Diagnostics of PEMFC Degradation

Frano Barbir , Gojmir Radica, Dario Bezmalinović,
Boris Šimić, Željko Penga, Nikolina Pivac and Ivan Pivac
FESB, University of Split

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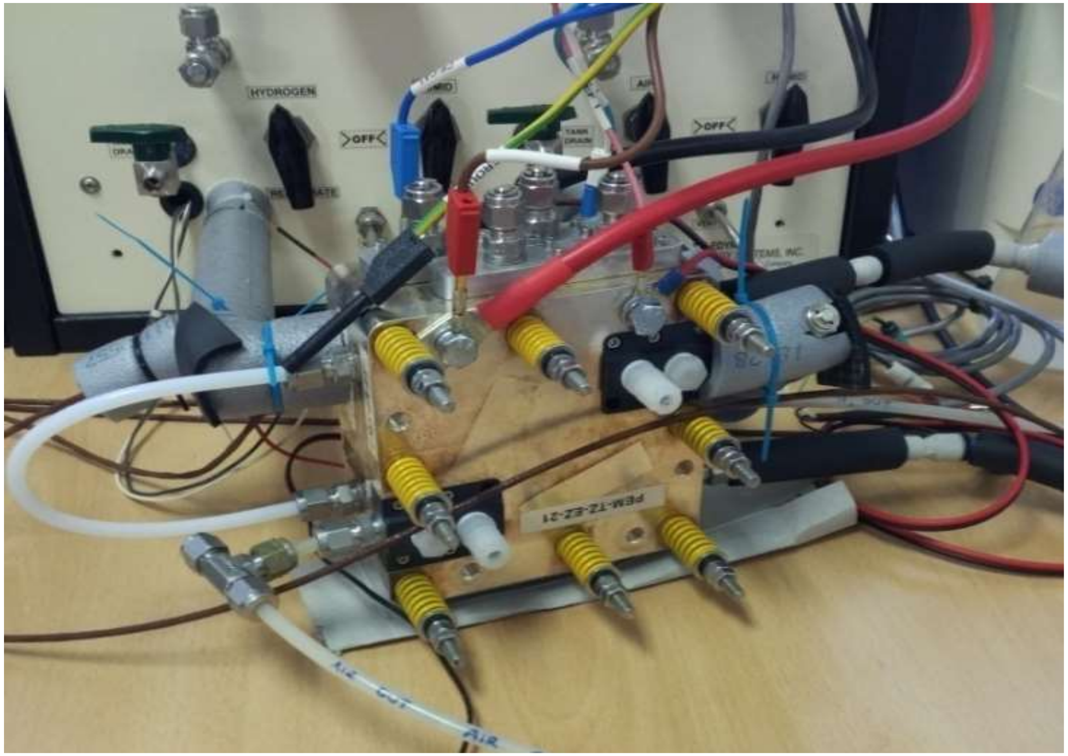
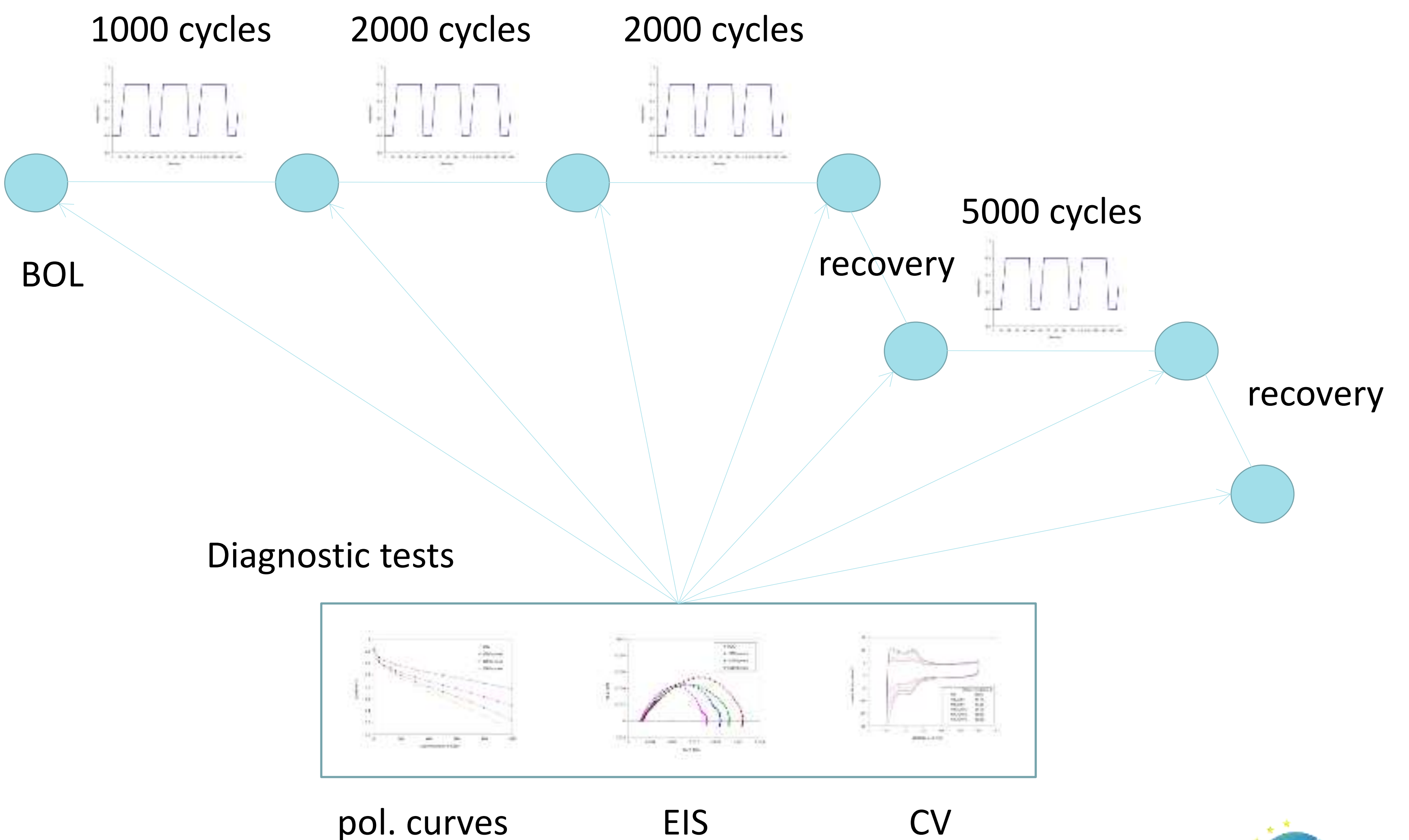
Results of AST of the EK single cell (50 cm^2)

