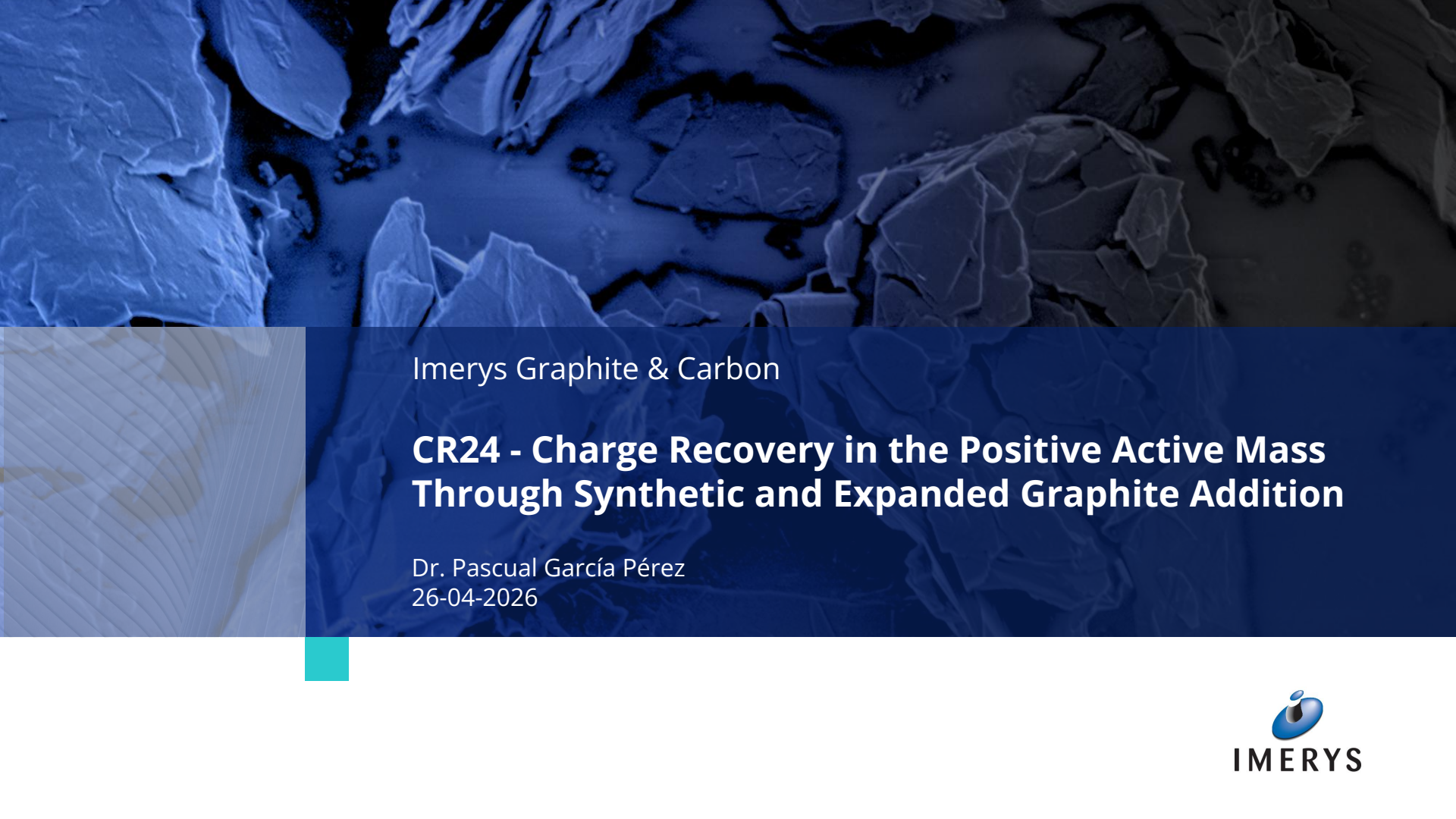


The background of the slide is a microscopic image of graphite flakes, showing their characteristic layered and flake-like structure. The image is tinted with a dark blue overlay. On the left side, there is a vertical rectangular inset showing a lighter, more detailed view of the graphite's surface texture, with a small teal square at its bottom.

