HIGREEW

Workshop -Flow batteries, bringing the technology to the market

Vitoria-Gasteiz

Printed seals in redox flow batteries

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C-Tech Innovation Ltd

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Introduction

- C-Tech & Redox Flow Batteries
- Why printed seals?
- What I mean and don’t mean by ‘printing’ seals
- Application technology
- RFB seal comments
- Frame / o’ring seals
- Bipolar plate seals
- Summary

C-Tech Innovation Ltd

- Independant Technology Development Company located near Chester in NW England.
- Origins were a UK R&D Centre for the Electricity Industry. C-Tech has about 20 staff, mostly engineers & scientists.
- Key Technology Areas:
  - Electrochemical Engineering
  - Process Heat (Microwave, RF, Ohmic, Induction)
  - Nuclear Decontamination
- C-Tech produce bespoke and standard products from laboratory scale to turn-key production plants.
- The company has design capability (mechanical, electrical, chemical), modelling, laboratories, pilot areas, workshops and analytical equipment.

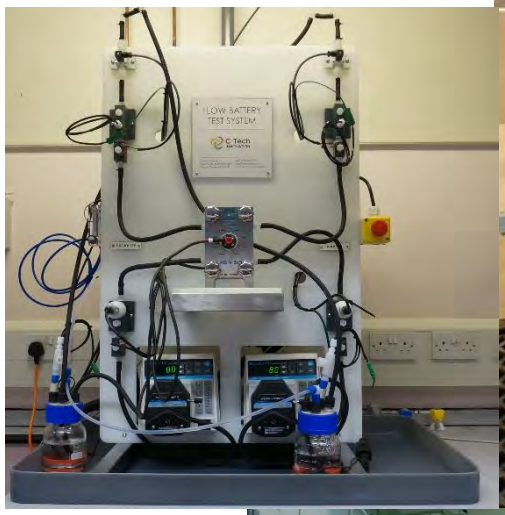
Electrochemical Technology at C-Tech

Selected Electrochemical Experience Highlights

- Electro-synthesis – organic and inorganic
- Recycling & hydrometallurgy
- Ionic liquids including aluminium electroplating systems
- Decontamination of nuclear infrastructure and waste minimisation.

Flow Battery Experience (consultancy & projects)

- Design & build of cell / stack / balance of plant / control
- Tests systems, process development, validation and Due Diligence.
- Soluble Lead (Innovate UK with Pletcher/Walsh/Wills)
- Vanadium (Contract & own funded)
- Zinc Air (FP7 Powair), Zinc Nickel and Zinc Cerium (Plurion)



Vanadium Electrolyte Manufacture

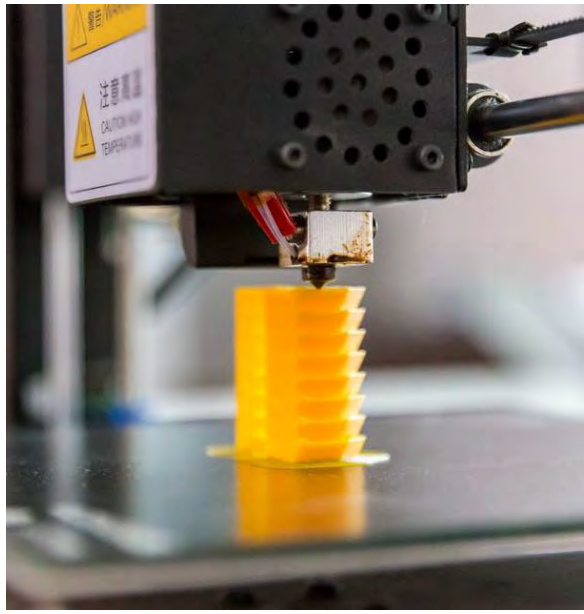
- C-Tech have a developed an electrochemical process to produce electrolyte for vanadium redox flow batteries requiring just vanadium oxides, sulfuric acid and electrons with no requirement for additional chemicals reagents.
- The process offers very high electrolyte purity and low production costs.
- C-Tech are supplying plant / process design services and the turn-key electrochemical systems including control.
- We have supplied vanadium electrolyte production systems to multiple large-scale manufacturers around the world **ranging from 1,000,000 litres to 8,000,000 litres per annum** with several additional installations currently in development**.**

Why look at printed seals?

