ARCACTIVE

ELBC
16-19 September
Milan, Italy 2024

ELBC 2024 - MILAN

HV GEM™
A Hollingsworth & Vose Innovation

"Novel glass fabric electrode material for grid replacement in lead batteries"

SHANE CHRISTIE – ARCACTIVE
NICOLAS CLEMENT – HOLLINGSWORTH AND VOSE

Hollingsworth & Vose®

ArcActive Fabric Structured Electrodes

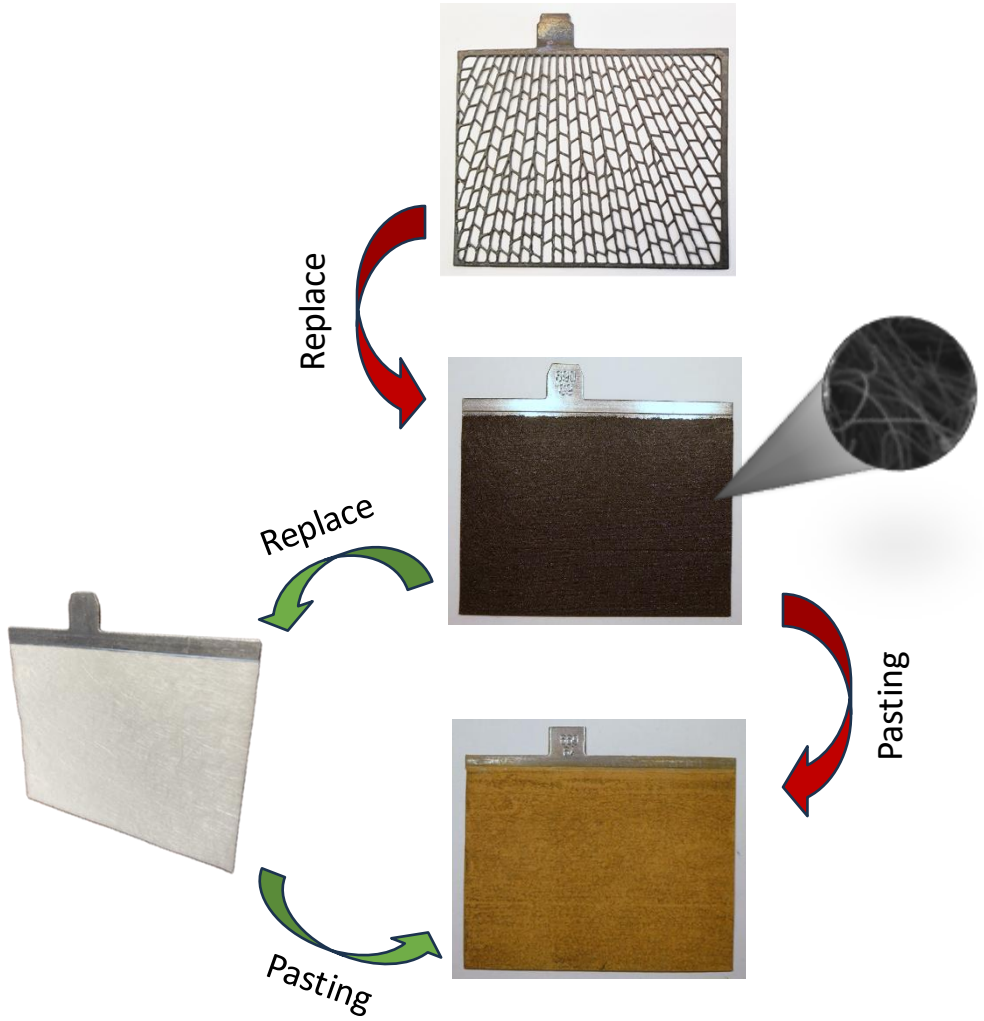
Gen 1: Carbon Fibre Fabric

Applications:

- ❑ Automotive: High DCA, Low Water Consumption
- ❑ UPS / Telecom: Delay AGM Dry Out

BCI Innovation Award: **Winner, 2020**

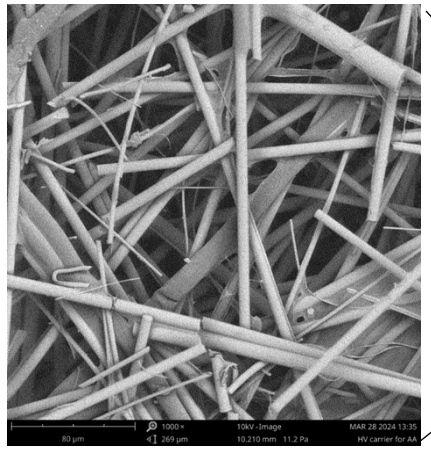
Battery Council International
INNOVATION AWARD
In honor of Sally Breidegam Miksiewicz

