Durability Testing of Polymer Electrolyte Fuel Cells Under Stationary and Automotive Conditions

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Contents

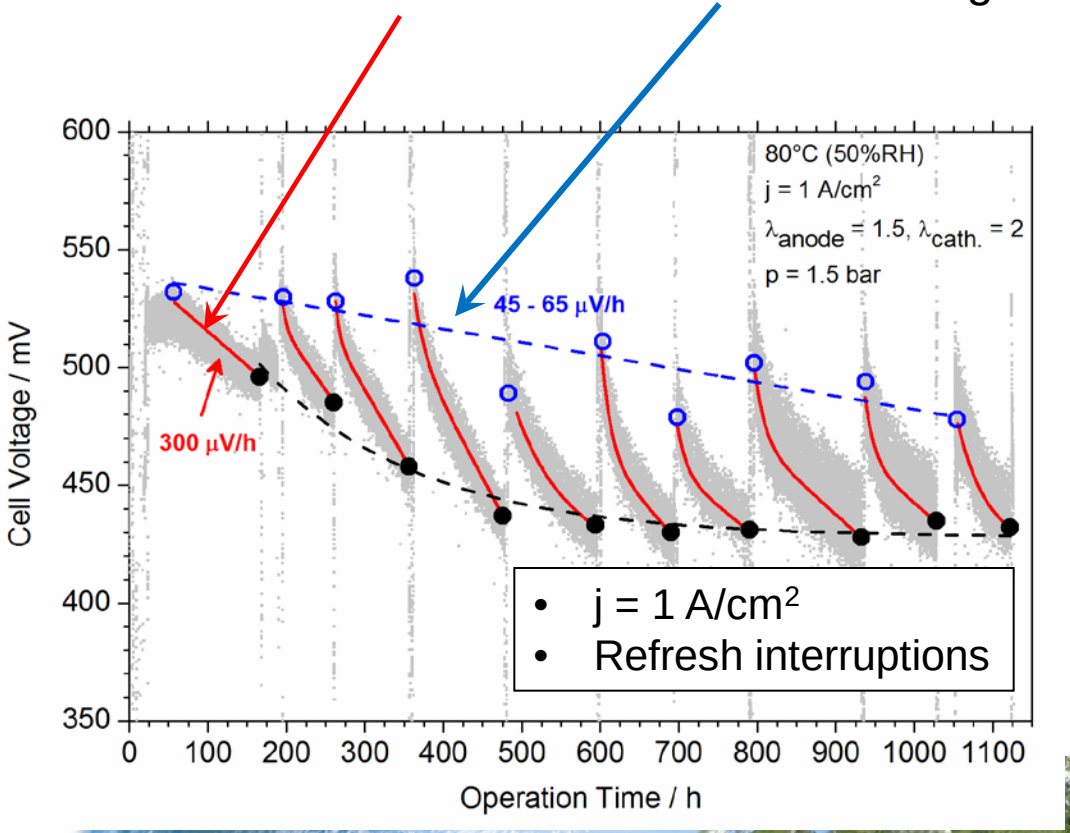
- Motivation
- Evaluation of irreversible degradation
- Evaluation of reversible degradation
- Recovery of reversible degradation
- Summary

Motivation

Performance targets clearly defined and well verifiable, BUT

determination of **degradation rates** is not well defined.
➔How to determine if **durability goals** are achieved?

Discrimination between **reversible** and **irreversible** degradation needed



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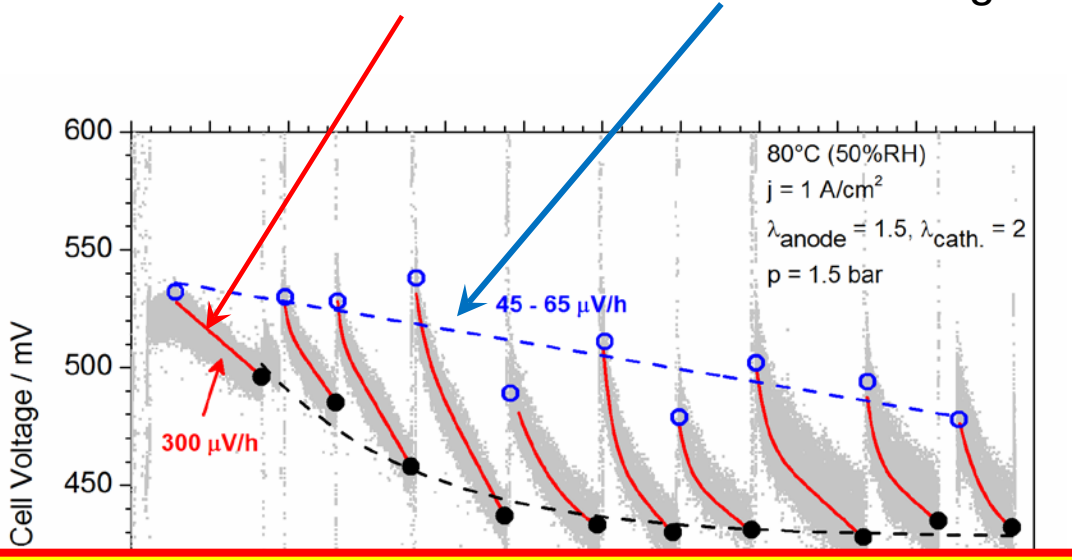
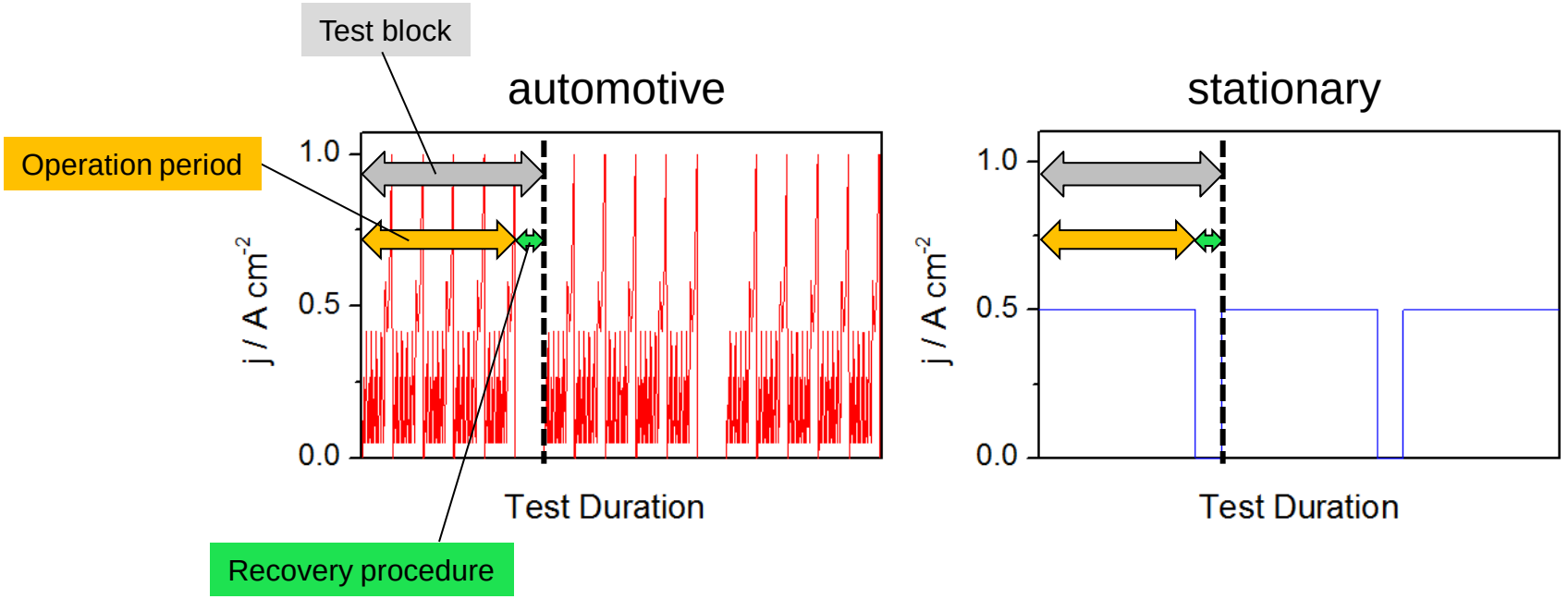


Questions:

1. How to describe reversible degradation?
2. How to determine irreversible degradation?
3. Does refresh procedure lead to full recovery of reversible losses?