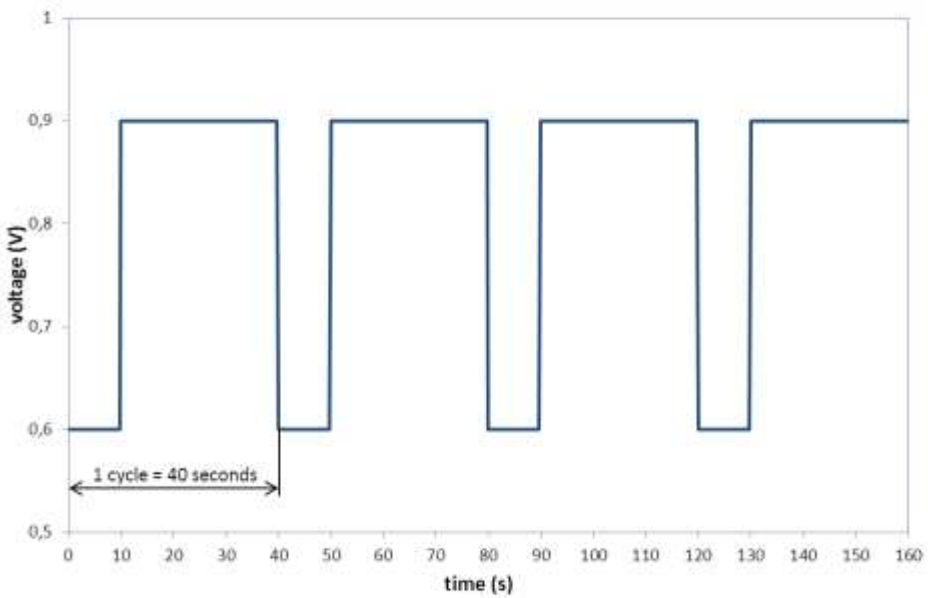


Accelerated Stress Test

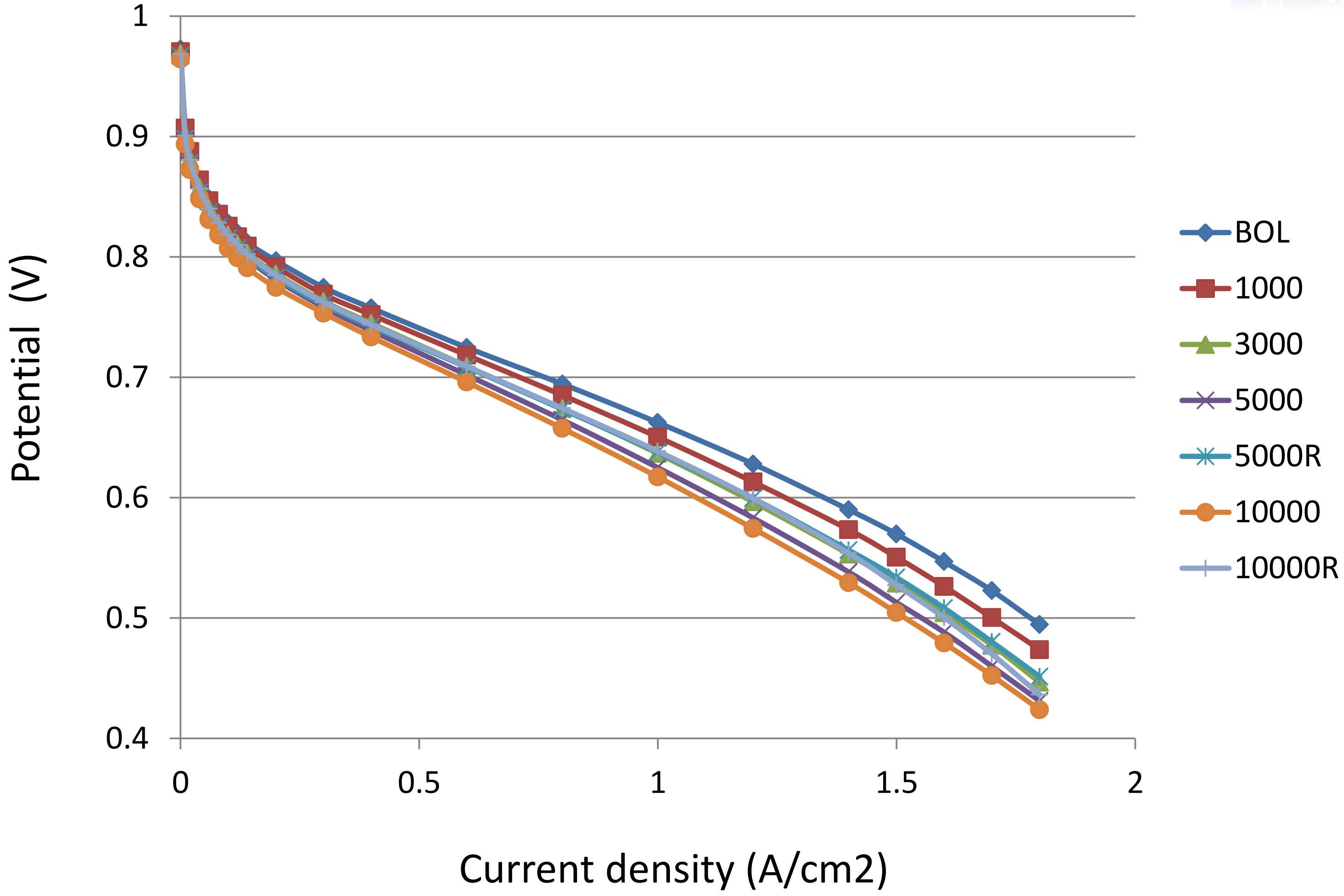


Accelerated stress test

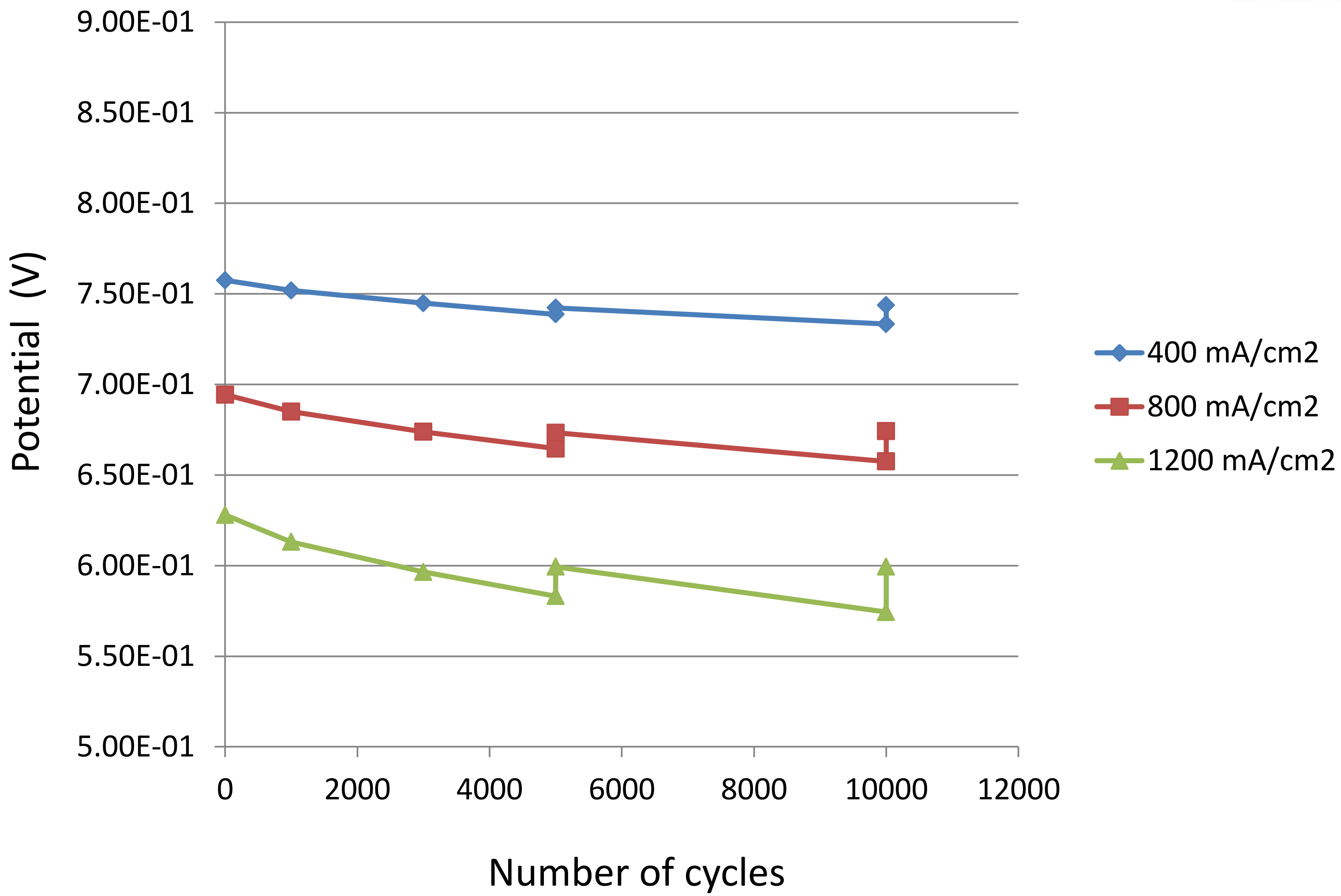
- The AST test is devised according to DOE recommendations for electrocatalyst degradation
- The cell in a "driven" mode → voltage imposed via external device
- Nitrogen on the cathode, hydrogen on the anode (RH 100%)
- Cycling between 0.9 V and 0.6 VS (voltage ramps 1 V s^{-1})
- Cycle duration 40 s (10 s @ 0.6 V; 30 s @ 0.9 V)