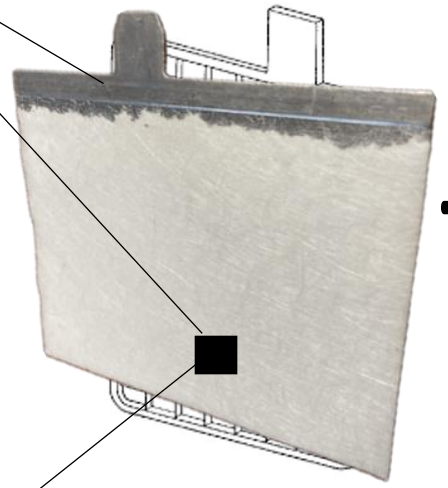


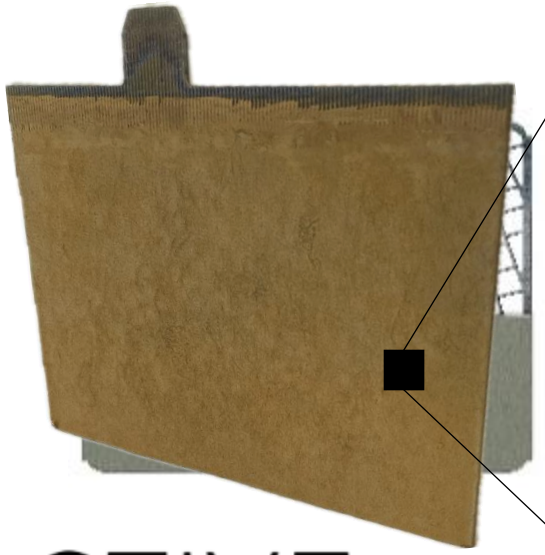
Gen 2: Glass Fiber Fabric → GEM

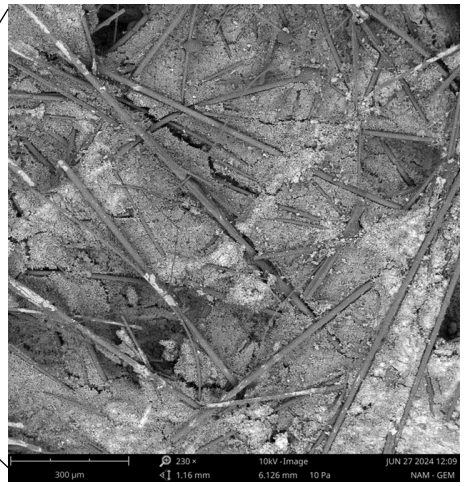
What is ArcActive GEM technology ?

Lead lug









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Process

GLASS BASE STRUCTURE

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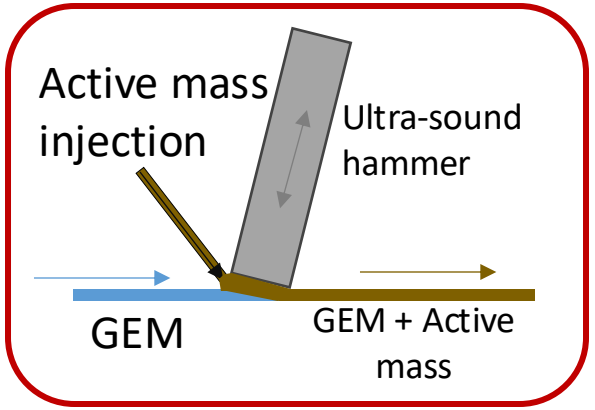

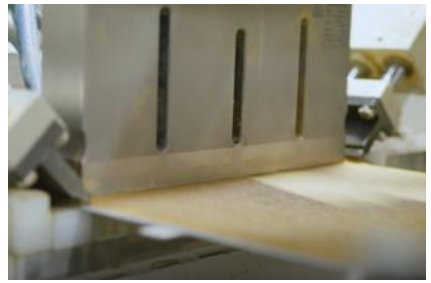

Process video for continuous lugging

Video of lug casting and pasting:

Coming soon to a PowerPoint near you: Filming is done.
Video edition in Progress.
This slide will be updated by Sept 12th
Aimee will update.

