Development of Durable High Temperature PEMFC MEA

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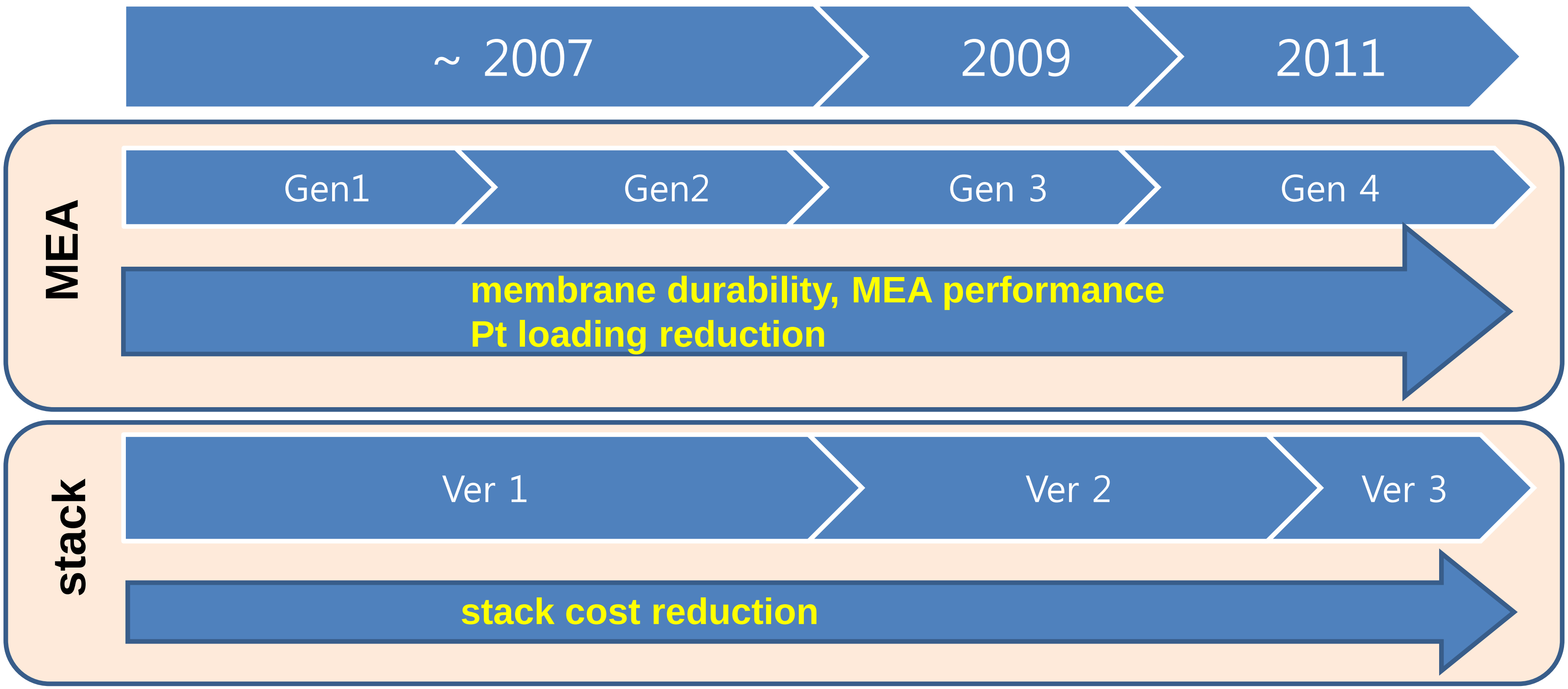
Development of High Temperature PEMFC MEA @SAIT

- Development of membrane, MEA, stack and reformer for high temperature PEMFC
  - target : low cost and durable PEMFC system for residential applications
- Accumulation of membrane and MEA accelerated life time evaluation techniques
- High performance and durable high temperature MEA