Imerys Graphite & Carbon

CR24 - Charge Recovery in the Positive Active Mass Through Synthetic and Expanded Graphite Addition

Dr. Pascual García Pérez
26-04-2026

CR24 - Charge Recovery in Positive Active Mass Through Graphite Addition

Graphite Properties: Assumptions and Expectations



Based on previous studies*, focus on **synthetic** and **expanded** graphite



Graphite remains, at least partially, in the positive plate **after formation**



Increase electrical conductivity, reducing formation time and energy

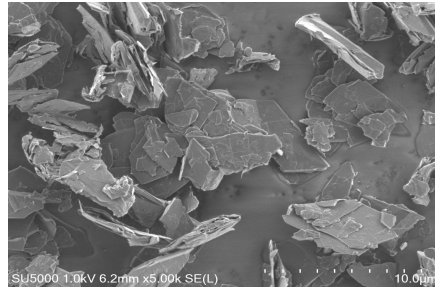


PAM microstructure modification (specific surface / pore size) increasing reactivity and active material utilisation

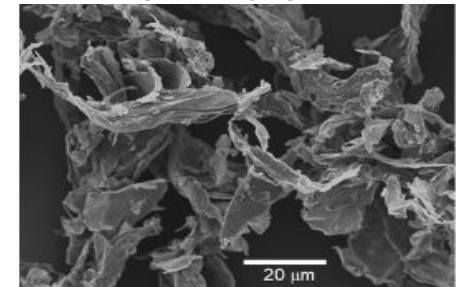


Improve capacity and **State of Function (SoF)** on **Charge Recovery** test for auxiliary batteries

Synthetic graphite



Expanded graphite



Carbon type	Synthetic Graphite				Expanded Graphite	
Product	KS 15	KS 44	KS 150	KS 500	BNB 90	BNB 30
BET (m ² /g)	12	9	6	5	22	25
Particle size d ₉₀ (microns)	15	45	150	570	105	35