Process video for continuous pasting

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SEM Formed Plates

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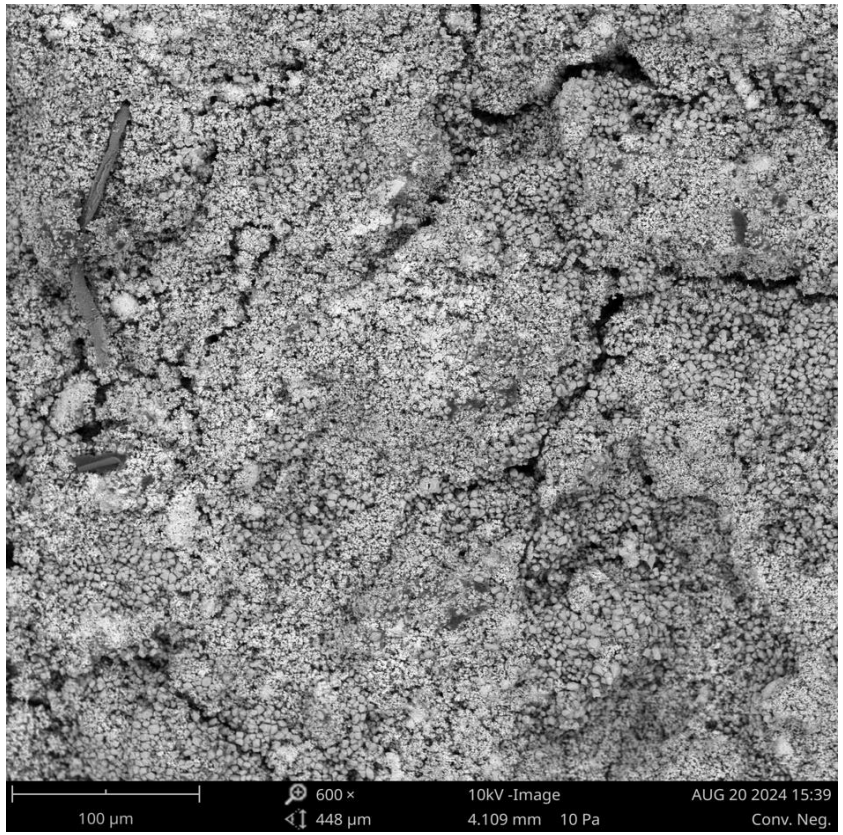
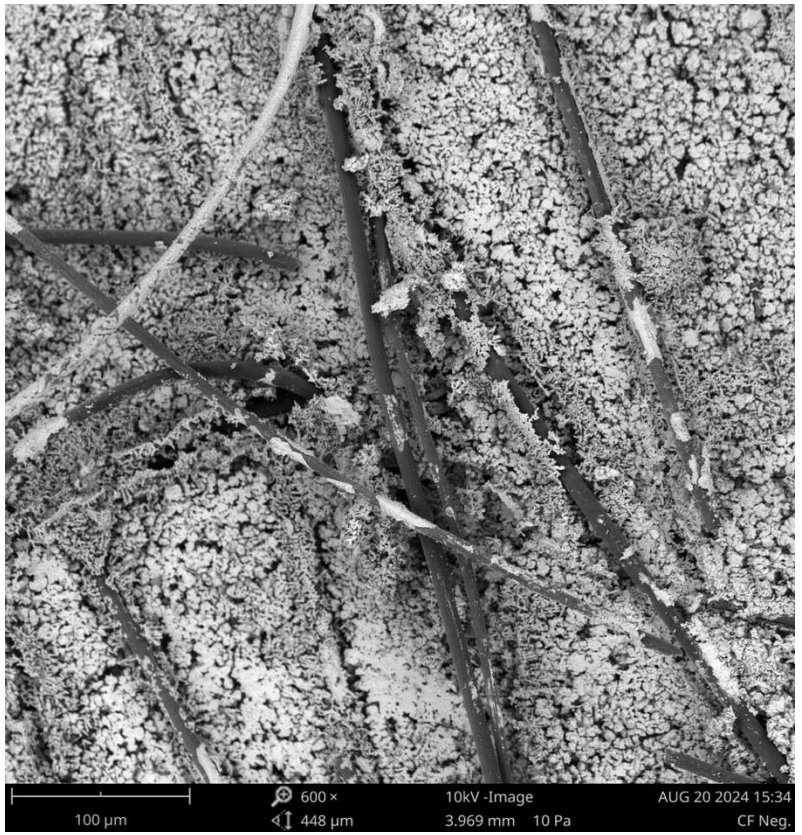
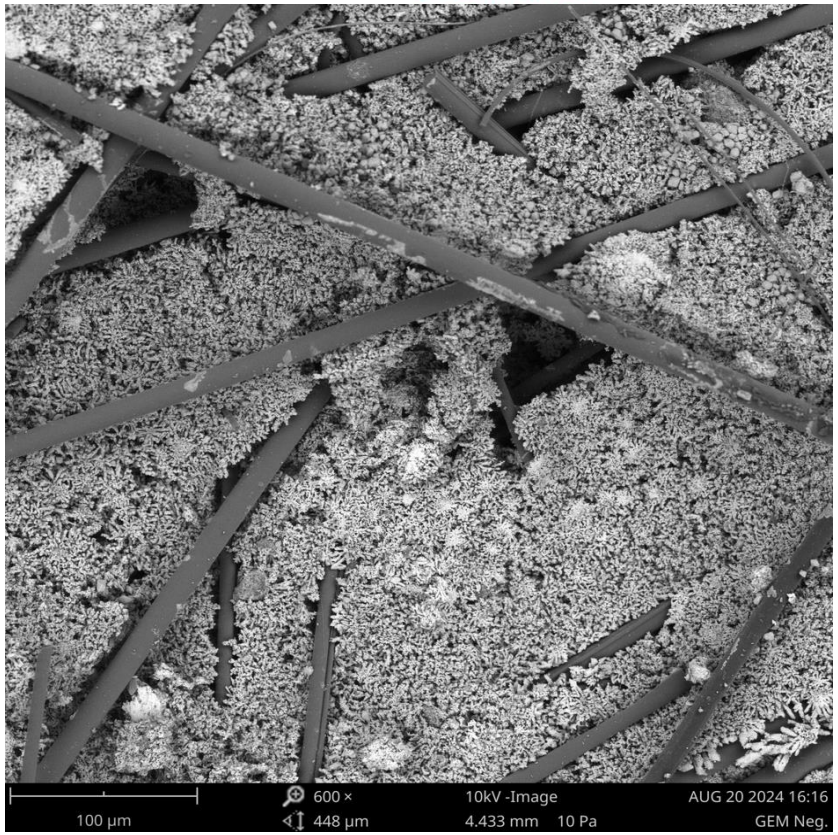
Standard NAM