Evaluation of irreversible degradation

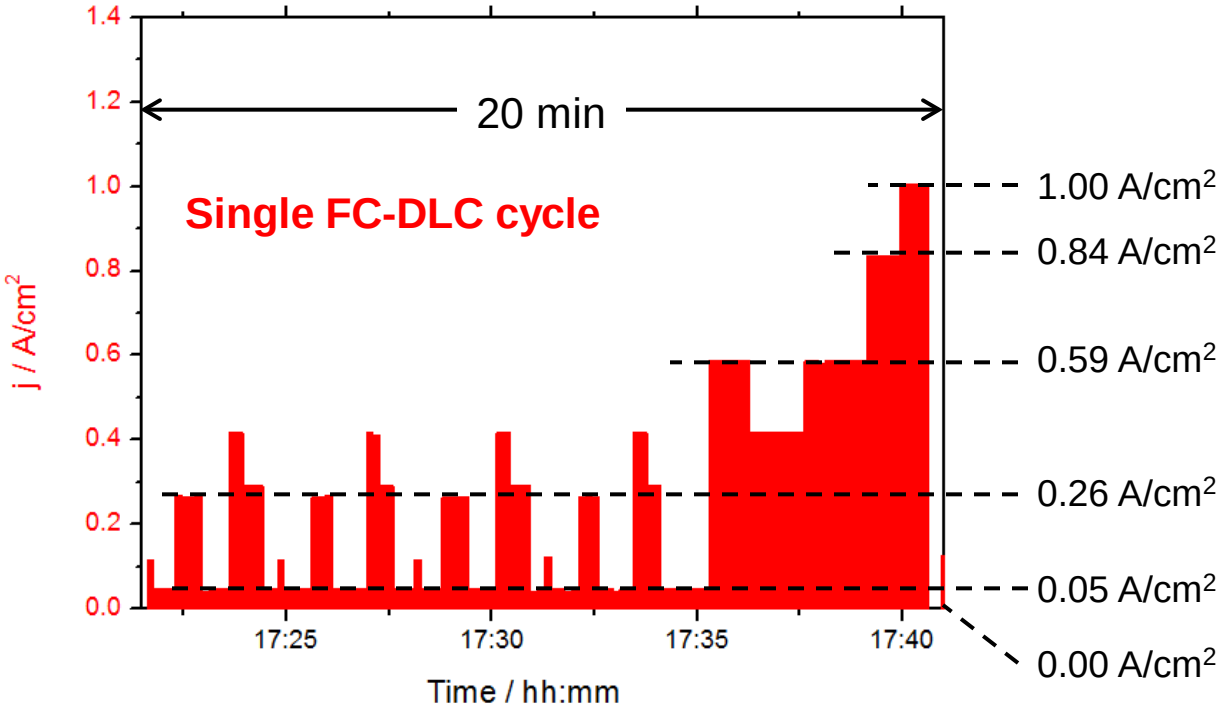
Durability tests consist of several test blocks of an **operation period** and a **recovery procedure**



Evaluation of irreversible degradation

FC dynamic load cycle (FC-DLC) according to FCH-JU StackTest project

➔ Automotive conditions



Step	Time [sec]	Dwell [sec]	Load [%]
1	0	15	0.0
2	15	13	12.5
3	28	33	5.0
4	61	35	26.7
5	96	47	5.0
6	143	20	41.7
7	163	25	29.2
8	188	22	5.0
9	210	13	12.5
10	223	33	5.0
11	256	35	26.7
12	291	47	5.0
13	338	20	41.7
14	358	25	29.2
15	383	22	5.0
16	405	13	12.5
17	418	33	5.0
18	451	35	26.7
19	486	47	5.0
20	533	20	41.7
21	553	25	29.2
22	578	22	5.0
23	600	13	12.5
24	613	33	5.0
25	646	35	26.7
26	681	47	5.0
27	728	20	41.7
28	748	25	29.2
29	773	68	5.0
30	841	58	58.3
31	899	82	41.7
32	981	85	58.3
33	1066	50	83.3
34	1116	44	100.0
35	1160	21	0.0

Evaluation of irreversible degradation

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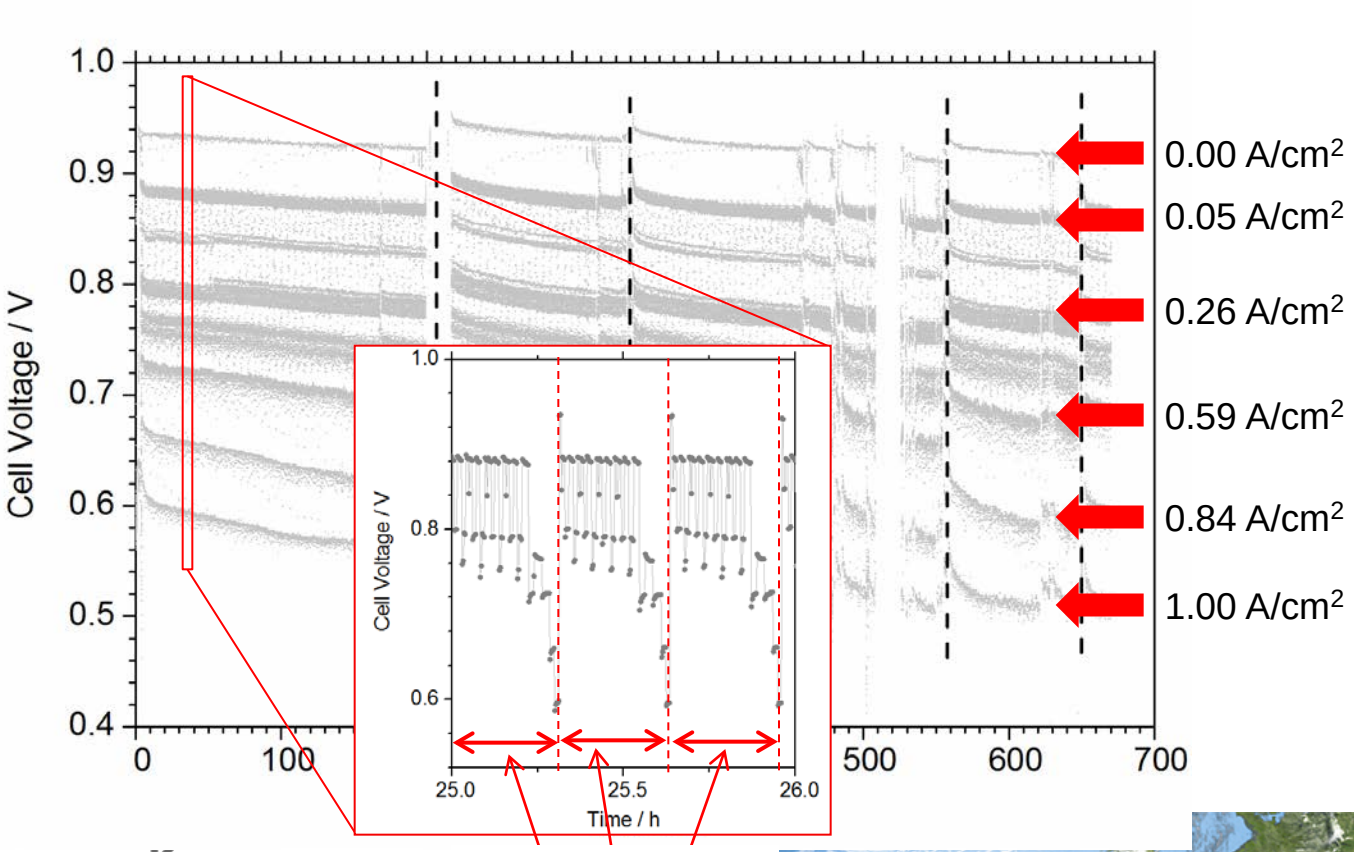
➔ Pseudo I-V curve obtained from each cycle