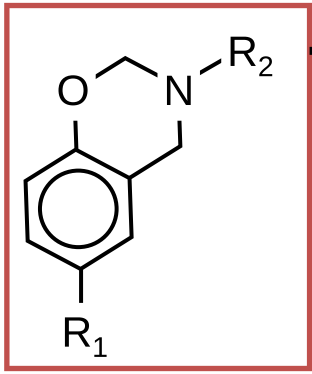


MEA Development Points

- High performance
  - proton conductivity of membrane
  - electrode design
- Durability
  - membrane stability in acid and high temperature environment
  - oxidation resistant catalyst
- Cost reduction
  - Pt loading reduction
  - Manufacturing process simplification

Polybenzoxazine (PBOA) Based Durable Membrane

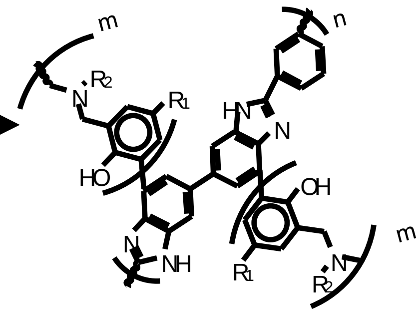
Benzoxazine (BOA)

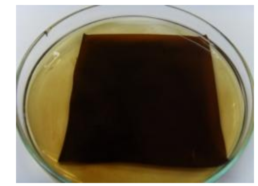


Thermosetting Resin
- Excellent mechanical properties
- High thermal stability
- No condensation product
- Low water uptake
- Molecular design flexibility
- Near zero shrinkage upon curing
- Low cost scale up production

△

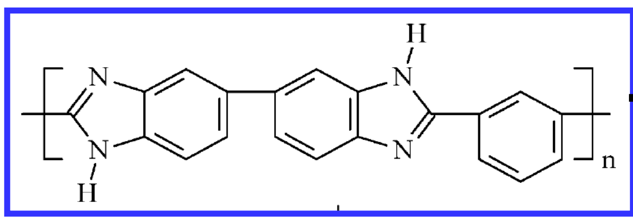
grafted copolymer



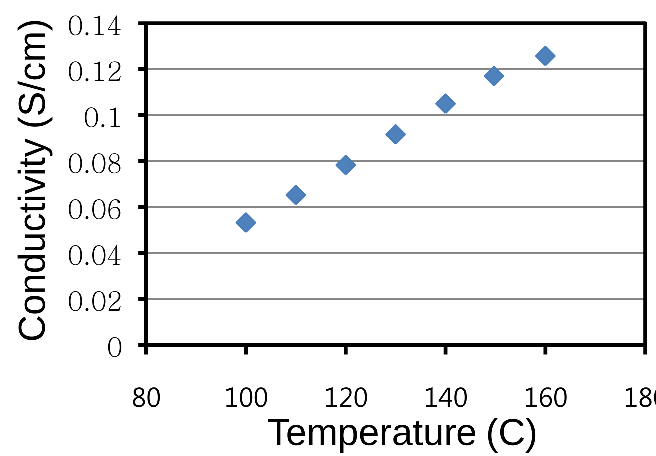


@160℃ after 24h

Polybenzimidazole (PBI)



