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Degradation of PEMFC at low loadings

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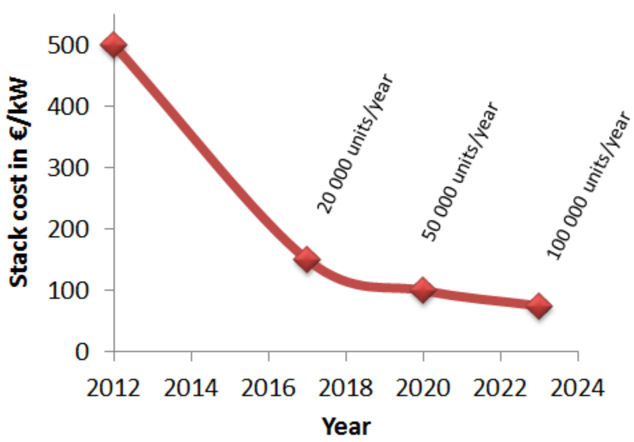
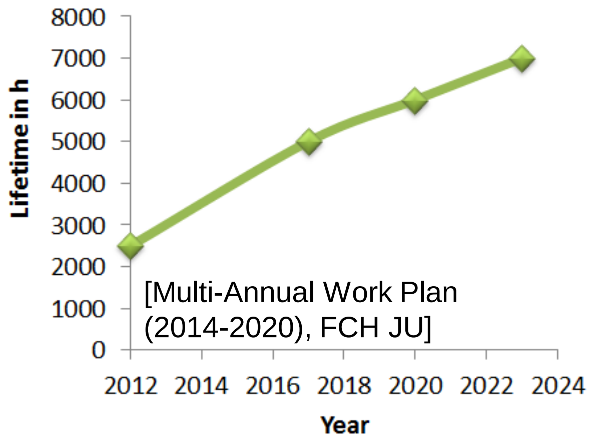
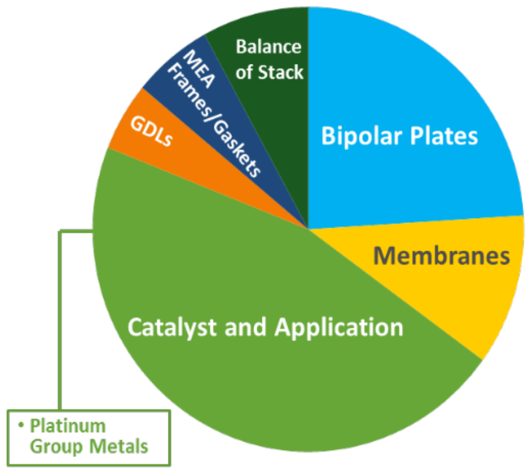
Requirements for PEMFC development

- ➢ Reduction of manufacturing cost at increased durability in order to compete with conventional technologies





[Multi-Annual Work Plan (2014-2020), FCH JU]



[U.S. DOE 2015 Annual Merit Review]

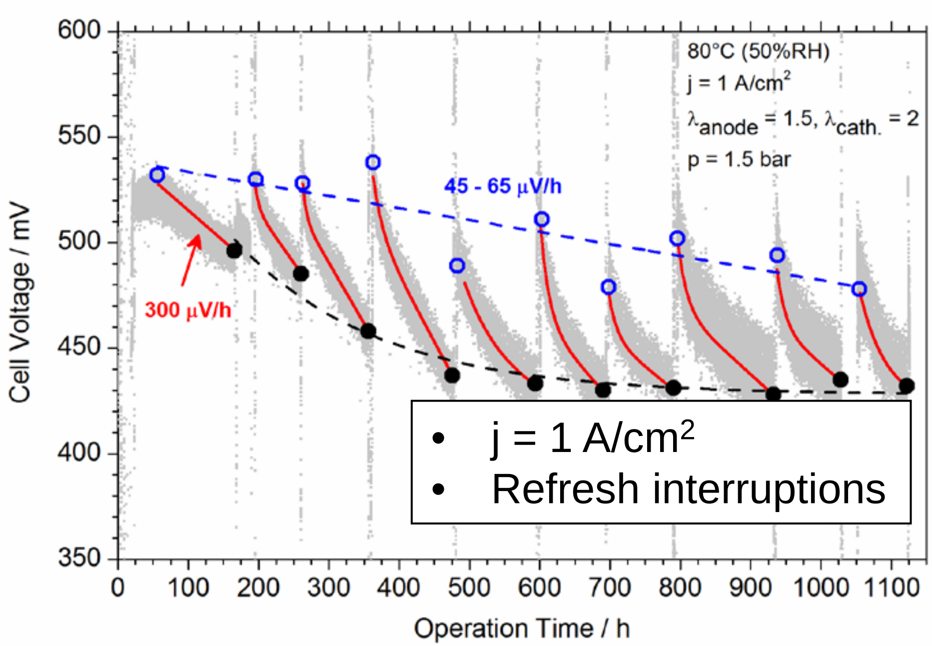
- ➢ Most promising regarding cost reduction: catalyst layer (45 % of stack cost)
  - **Low loadings**
  - Alternative catalysts

