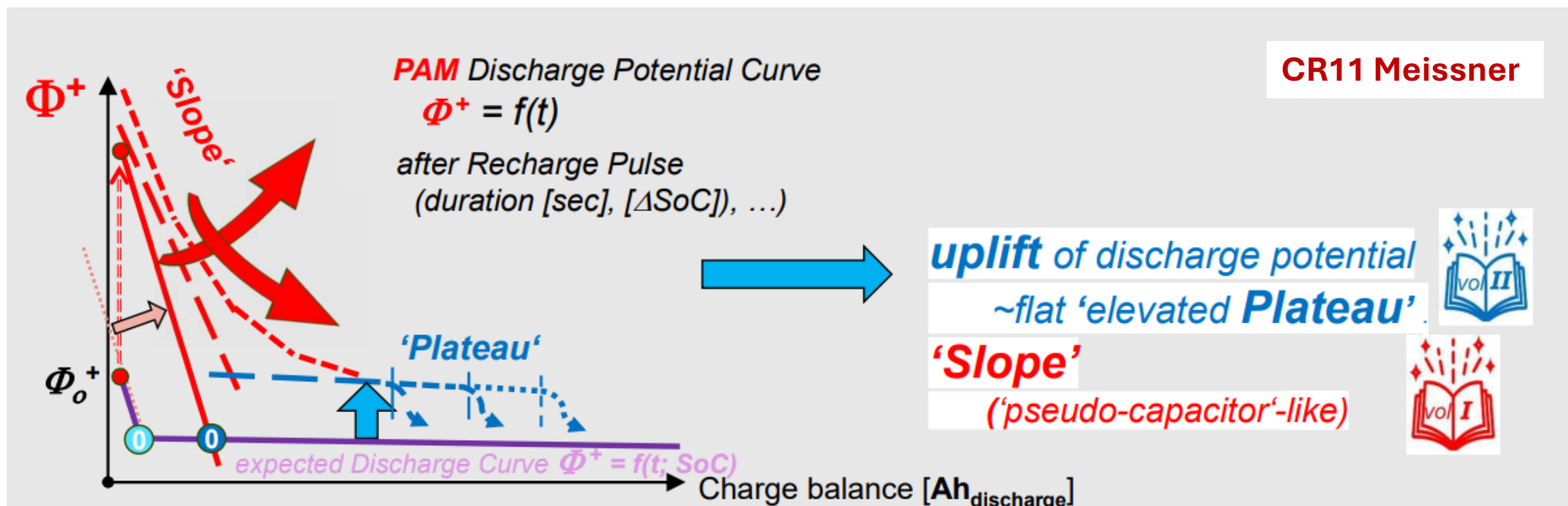


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Pseudo-capacitor-like discharge voltage profile
'**Slope**' in Charge recovery

