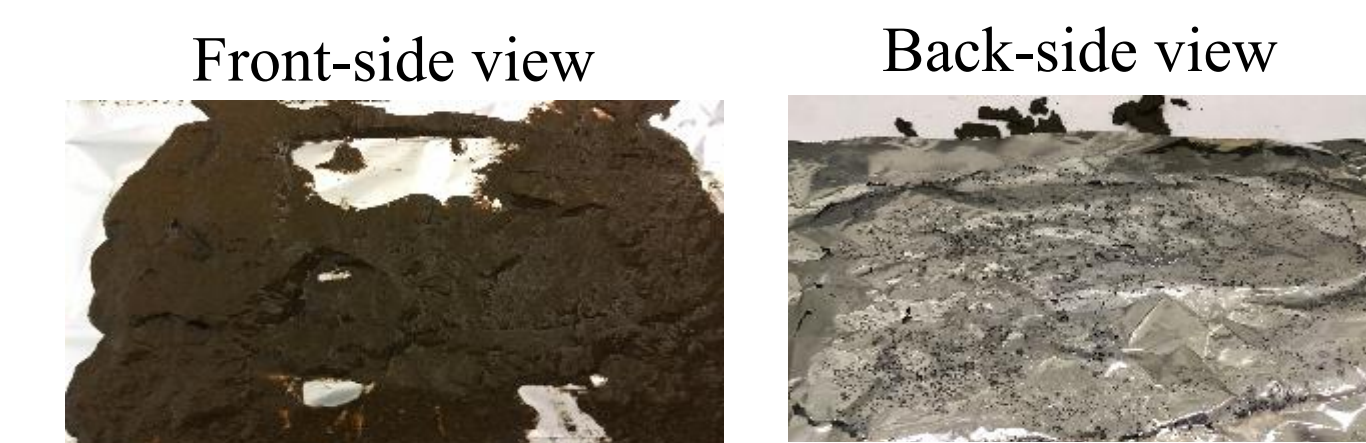
Aluminum (Al) foil, Carbon paper (5%, 20%, 40% Teflon)

Slurry Preparation & Electrode Printing

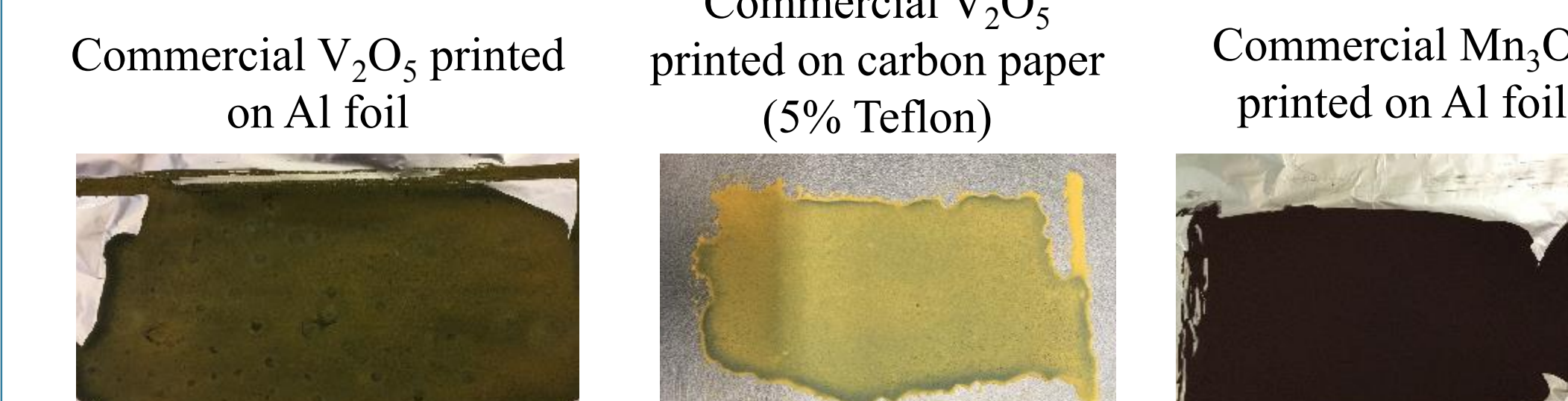
- Materials prepared based on percentage of total as listed in table above.
- Grind active powder and carbon black using mortar.
- Dissolving CMC into water (80° C) and stirring > 60 minutes
- Adding SBR and stir for another 60 minutes.
- Add grinded powder into solution 2 or 3 times every 30 minutes, mixing, vibration, degassing using SFM-7 Vacuum Mixer.
- Printing slurry on Al foil and carbon paper with controlled thickness (0.5 mm, 1 mm) with speed of 7 mm/sec using the MSK Film Coater.