Carbon fiber base NAM





Formed plates: From SEM Phenom XL

100µm

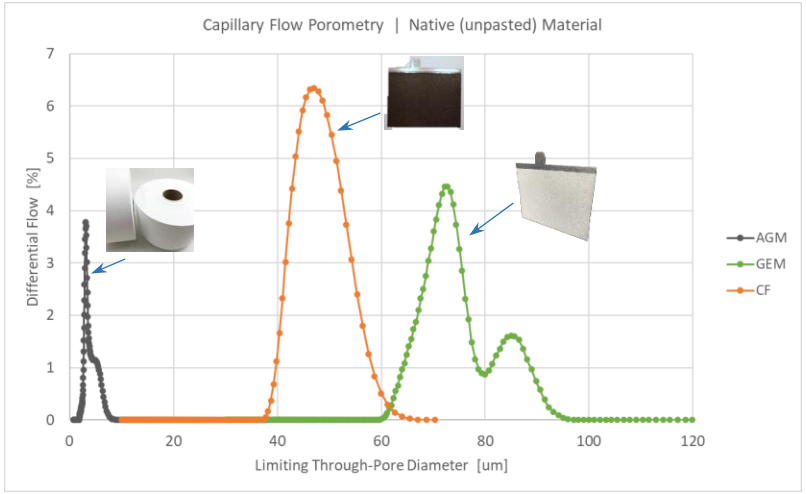
Hollingsworth & Vose®

Pore Structure

Pore structure of GEM is more “open” than AGM, and similar to Carbon Fiber Felt

- Active material (paste) is contained wholly within fibrous pore structure

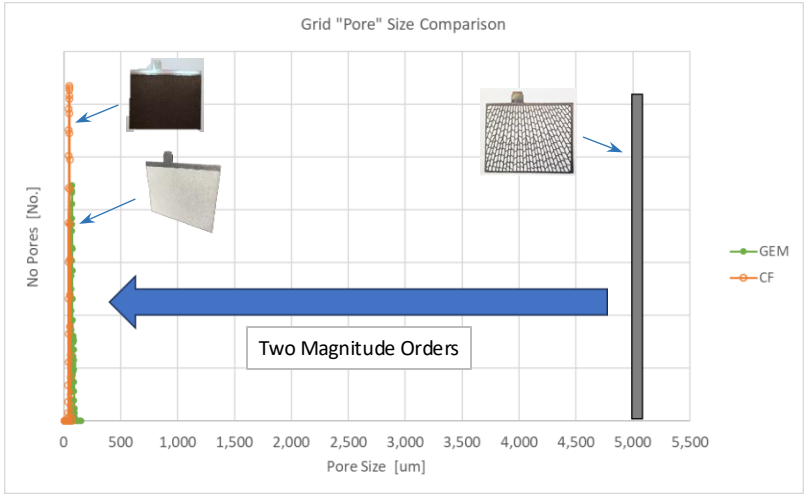
Fibrous Substrates: GEM, Carbon Fiber



Median Pore Sizes (unpasted):

AGM = ~4 µm | CF= ~50 µm | GEM = ~70 µm

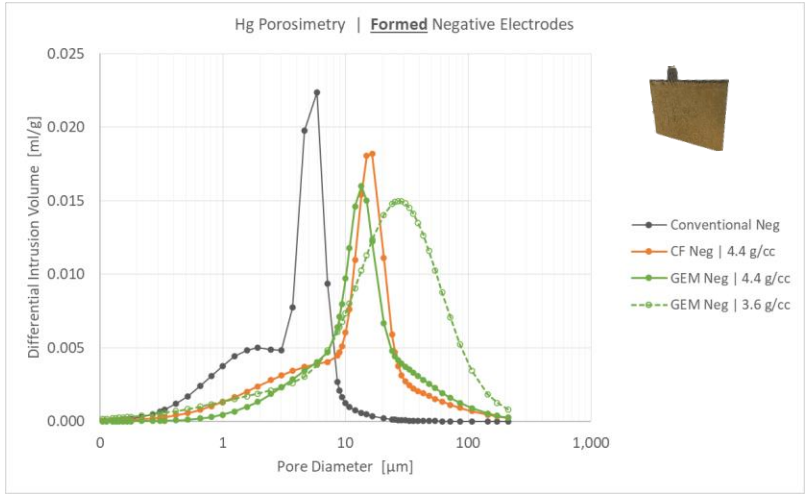
Grid Type Comparison



Active material (paste) is contained within the “pores” of the grid:

- Conventional lead grid “pores”: ~ 5 mm
- GEM/Carbon Fiber Pores are two magnitude orders smaller than a conventional Pb grid

Negative Electrodes (100% SoC)



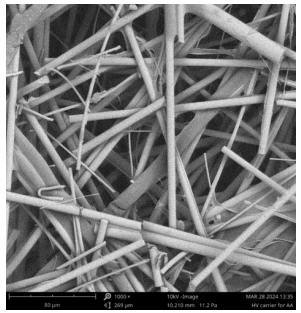
Formed Negative GEM / Carbon Fiber Electrodes feature pore structures similar to conventional negatives, albeit:

- **Increased pore volume in the 10-30 µm range**
- Fabric structure mechanically stabilizes active material
  - Lower density (more porous) paste recipes are possible

Breakthrough solution for lead acid battery

Application	Advantage	Customer Benefit
Auto: Micro Hybrid	High and Sustained DCA with very low Water Loss	Low-cost CO_2 compliance
Auto: EV Aux	High Charge Recoverability	Reduce likelihood of Aux battery having low SoF and rendering EV inoperable
Auto AGM (hot territories)	Long time to separator dryout	Reduce Dryout warranty claims