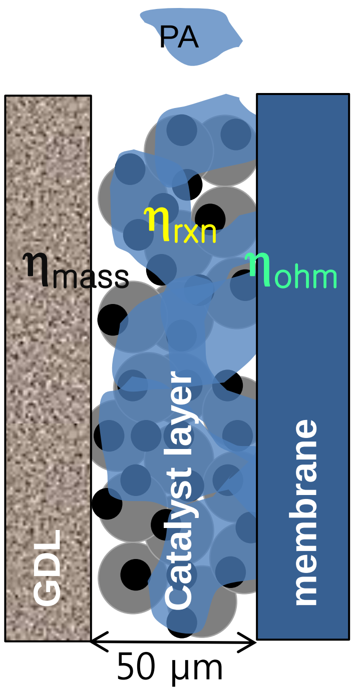
Thermoplastic Polymer



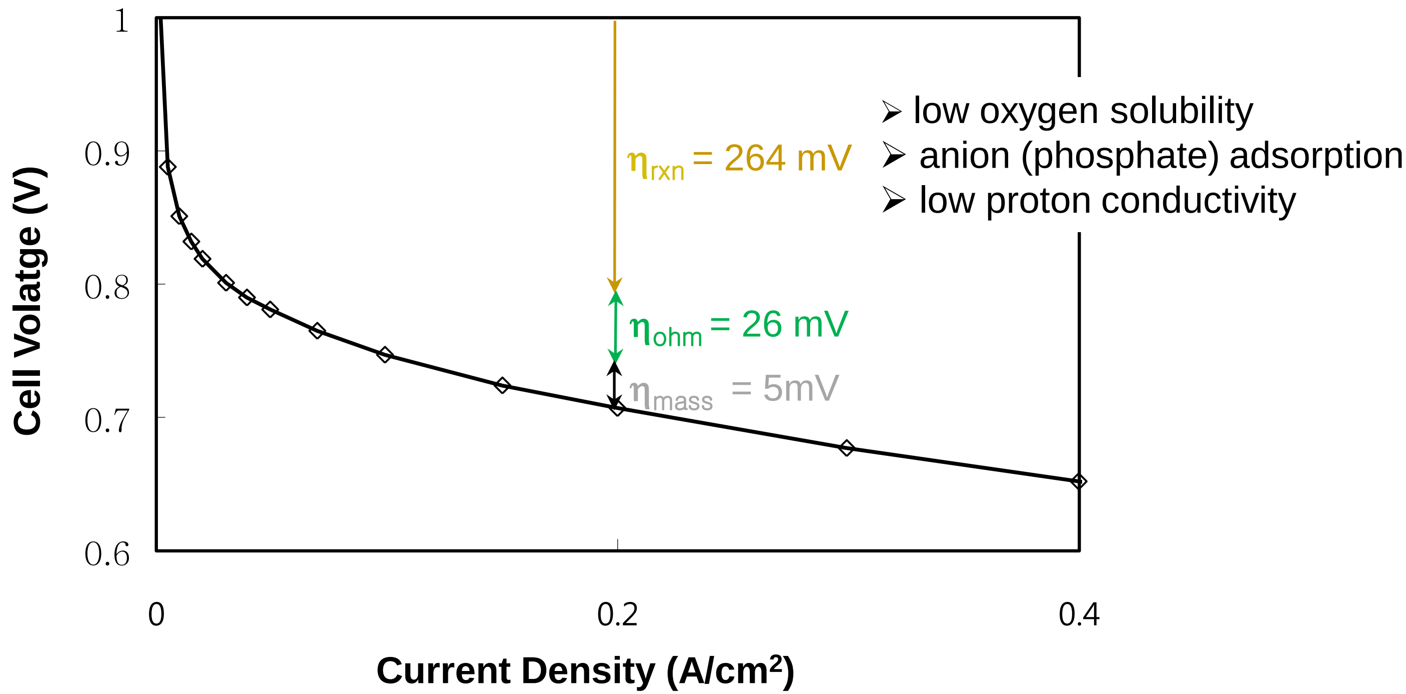
creation+

MEA Performance Analysis

- Break down of overpotentials : η_{rxn} >> η_{ohm} > η_{mass}
- Presence of phosphoric acid slows down ORR