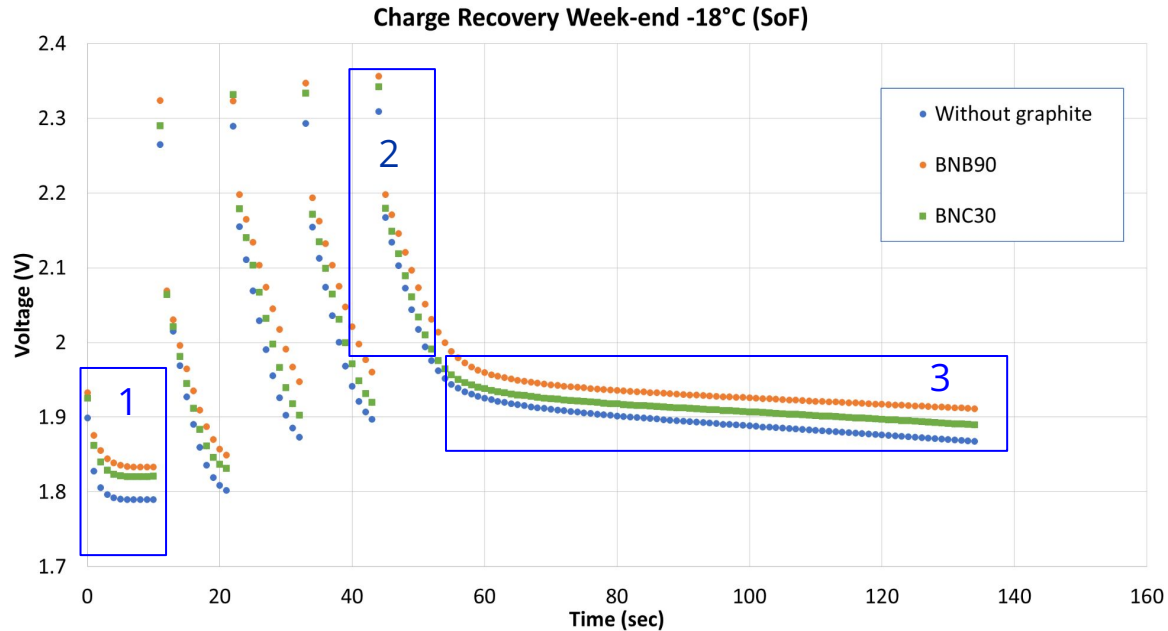
*References

- J. Kosack, "Studying The Effects Of New Additive Materials For The Improvement Of The Capacity And Cycle Life Performance Of The Lead-Acid Battery" (2021), PhD thesis, 3190.
- Effect of innovative carbon additives in the positive active mass of absorbent glass mat lead acid battery, M. Cattelana, et al., Electrochimica Acta 512 (2025) 145537
- Lead-Acid Batteries - Science and Technology, D. Pavlov, 2011, ISBN: 978-0-444-52882-7

CR24 - Charge Recovery in Positive Active Mass Through Graphite Addition

Results and Next Steps

- **Addition of graphite leads to formation optimization as well as capacity and cold cranking performance improvement**
- **Charge recovery** trials under the applied protocol and conditions show:
 - Different SoF behavior in function of **synthetic graphite** particle size (KS500 < KS15 < **KS44**)
 - **Optimal performance** for **BNB 90** expanded graphite (improved pseudo-capacitance slope and plateau)



Charge Recovery in Positive Active Mass Through Graphite Addition

Graphite Properties: Assumptions and Expectations



Based on previous studies*, focus on **synthetic** and **expanded** graphite



Graphite remains, at least partially, in the positive plate **after formation**



Increase electrical conductivity, reducing formation time and energy

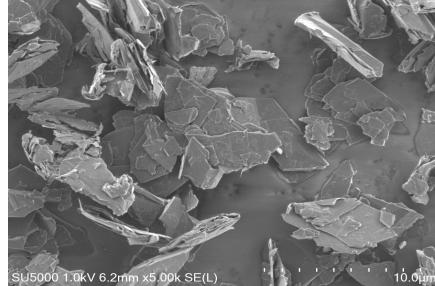


PAM microstructure modification (specific surface / pore size) increasing reactivity and active material utilisation

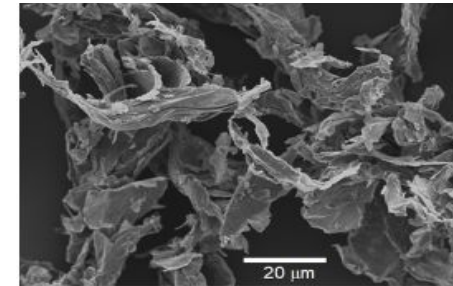


Improve capacity and **State of Function (SoF)** on **Charge Recovery** test for auxiliary batteries

Synthetic graphite



Expanded graphite



Carbon type	Synthetic Graphite	Expanded Graphite
Structure (crystallinity)	High crystallinity	High crystallinity
Surface area (BET)	Low / High BET	Low BET
Size (PSD)	Microns	Microns

*References

- J. Kosack, "Studying The Effects Of New Additive Materials For The Improvement Of The Capacity And Cycle Life Performance Of The Lead-Acid Battery" (2021), PhD thesis, 3190.
- Effect of innovative carbon additives in the positive active mass of absorbent glass mat lead acid battery, M. Cattelana, et al., Electrochimica Acta 512 (2025) 145537
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Charge Recovery in Positive Active Mass Through Graphite Addition

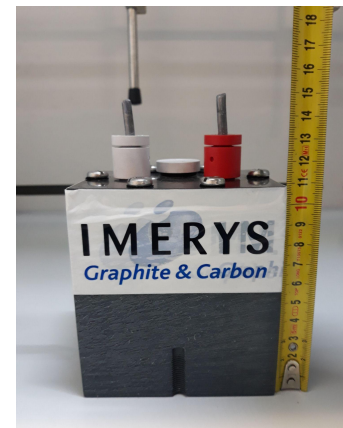
Graphite Addition: Carbon Type, Cell Design and Tests Procedures

Carbon type	Synthetic Graphite				Expanded Graphite	
Product	KS 15	KS 44	KS 125	KS 500	BNB 90	BNB 30
BET (m ² /g)	12	9	6	5	22	25
PSD d90 (microns)	15	45	125	570	105	35