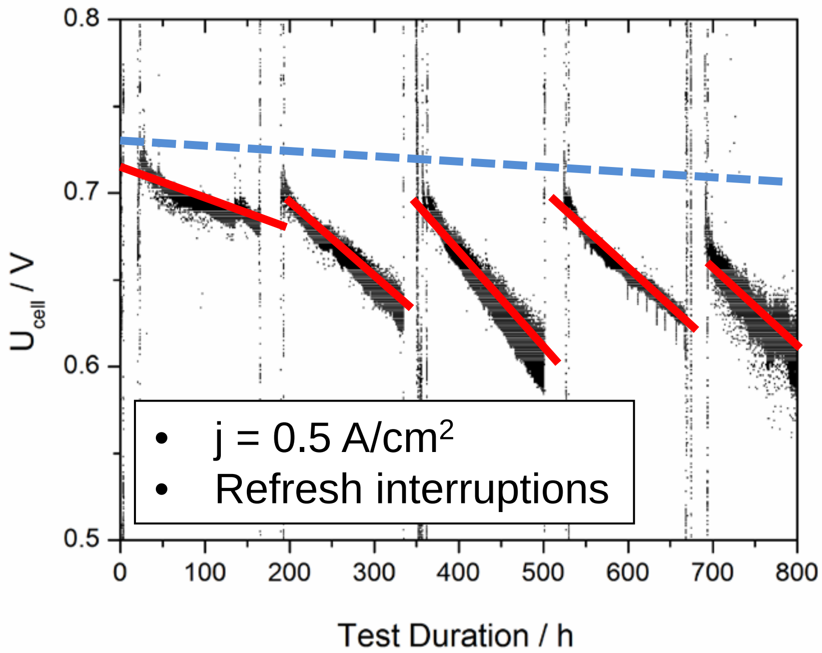
Motivation

Performance targets clearly defined and well verifiable, BUT

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

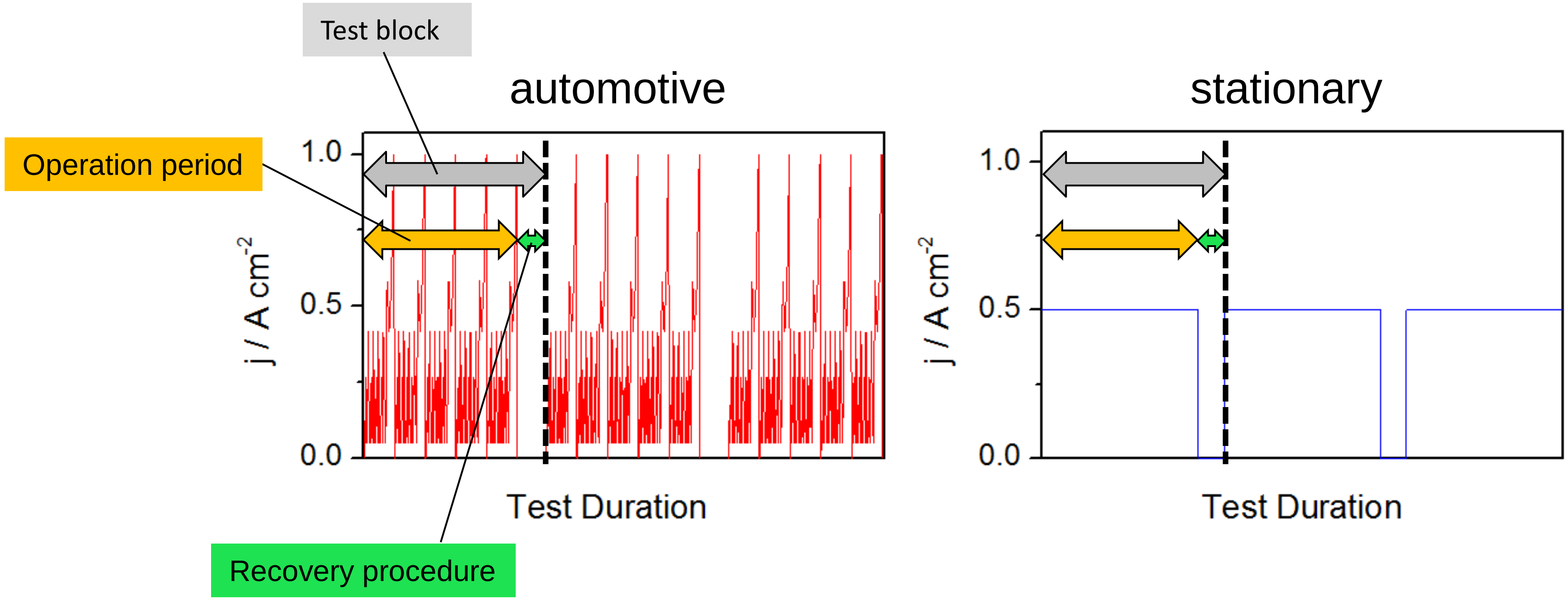
Discrimination between **reversible** and **irreversible** degradation needed





Evaluation of irreversible degradation

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



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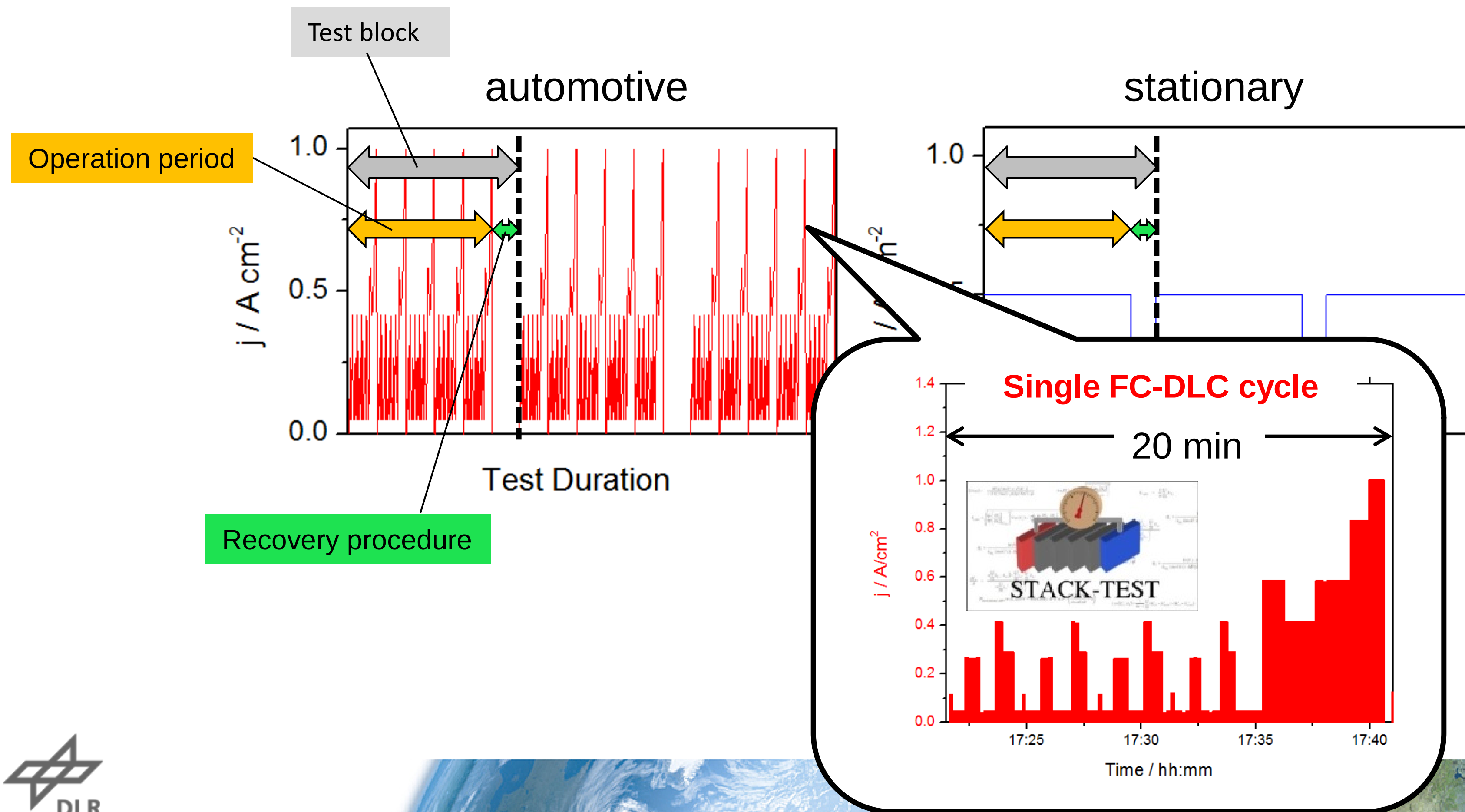
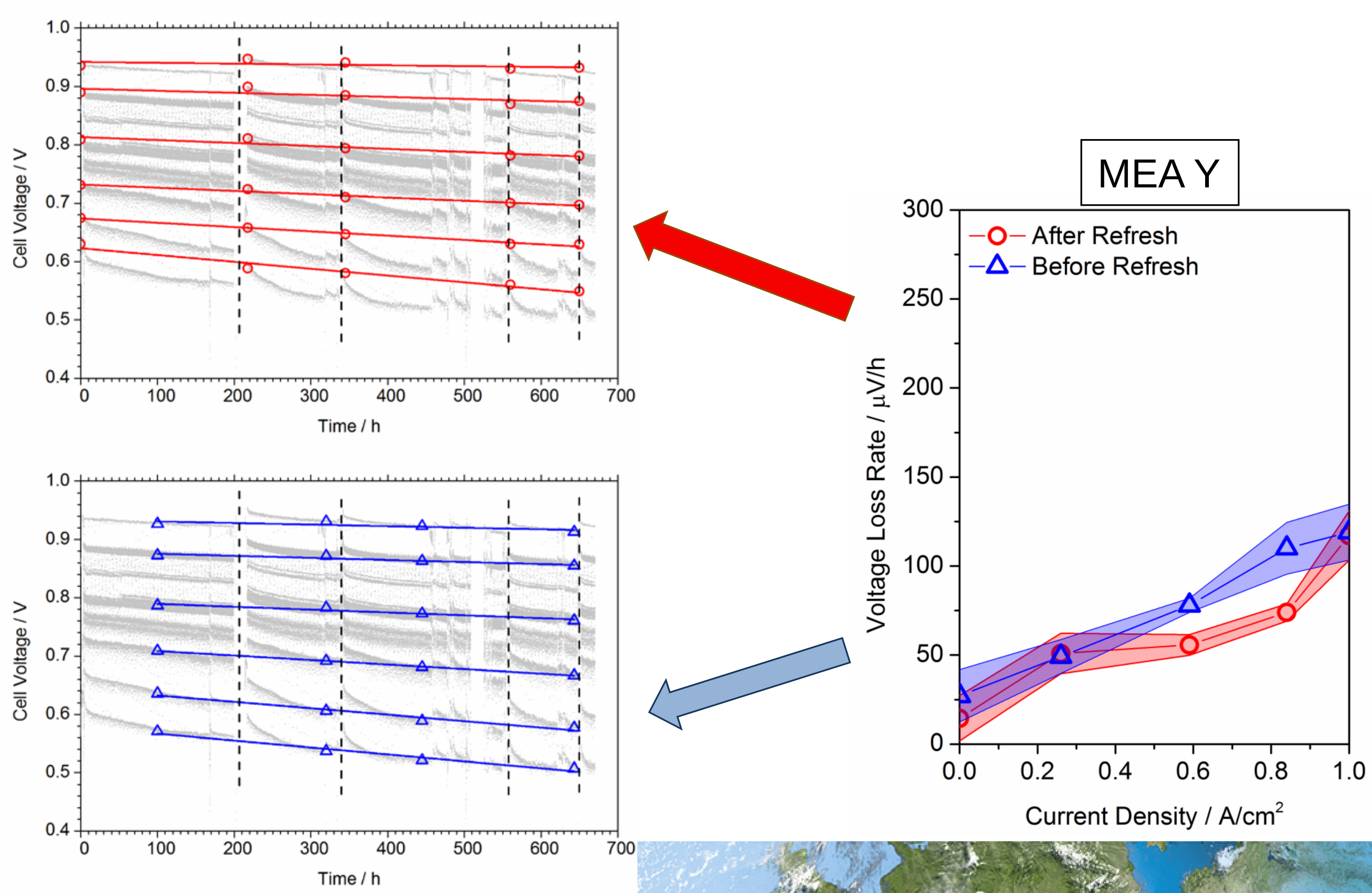
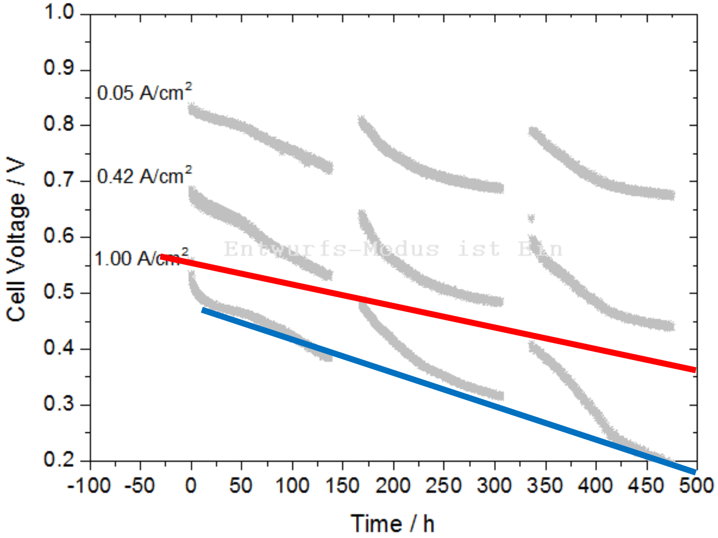