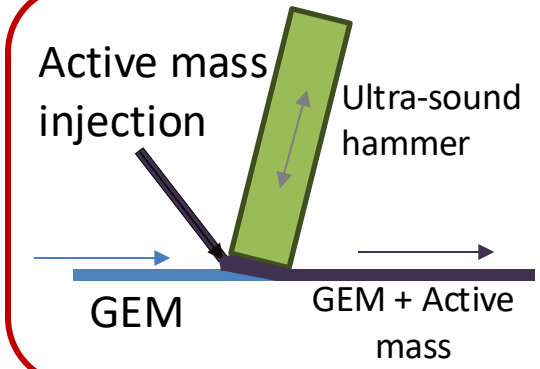
GEM Processing

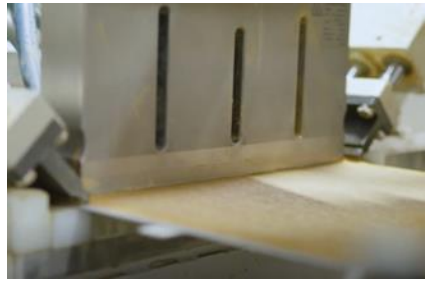


GEM is different than AGM but uses same production tools

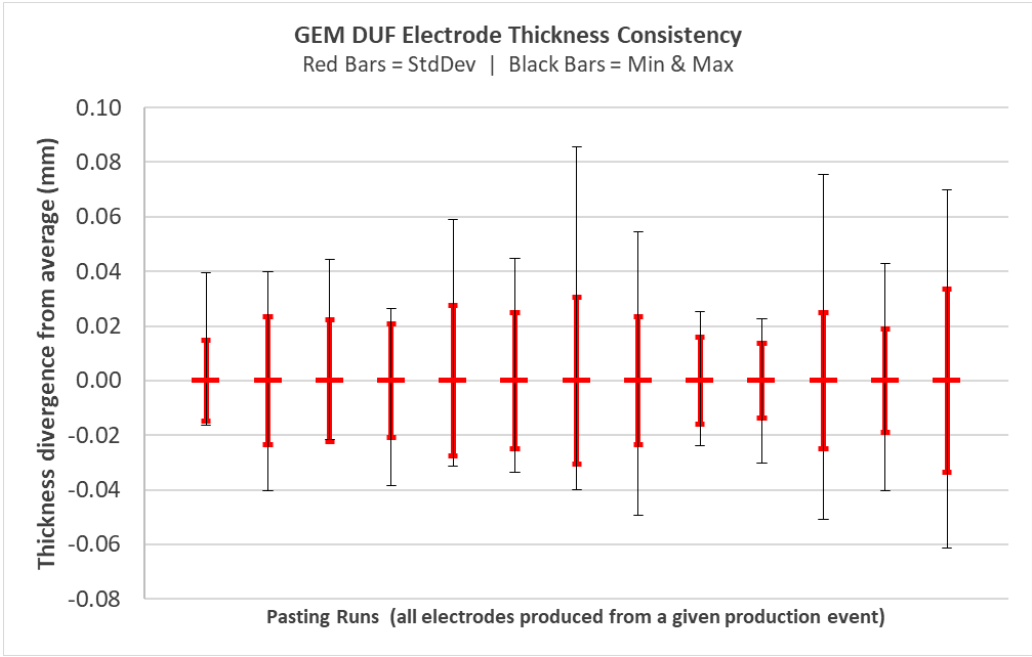
More than 8000 plates have been produced with GEM at ArcActive

GEM structure is **very open** to enable excellent paste-ability and **compressible** for best plate thickness control





Pasting GEM enable low plate thickness variation (**± 20µm**)



GEM Performance Summary

Extensive electrical testing performed on prismatic 2V cells:

Automotive Type: 60 Ah, 13 plates (6P, 7N)

	Negative Variant		
Battery Performance	**GEM**	**CF**	**Trad**
C_{20} / ResCap			
CCA			
Water Consumption			
DCA			
50% DoD (to date)			

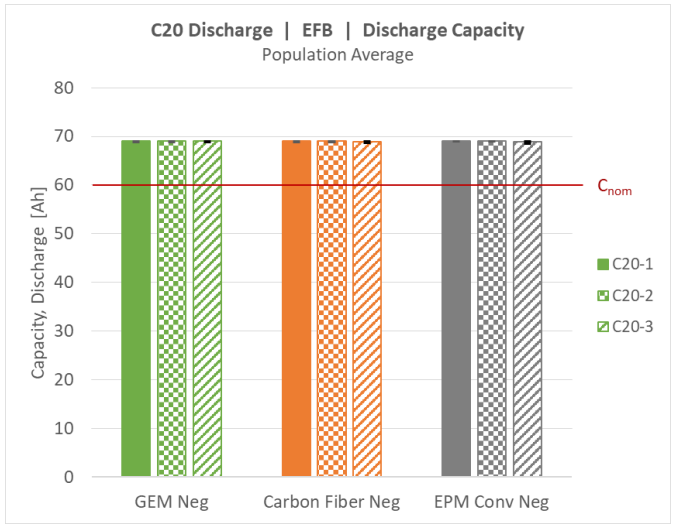
GEM preforms equivalently to Carbon Fiber in most battery tests.

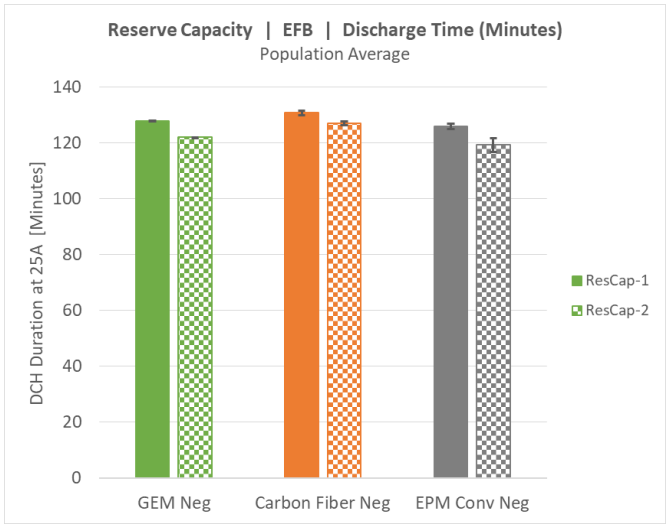
- Excels in water consumption testing.
- Strong, but slightly reduced CCA (cf Carbon Fiber)

