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21 ABC ASIAN BATTERY CONFERENCE AND EXHIBITION

Optimizing NAM structure with additive formulation for *Enhanced Charge Acceptance* for Auxiliary Application

Dr. Sreedhar Naidu D

R&D - New Materials & Testing

21st ABC, Sabah International Convention Centre, Kota Kinabalu, Malaysia. 2nd - 5th September 2025.

Amara Raja Group

CORE PURPOSE

To transform our increasing spheres of influence and to improve the quality of life by building institutions that provide better access to better opportunities to more people. . . all the time.

VALUES

About - ARE&M

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AMARA RAJA - TIRUPATHI

AMARA RAJA - CHITTOOR

~1.5 Billion US$ Revenue – FY 25

2 manufacturing Locations, 9 plants

Automotive – 65+ Mn batteries, Industrial – 3.2+ BnAh per annum

~3,00,000 MT lead per annum

11000+ Employees

Technology center with 150+ Employees

60+ Countries

ARE&M - Batteries Products and Application

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Amara Raja Batteries is the technology leader and one of the largest manufacturers of lead-acid batteries for both industrial and automotive applications in the Indian storage battery industry.

Application Segment & Product Range - **Industrial**

- Power Generation units
- Transmission & Distribution points
- Telecom
- Railways
- UPS
- Offshore units
- Other Industries


UPS


Telecom


Solar


Railways

Application Segment & Product Range – **Automotive**

- Passenger cars
- 3 wheelers
- 2 wheelers
- Tractors
- Trucks
- E-Rickshaw


Passenger car


3 Wheelers


Trucks


2 Wheelers


Inverters

Outline

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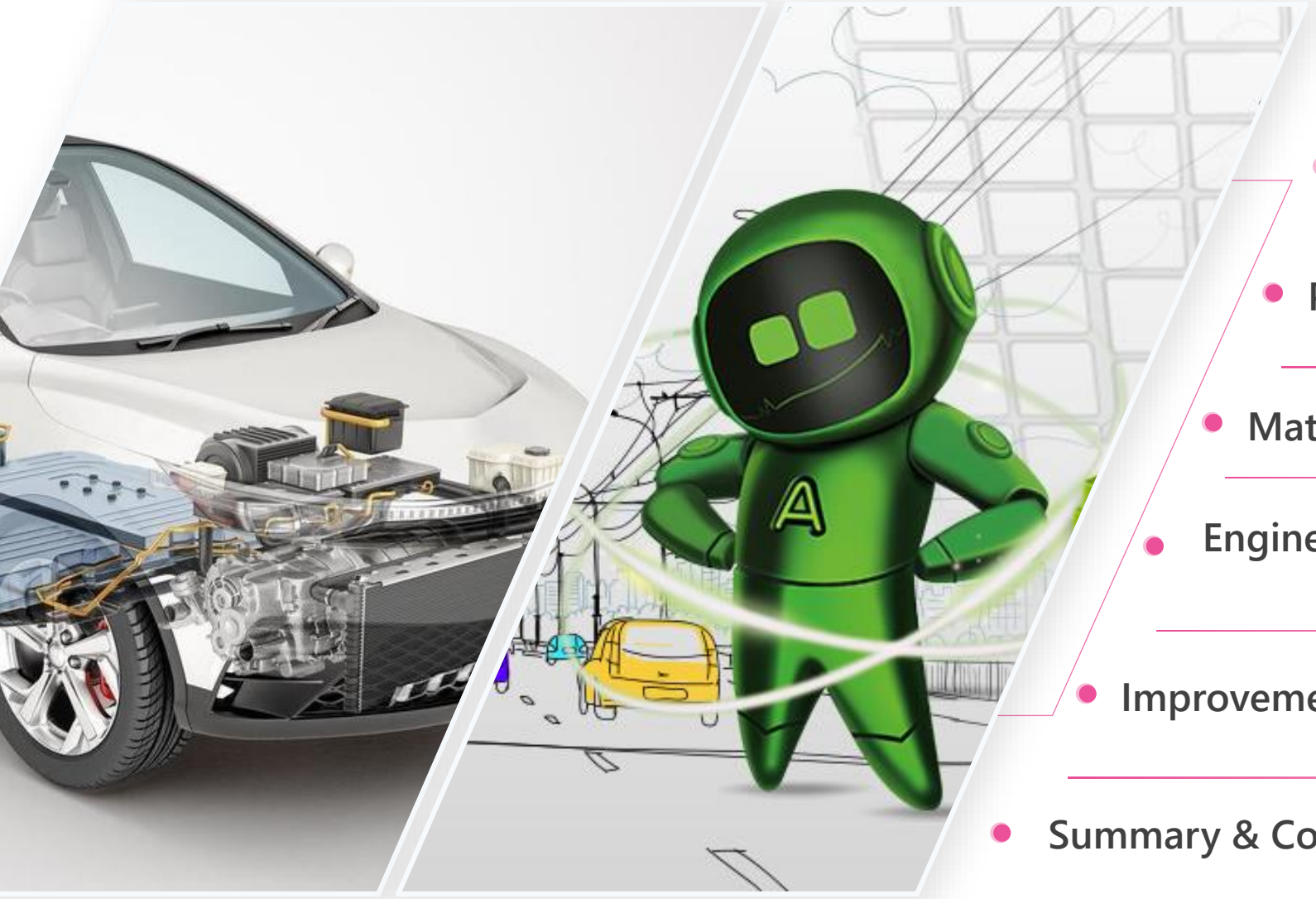
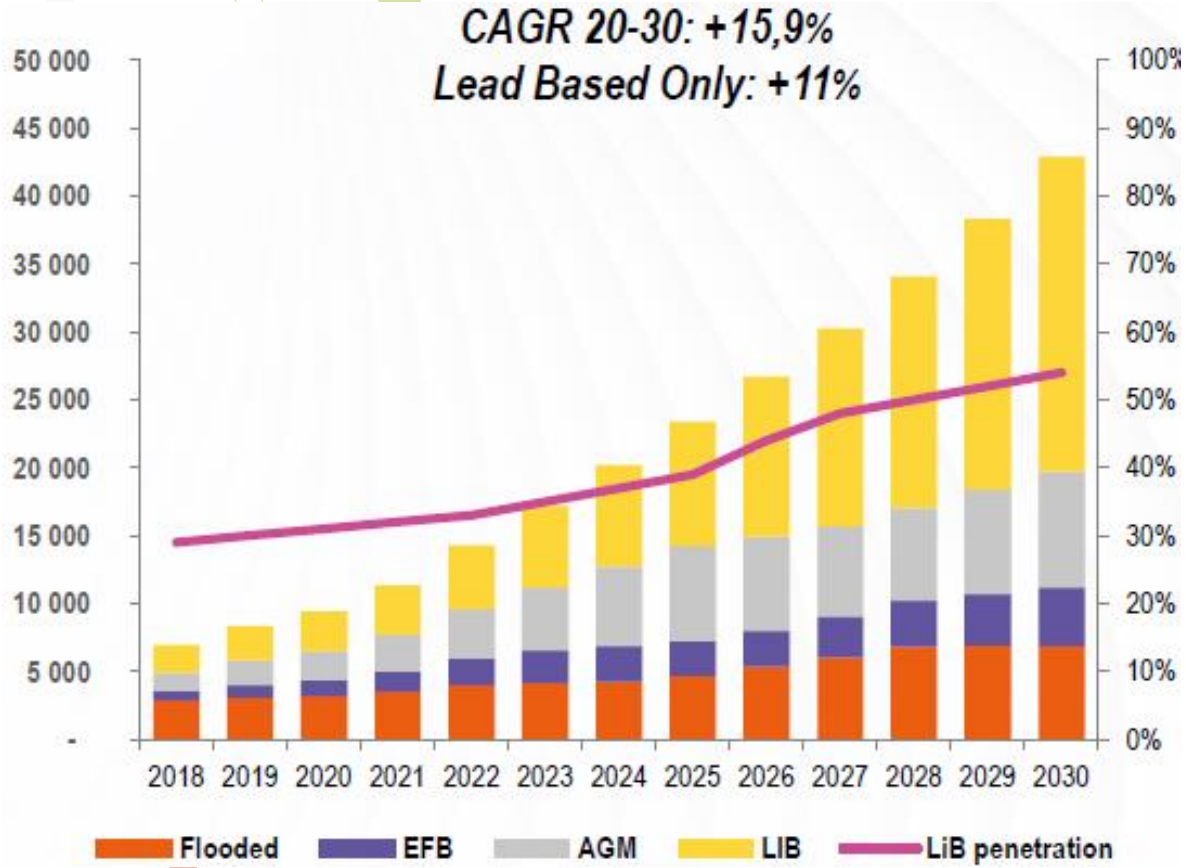