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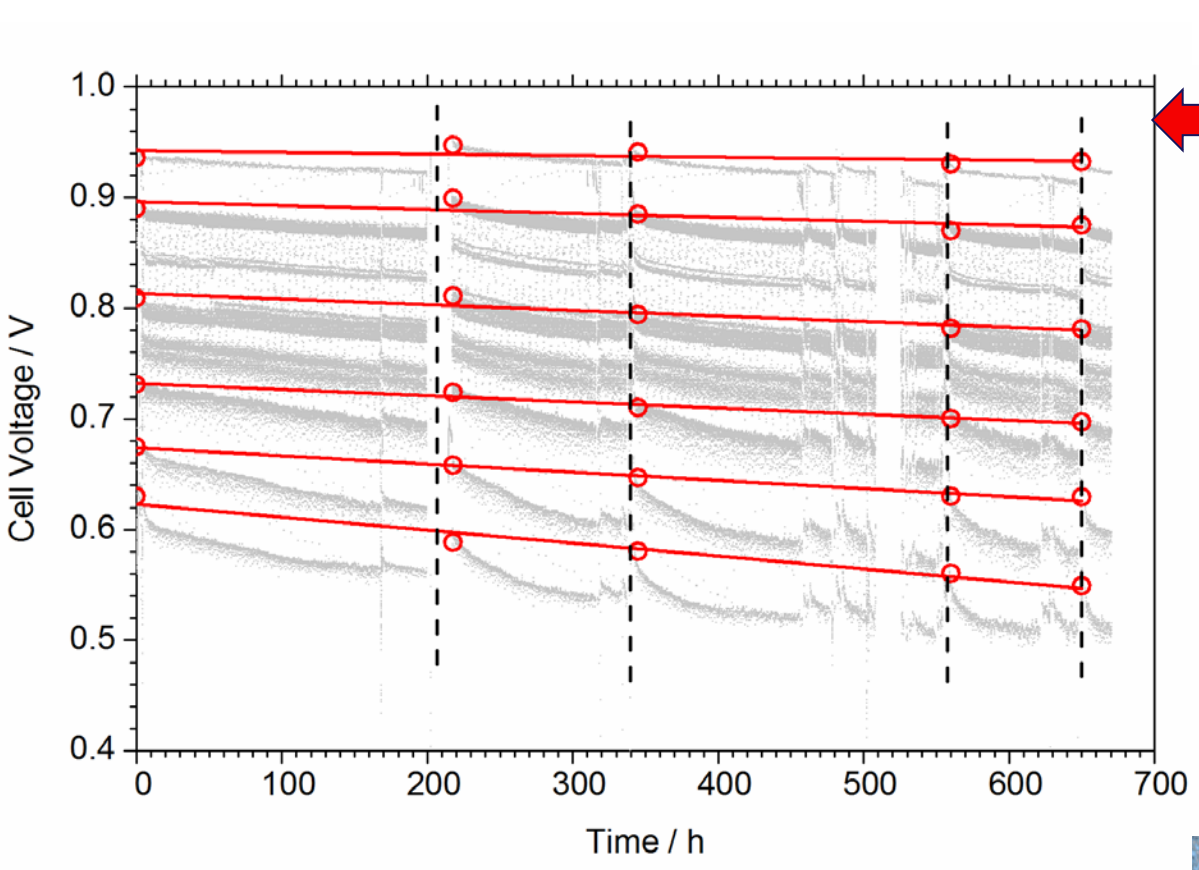

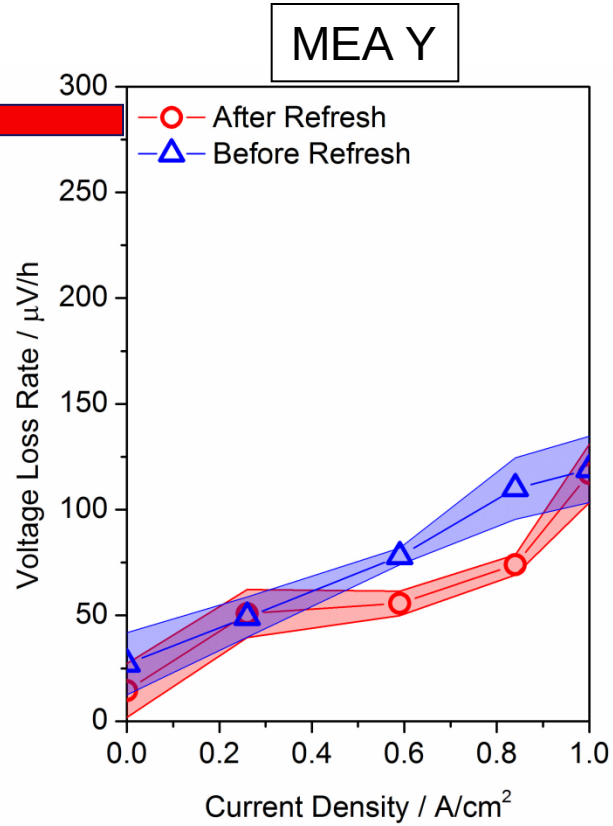

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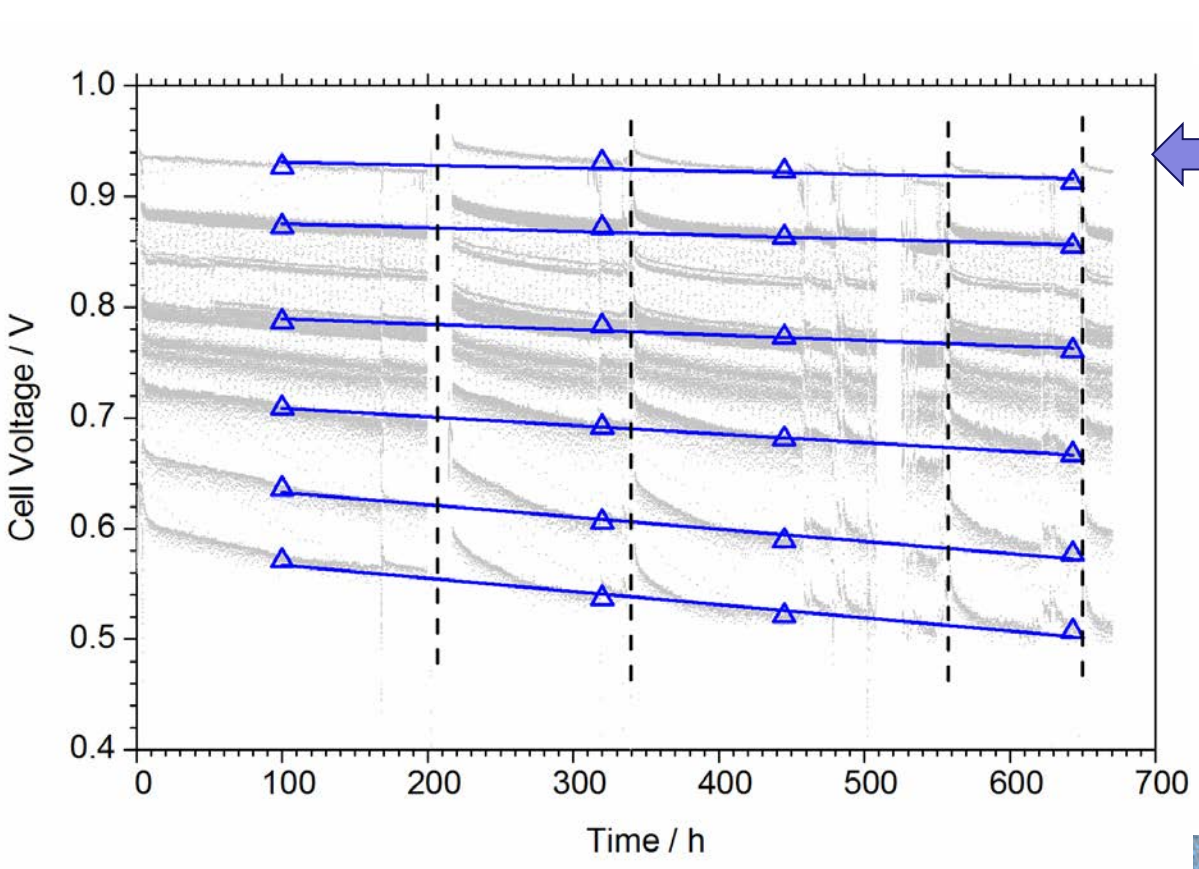