Test Data | Discharge Capacity - C_{20} , Reserve Capacity & CCA

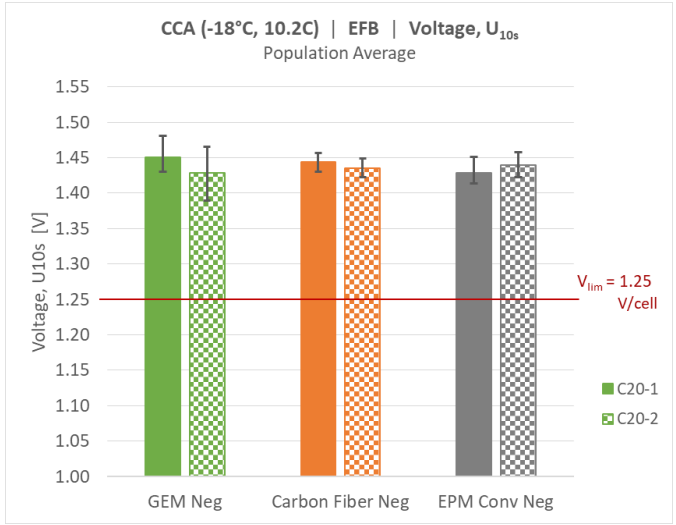
Standard: EN 50342-1: 2015

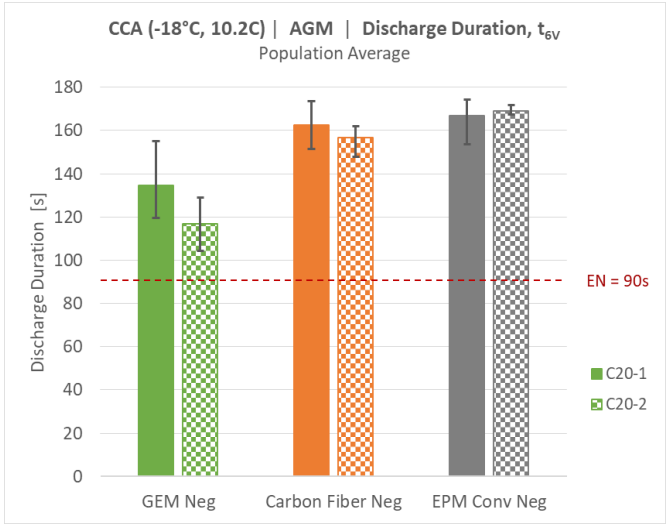
C_{20} | Reserve Capacity





CCA





Discharge Capacity:

- GEM and Carbon Fiber Negatives deliver equivalent performance to Conventical Negatives

CCA:

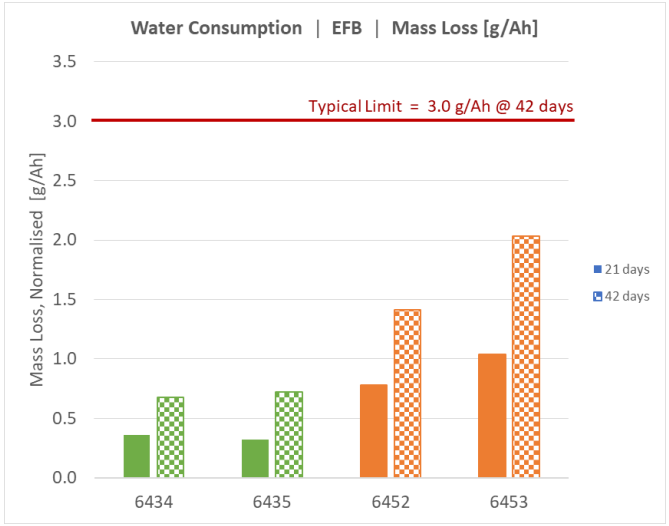
- GEM negatives equivalent CCA voltage
- Strong but slightly reduced energy

Test Data | Water Consumption

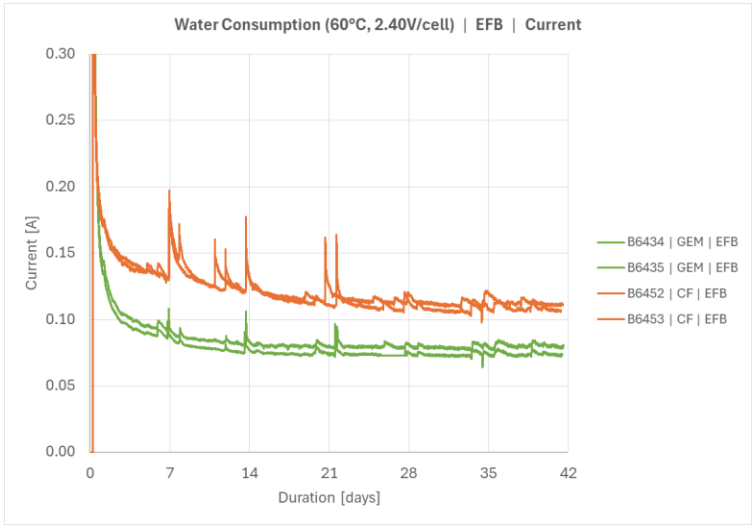
Standard: EN 50342-1: 2015, 6.9

Conditions: **Temp**: 60°C | **Voltage**: 2.40 V/cell (14.40 V equiv) | **Duration**: 42 / 84 days

Mass Loss



Current



AA GEM electrodes produce very low water consumption.