CR11-CR19: mechanisms & structures
CR21-CR29: optimizations



May 7, 2026

Jibo Zhang
John Wertz
Hollingsworth & Vose

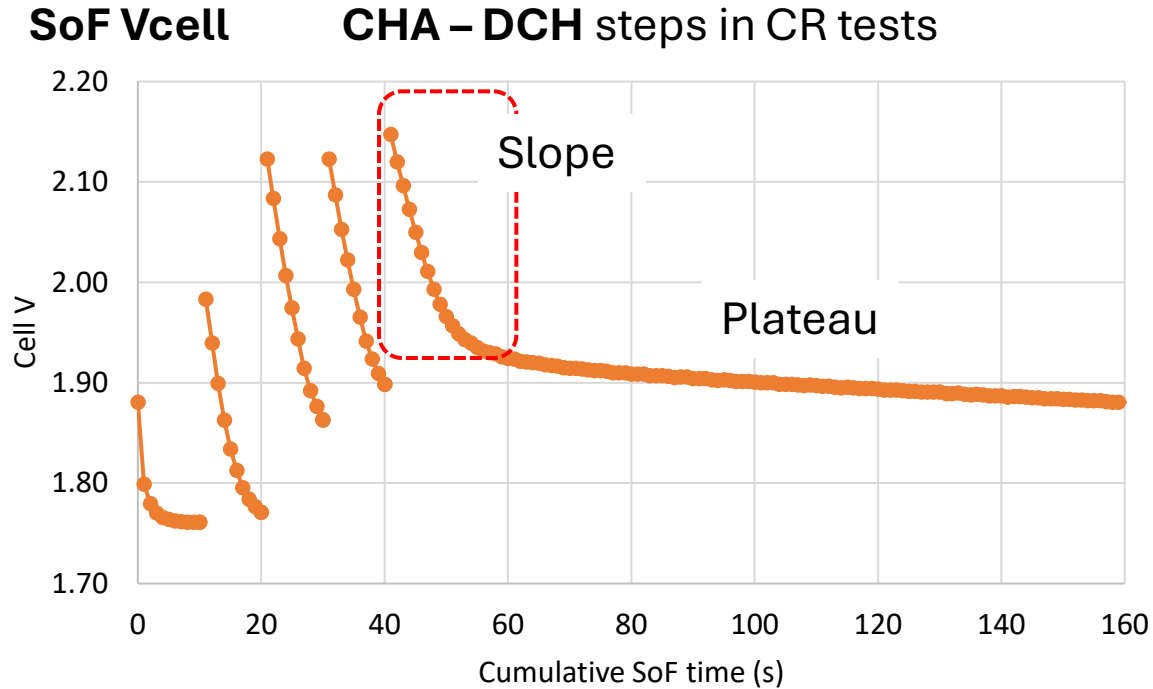
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Outline

1. Representative experimental observations and
Benefits of “pseudo-capacitance” in CR
2. Mechanism behind the phenomenon

1. Representative experimental observations

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SoF = U at 10s

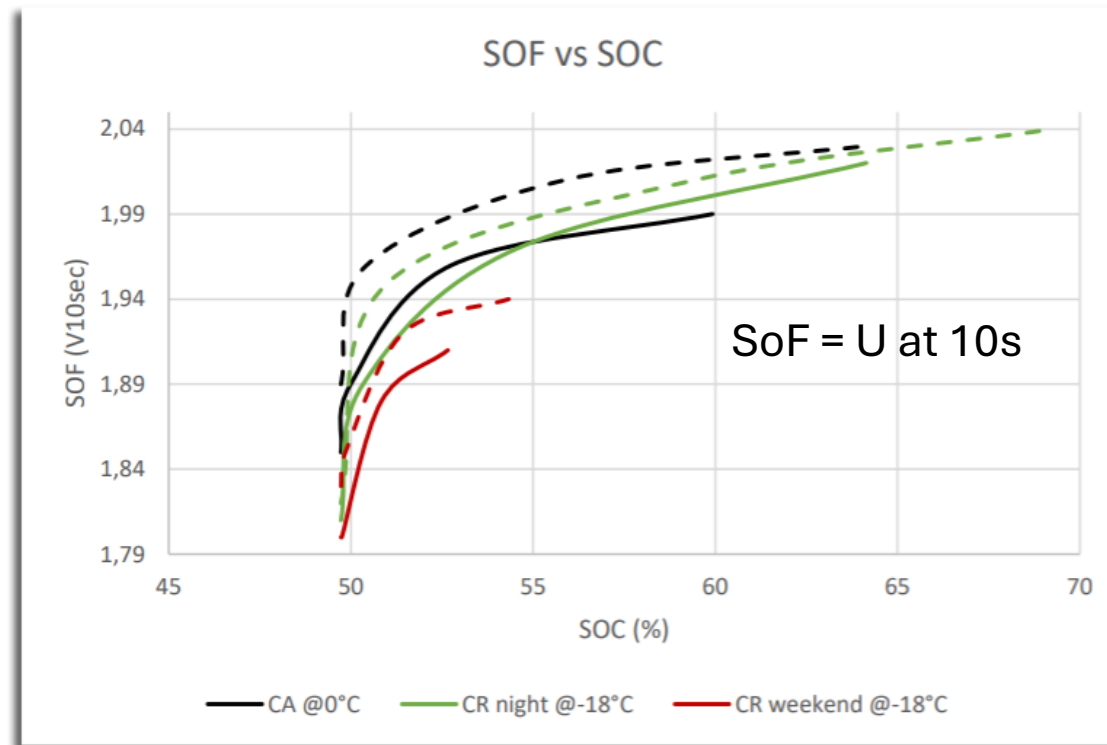
- A fast voltage decay region with $C = dQ/dU$ -like profile
- Much higher capacitance than double-layer (~ 30 - 40 uF/cm^2)
- Pseudo-capacitance involves charge transfer (Faradic) process

1. Representative experimental observations

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**CR08 Rocha
ALBA2024**

SoF recovers much faster than SoC!