Cell design and test procedures

- **Flooded 2V** cells with **H₂SO₄ excess** (d 1.24 g/cm³ H₂SO₄)
- **NPN Configuration**
 - **PAM additives & PbO:** Graphite (1.0%) ⇒ changes on graphite type
 - **NAM additive & PbO:** Total (1.5%) - Lignosulfonate (0.34%); BaSO₄ (0.66%); 0.5% Super C130 (Medium BET CB 135 m²/g)
- **Trials performed with different graphites**
 - C20 normalised - EN-50342-1 2015
 - Cold cranking normalised - EN-50342-1 2015
 - CR-weekend - IEC CD 60095-8 2024

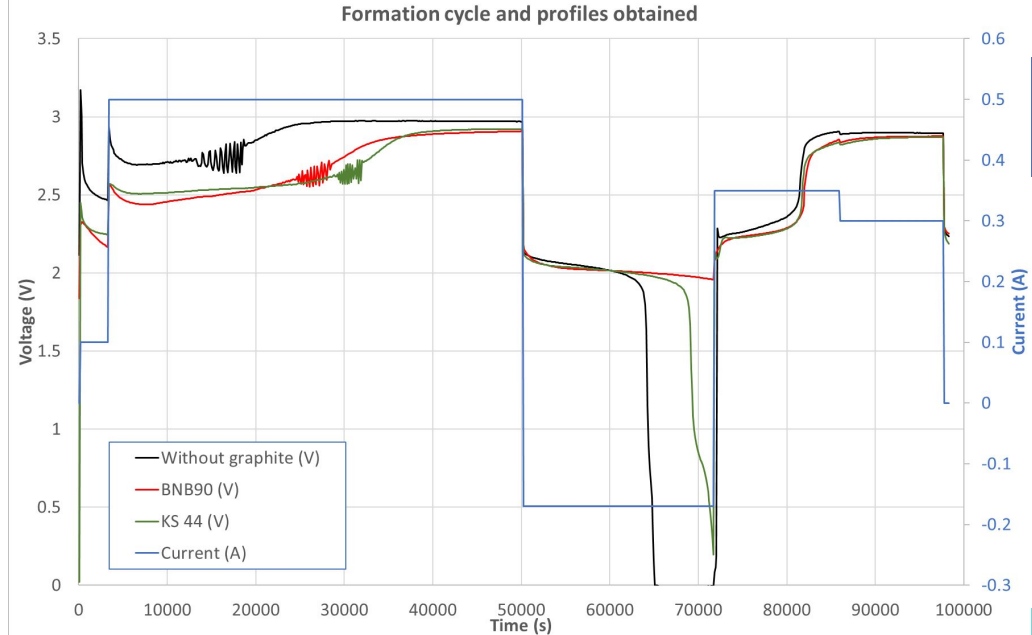
IMERYS lab cell size - 2V



Charge Recovery in Positive Active Mass Through Graphite Addition

Graphite Addition: Effect During Formation for 1% Graphite & PbO

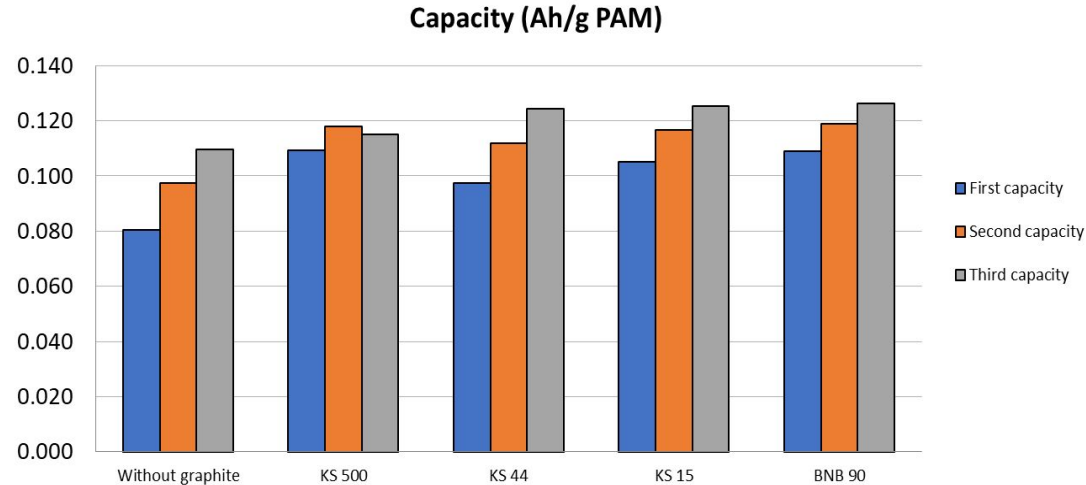
- **Optimised formation process:** cumulated current reduced from 12.9 Ah to 7.9 Ah (**cost and energy savings**)