WC Results @ 42 days

- ❑ GEM: < 1.0 g/Ah
- ❑ CF: 1.5 – 2.5 g/Ah

GEM fibers are non-conductive: do not present hydrogen-active surface area

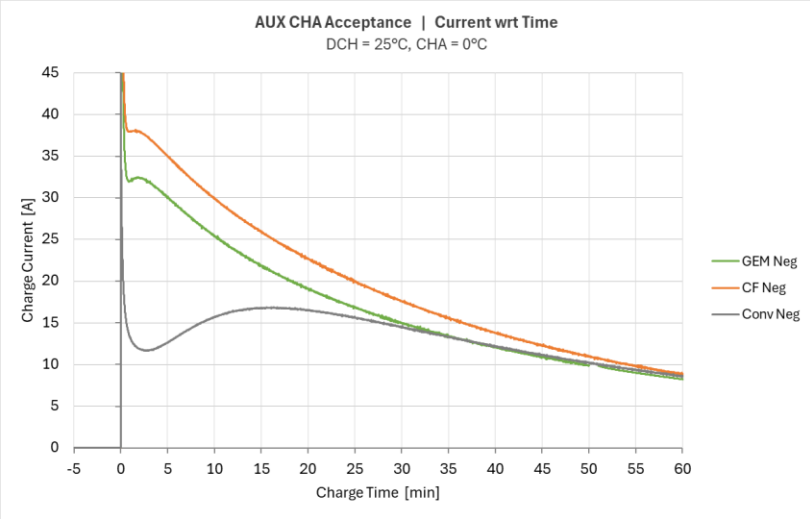
- ➢ Hydrogen overpotential increased, gassing current reduced.

Test Data | (Aux) Charge Acceptance

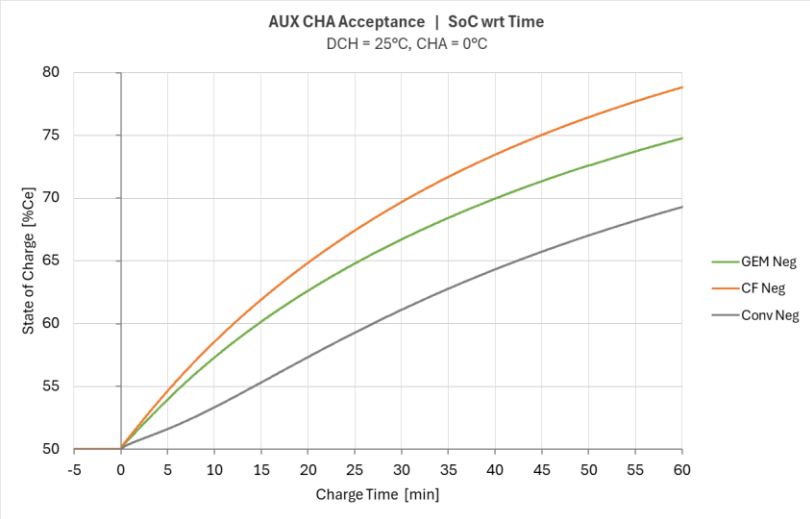
Standard: EN 50342-1: 2015, 6.4

Conditions: **DCH Temp**: 25°C | **CHA Temp**: 0°C | **SoC**: 50 %C_e

Current



State of Charge



Both GEM and Carbon Fiber electrodes have strong charge recovery at 0°C.

- Notably improved cf Conventional

State of charge increased more rapidly in the first 20-30 min

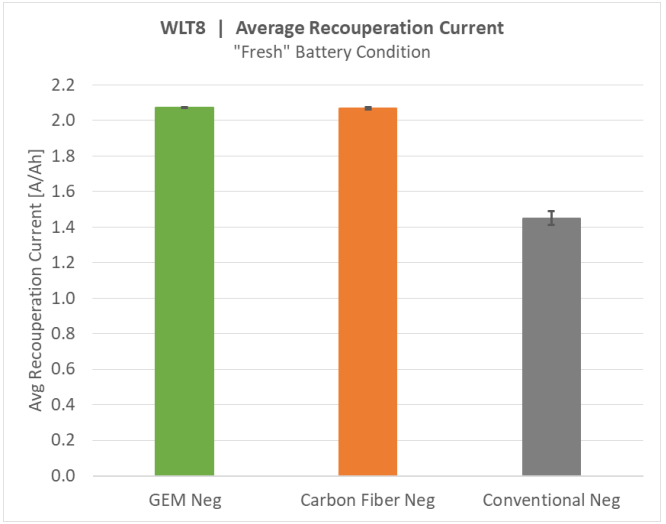
- SoC gain after 15 min:
  - AA CF Neg: 12 %C_e
  - AA GEM Neg: 10 % C_e
  - EPM Neg: 5 %C_e

Test Data | DCA - Homologation (WLT8) with Preconditioning

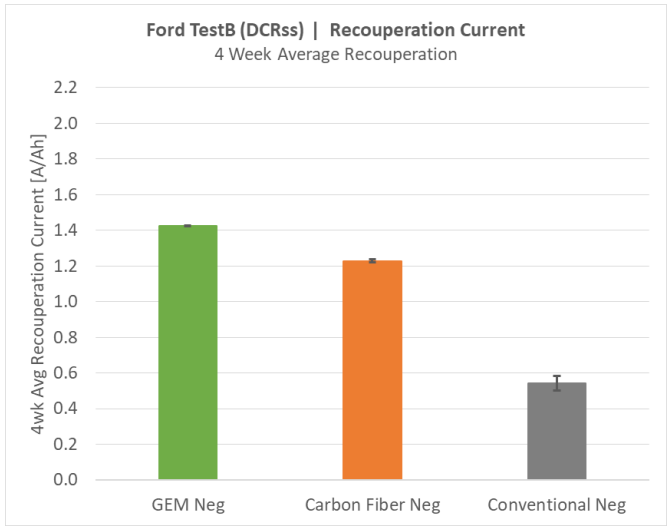
Standard: Homologation WLT8 Protocol (E.Karden, ALBA 2021) & "TestB" Reference DCA Test (Ford, 2012)