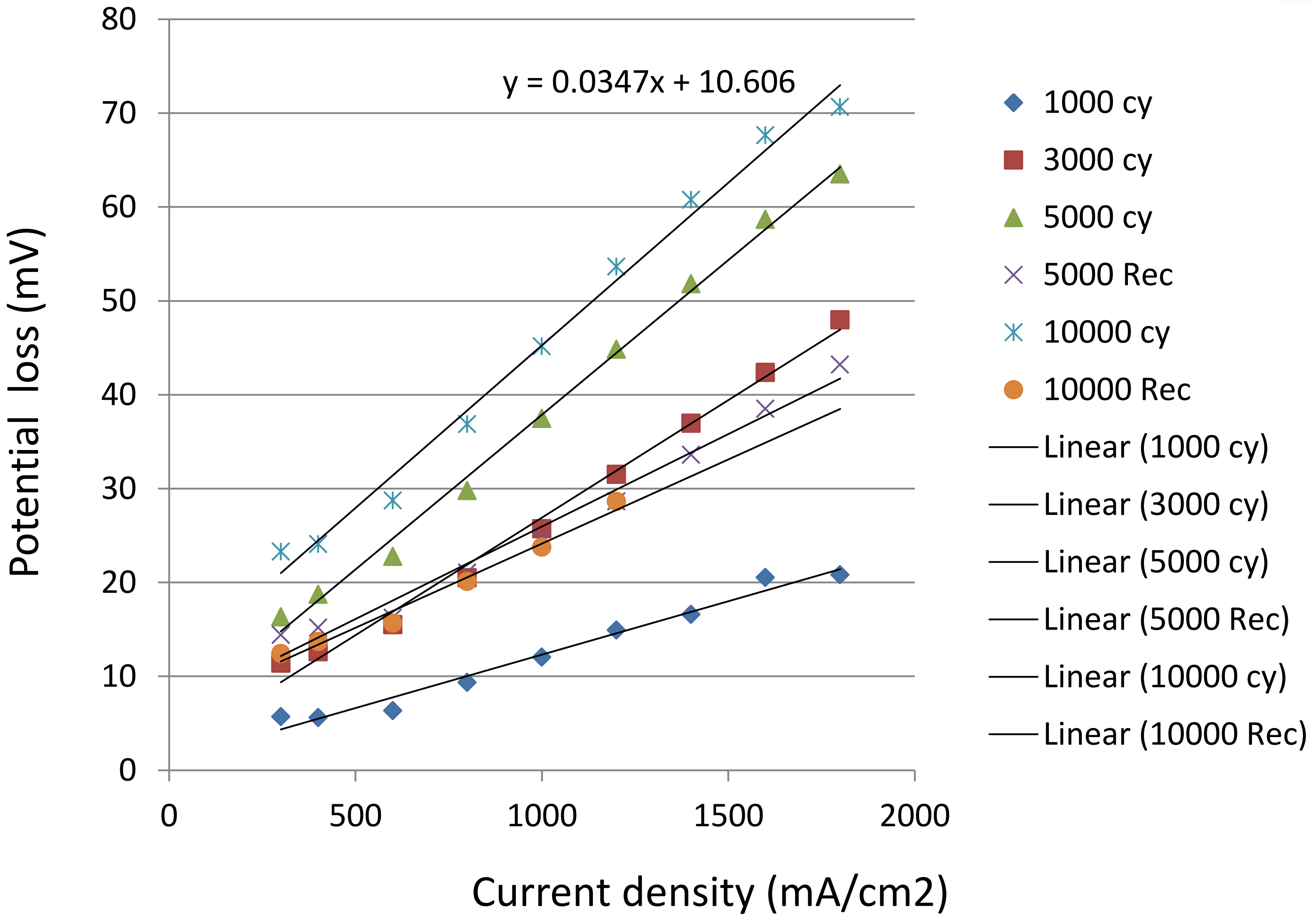
Polarization Curves



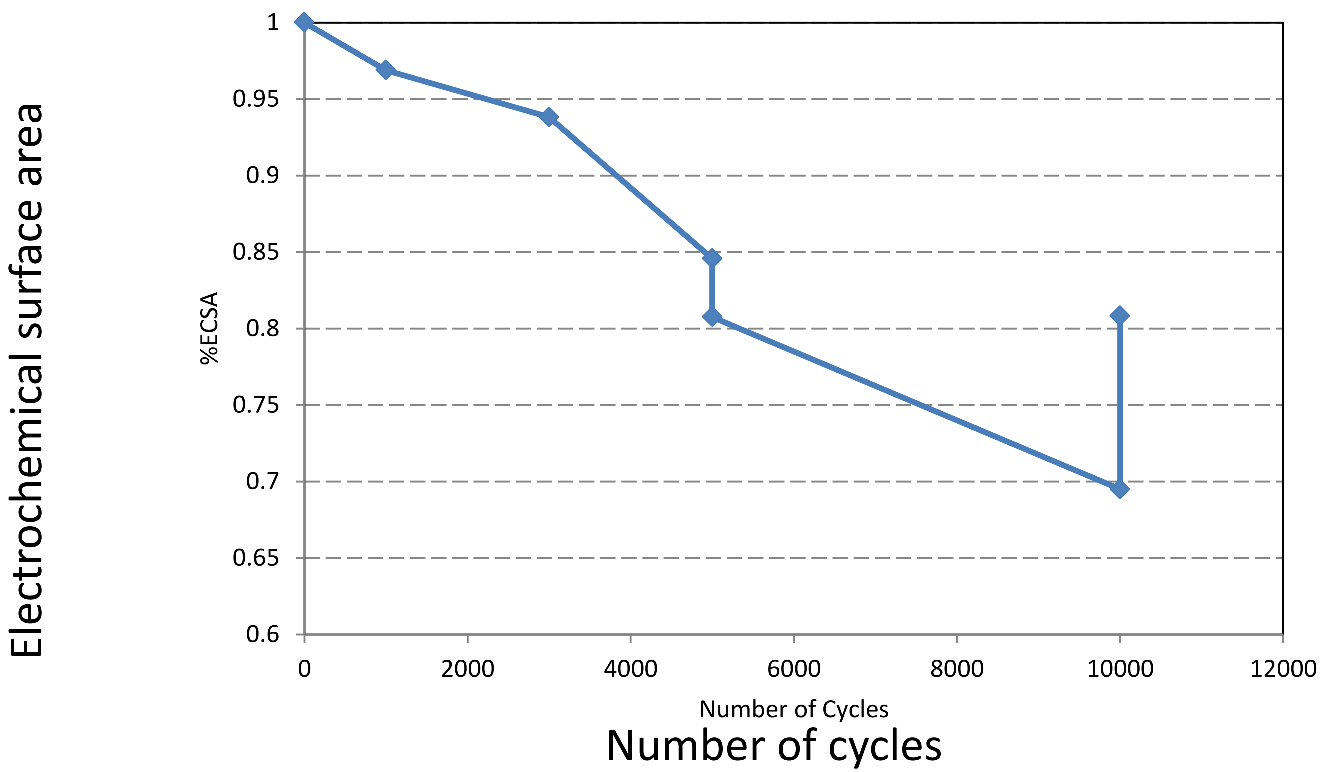
Degradation



Polarization Change Curves

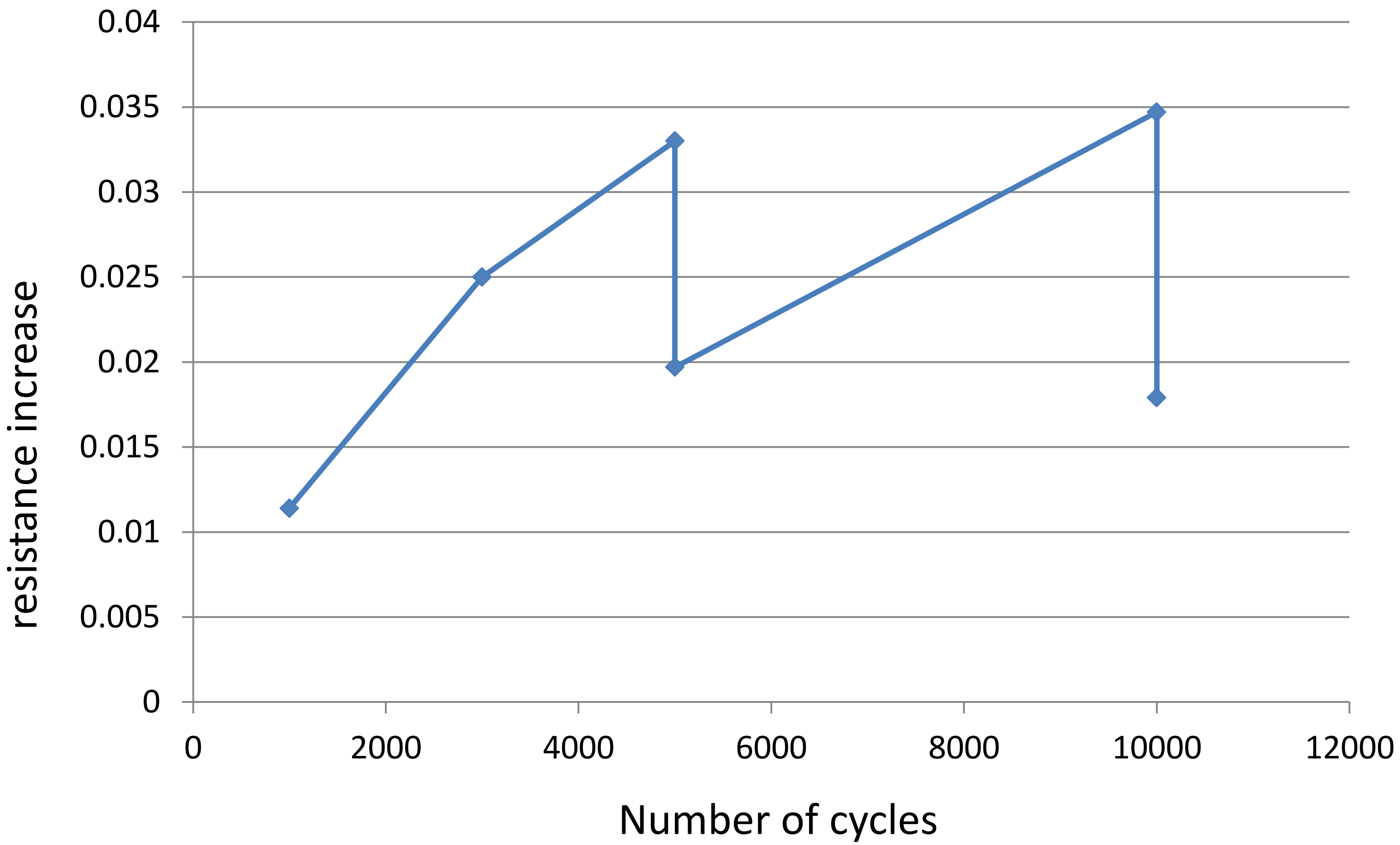


Electrochemical active surface area



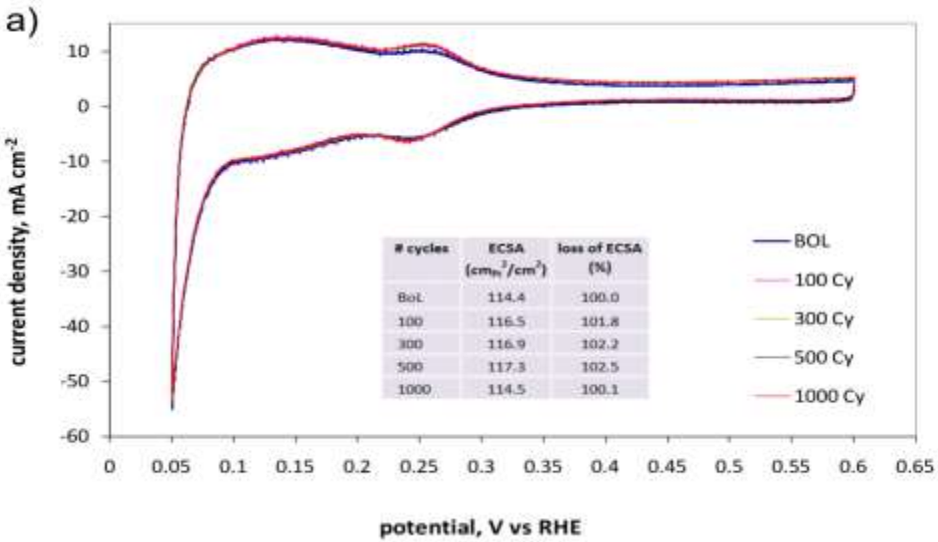
Calculated from intercept of the fitted polarization change curves

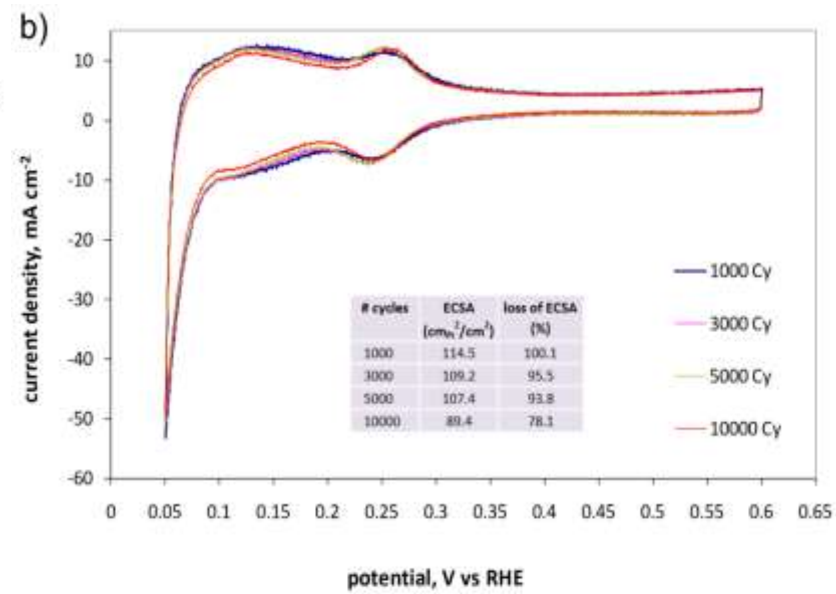