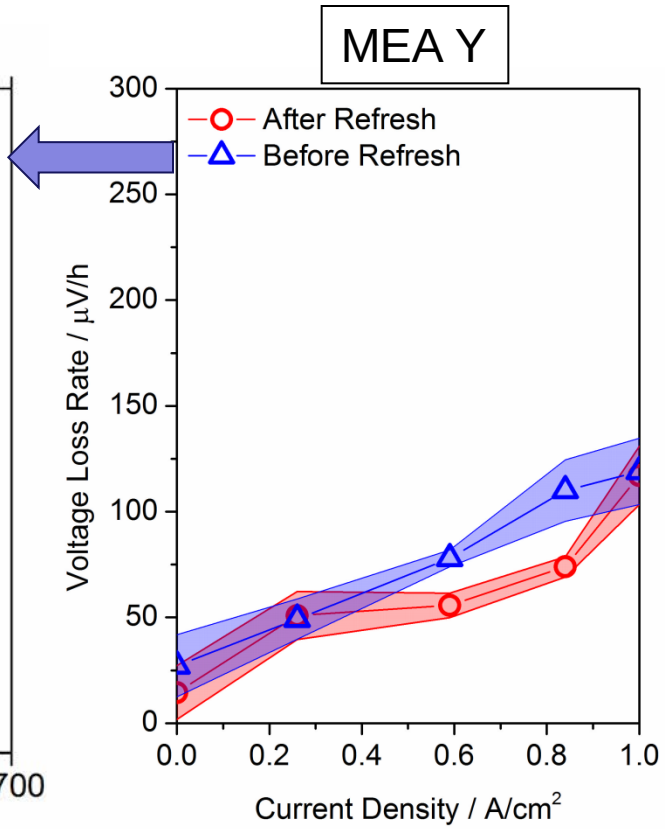

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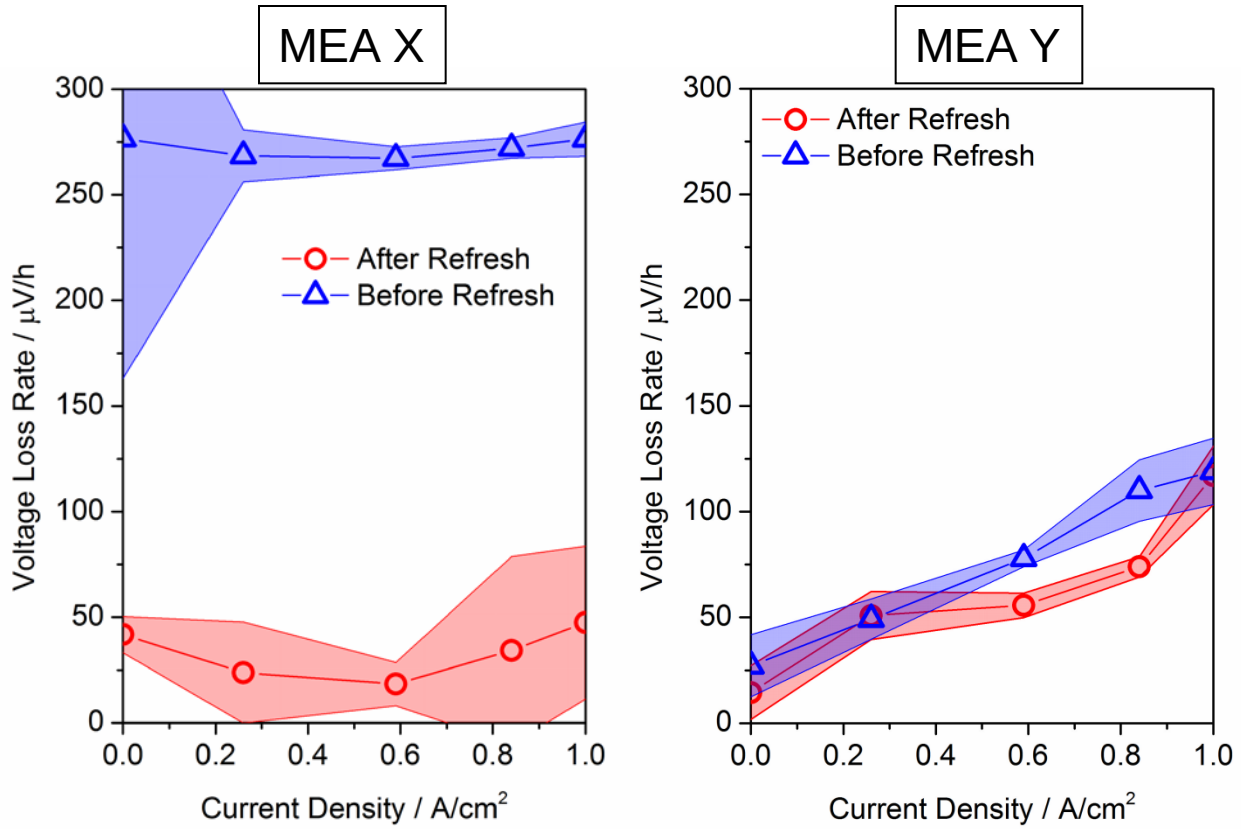

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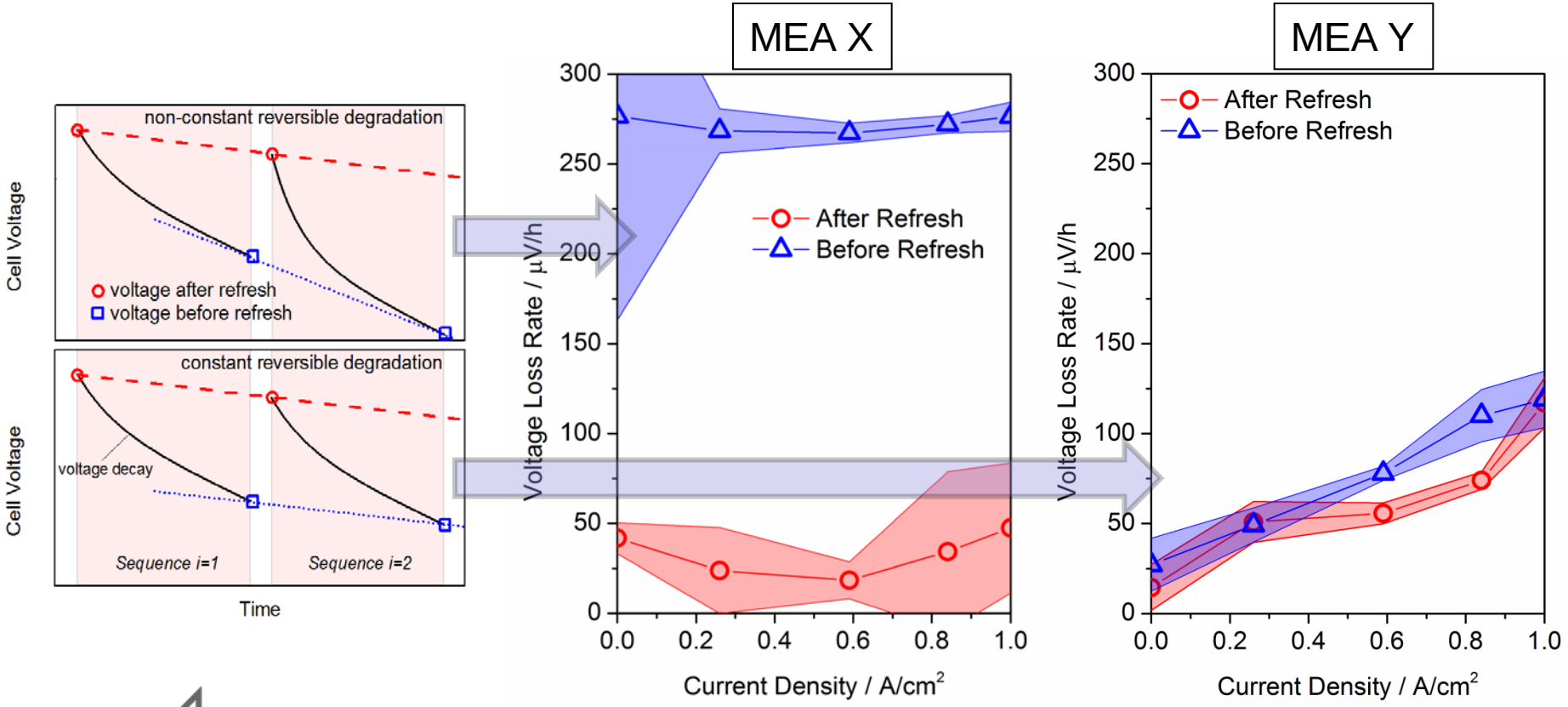
Evaluation of irreversible degradation