Evaluation of irreversible degradation

Use voltage values before or after refresh?



Evaluation of irreversible degradation



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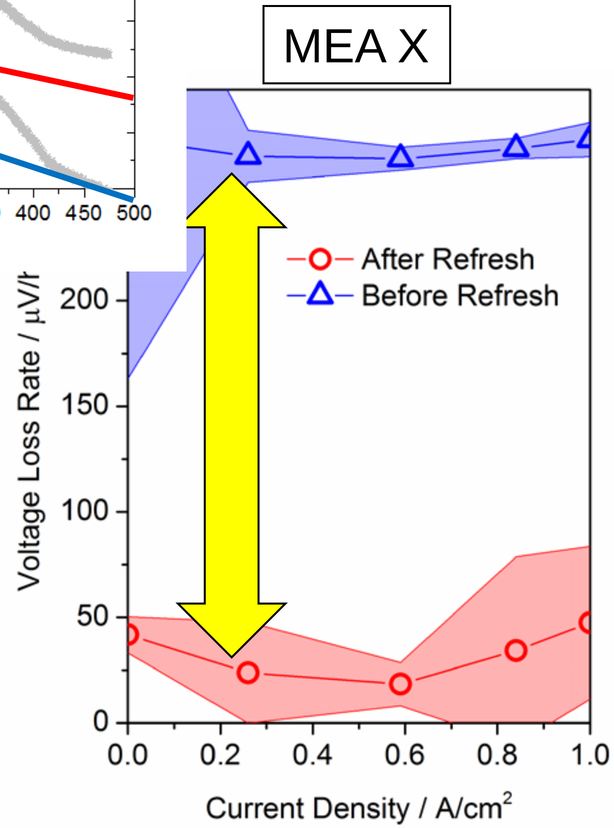

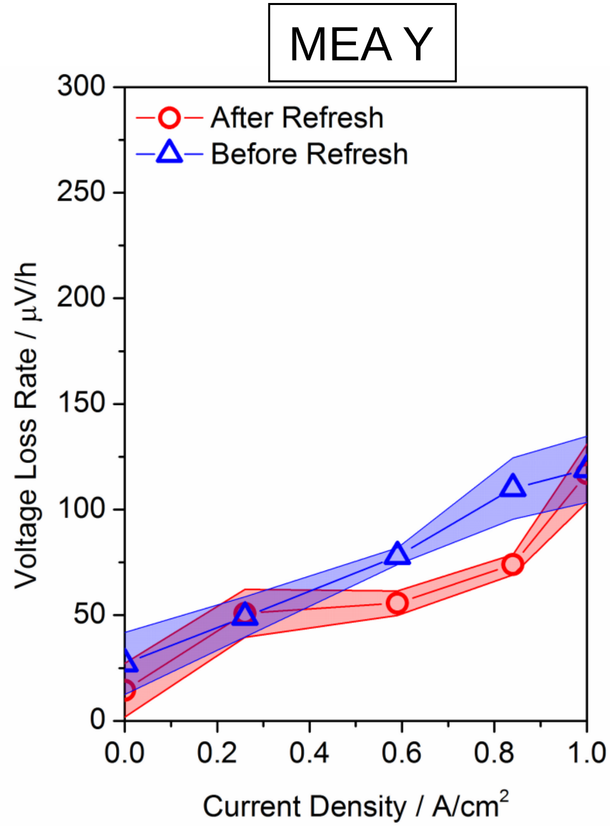

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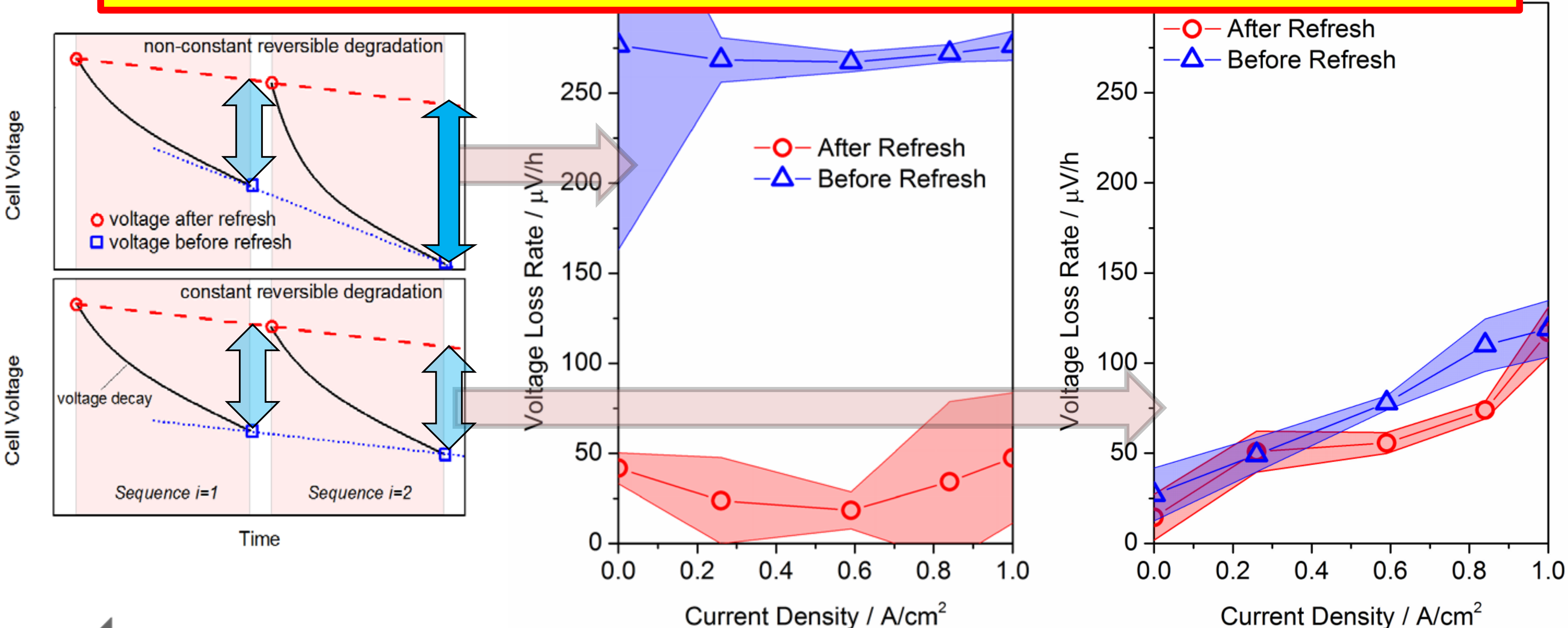
Evaluation of irreversible degradation