Resistance increase



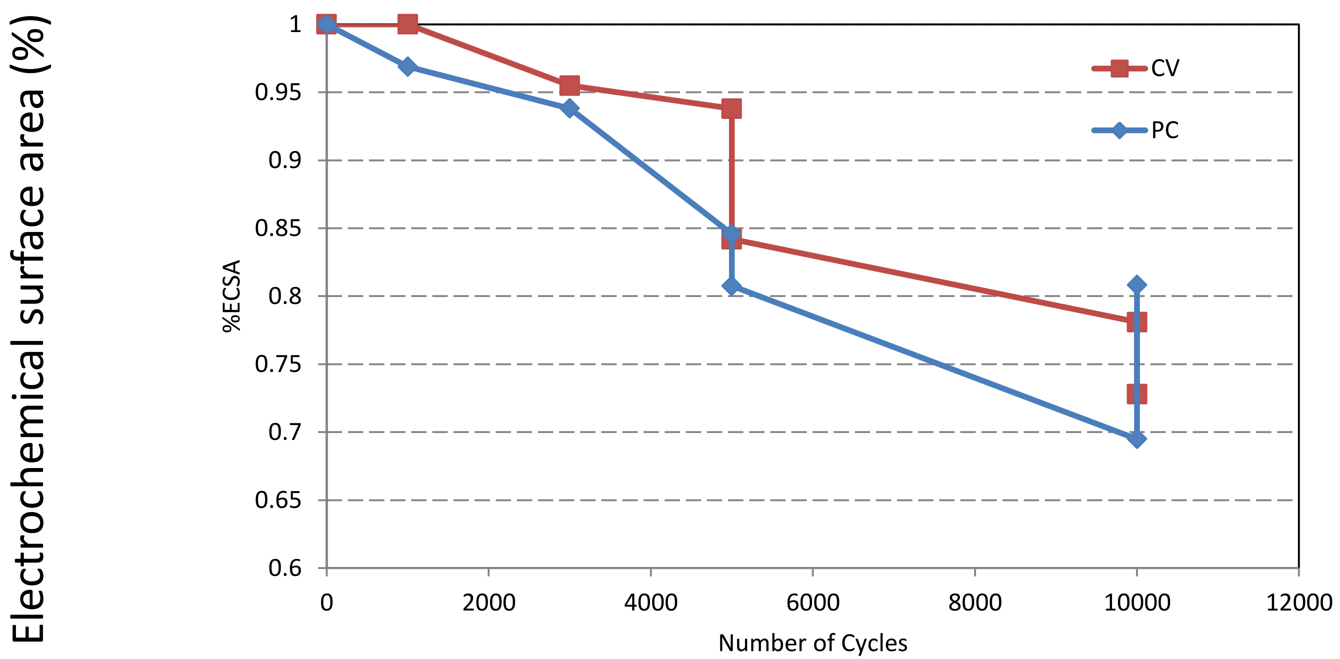
Calculated from the slope of the fitted polarization change curves

Results from Cyclic Voltammetry tests during AST





Comparison between results obtained by CV and Polarization Change Curves Analysis



Number of cycles

CV – calculated from cyclic voltammetry experiments
PCA – calculated from Polarization change curves analysis