Constant and non-constant reversible degradation



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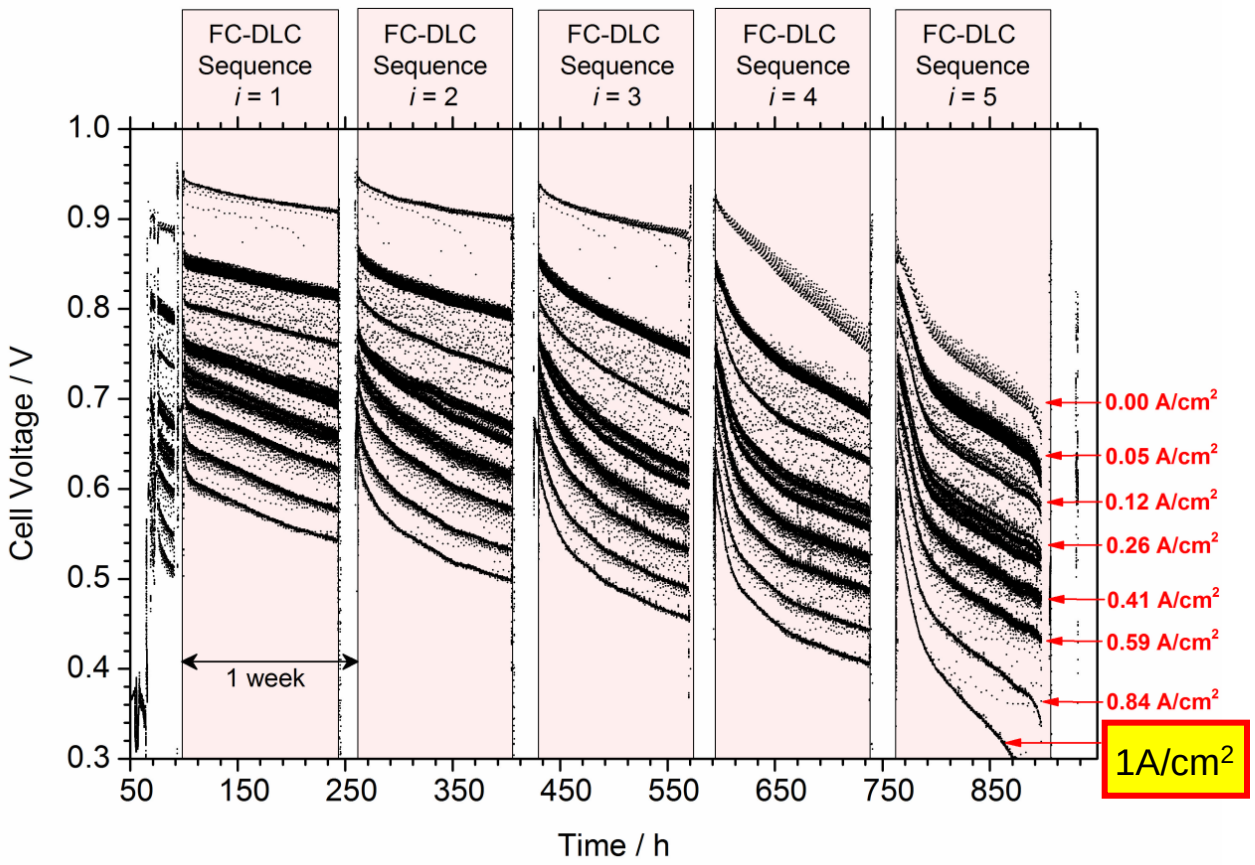
Evaluation of reversible degradation

Systematic FC dynamic load cycle (FC-DLC) for accurate determination of reversible degradation



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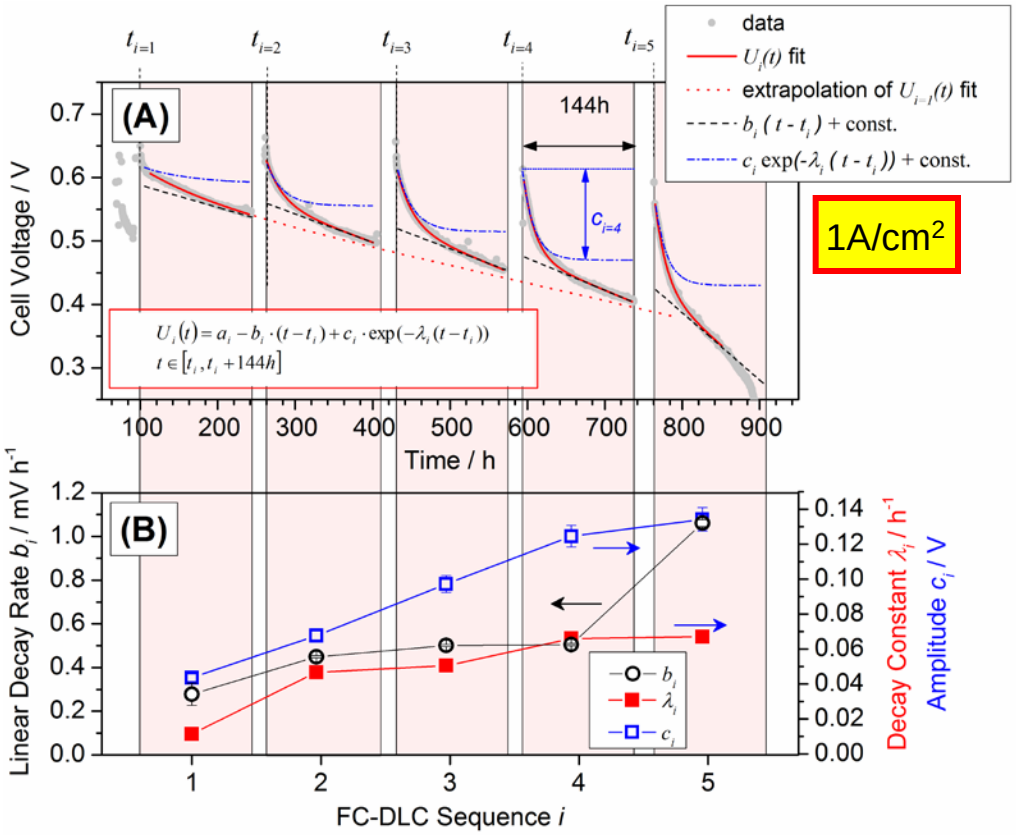
Evaluation of reversible degradation

Mathematical description of reversible degradation



1A/cm^2

Reversible degradation can be described by a linear-exponential function

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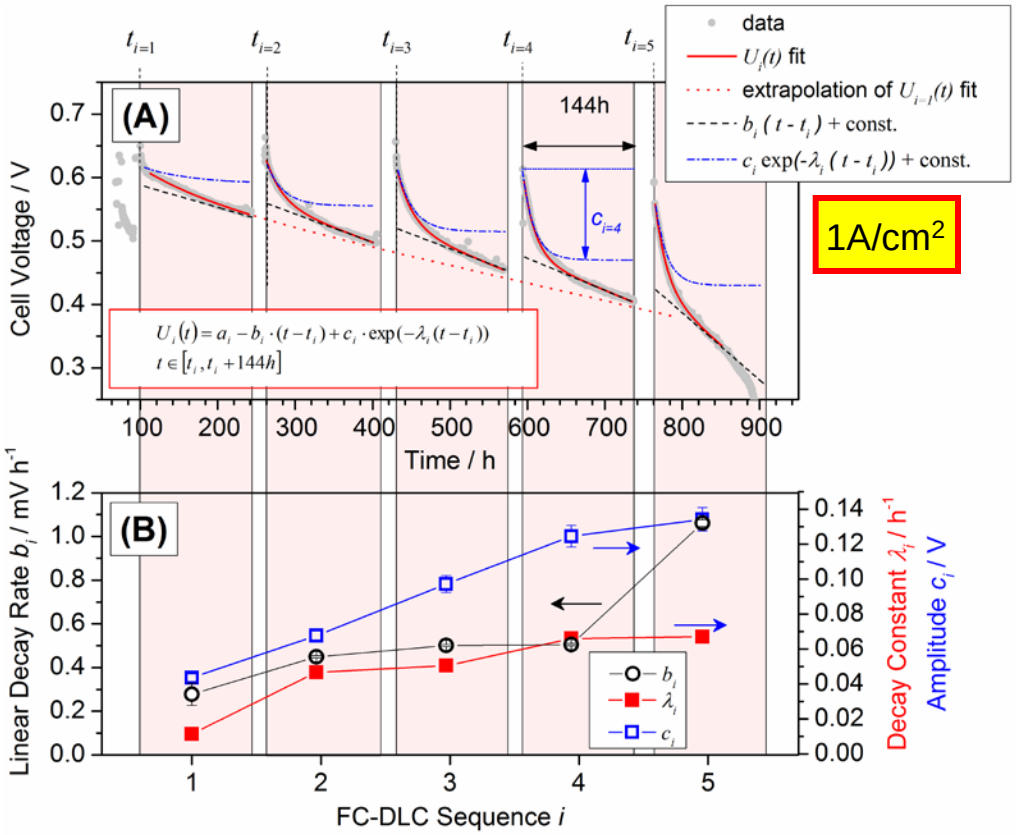

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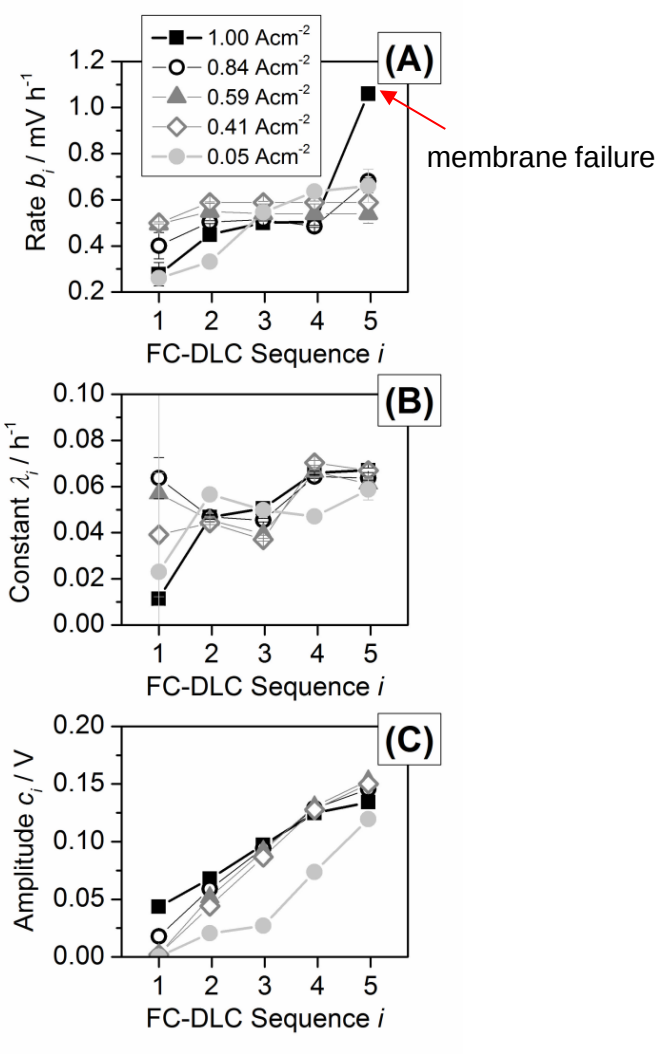