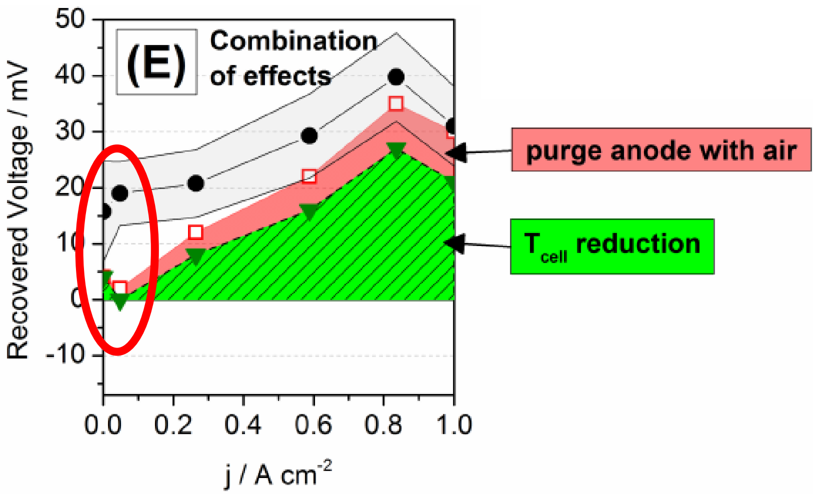
Constant and non-constant reversible degradation

➔ decay rate(...): combination or **reversible** an **irreversible** degradation

➔ decay rate(---): **irreversible** degradation



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 %

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

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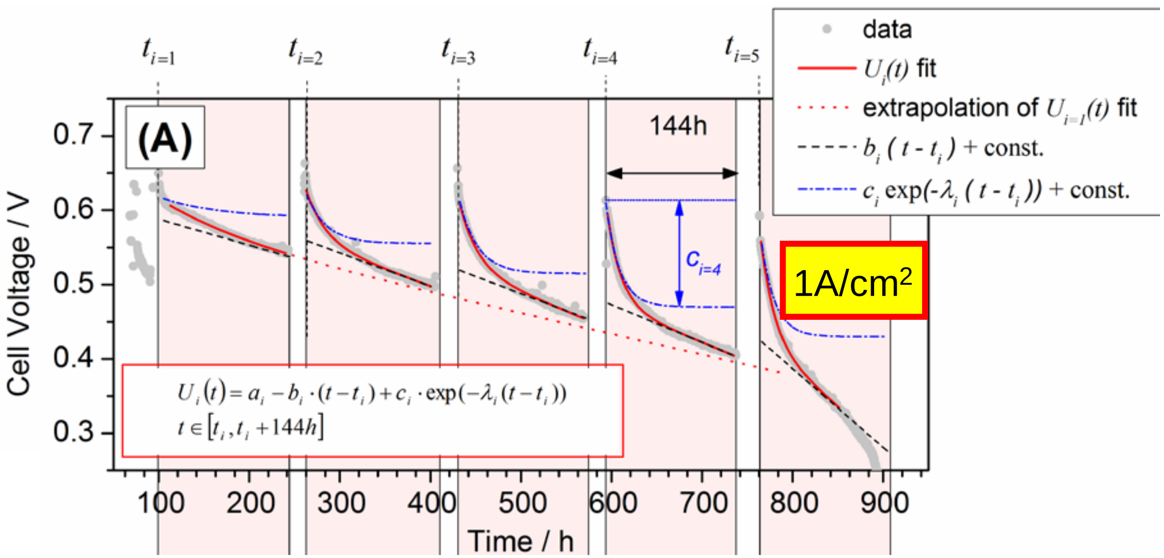
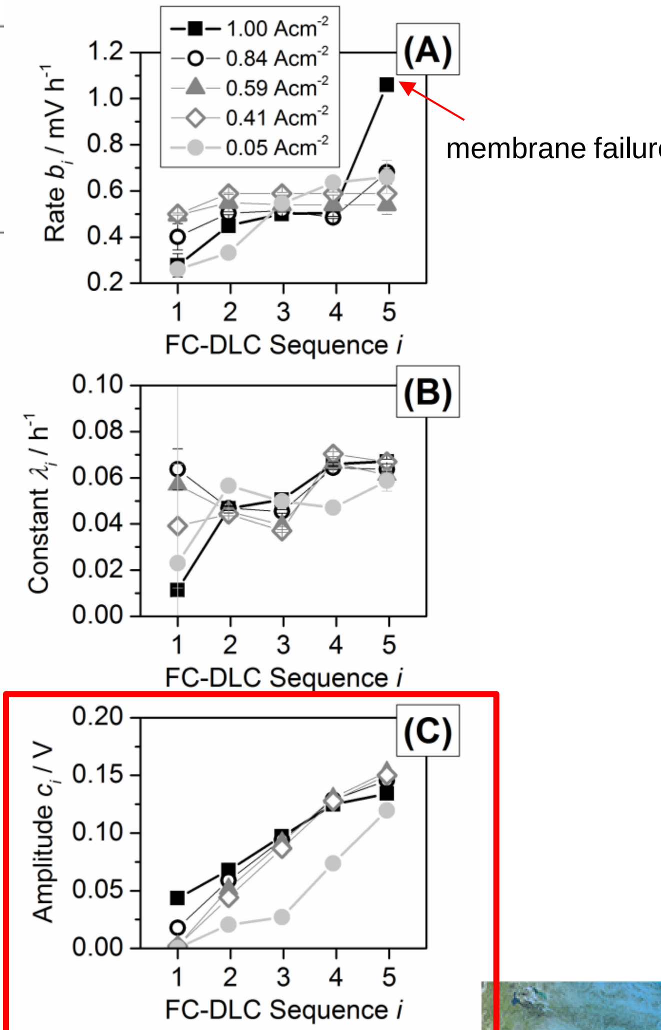
Gazdzicki et al. (2016) J. Power Sources, doi: 10.1016/j.jpowsour.2016.07.049