- Introduction
- Performance parameters
- Materials
- Engineering NAM
- Improvements
- Summary & Conclusion

Automotive Transformation



Ref: Auto/Hybrid Energy 2024

Auxiliary: <1.0KW
(Transient Load Response, Voltage Quality & Redundant Power Supply -SoF)

Critical Performance

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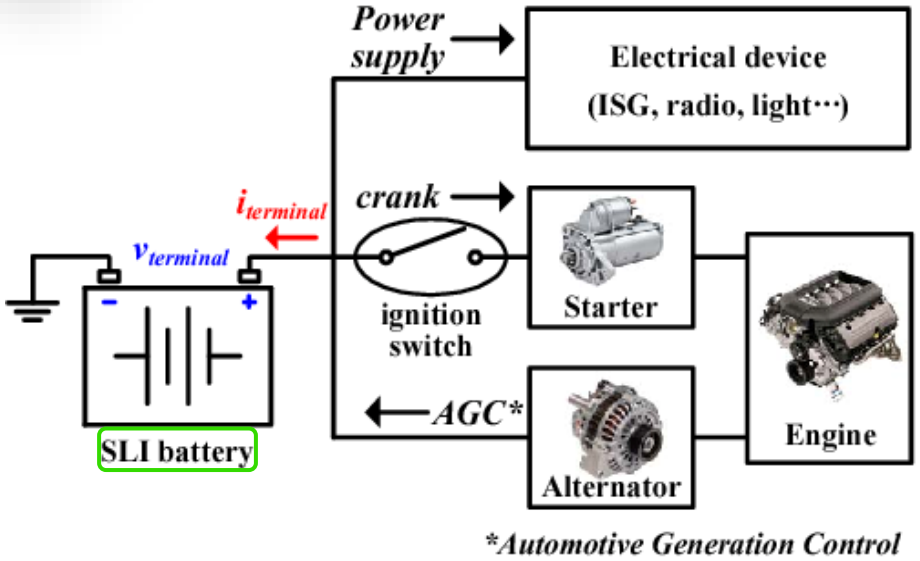
SLI

- Capacity

- Cranking

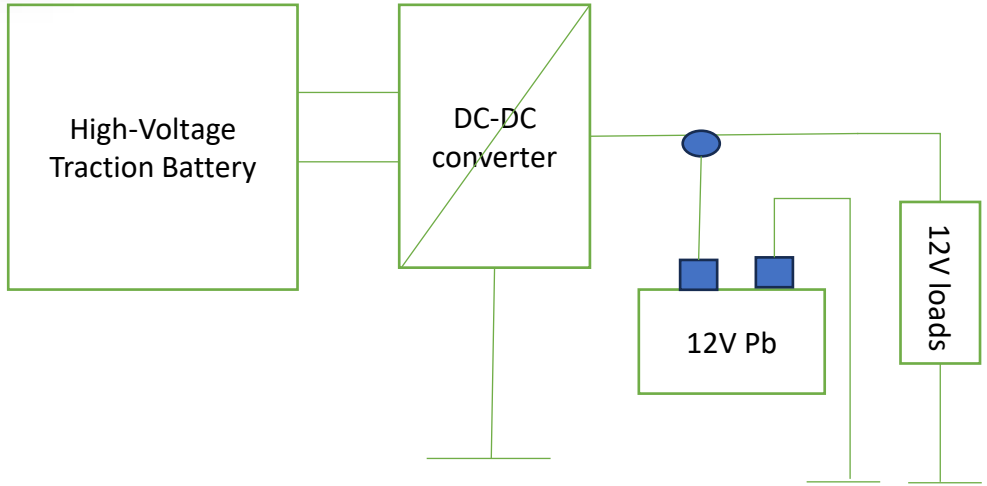


*Automotive Generation Control

Auxiliary (IEC)

- **Charge Acceptance** / Recovery

- Pulse Power



NAM Structure – Control (SLI)