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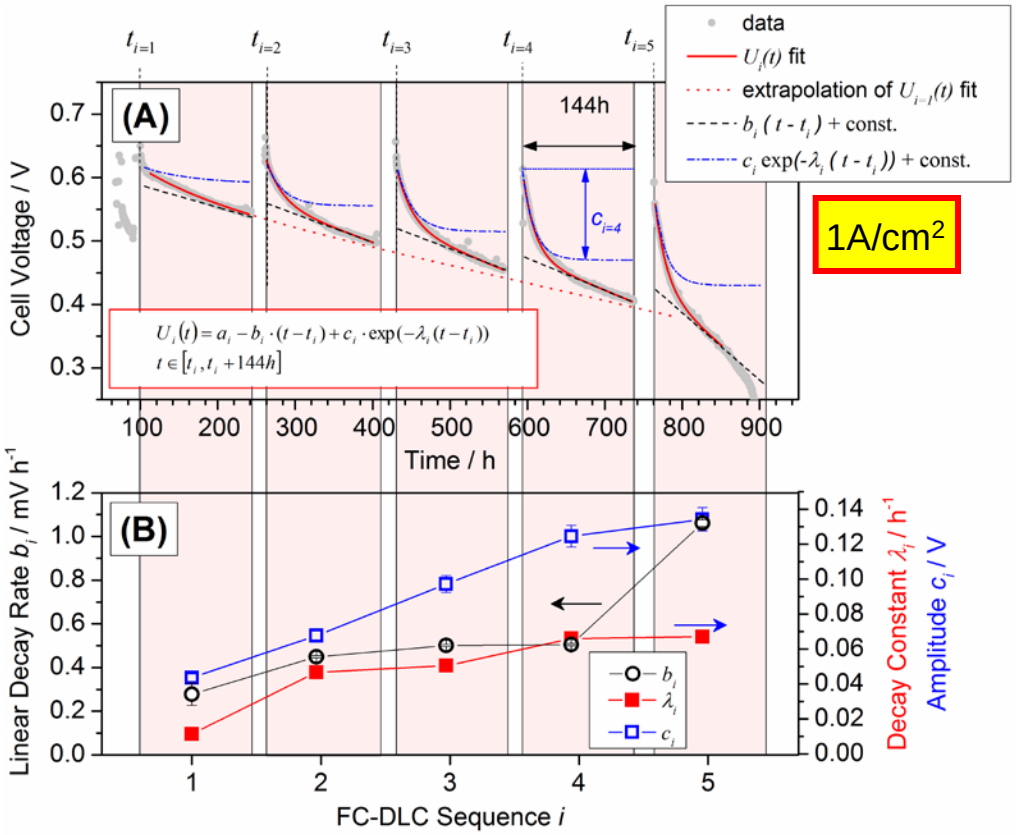

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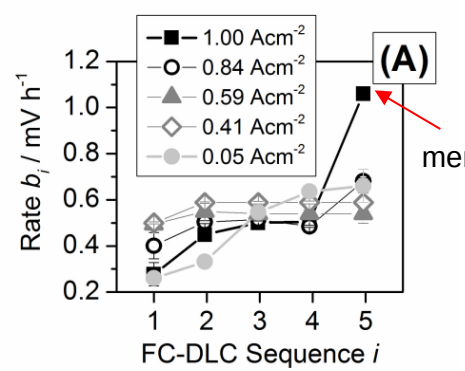
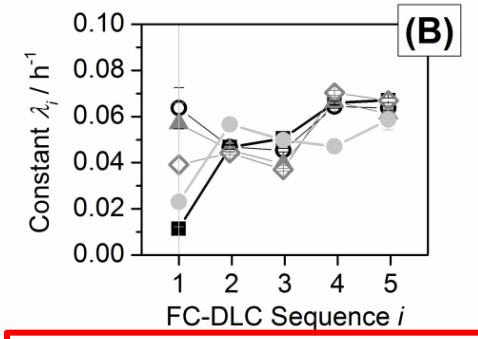
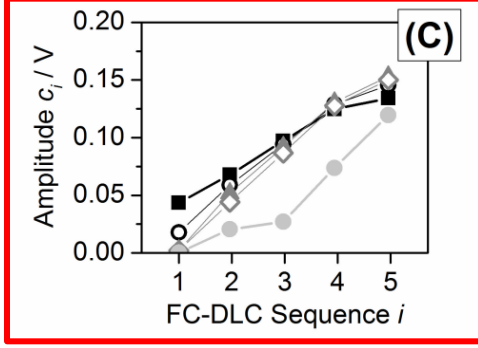






Amplitude of exp. part responsible for increase of reversible degradation with operation time

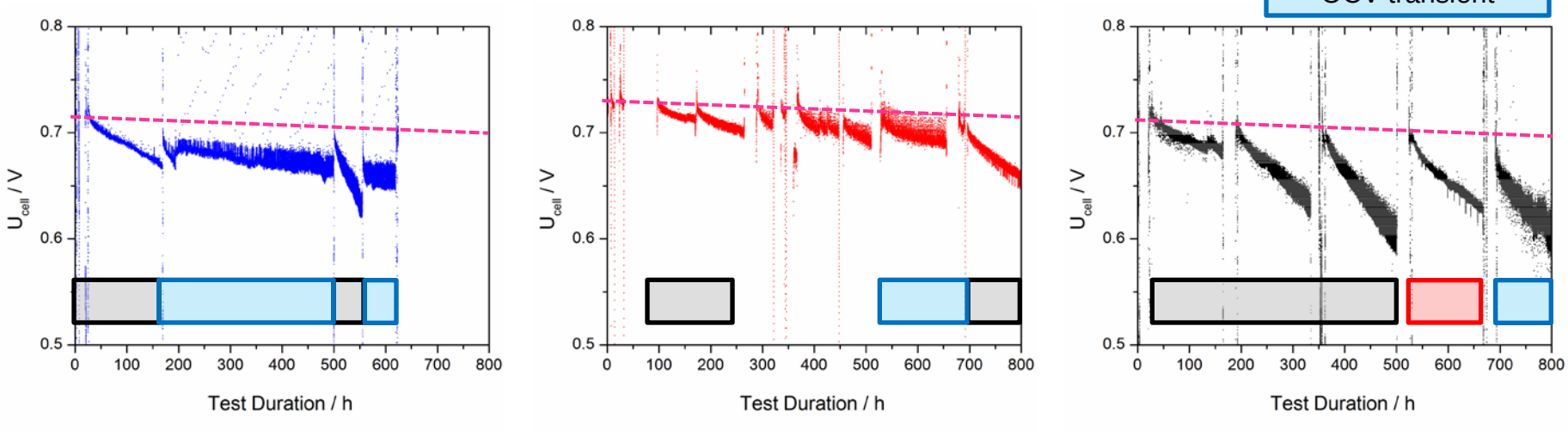
Evaluation of reversible degradation

const. load 80%RH

const. load 50%RH

OCV transient

Reversible degradation under stationary conditions



- Irreversibe degradation not sensitive to slight changes of operation conditions
- Reversible degradation depends on operation conditions