Evaluation of reversible degradation

Mathematical description of reversible degradation



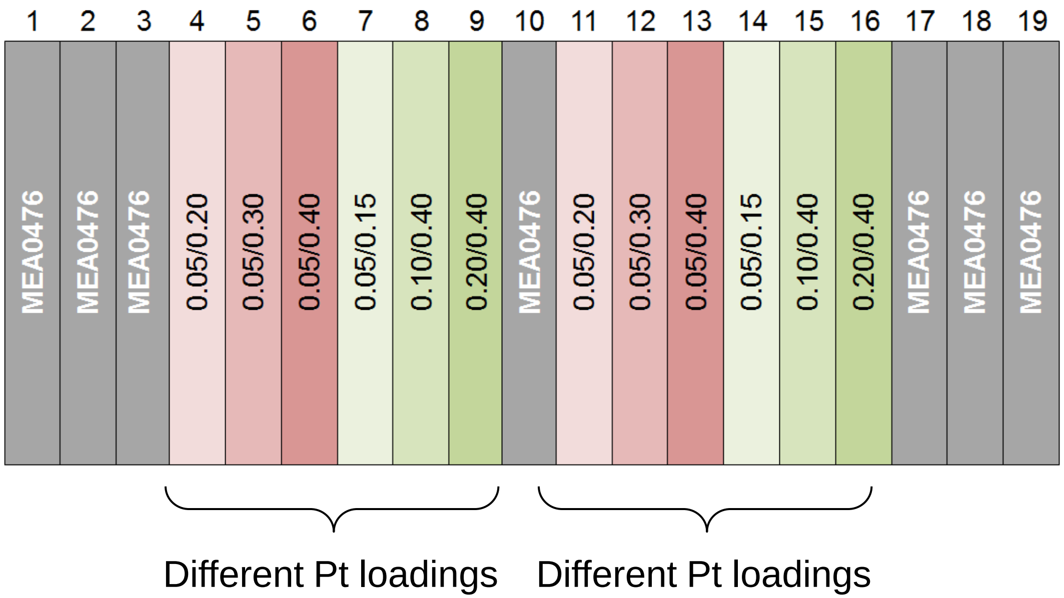


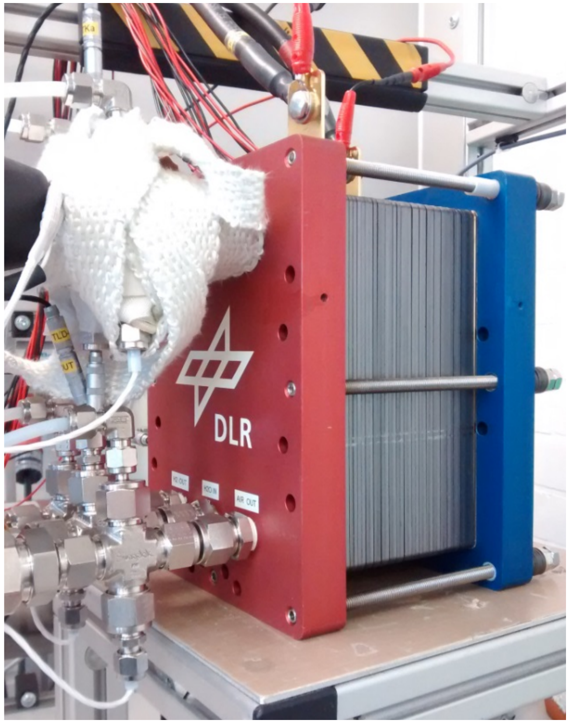
Amplitude of exp. part responsible for increase of reversible degradation with operation time

Pt-Loading Rainbow Stack Study

DLR Rainbow-Stack

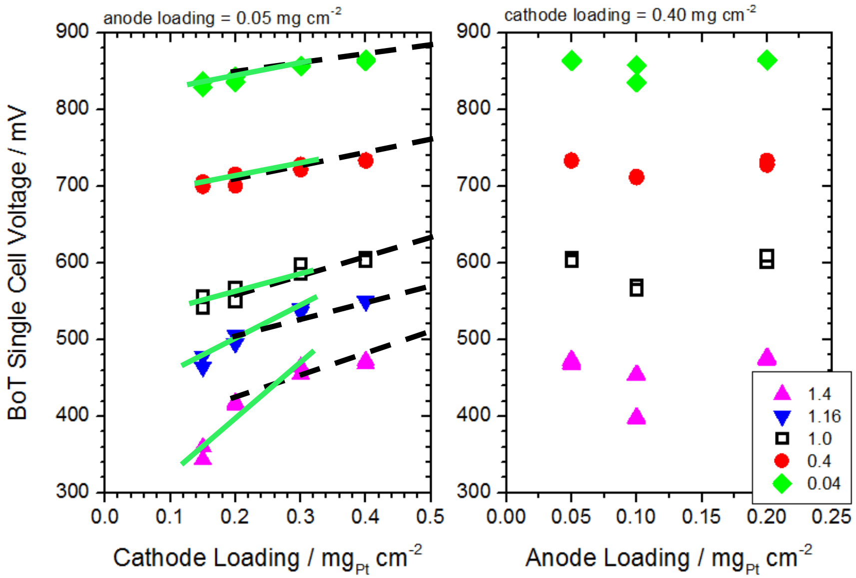
Pt-loadings at anode/cathode in mg_{Pt}/cm^2





Performance Vs Pt-loading

BoT Voltages versus Loading



Const. anode loading

Const. cathode loading

- Clear dependence of Cell Voltage on cathode Pt loading
- No dependence of Cell Voltage on anode Pt loading

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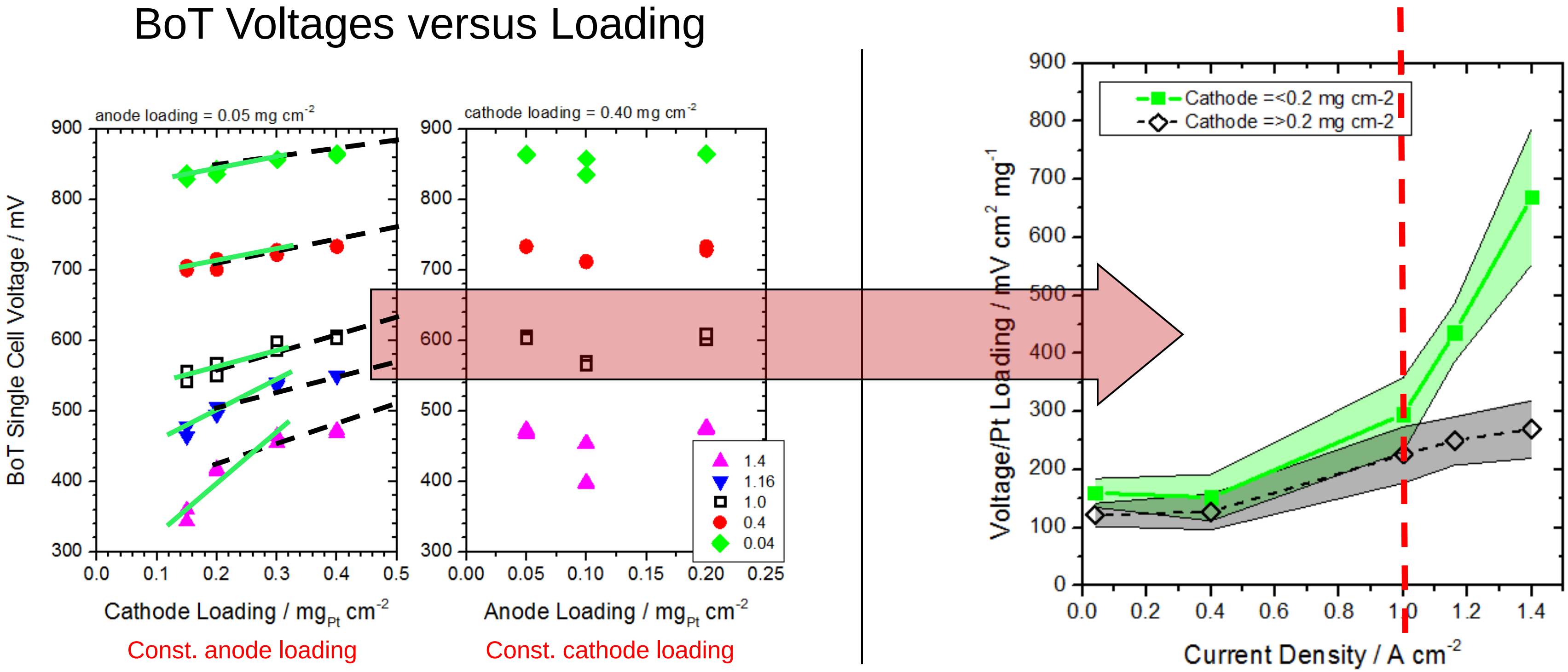

- Clear dependence of Cell Voltage on cathode Pt loading
- No dependence of Cell Voltage on anode Pt loading
- Onset of mass transport issues observed at cathode loading <u><=0.2 mg/cm2</u> and <u>j>1 A/cm2</u>