- We were designing a stack for the organic HIGREEW chemistry and wished to retain as much design flexibility as possible to look at optimising performance.
- COVID made the timescales and cost of tooling design / manufacture / modification / seal production difficult to manage within the project timescales.
- HIGREEW chemistry is near neutral pH and not very aggressive.
- Looked an interesting approach with some major possible major advantages plus we could re-design with gaskets / o'rings if it didn't work well.

What am I not talking about?

- Using a 3D printer (FDM, selective sintering, resin lithography, extrusion etc) to make the stack frames or seals.
- Why I did not use a 3D printer:
  - Designed to produce whole components by sequential deposition of many thin layers (say 0.1 mm) from the top or bottom across a whole flat plane.
  - Print heads generally are not designed for printing into cavities or at different heights on an existing part.
  - Deposition speed is often quite low particularly for liquid tight parts.
  - Some elastomer like materials are available but developed for mechanical properties rather than chemical resistance and are still rapidly evolving (changing).
  - Often need to heat the print bed or area which can cause distortion to lower melting point substrates e.g. PVC.
  - Didn’t want a technology development project to produce custom software / hardware / materials suitable for my needs.
- 3D printing is rapidly developing area and will overcome many of these limitations.



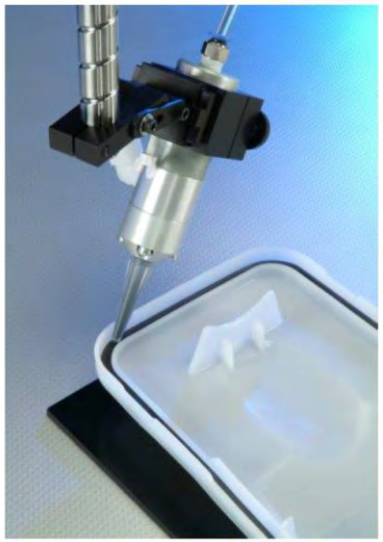
What I mean by printing seals

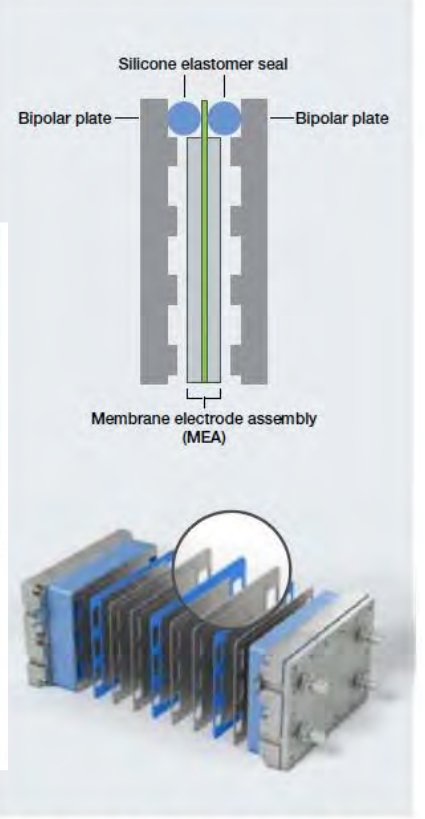
- CNC dispensing of liquid like elastomer / adhesive materials to quickly form seals in place in ideally one pass.
- Deposition of seals onto existing flow battery components (cell frames, membrane assemblies and bipolar plates) produced by traditional manufacturing processes such as machining or injection moulding.
- Works from CAD files to give flexibility in development / production with no tooling costs or delays. On demand production.
- Seal material adhered in place with no further assembly required.
- Support of printing at multiple heights (and angles).
- Industrially robust and interconnected CNC robots (up to 5 axis) with support. Readily integrated into production lines.
- Materials available from industrial suppliers providing consistency, QA and support.