Results

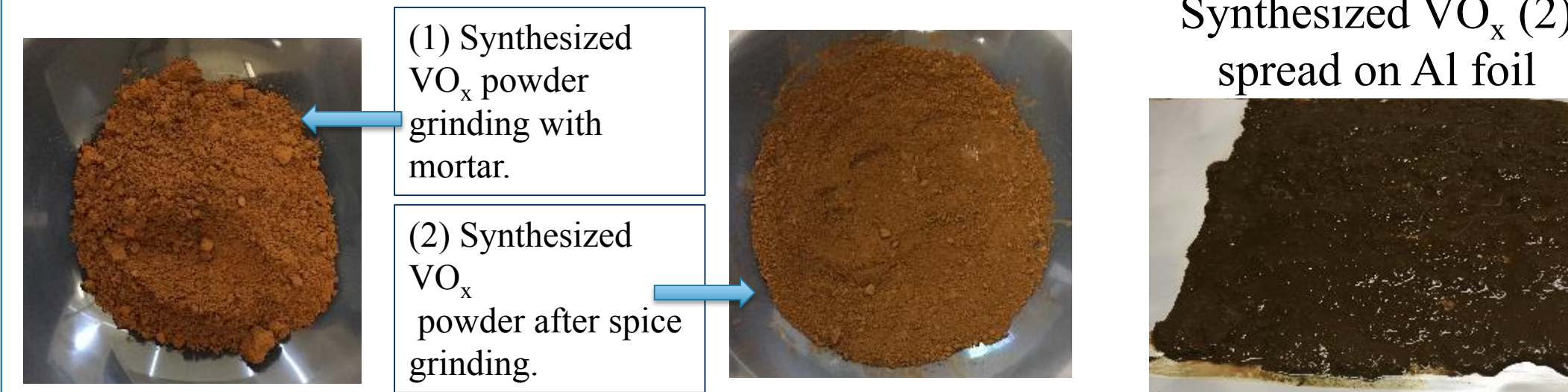
Initial printing of synthesized VO_x on Al foil



- The synthesized VO_x slurry did not print uniformly possibly due to the large particle size of active powder. Corrosion of Al foil was also observed.



- Commercial V₂O₅ (finer powder compared to synthesized VO_x) printed uniformly on Al, yet corrosion occurred on back side.
- No corrosion observed when printed commercial V₂O₅ on carbon paper but less adhesion compared to Al foil sample.
- Commercial Mn₃O₄ printed on carbon paper and Al foil without corrosion.



- The finer powder was better incorporated in slurry solution, yet still had an unsuccessful printing, no adhesion, further printing trials needed with increased amount of binder, less active powder and DI H₂O.

Conclusions

The ability to scale-up electrode printing is important to the future of energy storage devices. This project investigated the potential of VO_x to be used as battery materials with large-scale electrode printing for pouch cells.

1. Synthesized VO_x was obtained by stirring commercial V₂O₅ in NaCl solution.
2. SEM characterization revealed a rod morphology that we were looking for.
3. A printing recipe with procedures was applied to printing electrode materials (synthesize VO_x, V₂O₅, Mn₃O₄) on Al foil and carbon paper substrates.
4. VO_x when finely ground improved the quality of slurry for printing, but the printing not equal to commercial V₂O₅ and Mn₃O₄.
5. It is recommended to print VO_x on carbon paper to prevent reactions with Al foil.

Discussions and Future Work

1. It is necessary to improve the synthesis of VO_x access with different machinery reactor and drying container to scale up production.
2. The amounts of binder need to be fine-tuned as well as water amounts to improve VO_x slurry adherence to substrate.
3. Test the viscosity of the slurry prior to printing so that slurry is in the range of 5000 – 6000 CPS.
4. Modify the printing with substrate of carbon coated Al foil to prevent corrosion.
5. To improve film quality, a defined thickness of film should be established.
6. Assemble the pouch cell with printed electrodes, and tested using battery instrument in future.

Translating to the High School Classroom

Lesson – Scaling-up or scaling-down

- Student will use a predefined lab experiment and be required to scale up or down a randomized percentage for materials and test again original.

Lesson – Understanding Viscosity

- Student will design and perform an experiment about viscosity and explain results through a CER (Claim, Evidence, Reasoning) document.

Lesson – Energy Storage

- Student will research two different energy storage options to compare and contrast the potentials and limitations of the devices.

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