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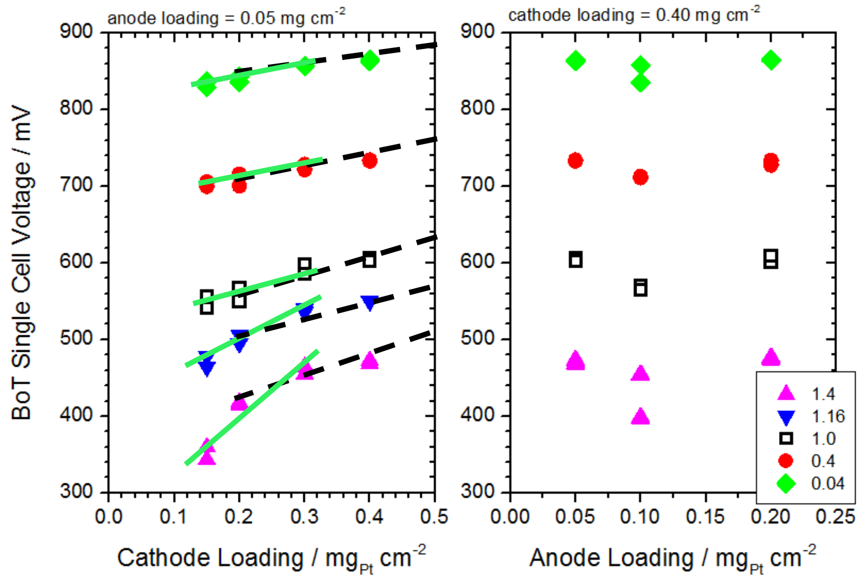
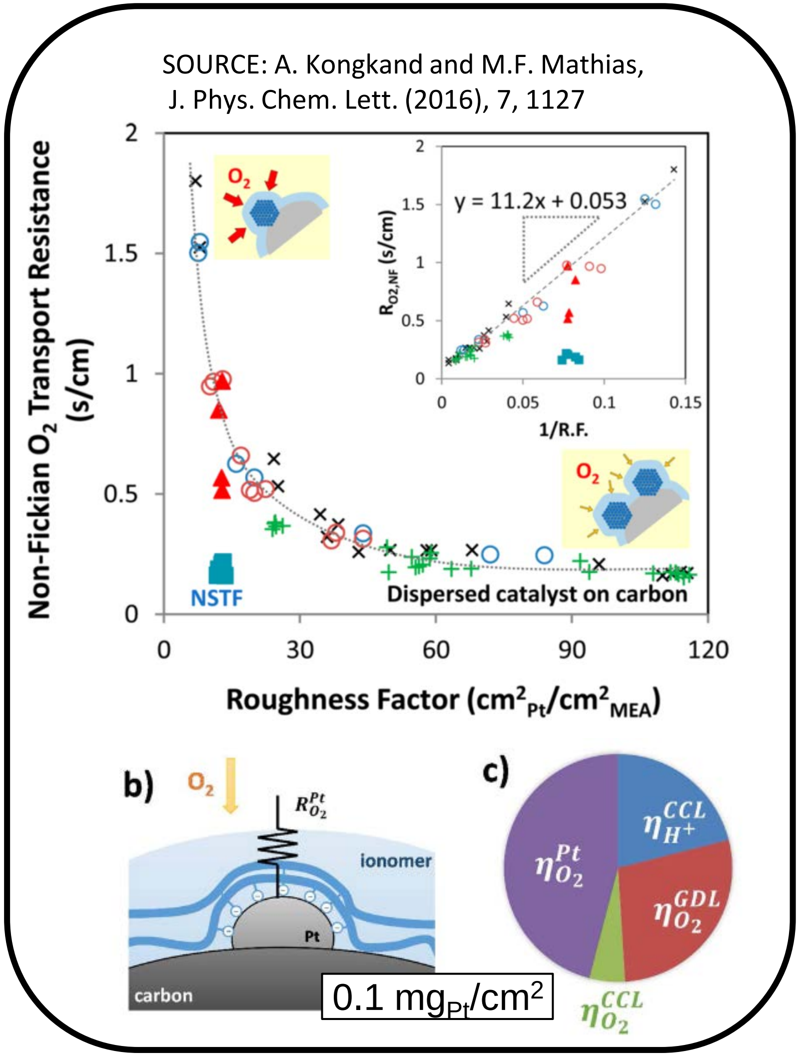


Const. anode loading

Const. cathode loading



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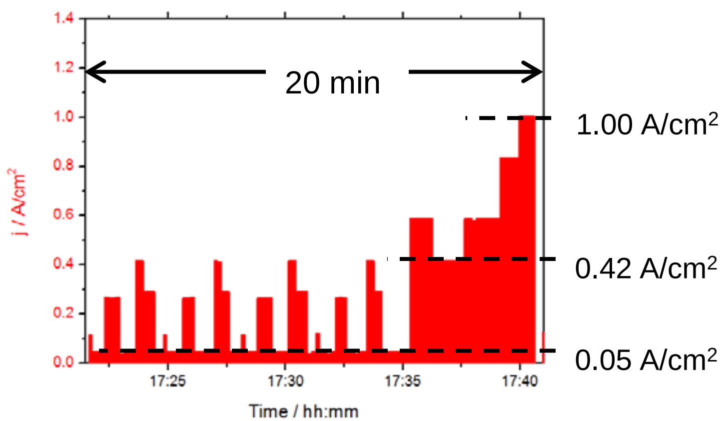
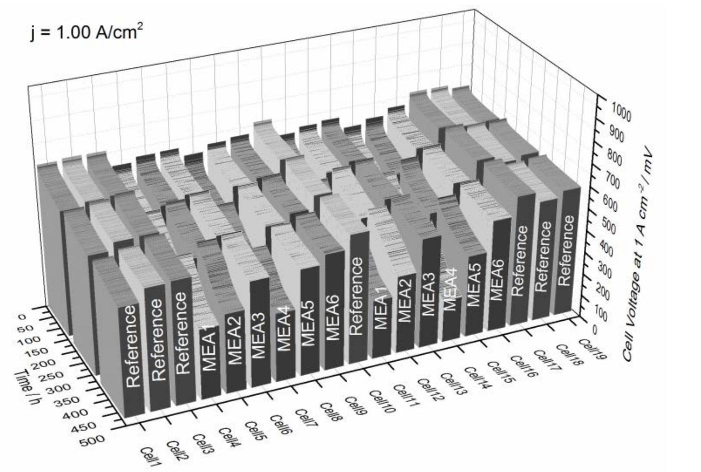
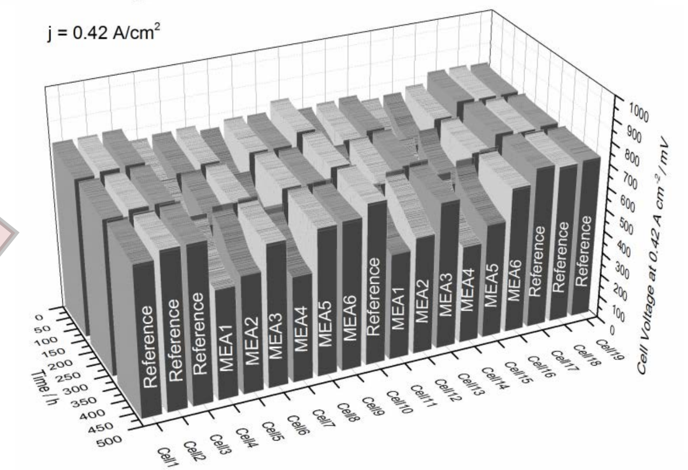
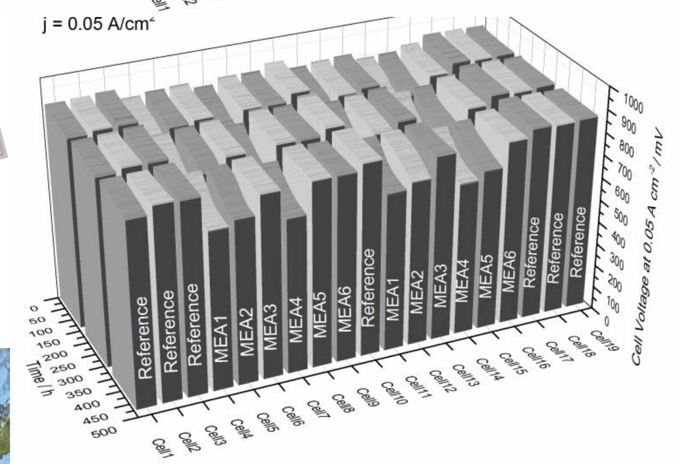
Degradation Vs Pt-loading