System
Robot – FISNAR F4403N Advance 3 Axis 400 x 400 mm deposition area
Dispenser - Preeflow ecoPEN600 extruder, Preeflow ecoController EC200-2.0 with a 16 gauge nozzle
Sealant- Wacker Elastosil N2189 (Neutral alkoxy silicone air cured)

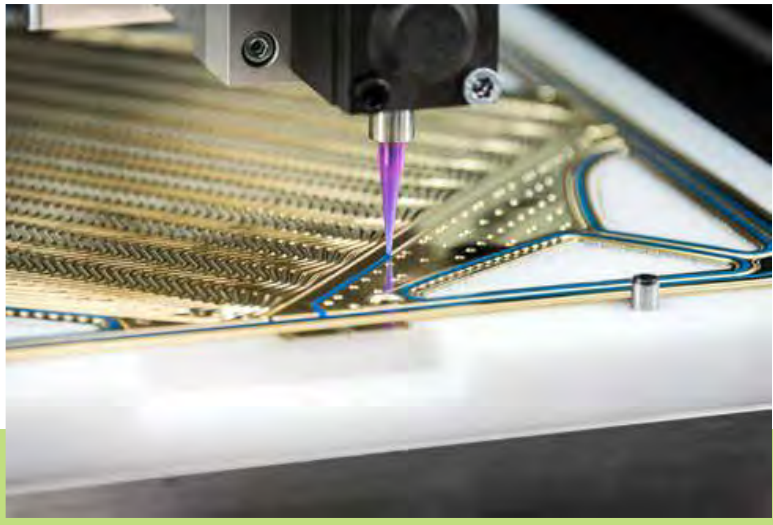
CNC Dispensing Technology

- Dispensing of a viscous liquid or slurry through a nozzle following a path defined by a robot.
- Deposited materials used for seals and adhesive binds including thermal / electrically conductive.
- Chemical compatibility testing essential. HIGREEW chemistry is not very aggressive. Little sign of degradation in V3.5 vanadium electrolyte after 3 months.
- Subsequent cure of the material (air, chemical reaction of a two part mixture, UV cure).
- Developed for electronics, enclosures and automotive industries.
- Some examples of in battery packs and fuel cell usage – ZBT Duisburg & Wacker
- Limited information on applications in RFBs apart from some trials by Fraunhofer ICT.
- The dispense operation is highly controllable:
  - Dispense (nozzle diameter, dispense rate, start/stop dispense behaviour, suck back at end of dispense…..)
  - Robot (line speed, height above workpiece, start / stop speeds, retraction at end of dispense, corner speeds……)
  - Parameters are material dependent and needs to be optimised.





Fuel cell stack with exploded schematic fuel cell design.



Form in place or cure in place seals

Form in place (FIP) seals take up the shape of cavity between the parts tp be joined and rely upon the cured adhesive bond of the two joints for their integrity.

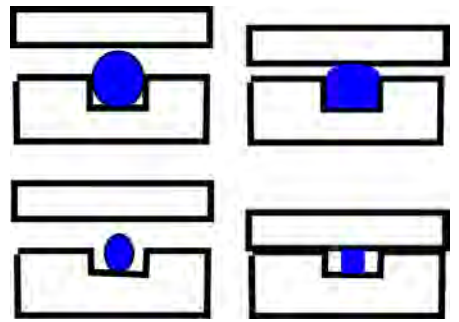
- Final assembly technique with no disassembly possible
- Relies upon two adhesive bonds to maintain seal over the varying operating conditions of a stack with no mechanical pushback from the seal material.

Cure in place (CIP) deposits an elastomer onto a surface (adhered) and the resultant cured deposits acts as a mechanical seal like a gasket or o'ring.

- Seals added to a face of a component with later assembly (and disassembly).
- Predictable mechanical seal response with no requirements for long term bond strength just sufficient adhesion to one surface to stay in place.