EIS degradation testing of EK single cell

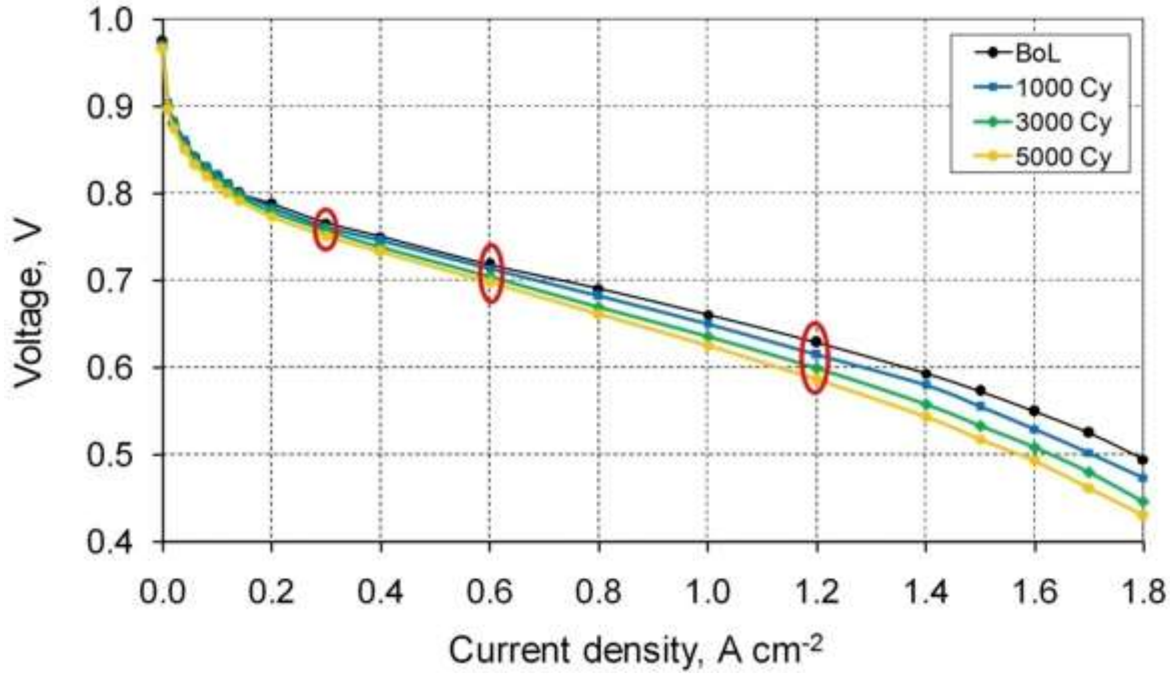


Table 1. Measuring parameters for EIS measurements

Measuring parameter for EIS	Value
AC perturbation amplitude	10% of DC current
upper frequency limit	3981.1 Hz
lower frequency limit	0.01 Hz
duration of stabilization phase	5 min
duration of EIS measurement + DC point	30 min

Table 2. Operating parameters for EIS measurements

Operating parameter for EIS	Value
hydrogen flow stoichiometry on anode	2.0
air flow stoichiometry on cathode	4.0
inlet relative humidity of H_2 at anode	83.4% RH (61 °C DPT)
inlet relative humidity of air at cathode	83.4% RH (61 °C DPT)
anode backpressure	0.5 bar(g)
cathode backpressure	0.5 bar(g)
current densities	0.3, 0.6, 1.2 A cm^{-2}
fuel cell temperature at inlet	65 °C

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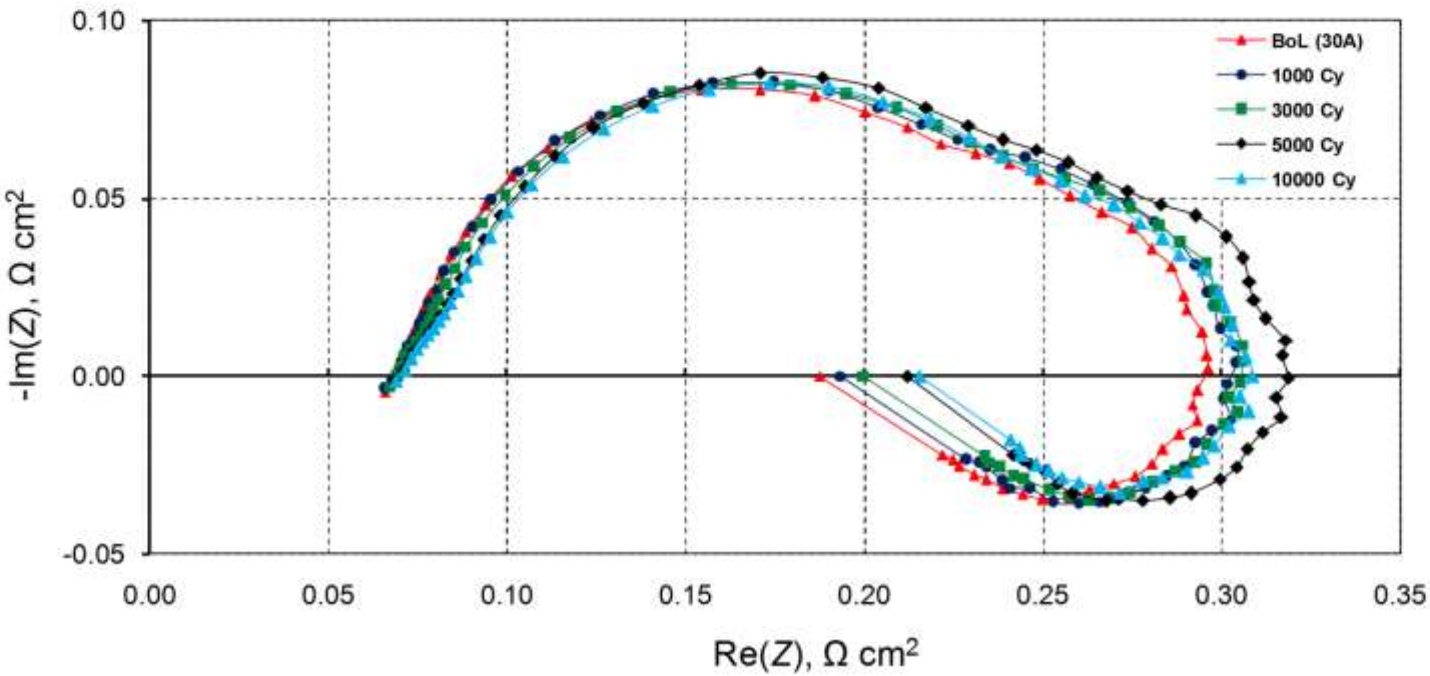
Measured EIS during AST
30 A (0.6 A/cm²)