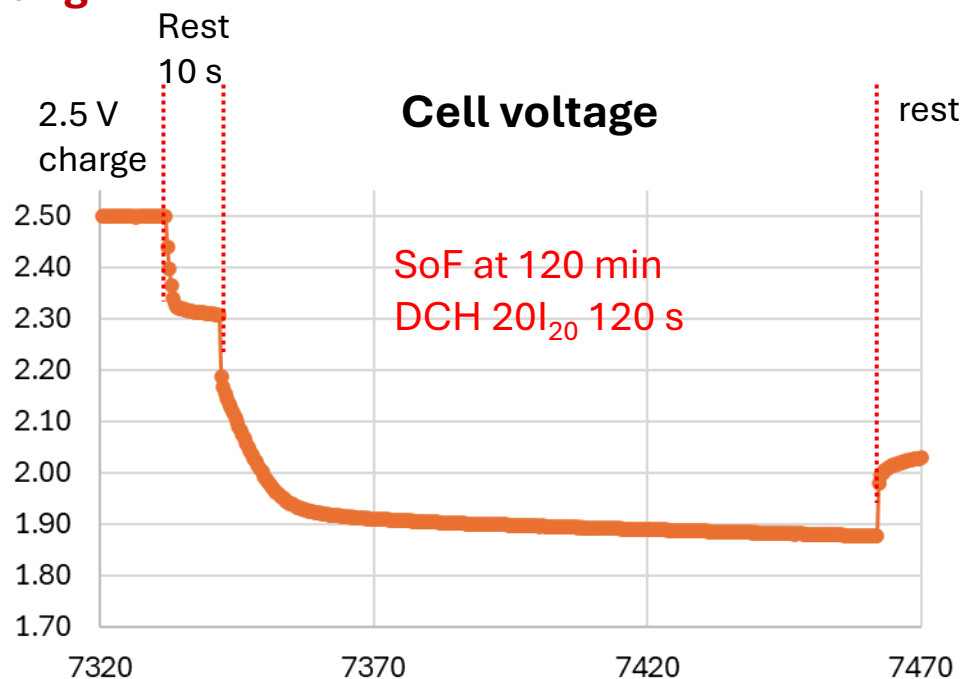


Fast recovery of SoF is essential to recover a battery's function.

SoF is benefiting from “slope”

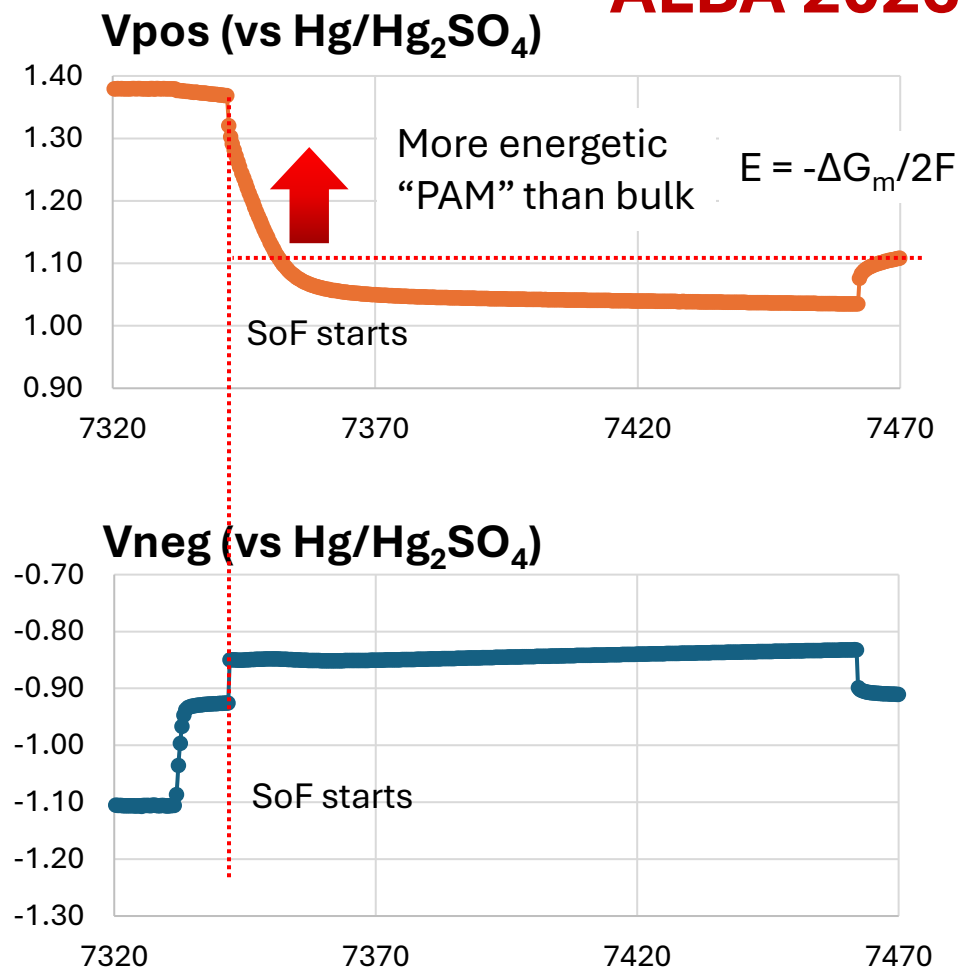
1. Representative experimental observations