RFB Seals

- A variety of methods are currently used or in development – o'rings, full face gaskets, gaskets with stress raisers, injection moulded into plastic frames, welded…….
- Flow battery stack seals: Manifold, Bipolar plates, Membrane / membrane assembly, External seal
- Flat gaskets can be readily deposited but our preference was for o'ring seals as they gave defined face to face contact of the rigid components(plastic frames and bipolar plates) through which force is transmitted during compression of the cell stack.
  - Well adhered o'rings are deposited in the grooves. But can be readily removed.
  - Much smaller diameter seals can be deposited than can be handled and manually inserted in a groove.
  - Need to allow room in the groove for the elastomer to move into, so the mating surfaces sit flat.
  - Seal compression is similar to normal o'ring seals (but check properties) and are typically 30-40%
  - Tolerances are important – machined groove (depth, width, position), nozzle position (depth and position, extruded seal material and placement onto robot. Need to be allowed for in defining the groove width.
  - Shallow seals worked well - 1.2 mm diameter seals deposited into a 0.9 +/- 0.1 mm groove of 4 mm wide worked well. Held 3 bar. (Not optimised of a limit)



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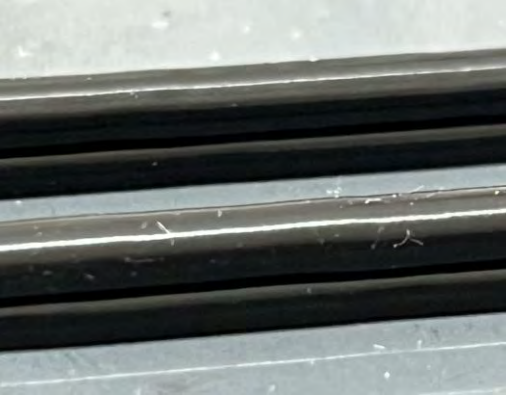
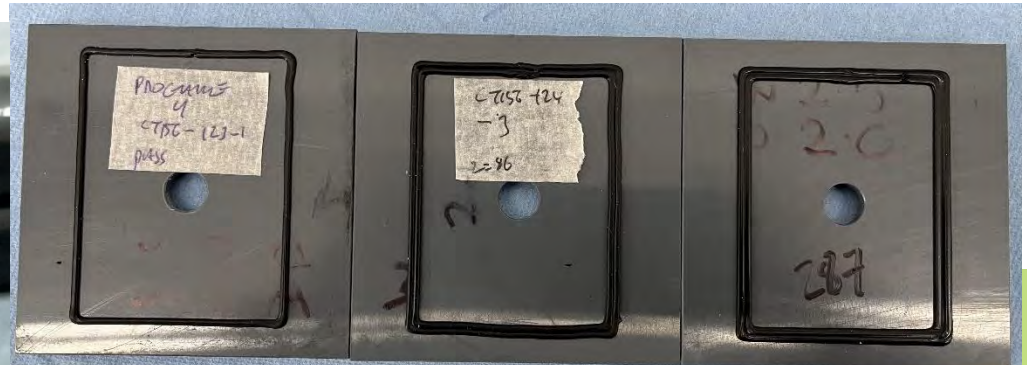
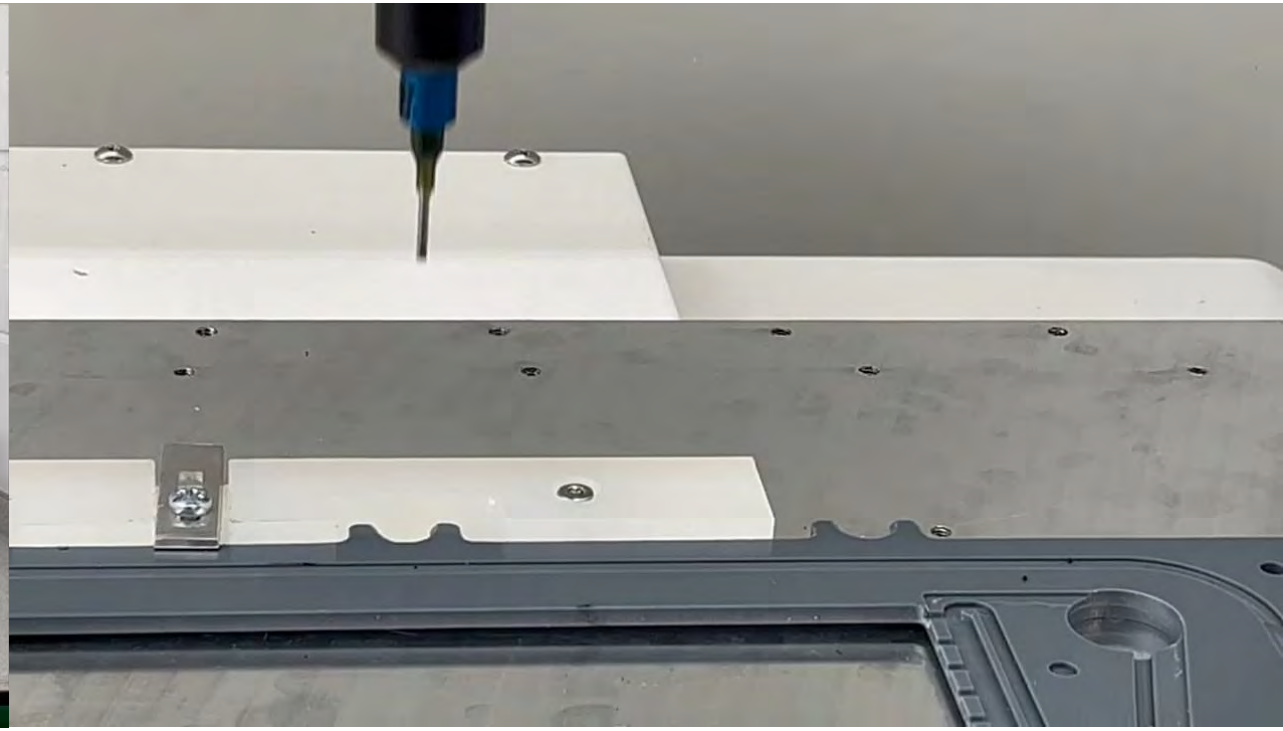


