The Challenges of Battery Scale-Up

Project: Battery Scale Up Facility for Capability Demonstration and Prototyping

Hamza Al-Aqqad

Supervisors: Professor John Irvine, Dr Jiyu Tian, Cameron Bathgate, Debbie Redpath

What is Battery Scale-up?

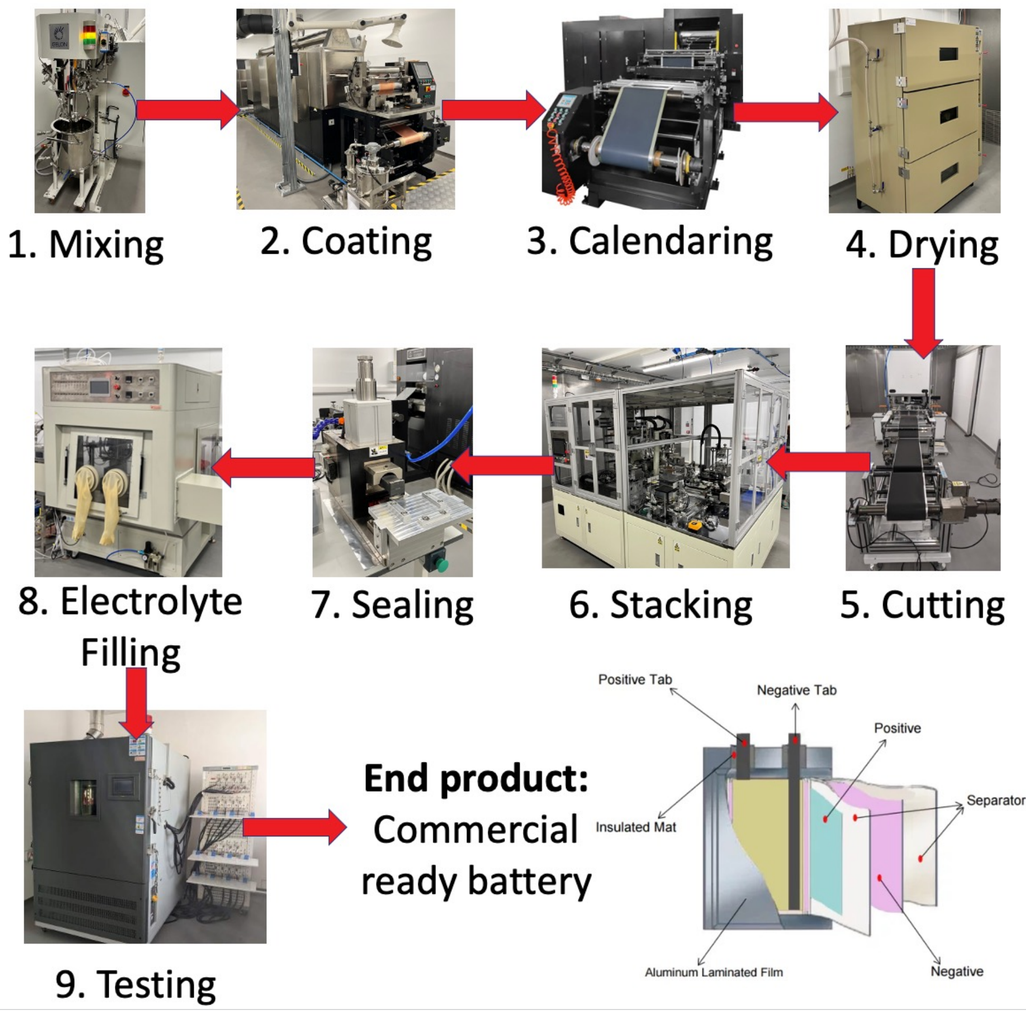
You may think battery making is a simple process at first sight; two electrodes with different potentials use an electrolyte to transfer electricity. Practically; however, battery production is extremely sensitive to material choice, temperature, electrode thickness, mixing method, and many more variables.

Thus, there is an inherent challenge in researching new electrode materials, and then being able to replicate performance on the larger scale. **Battery scale up is the process of going from testing potential electrode materials in small "coin cells", to having large scale batteries with predictable behaviour.**

Research is performed on these small button "half" cells with the end goal of producing a suitable pouch, cylindrical or prismatic cell.

Large-Scale Assembly Line

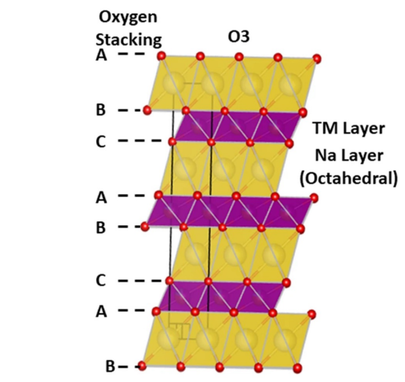
Once a material has been proven to have satisfactory performance and life, it can move into larger scale production. The electrode slurry that previously was manufactured in milliliters is now scaled up to liters, **a 3 order of magnitude increase!** This gives an idea of how much added complexity there is at large scale production. The images below are from the university of St Andrews' scale up facility at the Eden campus.



Small-Scale Battery Making Process

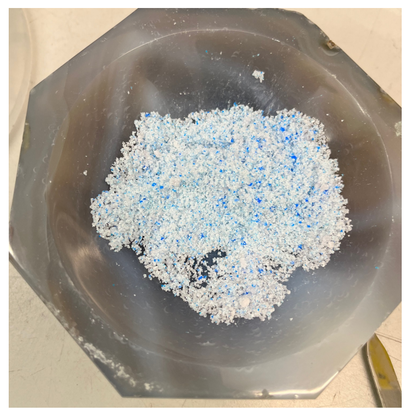
1. Material Selection:

- Choose a suitable cathode or anode material.
- This is based on electrochemistry and materials science.
- This project researched sodium oxides that form biphasic P2/O3 structures when used as a cathode.