Conditions: **Temp**: 25°C | **Preconditioning**: 4wks DCRss

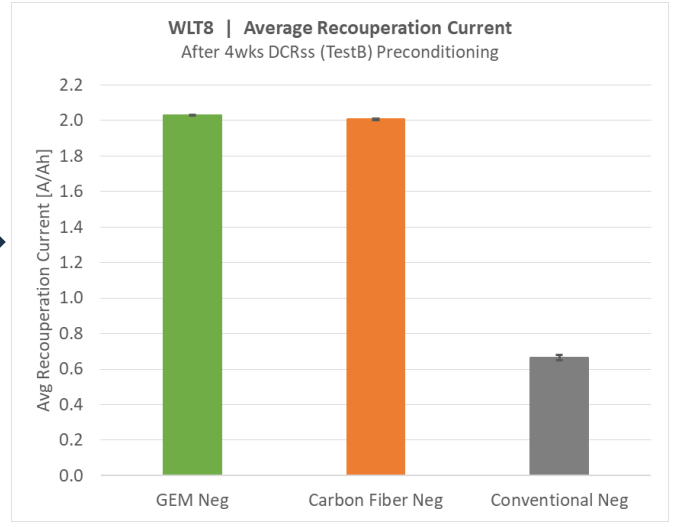
Homologation DCA: Fresh (new) Battery



Simulated Vehicle Operation: 4wks



Homologation DCA: After 4 Weeks Operation



Homologation DCA: "Fresh" battery

- Performance typically good for many battery designs
- Many territories outside of Europe do not allow recharge of battery before homologation testing
  - "Fresh battery" DCA not observed in these territories

Simulated Vehicle Operation:

- 4 weeks of simulated vehicle operation by Ford TestB DCA
- DCA of conventional negatives tends to decrease in real-world operation
  - TestB reproduces this effect

Homologation DCA on "used" batteries:

- Conventional Negative performance is reduced compared to "fresh" state
- ArcActive fabric structured electrode performance remains high
  - 2 A/Ah approx. maximises alternator power & therefore maximises CO_2 reduction

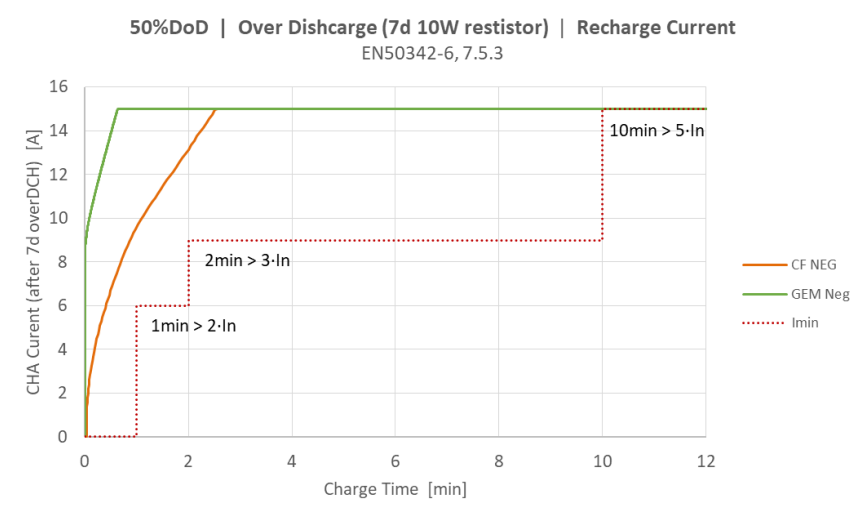
Test Data | Durability Cycling - 50% DoD w/ OverDCH Precond

Standard: EN 50342-6: 2015, 7.5

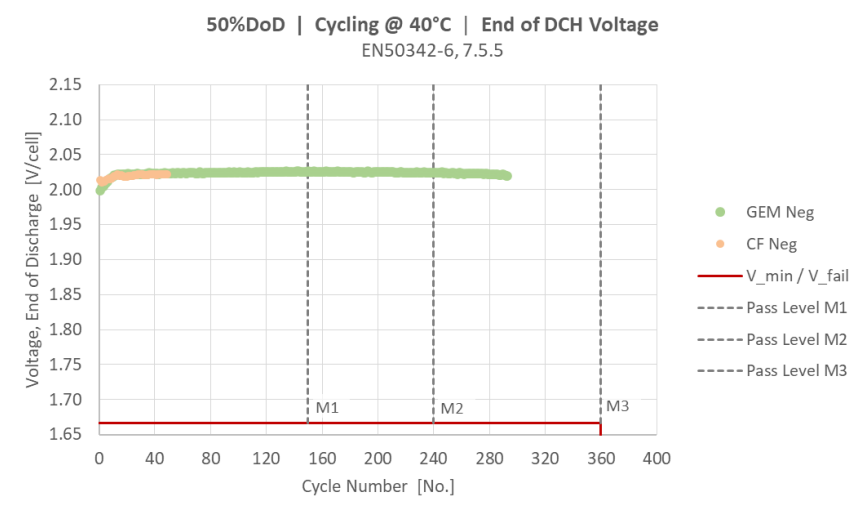
Conditions: **Temp**: 40°C | **Preconditioning:** Over-discharge, 7 days 10W Resistor

Testing in Progress

Preconditioning



Cycling



Fabric-reinforced negative electrodes tolerate over-discharge

- GEM electrodes easily exceed minimum current requirements after 7-day over-discharge.

50% DoD cycling durability on-track to achieve "M3" (360 cycles) performance requirement

- Cycling in progress - progressing well.

ArcActive technology + **GEM** from Hollingsworth & Vose → **New way of making electrode**

Questions ?

Reach out for Shane Christie or Nicolas Clement