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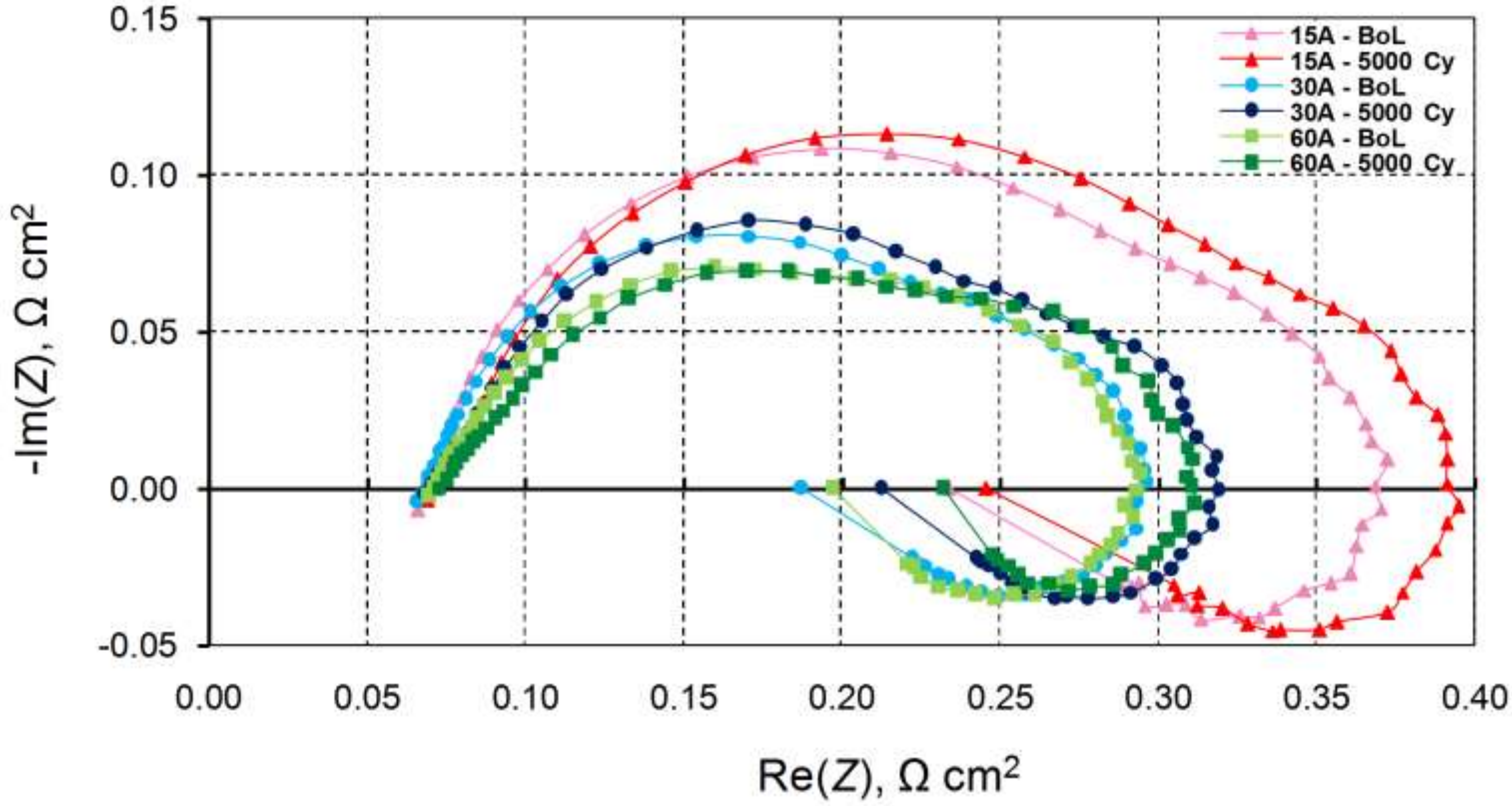
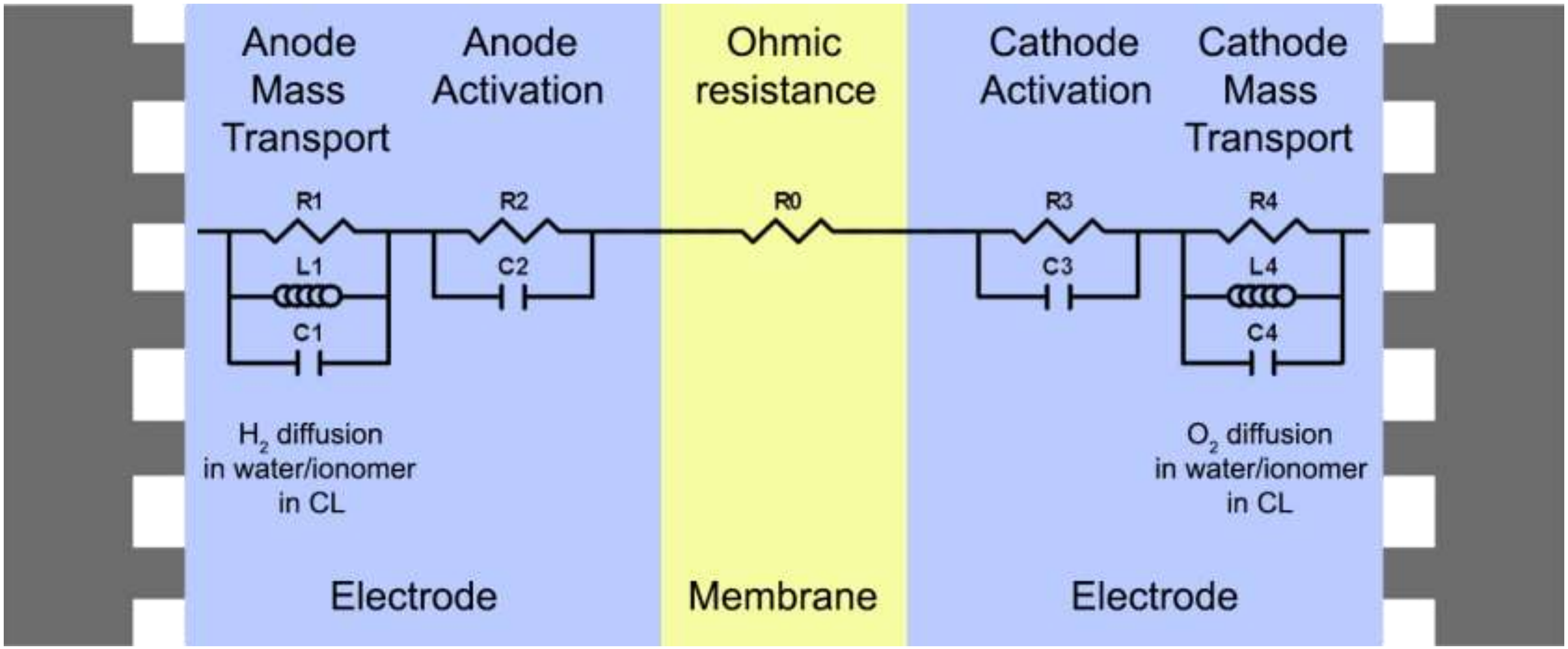
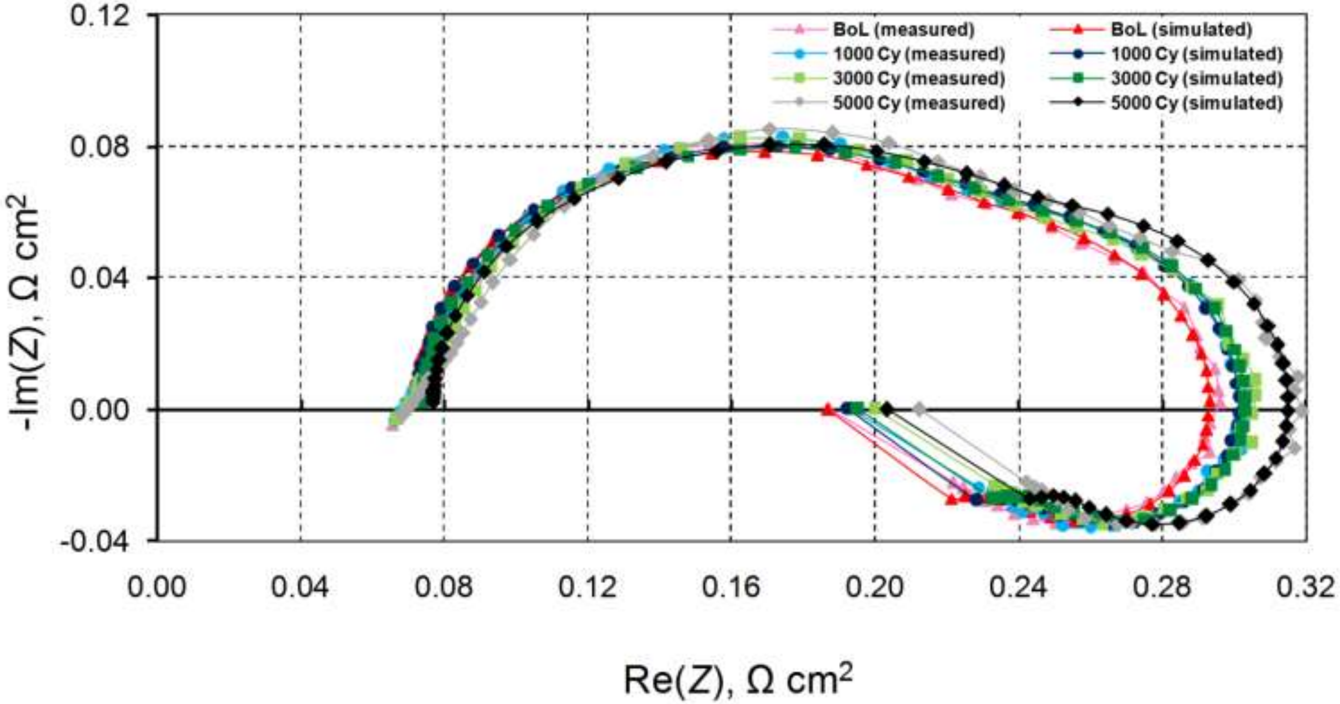
Measured EIS @ BoL vs. 5000 Cy

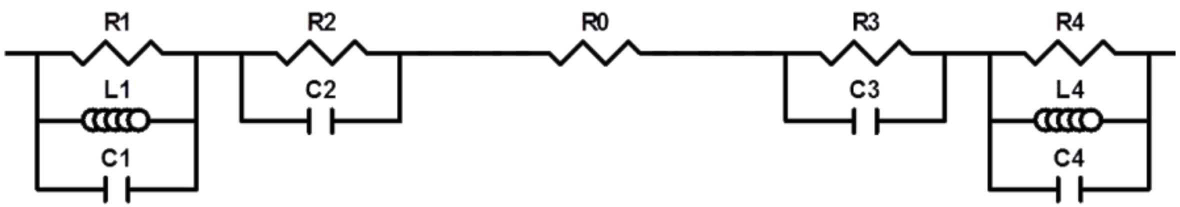


Impedance model of a PEM fuel cell



Measured and simulated EIS during AST 30 A (0.6 A/cm²)