CR26 Zhang



- Discharge of pseudo-capacitance in SoF
- Positive dominates the capacitor profile
- Apparently, PAM “holds” high energy (polarizations) from charging

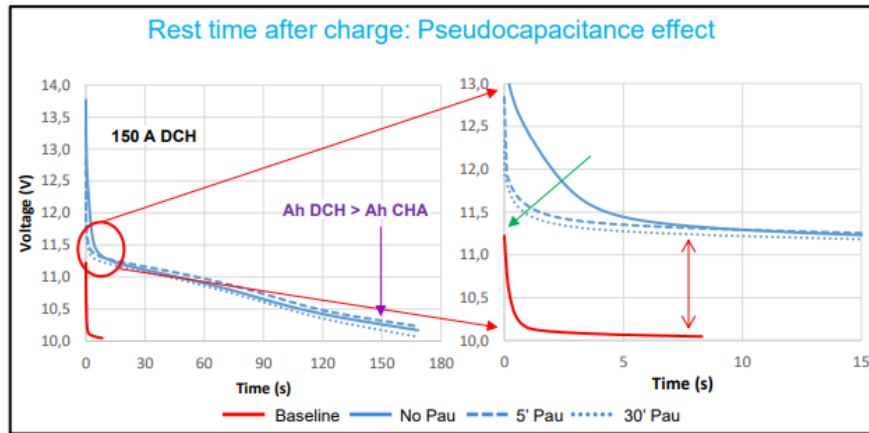
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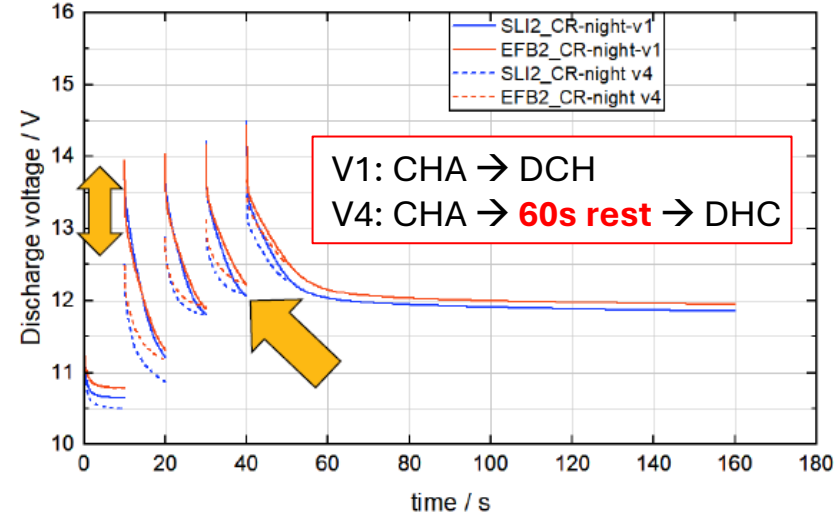
1. Representative experimental observations