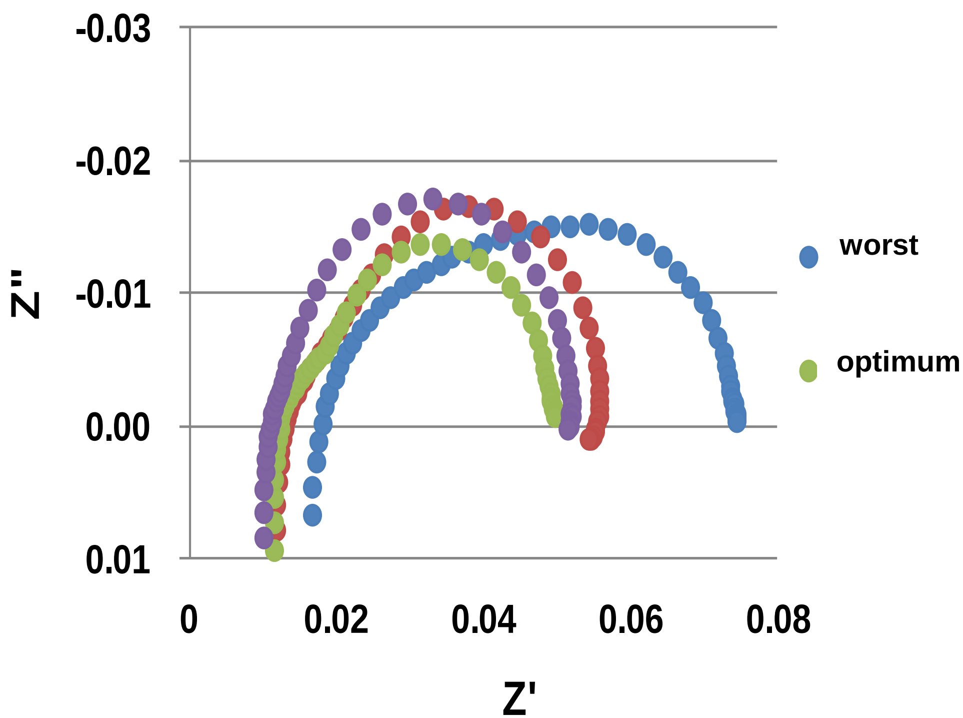


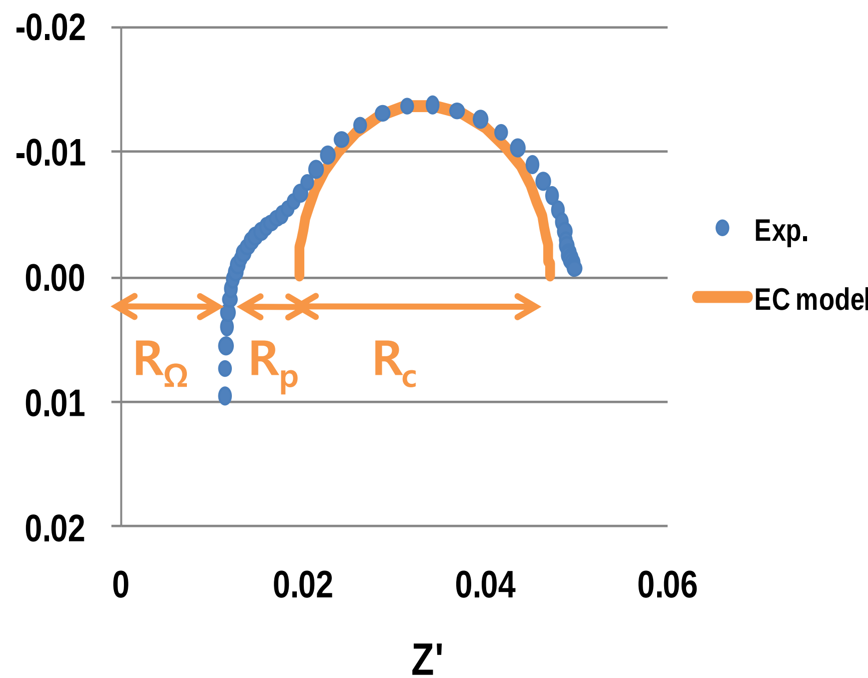
cathode



Impedance Analysis

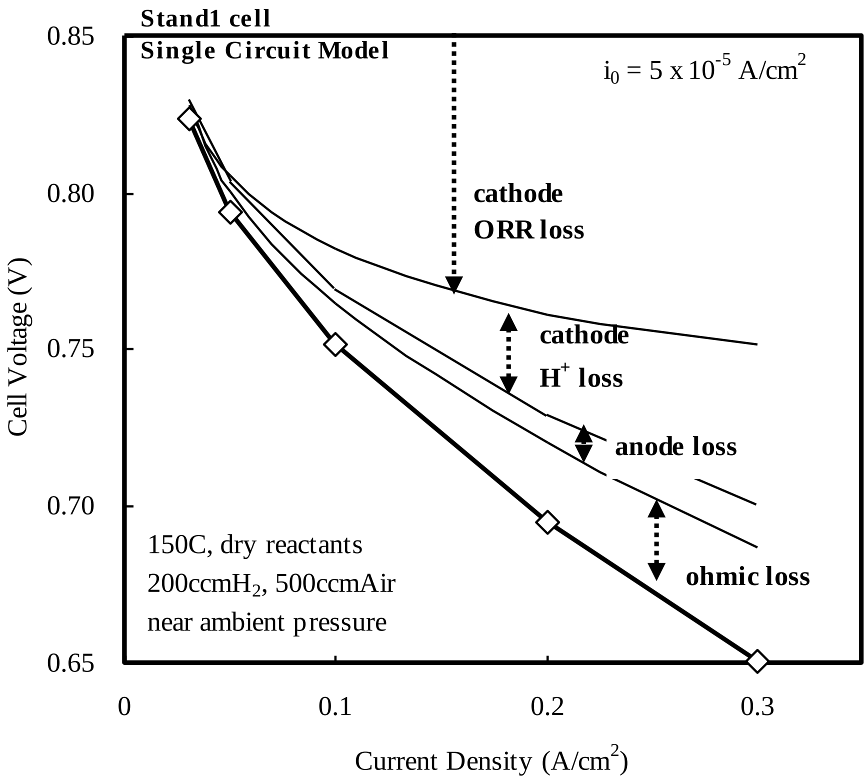
- charge transfer resistance shape vary with acid distribution
- Separation of impedance into ohmic (R_Ω), proton transfer (R_p) and charge transfer (R_c) resistance



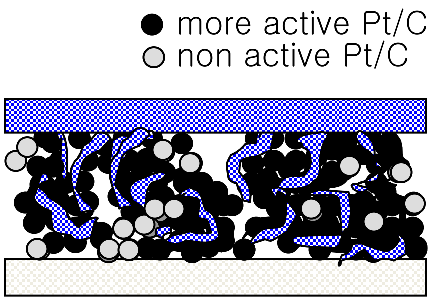


Impedance Analysis

- losses caused by ohmic, proton transfer, ORR resistances can be quantified.
- necessary improvements in the MEA can be proposed.