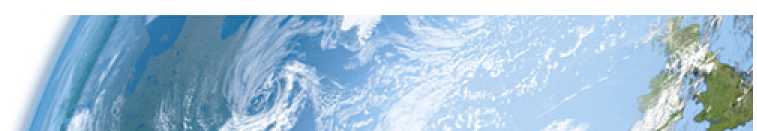
~500 h FC-DLC degradation test



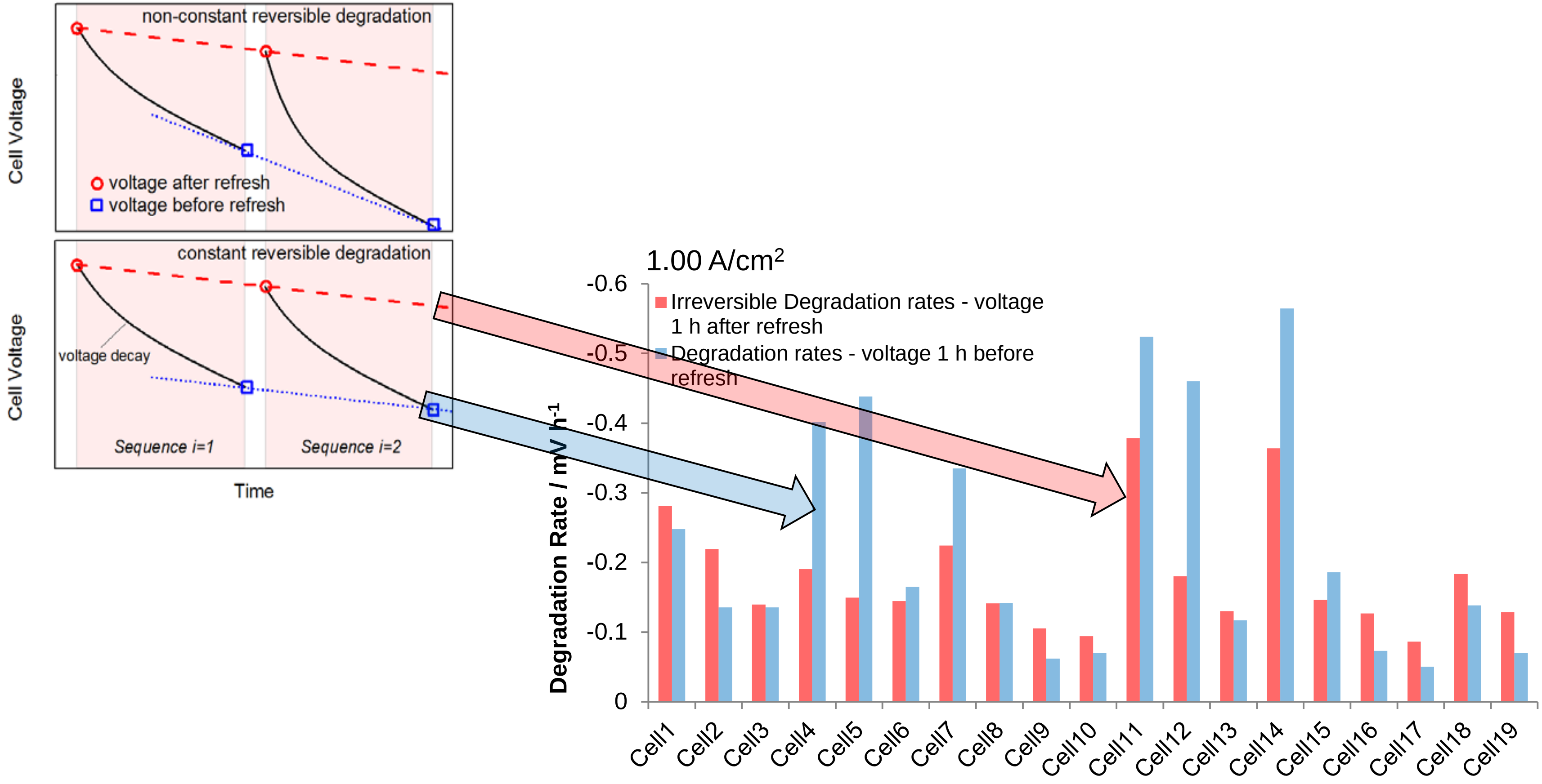








Degradation Vs Pt-loading: evaluation of rev. degradation



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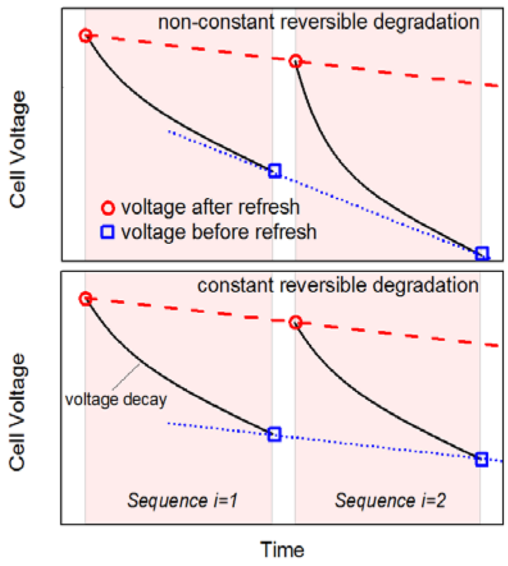