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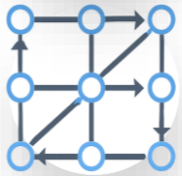
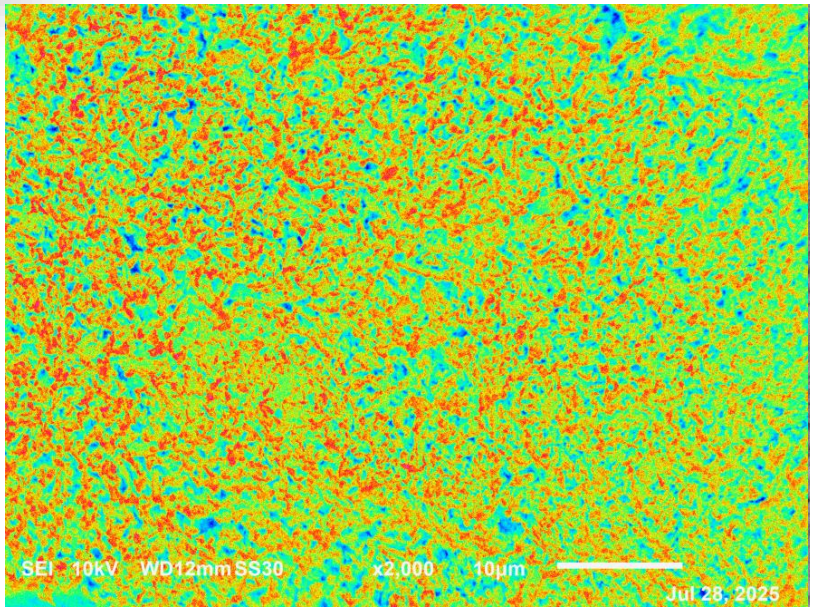
Morphology

- Particle Distribution



- Anisotropic Channel



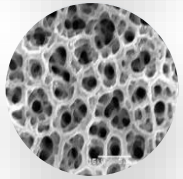
Conductive

Reactivity Zone

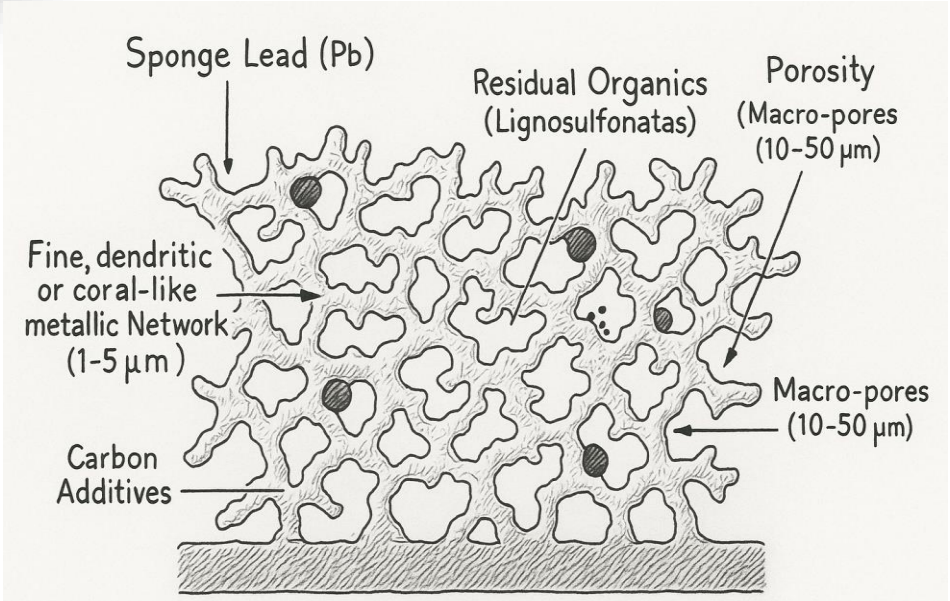
Insulative

Structure

- Surface Area



- Pore Network



Ref:
1. **Effect of carbon surface area and sodium lignosulfonate interaction** (https://doi.org/10.1590/PYTQ9316)

Materials – Oxygenated / Deoxygenated

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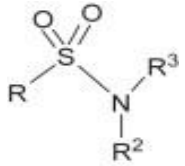
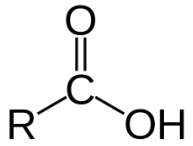
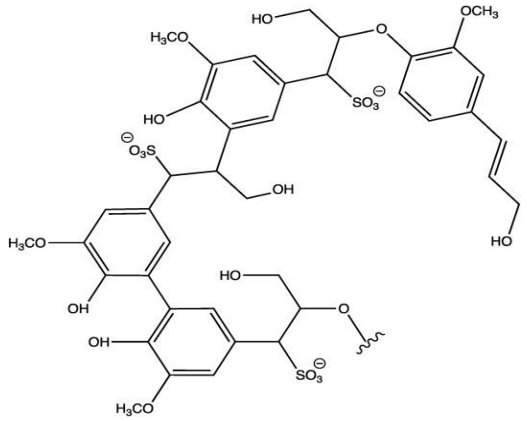
Organic Lignin



- SO_x



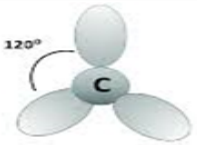
- OH / COOH / OCH3 / C=O



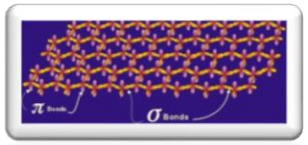
Lignosulphonate [1]

Ref:
1. Lignosulfonate-Modified Electrodes (https://pubs.acs.org/doi/10.1021/la9008575)
2. Lignin/Carbon Composite Electrodes (https://pubs.acs.org/doi/10.1021/acssuschemeng.0c05397)

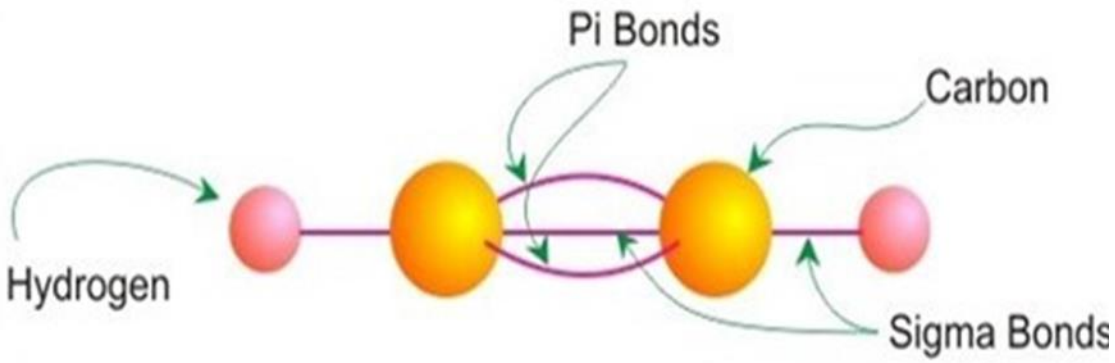
Carbon Allotropes



- Sp2 (120°) / Sp3 (109°)