- Cell with graphite in the PAM **maintains its potential longer over time**, compared to the cell without graphite during discharge step
- This suggests improved PAM formation when KS 44 graphite is added
- Best performance obtained with BNB90



Charge Recovery in Positive Active Mass Through Graphite Addition

Graphite Addition: Effect on Capacity for 1% Graphite & PbO

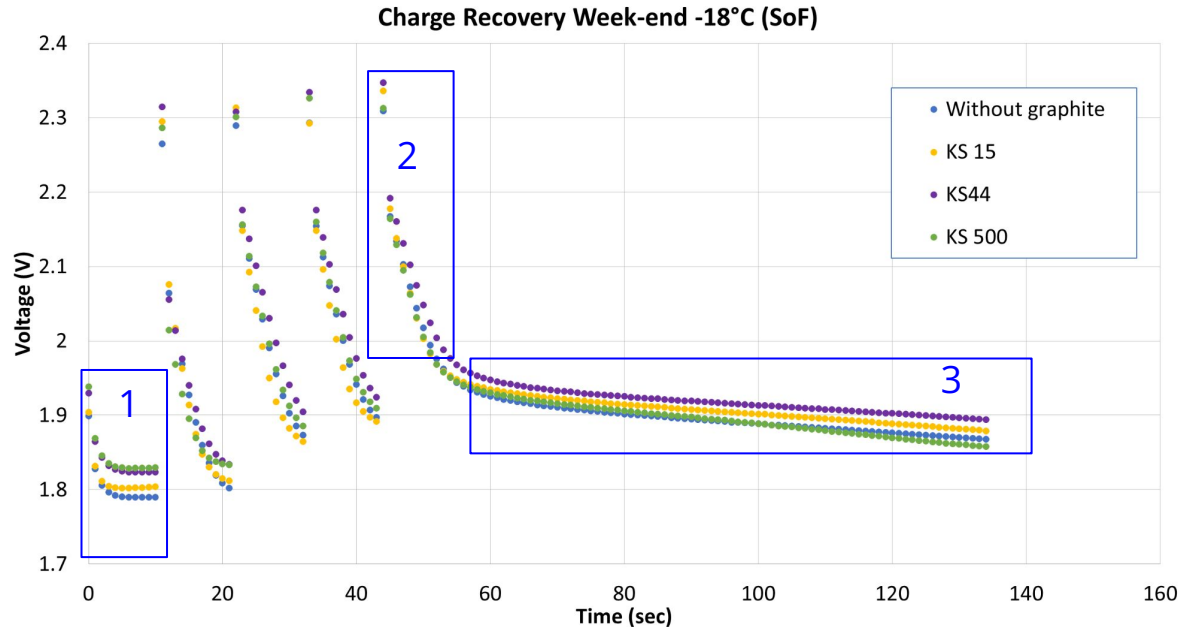
- PAMs with graphite show 20-40% higher initial C20 capacity compared to cells without graphite
- Improvement decreases after cycling but remains present through multiple measurements
- Large particle size (KS 500) shows the highest initial capacity but lower performance effect on third capacity
- Both synthetic and expanded graphite improve PAM formation efficiency and cell capacity