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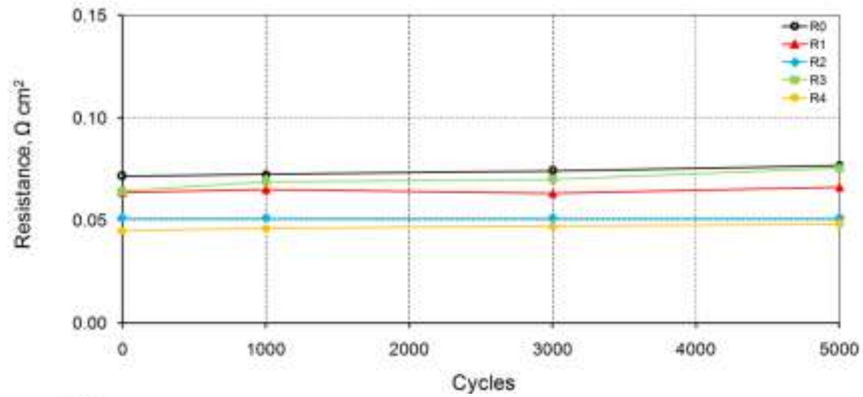
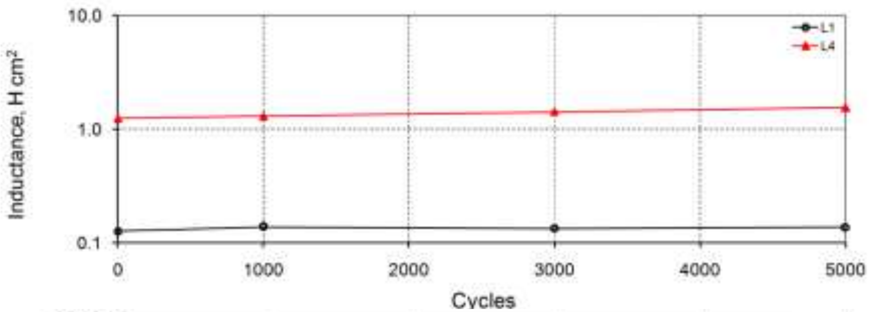
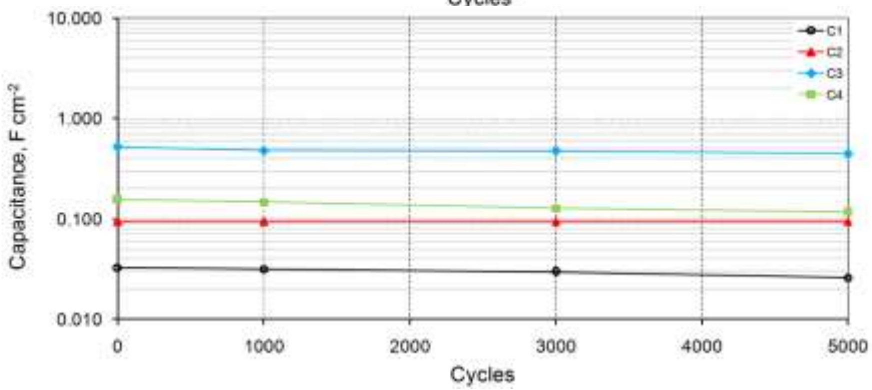
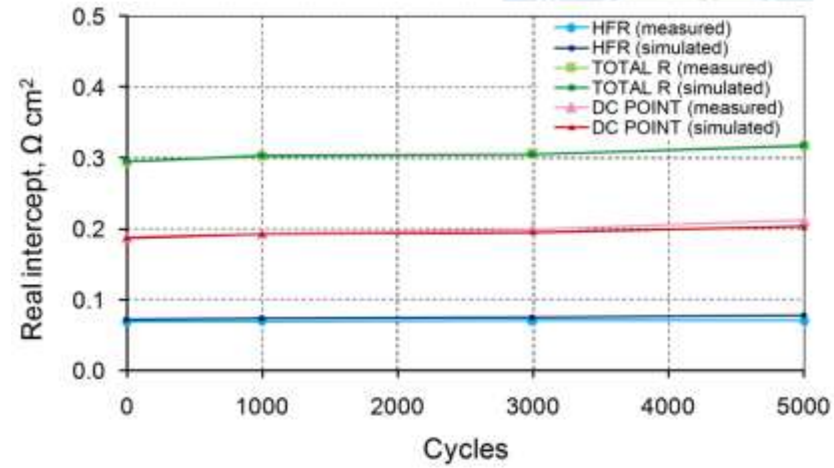
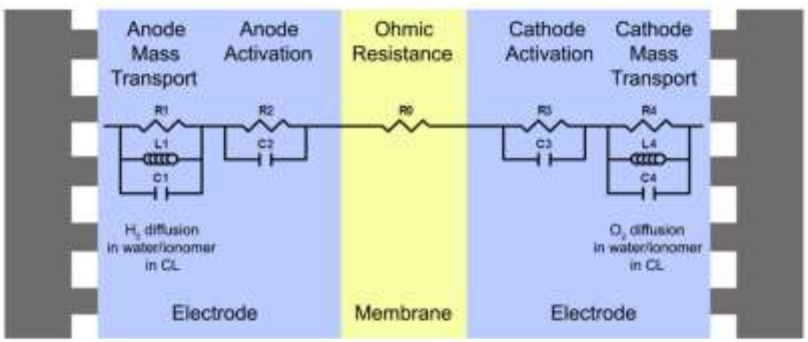
Extracted parameters from EIS during AST 30 A (0.6 A/cm^2)











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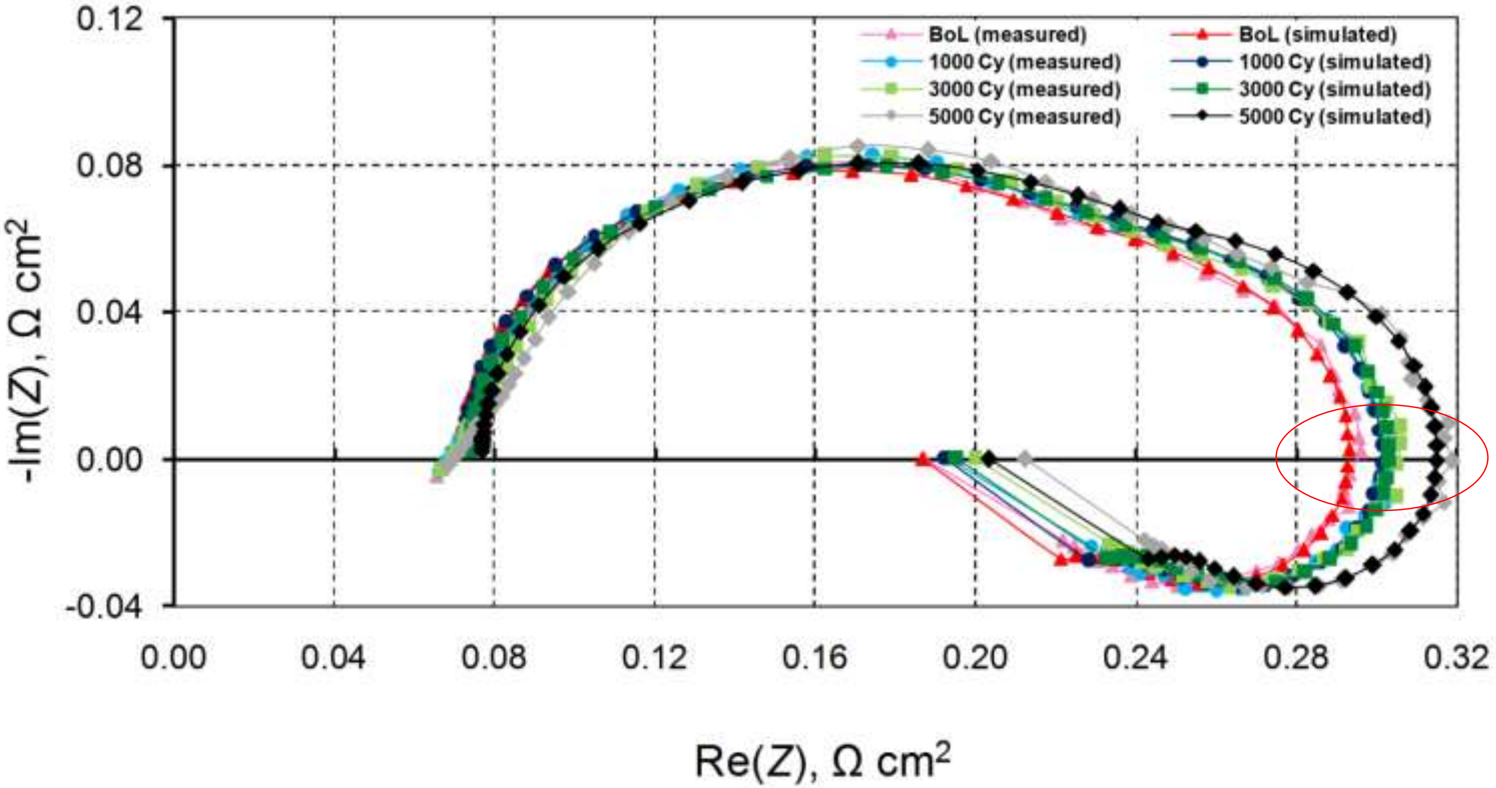
LF intercepts at different current densities during AST