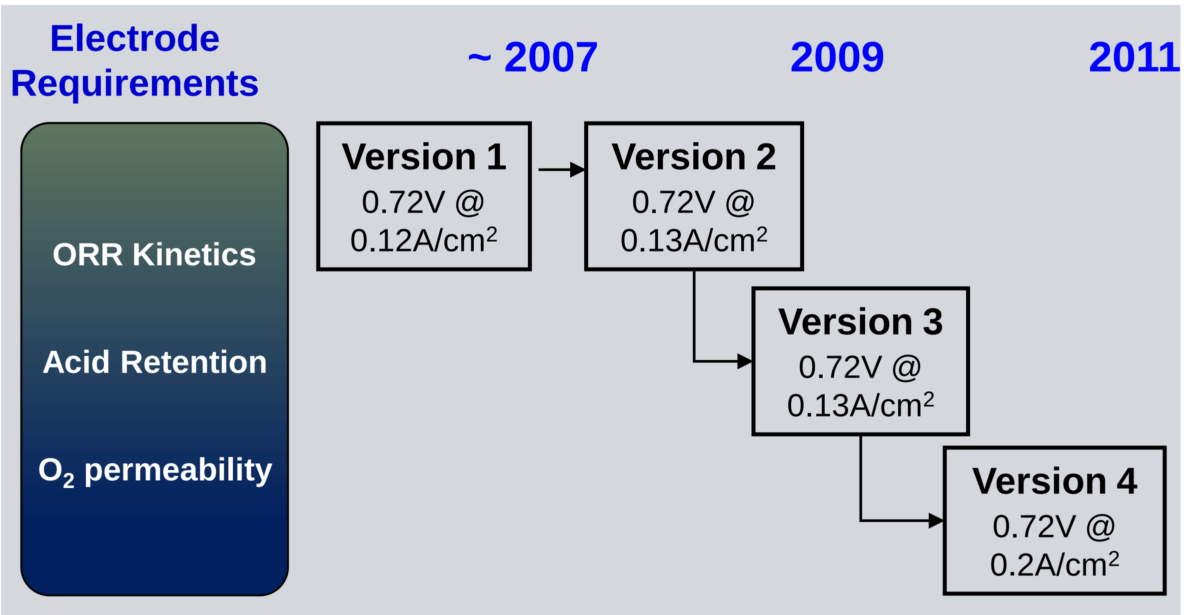


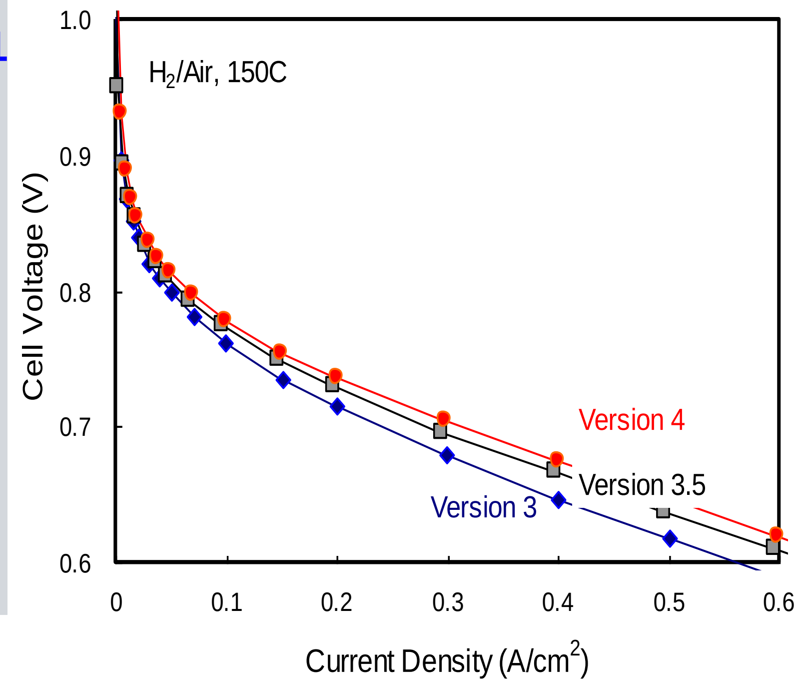
Impedance	Improvements
Ohmic	Conductivity of membrane Memb/catalyst layer interface
H^+ transfer	Acid distribution in catalyst layer
ORR	Catalyst improvement O_2 concentration in catalyst layer