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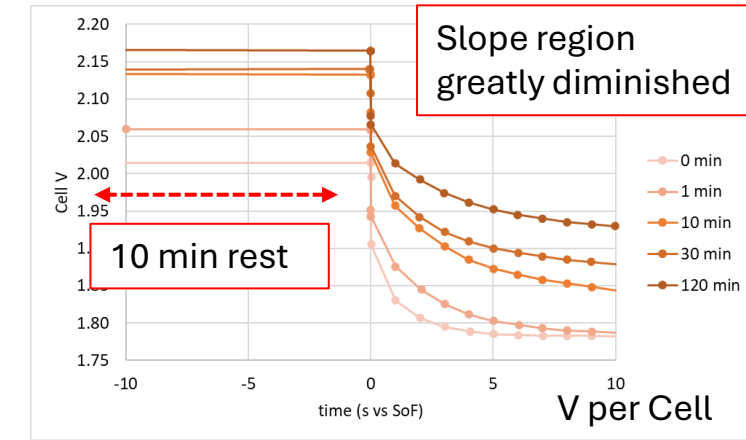
CR13 M Garcia



CR17 Settelein



CR26 Zhang



SoF Energy = Ah * V: **OCV rest lowers V, NOT Ah (non-Faradic self reorganization)**

- The pseudo-capacitance-based capacity can diminish after rest, ~ minutes
- Long discharge profile more dependent on “bulk” PAM: **Plateau uplift**

$$dG = Vdp - SdT + \mu dN$$

Enthalpy Entropy

Energy per “PbO₂” redox =
P electrode voltage

2. Mechanism behind the phenomenon

CR11 Meissner

CR11: PbO₂ Structure and SoF Recovery: bottom-up analysis and hypotheses

C.I Mechanisms behind 'pseudo-capacitance' Slope

a) .. PSEUDO-Capacitor has two INDEPENDENT dimensions !

- (i) "Size C" of capacitance [F], related to total surface area of all types of PbO₂ material
- (ii) "SoC" of capacitance [%], related to actual potential $\sim (\Phi^+ - \Phi^+_{\circ})$



↑ Size C: more pseudo-capacitors

- Referring to fresh/finer PAM: **PAM structure and SoC optimizations: sensitive to P electrode polarizations**
- Time is critical, finer PAM spontaneously reorganizes to larger particles

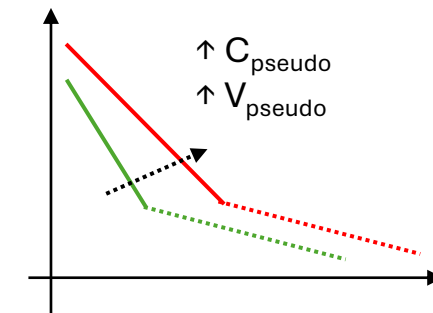
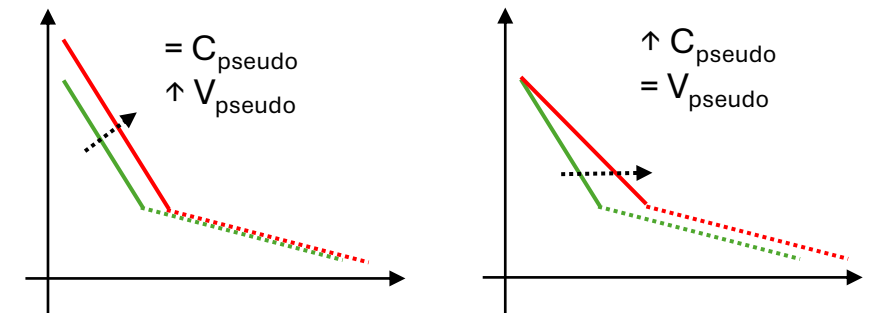
↑ SoC of C: charging the pseudo-caps to high V

- $dU = C \cdot dQ$, higher V_{pos} during charging, higher energy stored: **P electrode polarizations**
- V_{neg} limits V_{pos} in a CV charging step

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CR11-CR19: mechanisms & structures