O'Ring Seals in Cell Frames

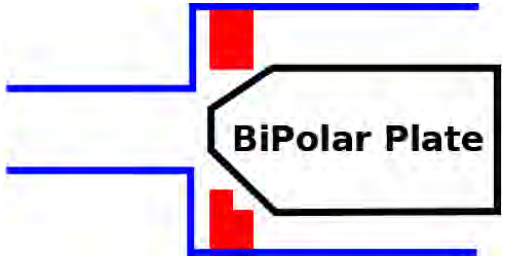
- Start and stop of a deposition is the most critical part to get right.
- However it does not need to be perfect. There may be small gaps in the overlap region but these close up under compression.
- Seals of two or more continuous adjacent seals could provide a wider or double seal.
- High aspect ratio seals can be produced by depositing seals on top of each other in a continuous deposition. (2:1)



O’ring seals in plastic unit cell frames



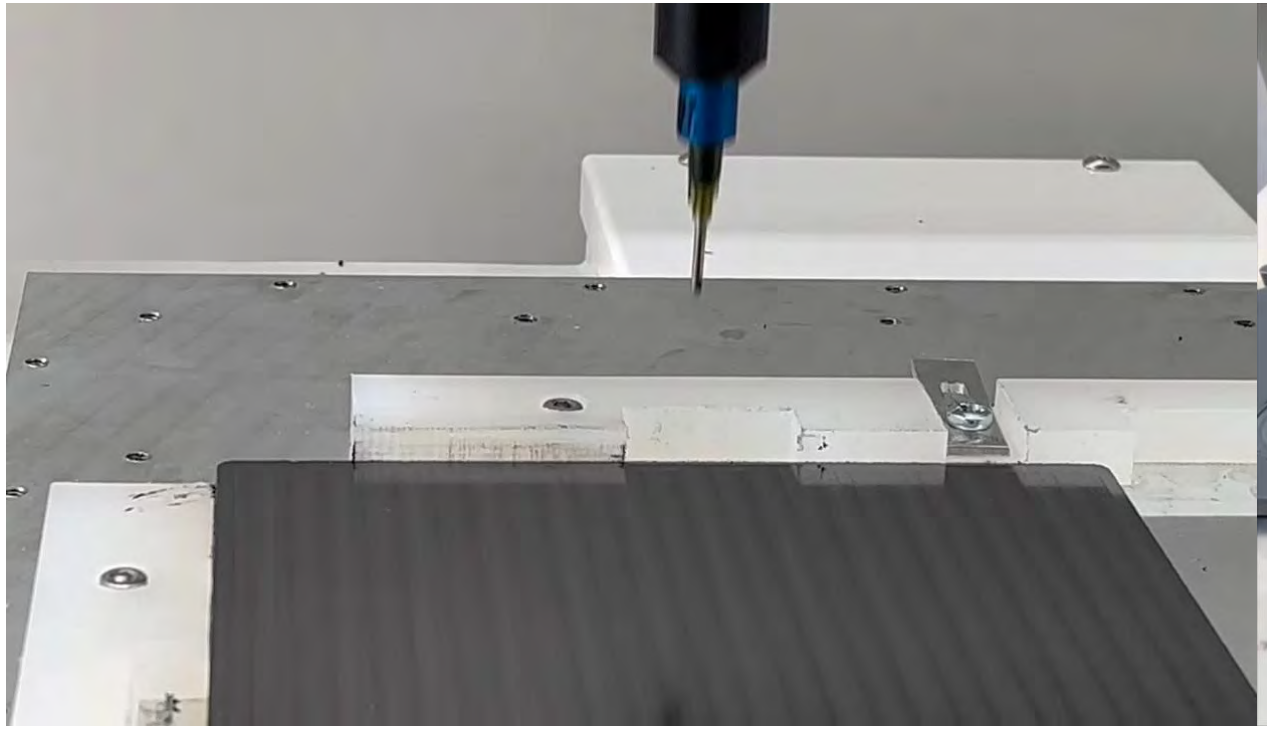
Bipolar plate seals



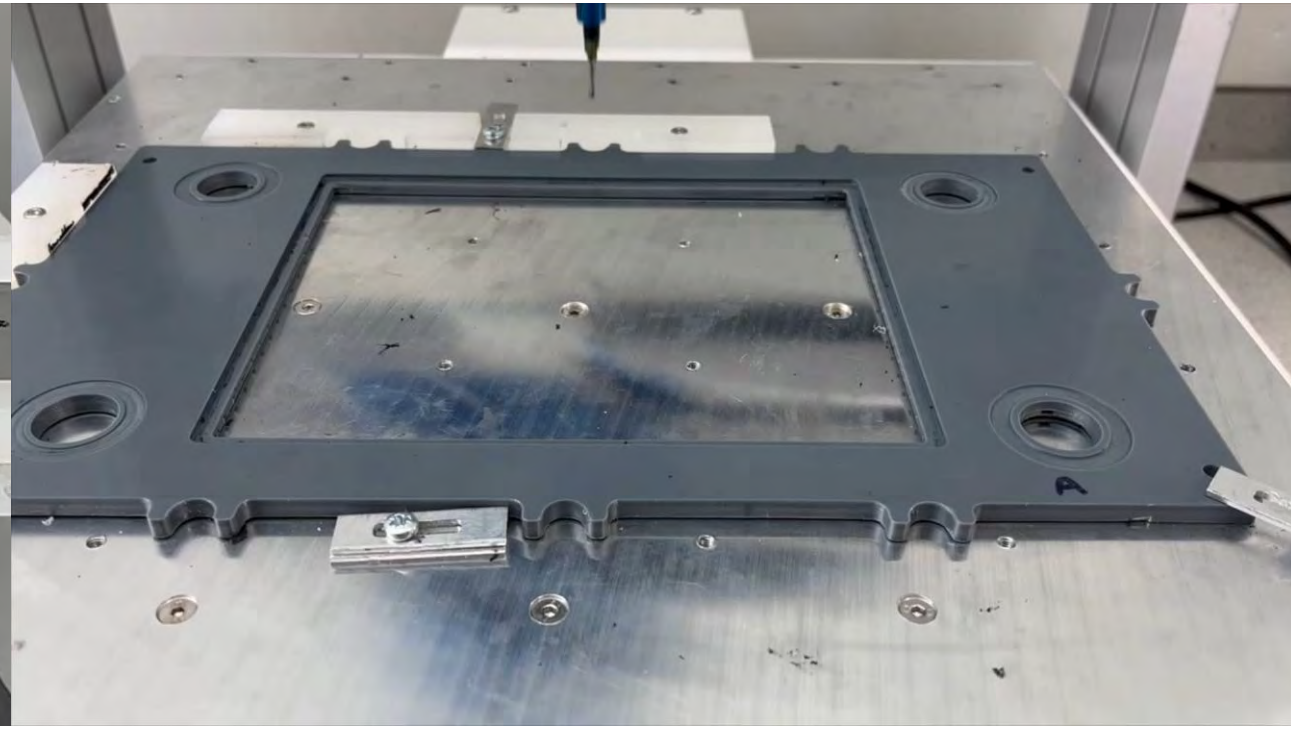
- Corner seal using a chamfered edge on BPP and a seal deposited into the corner of the cavity. No depth required in polymer plate for seal.
- Rebate around edges of BPP – 0.8 mm used. Seal deposited on the BPP rebate. No depth required in polymer plate for seal. Less precision required in BPP machining and seal deposition.
- Similarly a shallow o’ring groove could be used polymer plate but this would require some depth for the seal.