2. Electrode Synthesis:

- Two methods: Sol-Gel or Solid State.
- Synthesis is highly sensitive to variables such as temperature and particle size.
- X-Ray diffraction tests are performed to see if the predicted structures were formed.
- This is $Na_{0.77}Mn_{0.4}Fe_{0.4}Cu_{0.1}Ti_{0.1}O_2$.

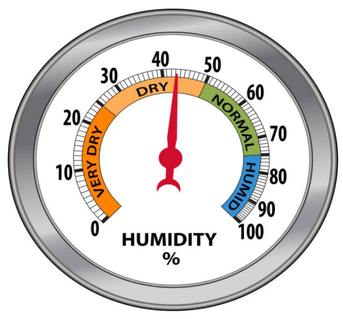


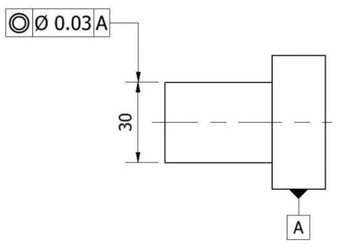
3. Make & Test the cell:

- Must be done in a glove box as electrode materials react with water. **That's me in there!**
- Electrode is made into a slurry and coated onto aluminium or copper.
- The cell is filled with electrolyte.
- The cell undergoes formation and aging cycles that characterise performance and life.

Engineering Challenges of Large-Scale Production

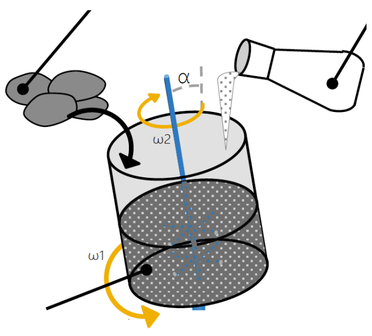
- **Dry Room:** Battery electrodes, particularly sodium-based cathodes, are highly sensitive to moisture. Thus, a large portion of the process is done in a "dry lab", where the relative humidity is under 1%!





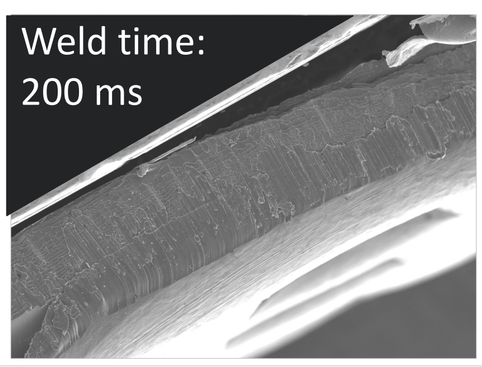
- **Machine Tolerances:** large scale production is a "reel-to-reel" process, meaning lots of rollers are used. Thus, concentricity tolerance should be minimized, and the surface should be machined to a low roughness to maintain homogeneity in the coat.

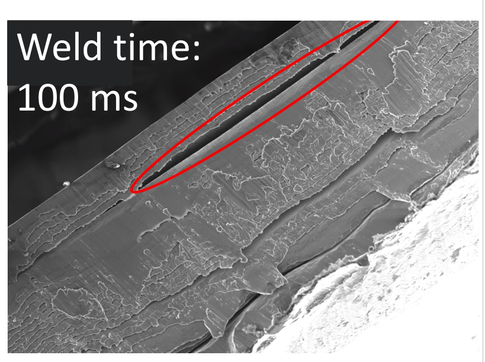
- **Mixing Method:** Planetary mixing, or spiral mixing? – that is the question. Different mixing methods will result in differing viscosities for the same slurry. This will affect the coating process and hence performance through volumetric efficiency and solid content.



Interesting Result from Welding Test

- Ultrasonic welding is used to weld the large scale battery current collector foils to tabs. This is the main point of connection between the battery and whatever is being powered.
- Scanning Electron Microscopy (SEM) was used to characterise the efficacy of the welds.
- The left image shows a "good" weld with no gaps between the 27 foils. The right image has a large gap that increases resistance.





References

- Maughan, P.A., Naden, A.B., Irvine, J.T.S. *et al.* Manipulating O3/P2 phase ratio in bi-phasic sodium layered oxides via ionic radius control. *Commun Mater* **4**, 6 (2023). https://doi.org/10.1038/s43246-023-00337-8
- Heimes, H.H. and Michaelis, S, et al. (2018) *Lithium-ion battery cell production process - RWTH Aachen University*, *LITHIUM-ION BATTERY CELL PRODUCTION PROCESS*.
- Images from:
- Zschornak M, Meutzner F, Lück J, Latz A, Leisegang T, Hanzig J, et al. Fundamental principles of battery design. *Physical Sciences Reviews.* 2018; 3 111. 10.1515/psr-2017-0111
- https://www.intertek.com/blog/2016-04-12-batteries/
- https://www.dnkpower.com/cylindrical-vs-prismatic-vs-pouch-lithium-ion-batteries/
- https://fractory.com/concentricity-gdt-explained/

Intern bio

Hamza Al-Aqqad is studying Mechanical Engineering at Imperial College London. He is interested in working in the battery industry. He believes it his responsibility as an engineer to provide society with sustainable energy solutions.

Hamza is interested in large scale battery manufacture projects, as well as battery pack design and thermal management. Aside from engineering, he enjoys photography & football.

Click the icon for Hamza's LinkedIn!

THE FARADAY INSTITUTION NEXGENNA
NEXT GENERATION SODIUM-ION BATTERIES

University of St Andrews

UK Research and Innovation