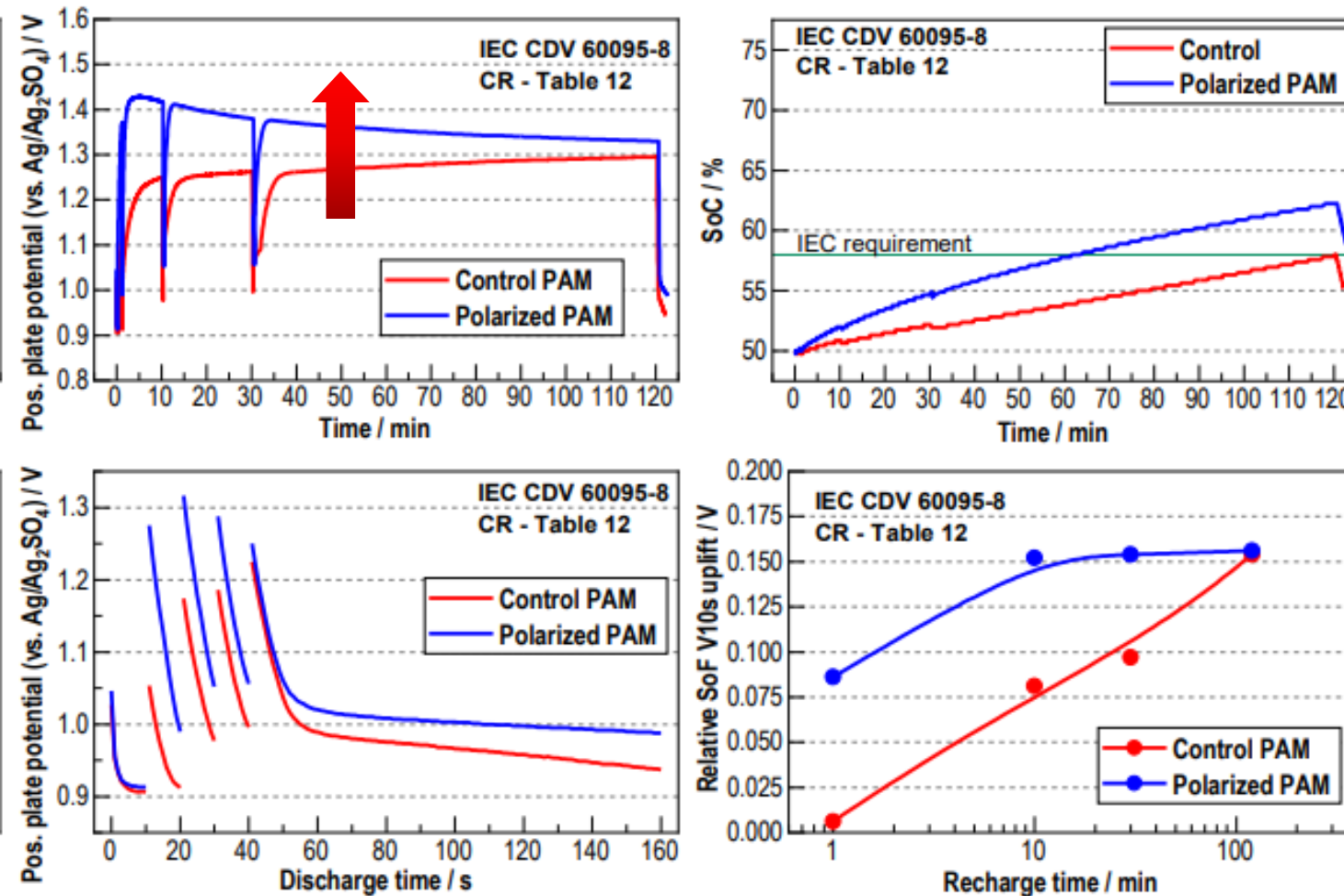
CR21-CR29: optimizations



2. Mechanism behind the phenomenon

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CR18 Nikolov



PAM polarization benefits SoF (pseudo-capacitance)