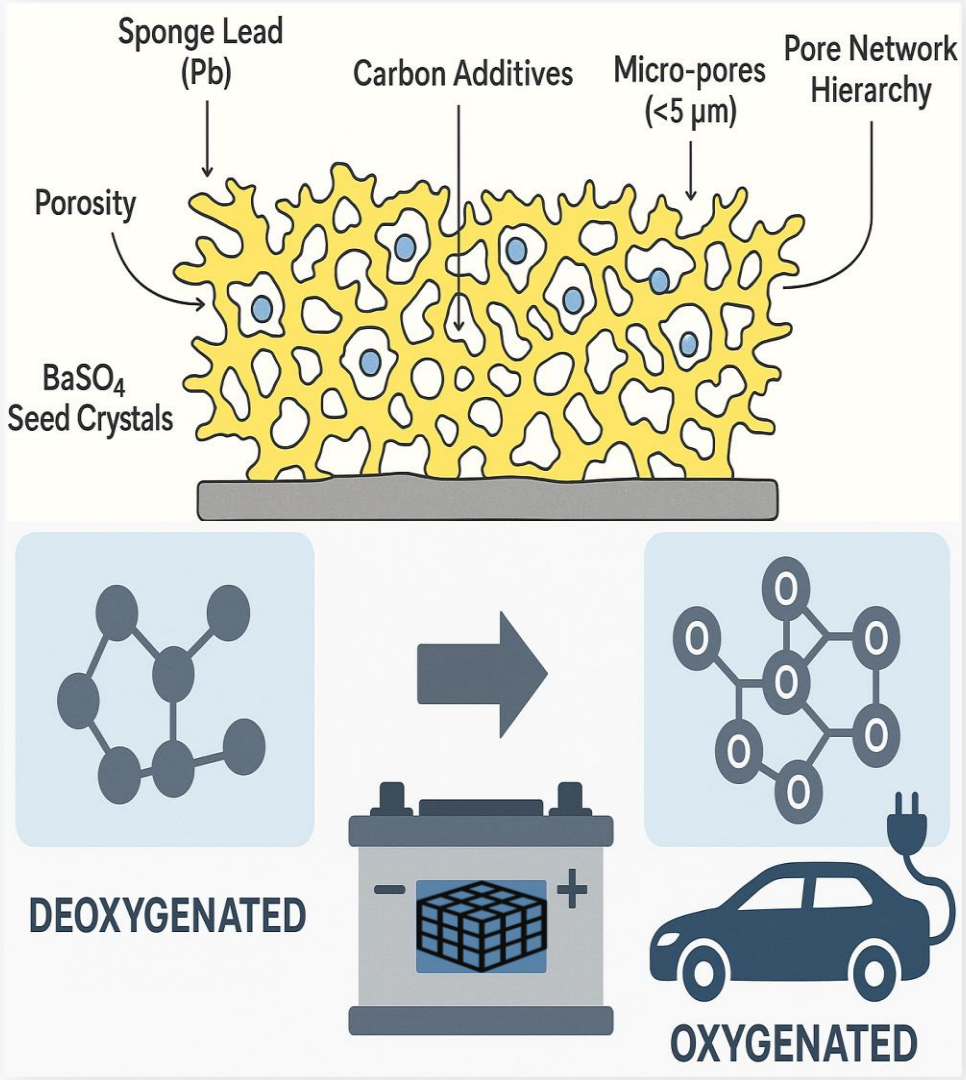


- **σ / π** (Bonds)



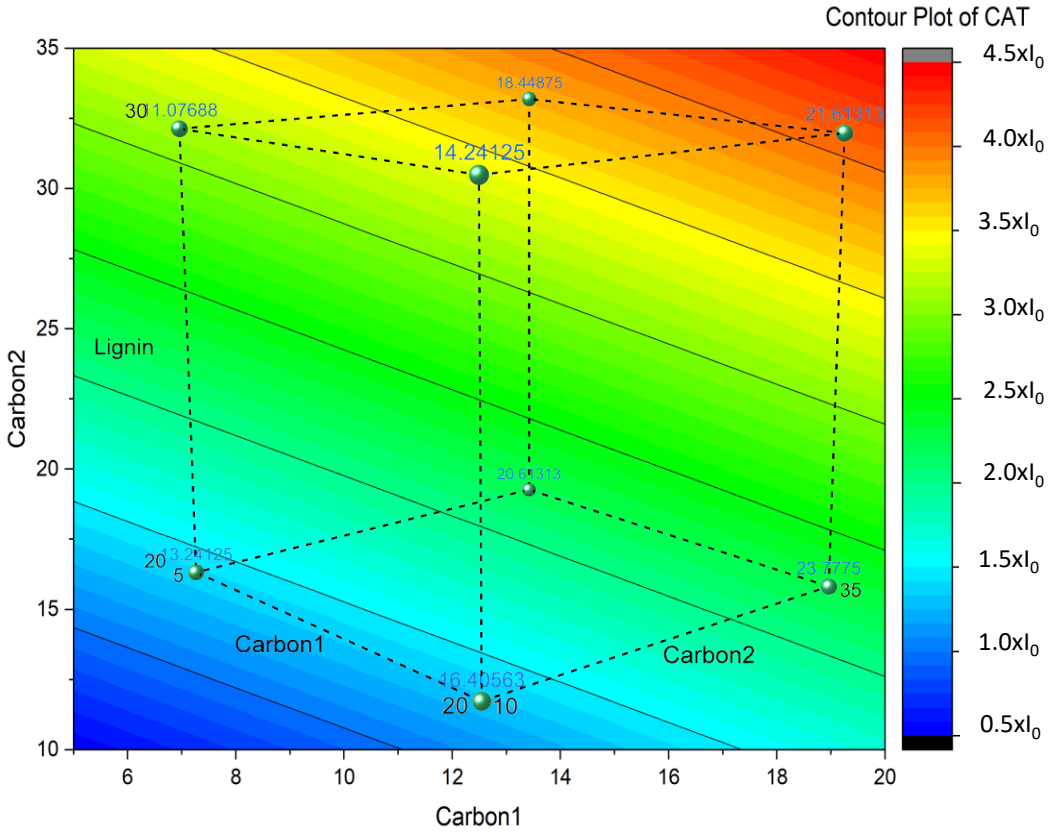
Ref:
1. Carbon allotropes: (https://doi.org/10.1002/jctb.1693)
2. *Sp²* and *Sp³* Hybridized Carbon (https://doi.org/10.1002/adma.202310422)