Charge Recovery in Positive Active Mass Through Graphite Addition

Graphite Addition: Effect on State of Function for 1% Synthetic Graphite & PbO

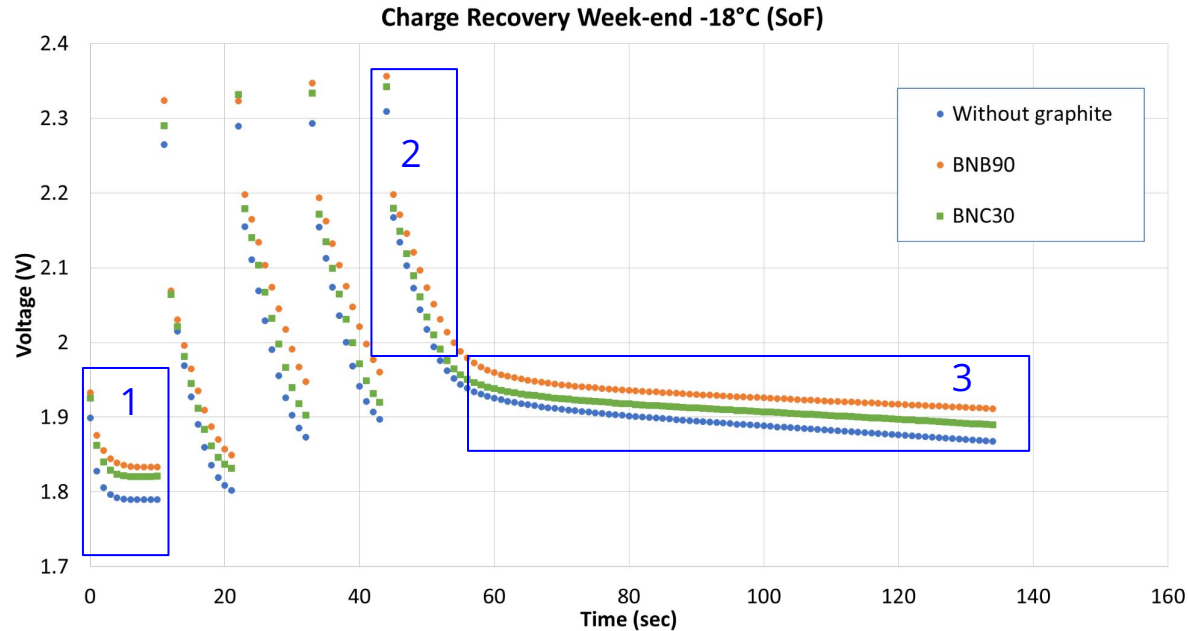
1. Higher voltage for the initial plateau at the first pulse
 2. Small difference in the slope for the final pulse
 3. Similar behavior on the plateau for synthetic graphite vs no graphite PAM
- PSD optimal seems to be placed on d90 around 45 microns
 - **Slightly better performance is observed when KS 44 is added to the PAM**



Charge Recovery in Positive Active Mass Through Graphite Addition

Graphite Addition: Effect on State of Function for 1% Expanded Graphite & PbO

1. Different position for the initial plateau at the first pulse
 2. Different slope - pseudo-capacitance for Timrex BNB 90 for final pulse
 3. Lower drop on potential plateau with BNB90
- **BNB 90 expanded graphite shows:**
 - Different slope for pseudo-capacitance
 - Lower voltage drop on the plateau improving the SoF performance



Charge Recovery in Positive Active Mass Through Graphite Addition

Conclusions and Next Steps

Conclusions

- Graphite addition increases formation efficiency, while improving capacity and cold cranking performance
- Charge recovery trials under the applied protocol and conditions show:
 - SoF behavior depends on synthetic graphite PSD $\Rightarrow$ optimal performance for KS 44
 - Best performance for BNB 90

Next steps and suggestion

- **Effect of synthetic and expanded graphite grades on PAM performance should be further studied**
- Potentially synergetic effect: enhanced NAM (high BET CB) combined with PAM incorporating graphite
- Effect of lowering graphite concentration to 0.5% within PAM



IMERYS

28.04.2026 | CR24: Charge Recovery in Positive Active Mass Through Synthetic and Expanded Graphite Addition

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Thank you for your time

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