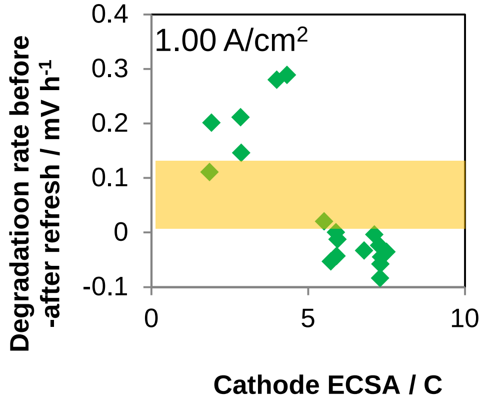

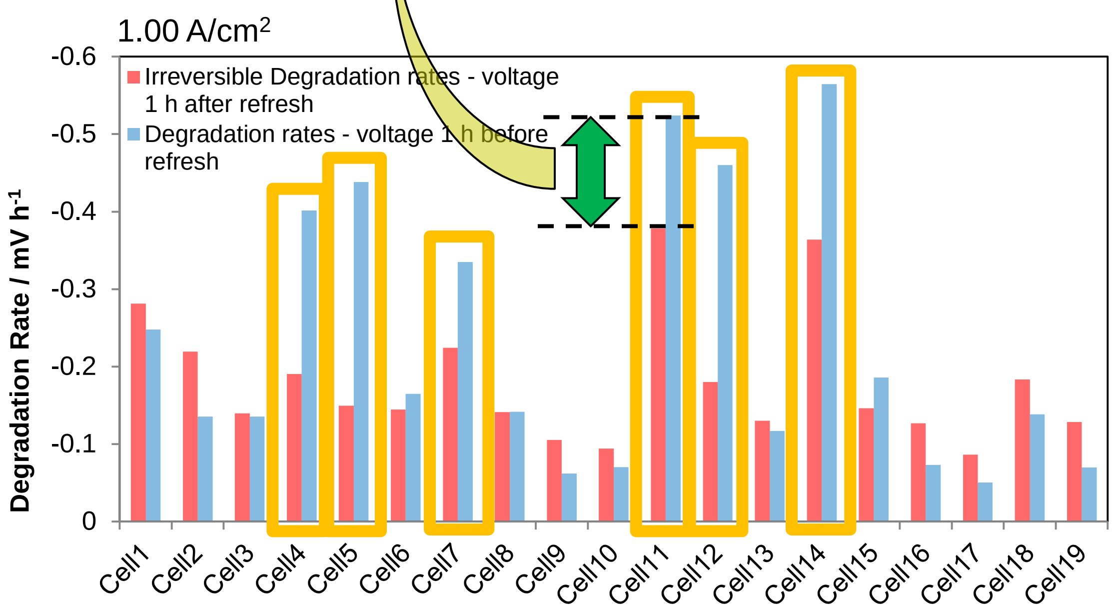

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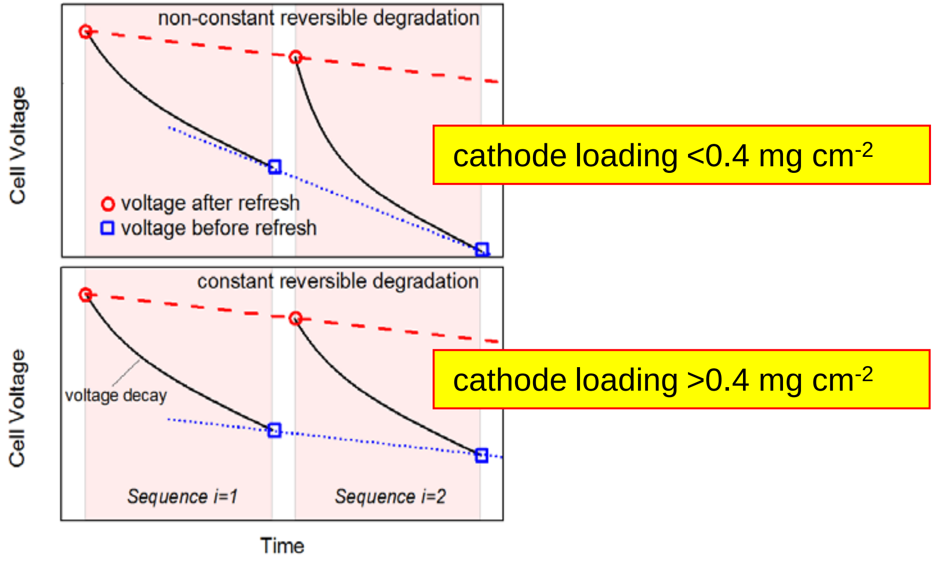
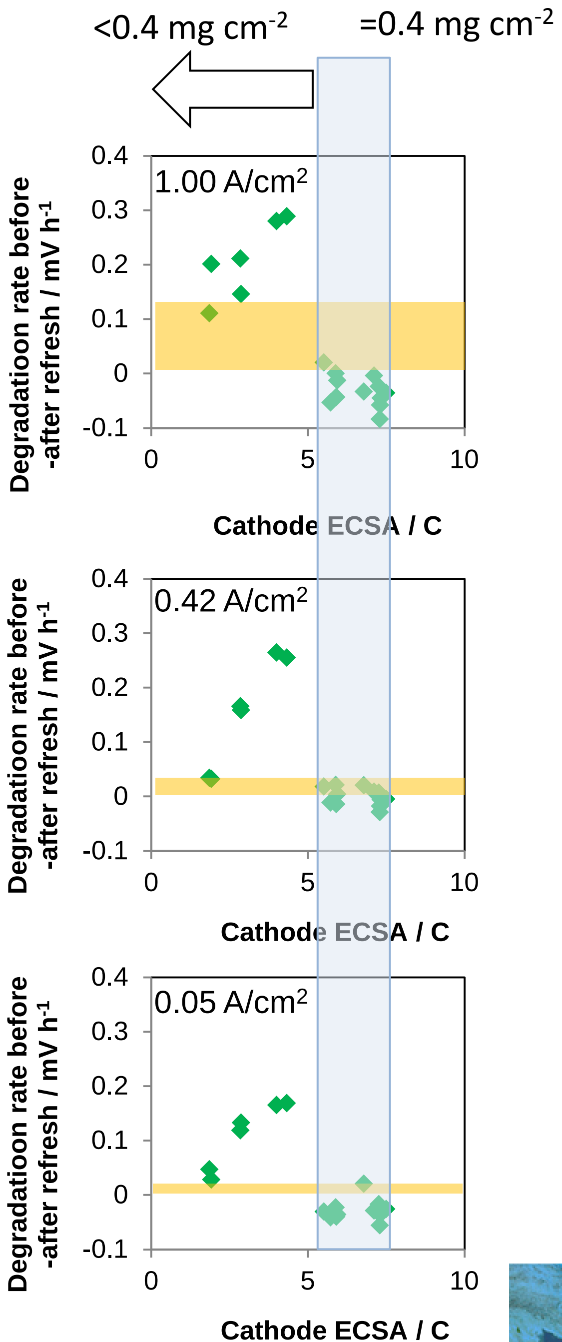
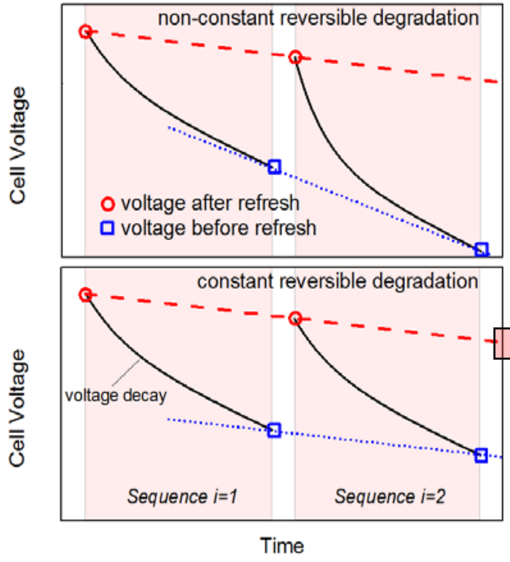




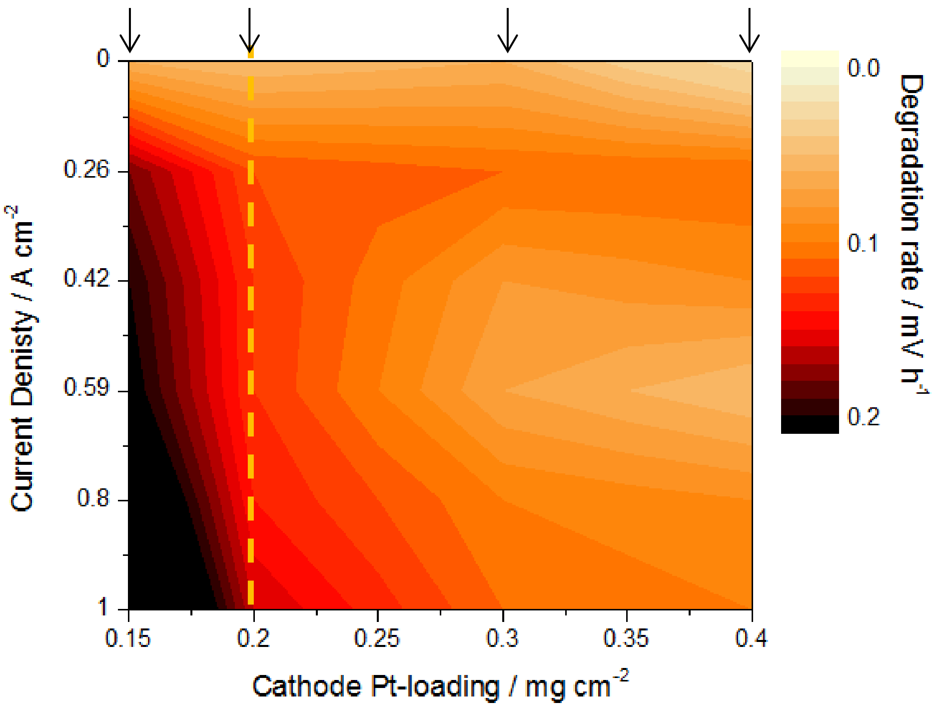
- MEAs with cathode loading <0.4 mg cm^{-2} exhibit non-constant reversible degradation
- Effect strongest at high current density

Degradation Vs Pt-loading: evaluation of irrev. degradation

Significant increase of irrev. degradation for cathode loading <0.2 mg/cm² and high loads

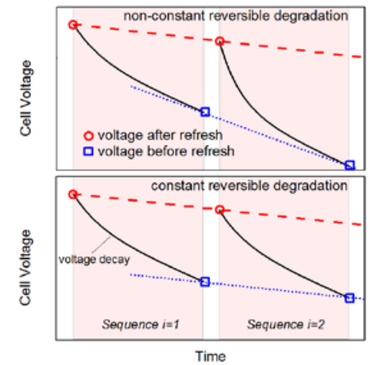


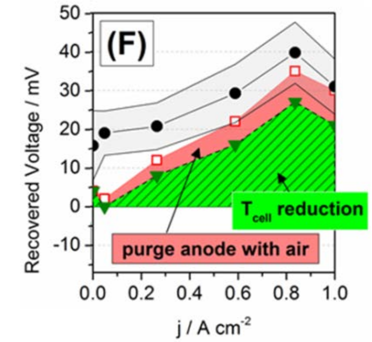
Determination of irrev. degradation (cells 4..9)

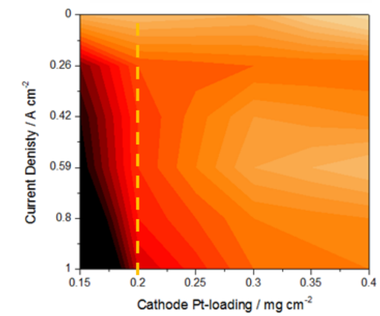


Summary

- Irreversible degradation rate: linear regression of voltage values after refresh
- Voltage recovery: water management, removal of anodic contaminants
- Degradation Vs Pt-loading:
  - accelerated rev. degradation for cathode loadings <0.4 mg cm^{-2}
  - increased irrev. degradation for cathode loading <0.2 mg cm^{-2}







Acknowledgements

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