Development of new formulation - CA



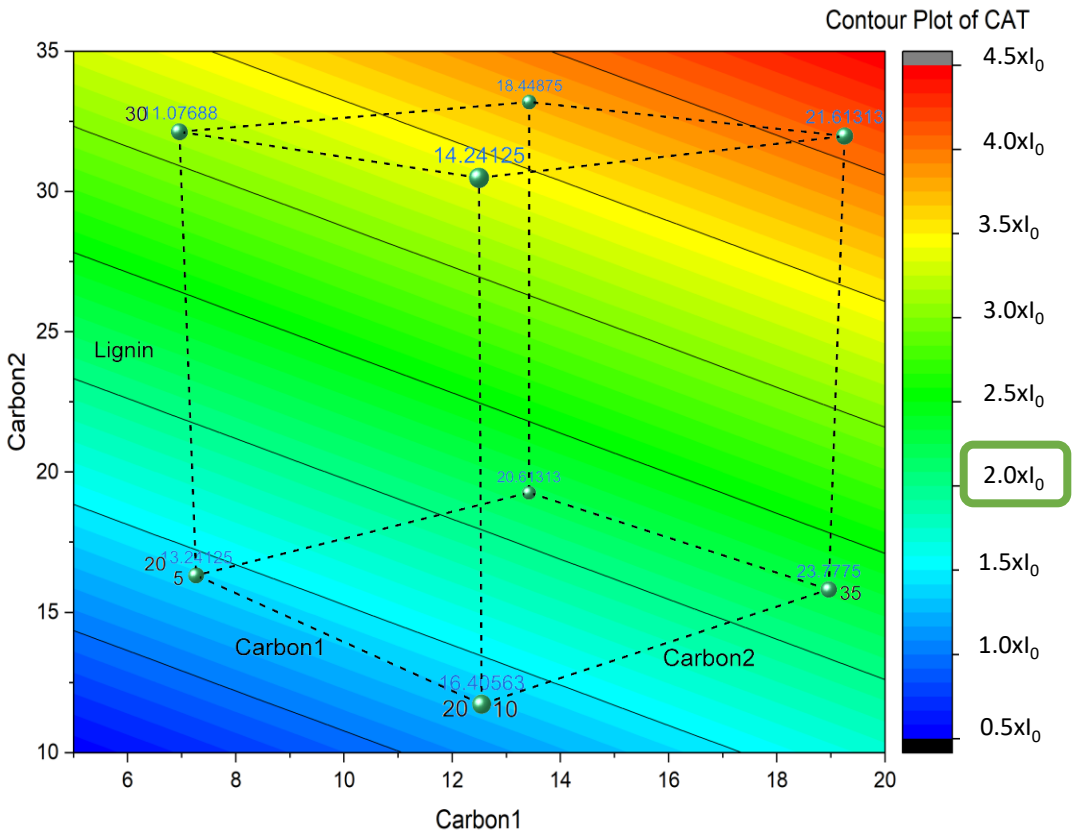
- NAM Additives (BaSO4, Lignin & Carbon)
- Functional groups
- Hybridization (Sp^2 / Sp^3)
- Ionic / Electronic Conductivity
- Surface Area Characteristics
- Thermal Stability