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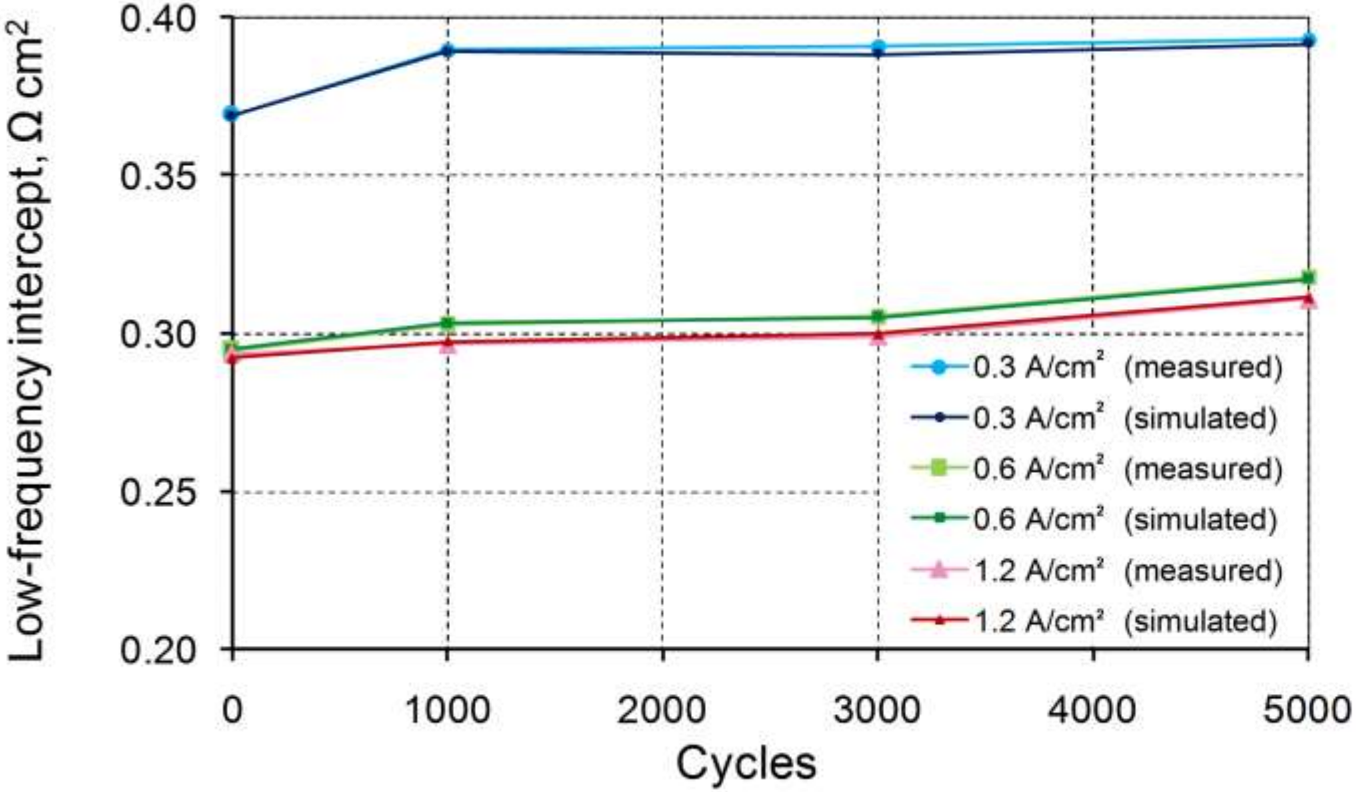
LF intercepts at different current densities during AST



I. Pivac, I. J. Halvorsen, D. Bezmalinović, F. Barbir, F. Zenith: *Low-frequency EIS intercept as a diagnostic tool for PEM fuel cells degradation*, European Fuel Cell Technology & Applications Piero Lunghi Conference (EFC17), Naples, December 12-15, 2017 - submitted

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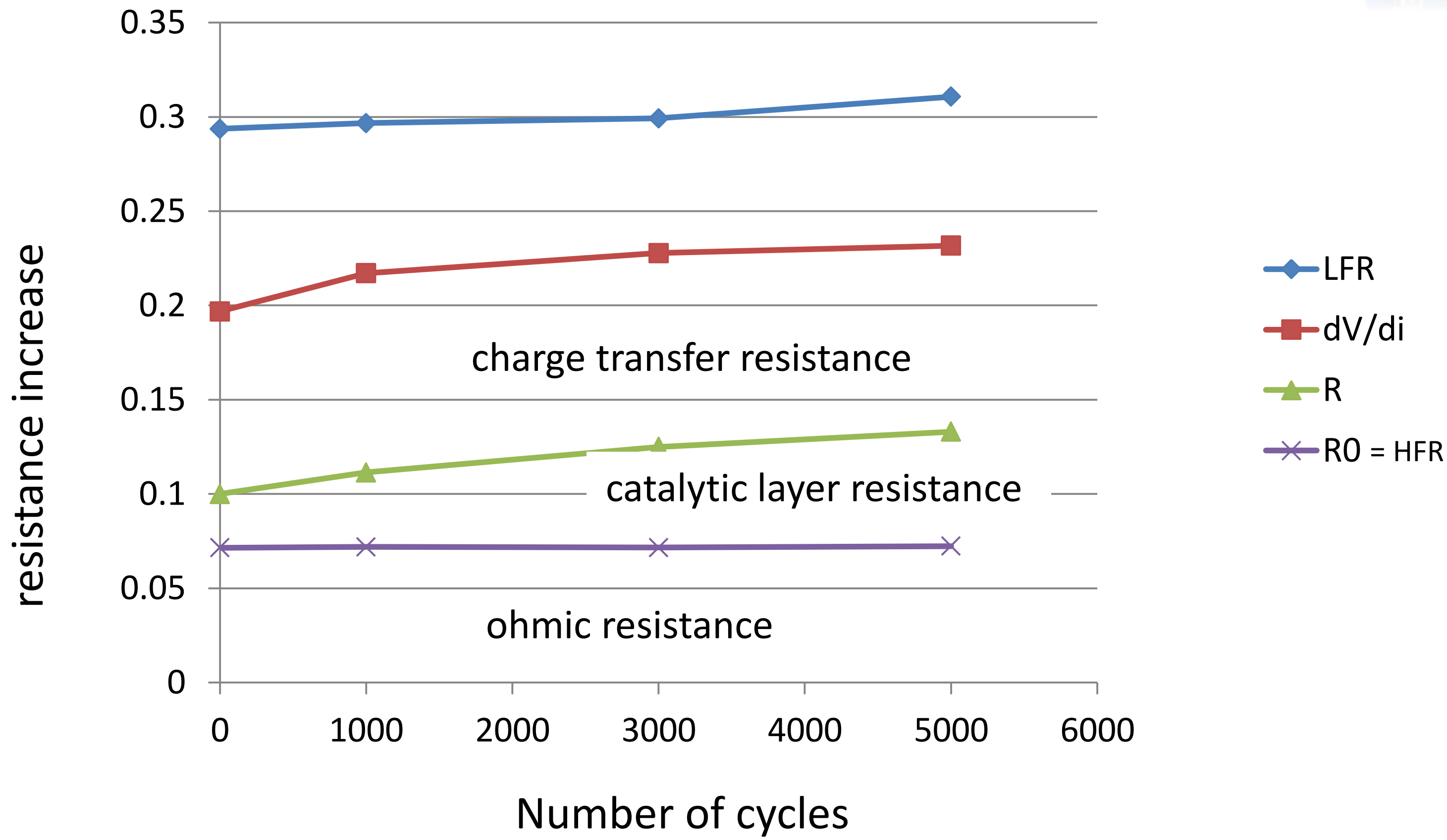
Resistance change during AST



LFR – low frequency intercept from EIS
dV/di – slope of the polarization curve at EIS current
R – resistance from polarization curve fitting
R0 – High frequency resistance from EIS

Key Findings and Conclusions

- The cell moderately degraded over 10000 cycls
- Significant recovery over weekends
- Polarization change curves analysis indicates slight loss of ECSA and slight increase in resistance
- Relatively good agreement (at least qualitatively) between
  - -polarization change curves analysis and EIS measurements
  - -polarization change curves analysis and CV measurements
- Low frequency intercept seems to be a good and easily measured indicator of degradation
- Better understanding of permanent/recoverable degradation and recovery mechanisms needed

Acknowledgments

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Thank you for your attention!