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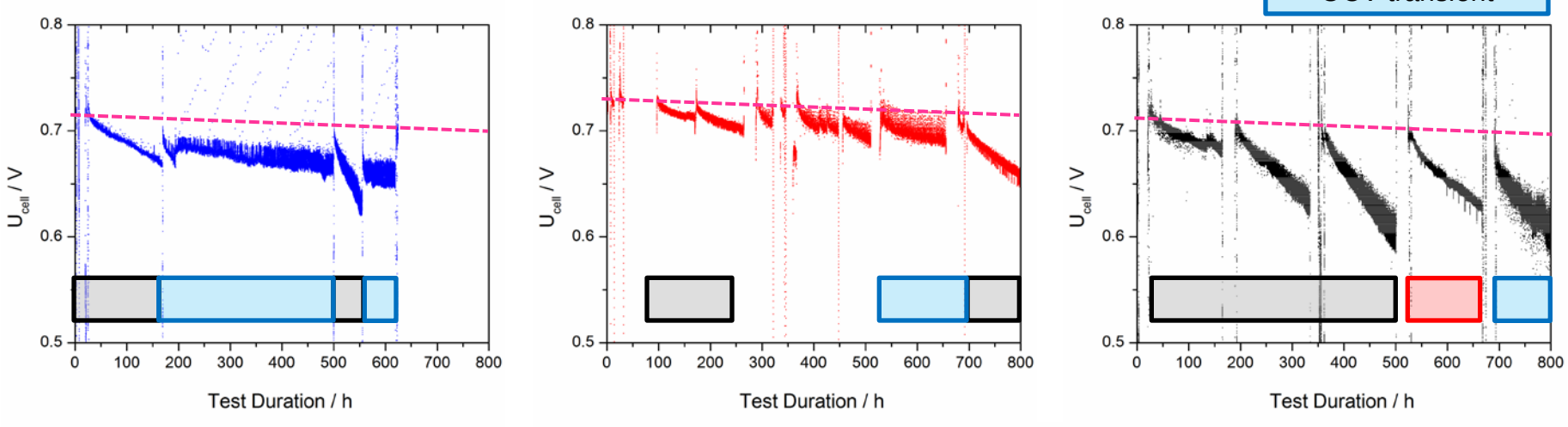

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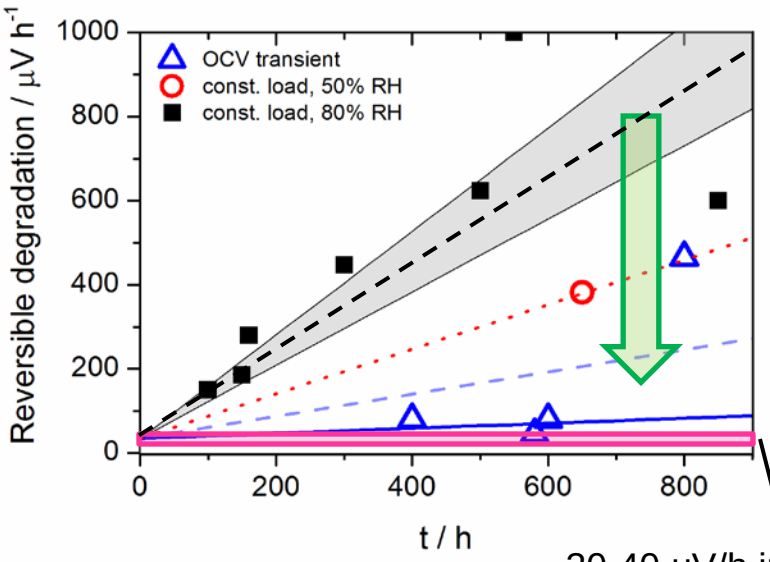
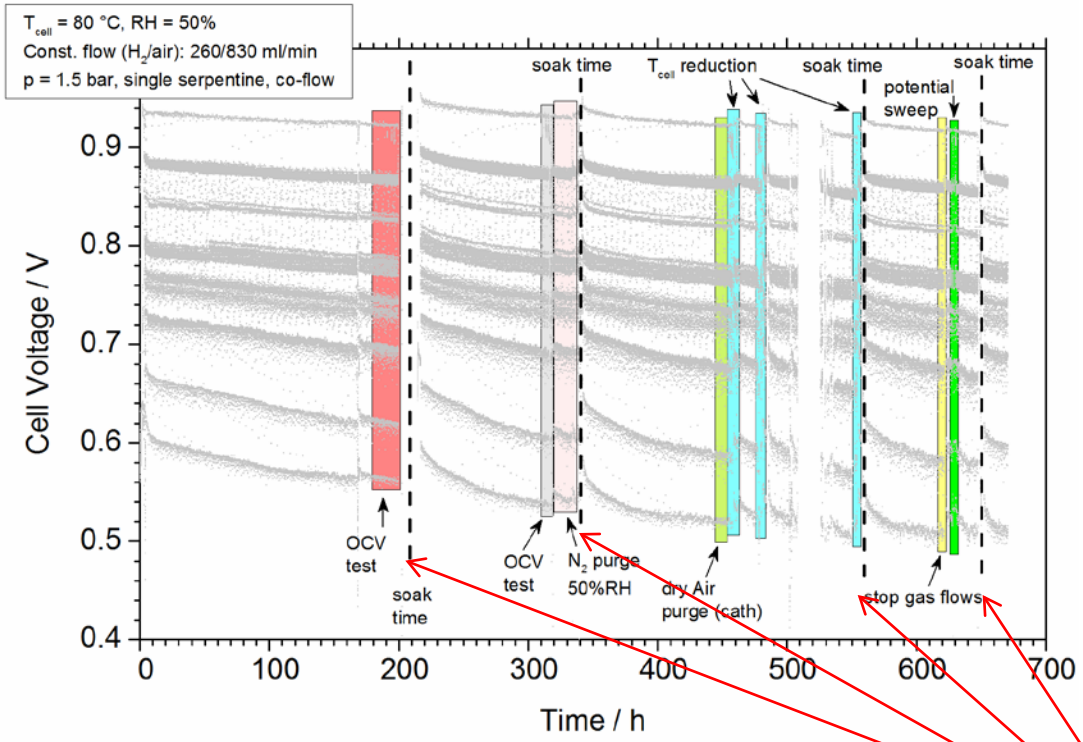


Reversible degradation reduced by ~70% by applying OCV transient

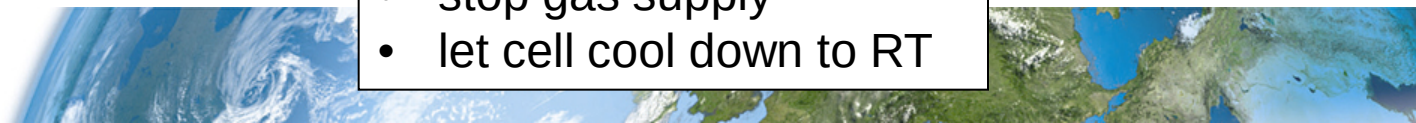
Recovery of reversible degradation

Test of conditions that occur during **shutdown recovery procedure** and could be the reason for recovery



- **Stop gas supply**
- **Drying**
- **reduction of T_{cell}**
- **OCV period**
- **purging anode with air**
- **potential sweep**
- **low potential, N_2 purge**

- Switch off load
- stop gas supply
- let cell cool down to RT



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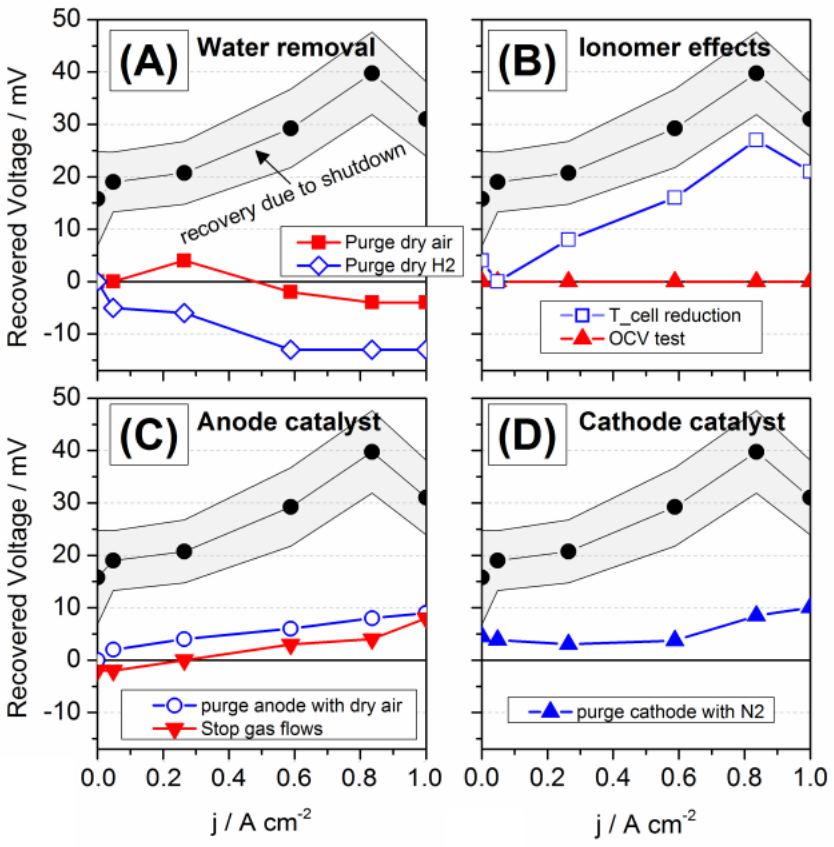