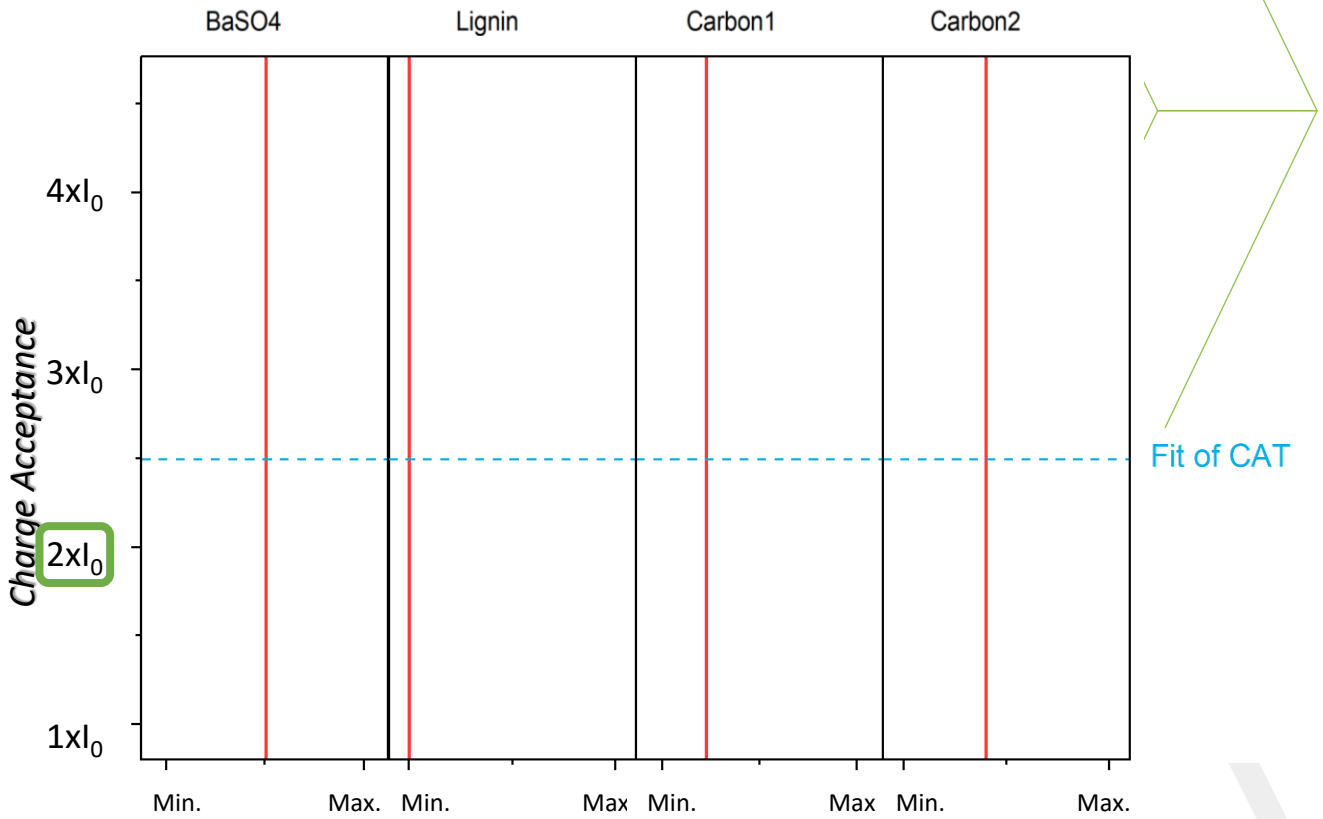
DoE - Optimum Solution



DoE Run: Design → Analyze → Optimization

DoE - Optimum Solution





DoE Run: Design → Analyze → Optimize

Approx.: BaSO4: ≤60%; Lignins: ≤30%; Carbon1: ≥2% & Carbon2: ≥8%

NAM Structure - Experimental

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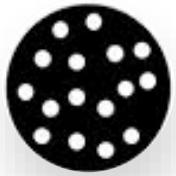
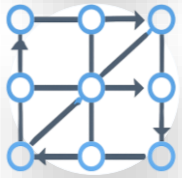
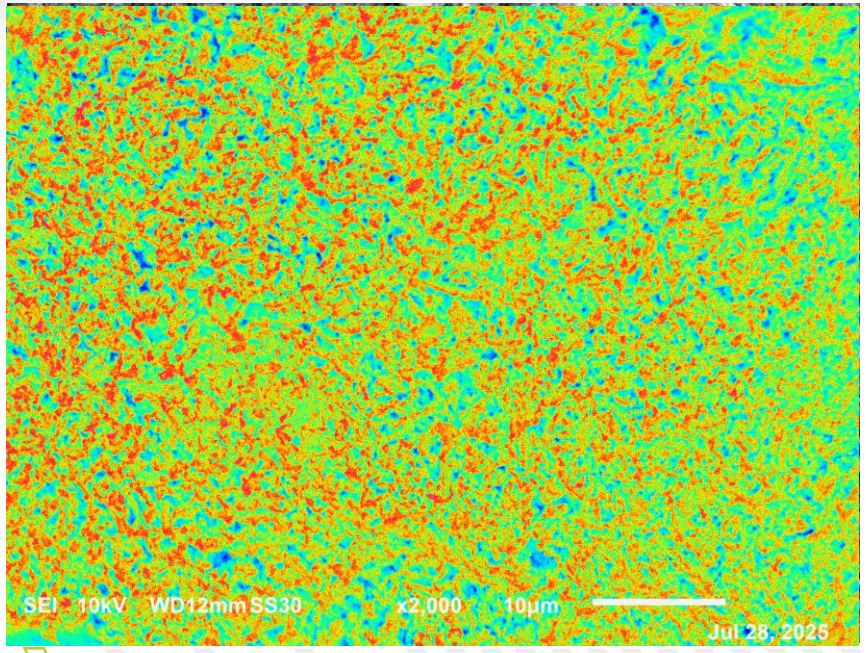
Control