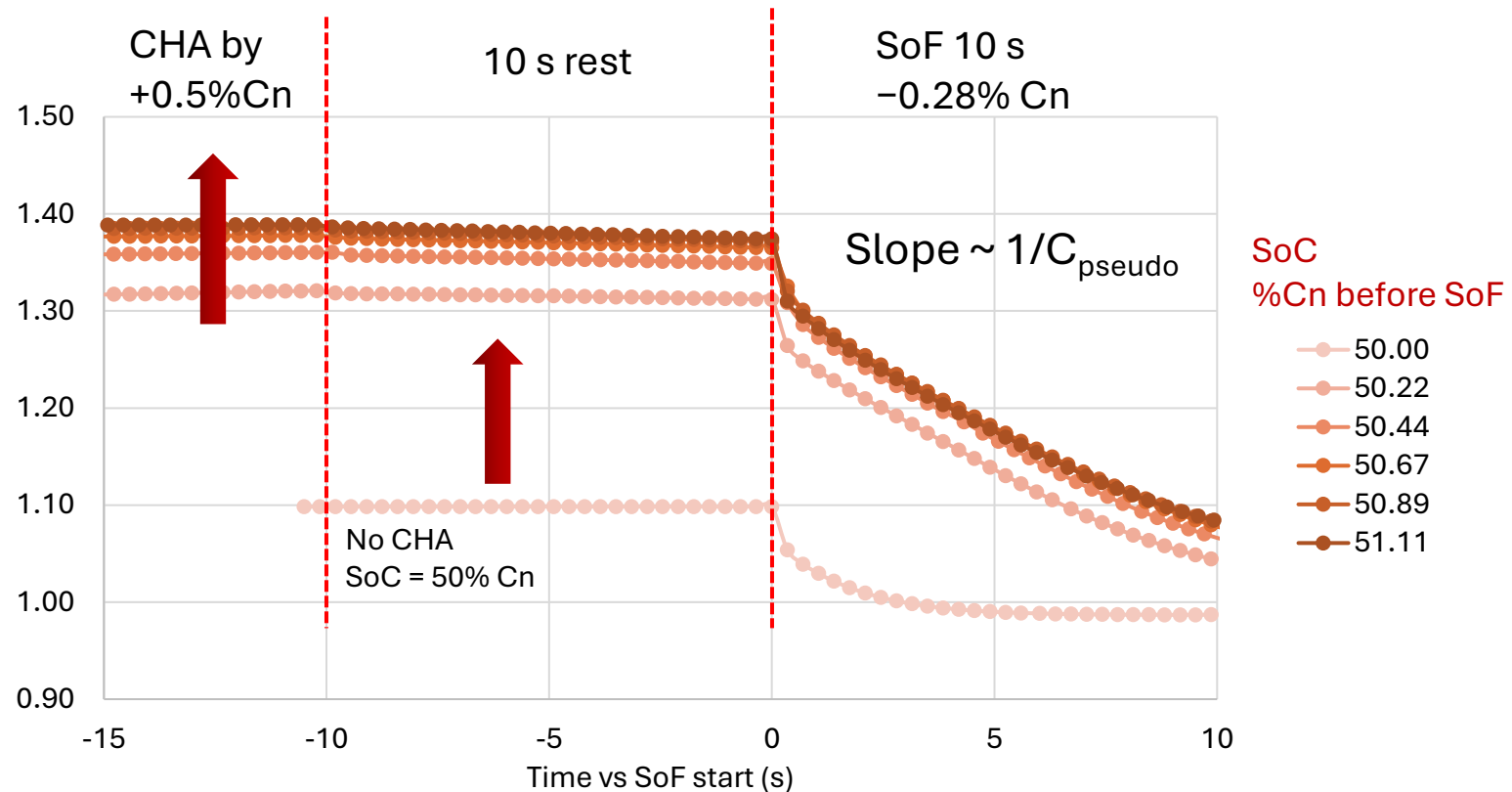
- High PAM polarization results in higher SoF recovery within same time
- Rest before SoF suppressed pseudo-capacitance

2. Mechanism behind the phenomenon

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CR26 Zhang

V_{pos} (vs $\text{Hg}/\text{Hg}_2\text{SO}_4$)



Development of Pseudo-capacitance Slope highly depends on V_{pos}

- Positive electrodes “holds” the polarization from charging step
- More energetic “fresh PAM” than bulk, and capacitor-like behavior

Thank You!

Questions ?