Recovery by shutdown could not be exceeded by any other procedure

➔ It is assumed that shutdown leads to **full recovery** of reversible losses

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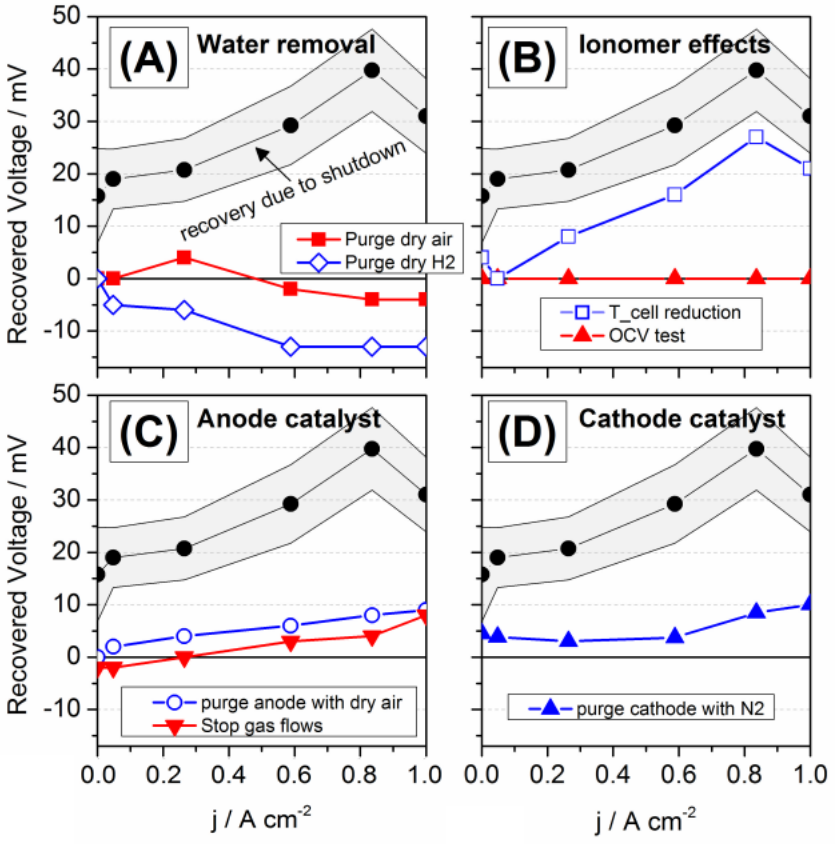
Recovery of reversible degradation



Recovery test	Intention	Recovered voltage @ 0.2 A cm^{-2}	Recovered voltage @ 0.8 A cm^{-2}
Purging anode with dry H_2	Remove water from anode	-28 %	-20 %
Purging cathode with dry air	Remove water from cathode	19 %	-10 %
Reduction of cell temperature	Increase humidity and decrease mechanical membrane stress	38 %	68 %
OCV-Test	Drying of MEA and increase of cathode potential	0 %	0 %
Purging anode with air	Increase anode potential to remove contaminants	19 %	20 %
Stopping gas flow	Increase anode potential to remove contaminants	0 %	10 %
Purging cathode with N_2	Decrease cathode potential to reduce platinum oxide	14 %	21 %

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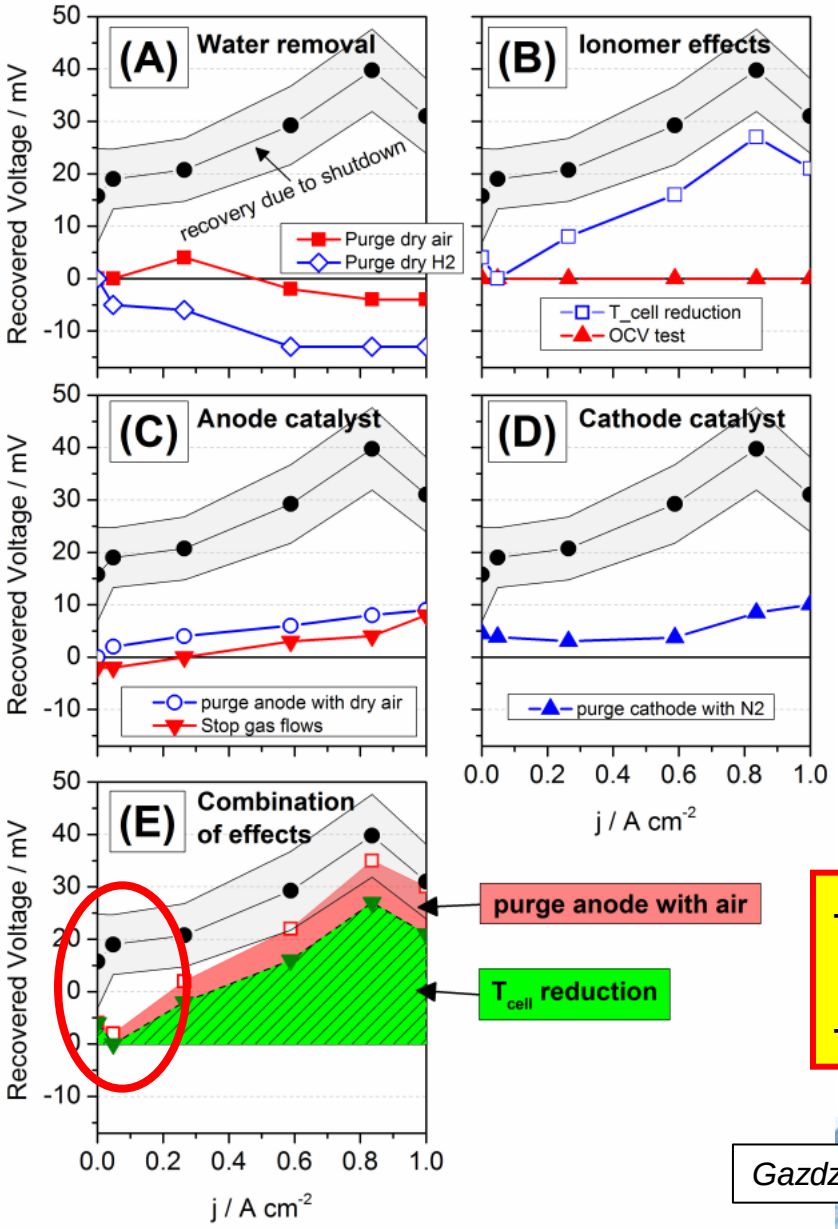

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- Water management plays major role in recovery
- Reason for recovery at low loads unclear

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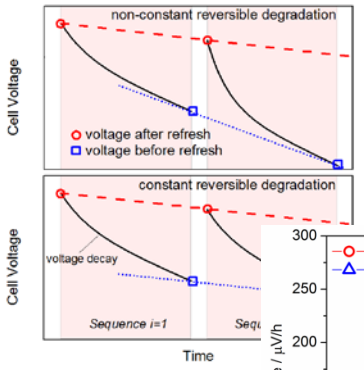
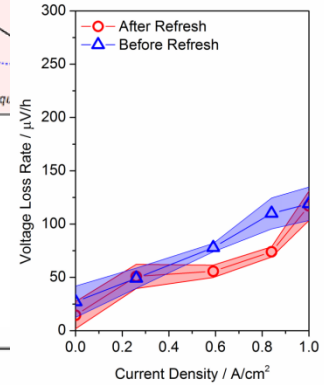
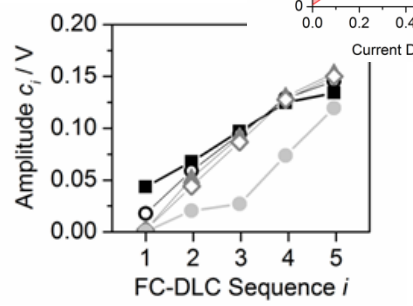
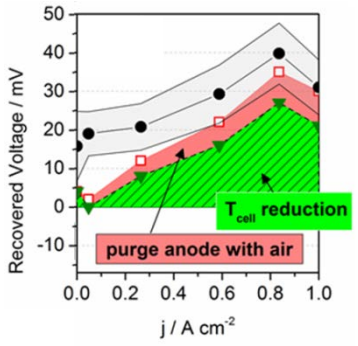
Conclusions

- Irreversible degradation rate corresponds to linear regression of voltage values after refresh
- Propose to use voltage loss diagrams instead of single value if possible
- Reversible degradation can be described by linear-exponential function
  - parameter c_i responsible for acceleration of reversible degradation with time
- Reason for voltage recovery:
  - Water management plays a role in voltage recovery, especially at high loads
  - Recovery at low load not yet explained









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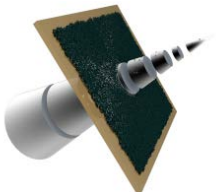

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