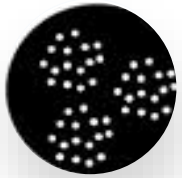
Macro



Anisotropic



Modified



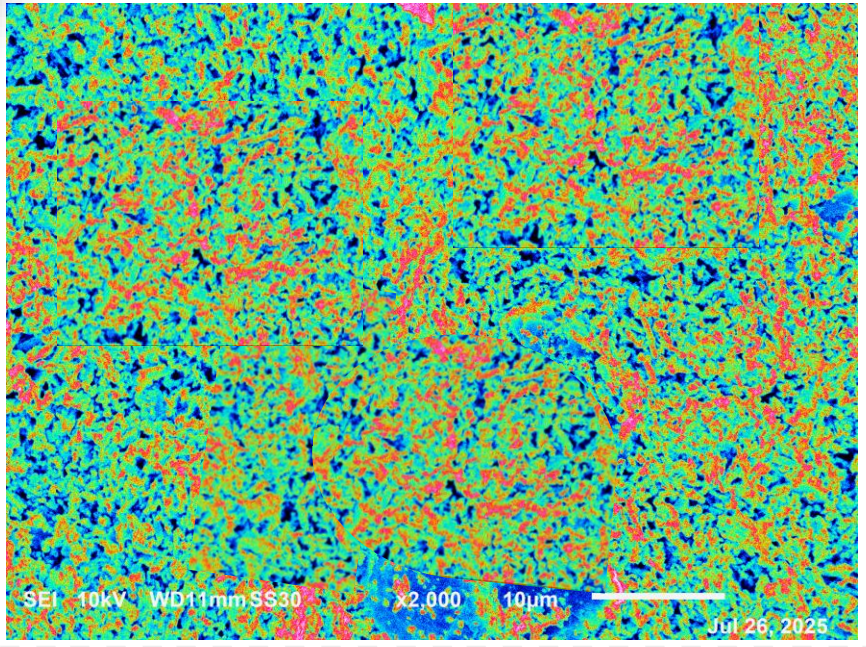
Meso

Isotropic

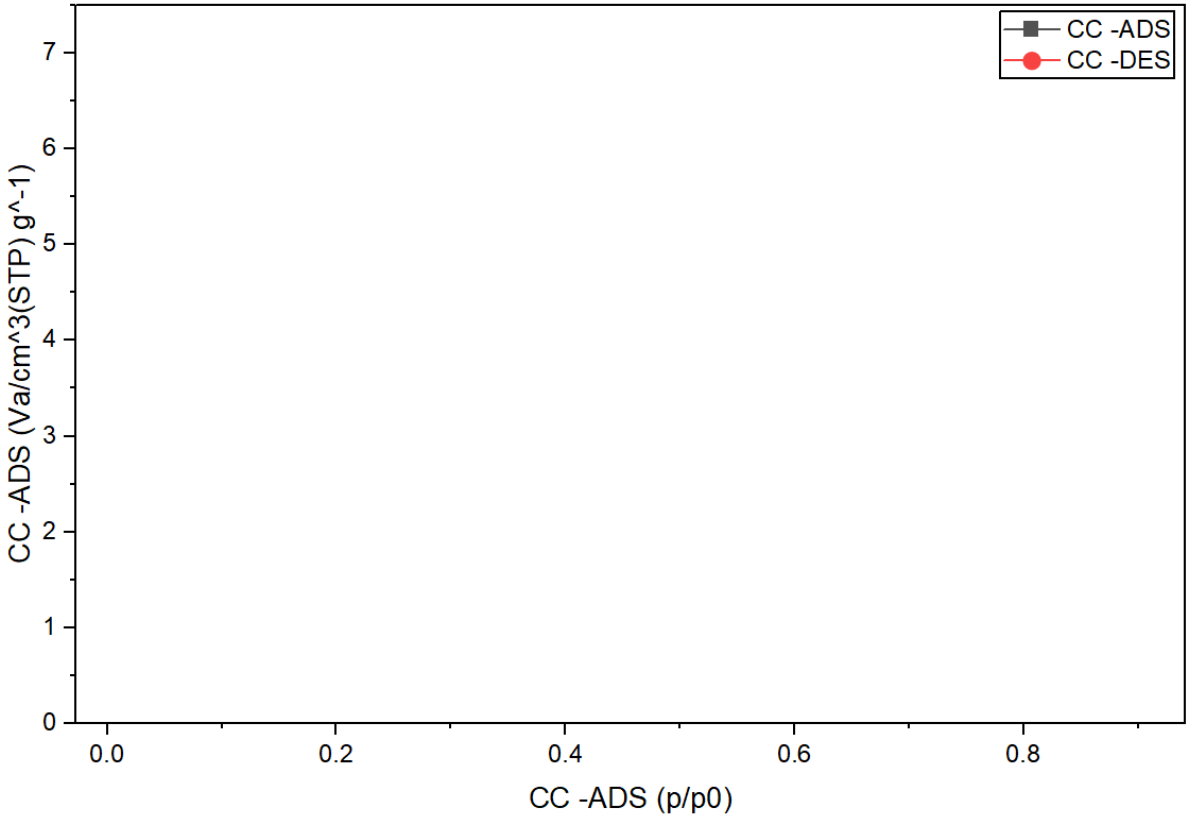
Conductive

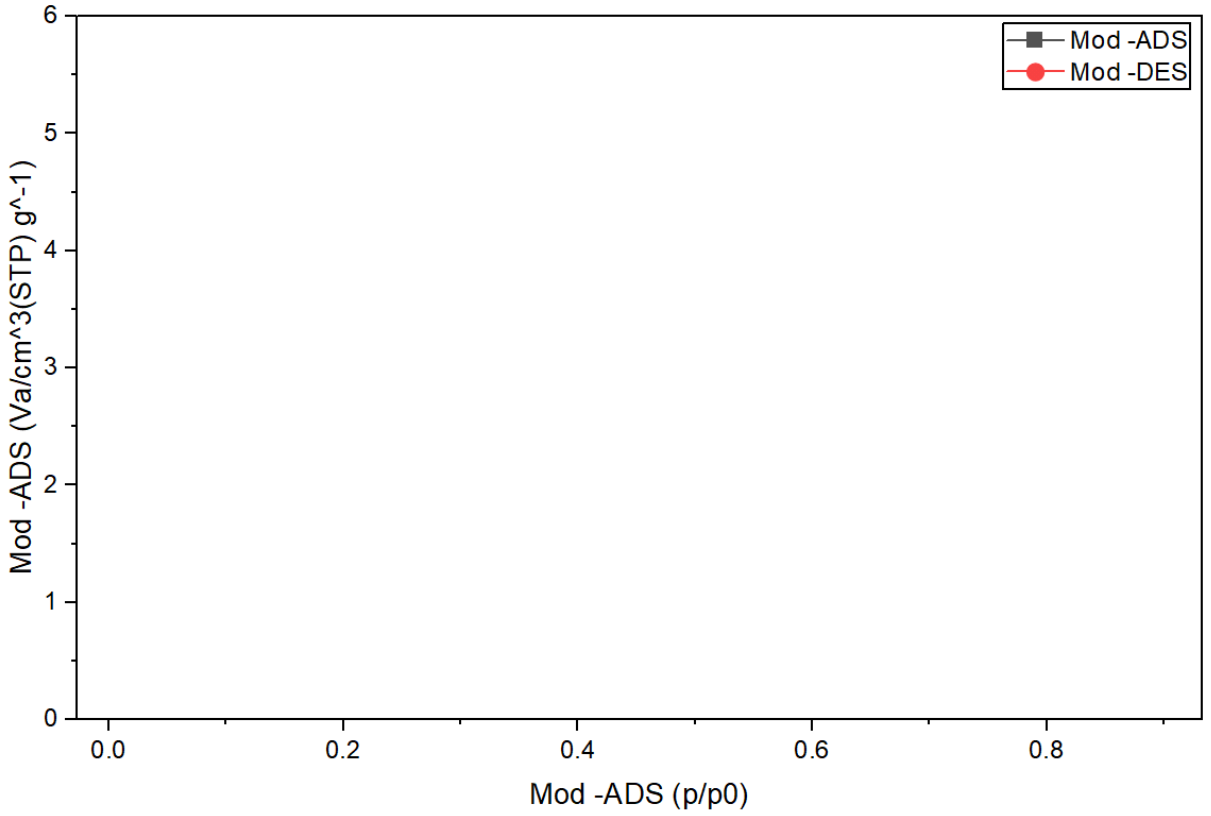
Reactivity Zone

Insulative



Results – Surface Isotherms

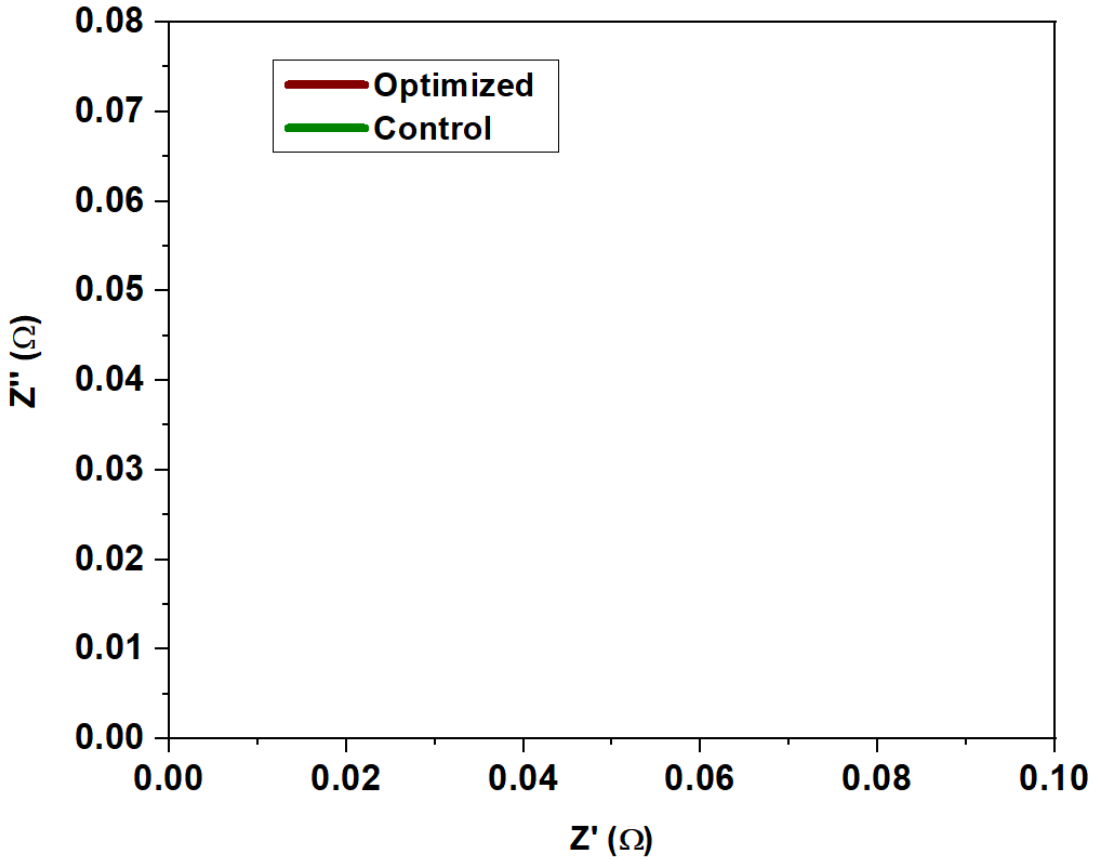


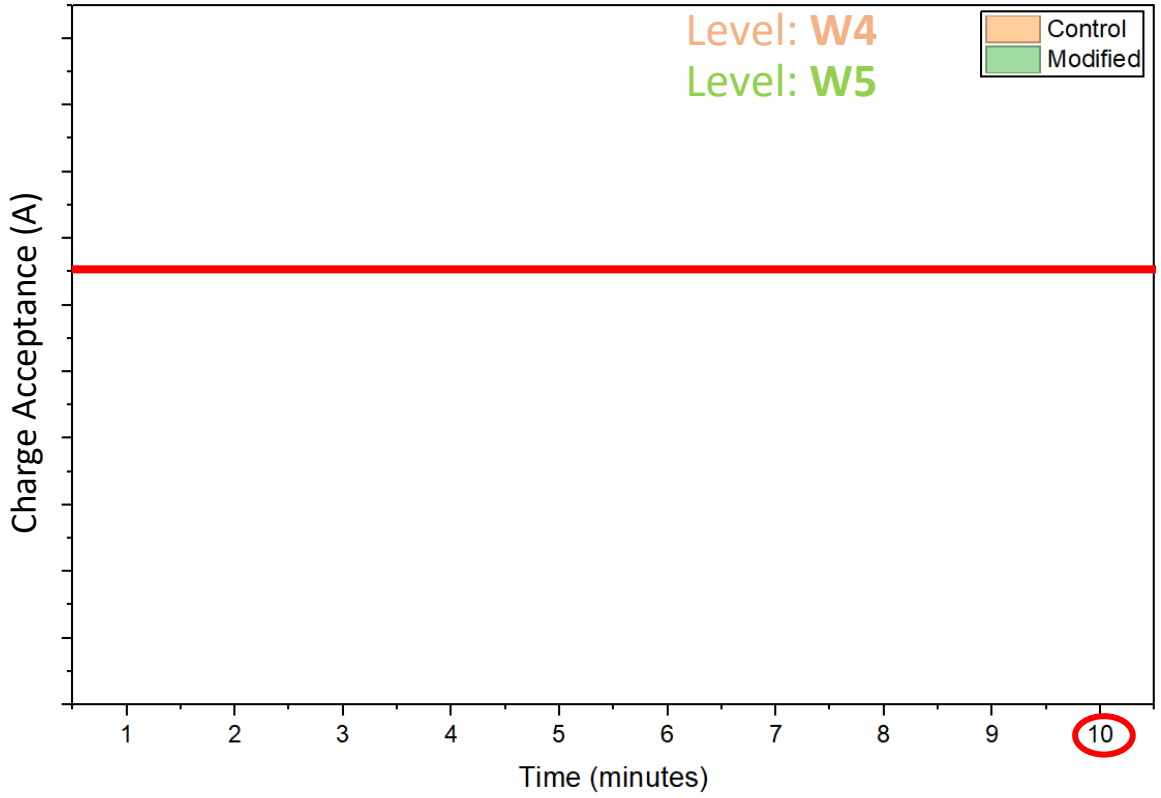


Adsorption /Desorption:

- Similar Surface area (p/p0: 0.2 – 0.4) in both control & modified
- Lowered pore volume leading to mesopore in the modified version.

Results - EC

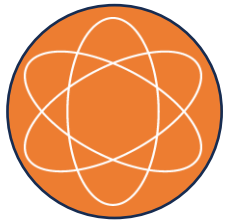




Modified NAM Electrode: R_{ct}: ~20%↓

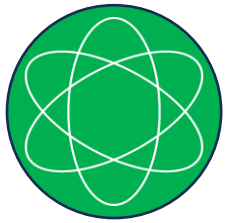
CAT: ~45% Higher & **WL**: ~25% Lower
(12V-AGM-65Ah)

Summary & Conclusion



NAM Optimized to achieve desirable performance

- Oxygenated / Deoxygenated influence the pore structure of NAM
- Hybridized carbons improve the electrodes isotropic network



Achieving the necessary performance makes Lead batteries a strong candidate for automotives as Low-Volt (12V-AUX) storage.

Acknowledgement

Sincere thanks to our management / staff & the conference organisers for giving the opportunity to present & represent the work we carriedout.

INDUSTRIAL

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AUTOMOTIVE 2W

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Thank You

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