Bipolar plate seal deposition

Onto 0.8 mm rebate on BPP

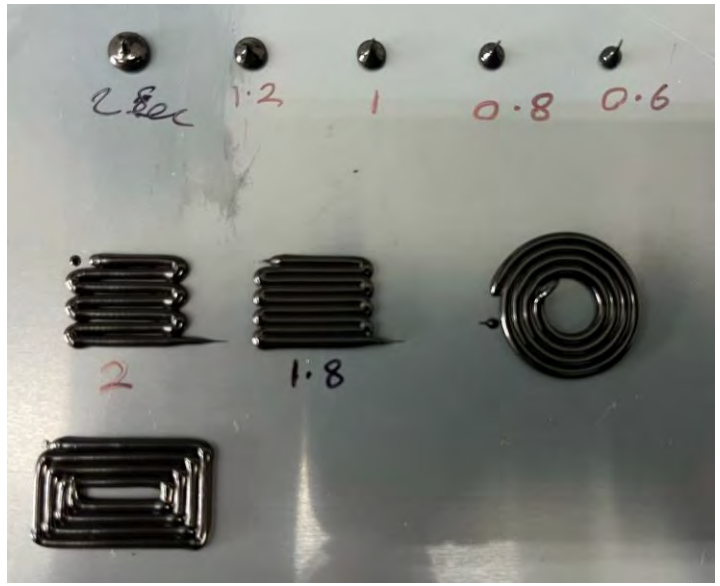


Deposition into cavity 2.3 mm from top surface



Adhesives in stack assembly

- Adhesives could be used to hold parts in place either permanently or for assembly.
- Examples of dot and brushed depositions shown below:



- Assembly of a complete unit cell assembly - BPP, internal seals, plastic frames, cover plates. PVC solvent welded example below:

Summary

- CNC deposited cure in place seals can be used to seal flow battery stacks (manifolds, bipolar plates, external / membrane seals).
- Chemical resistance could limit the battery chemistries to which it can be applied but sealant chemistry is rapidly developing. Testing is essential.
- Depending upon the application and production volumes it **could** offer benefits over other techniques for some or all stack seals.
- Potential advantages:
  - No mould tooling requirements
  - Seals deposited on demand with no stock requirements or external suppliers.
  - CNC driven from CAD data so offers flexibility
  - Reduced manual assembly compared with o'rings and gaskets.
  - O'ring grooves can be quite shallow which offers design freedom in stack frames.

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Thank you!

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