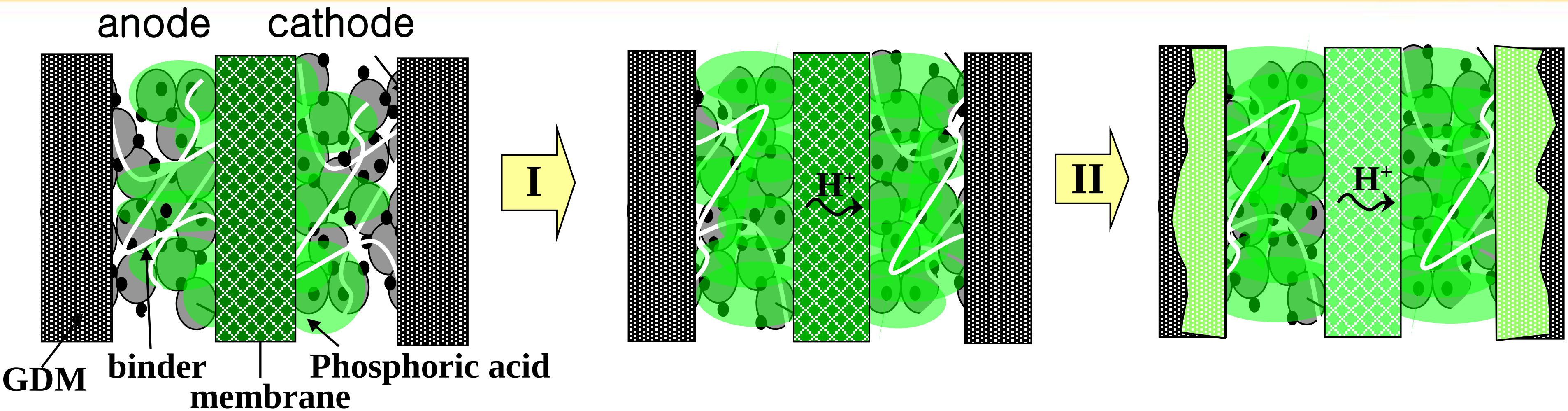
MEA Development

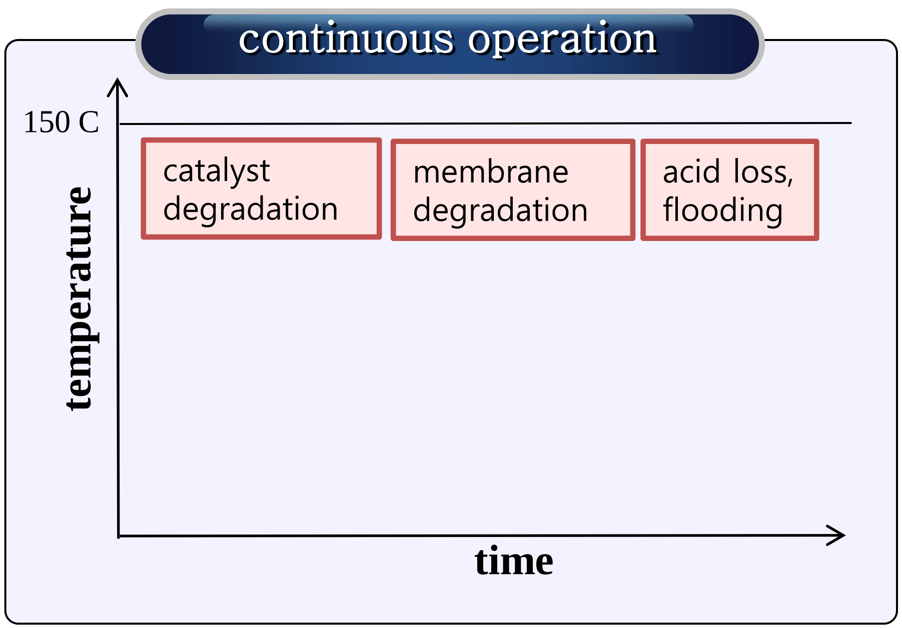
- Improvements in cell voltage → 0.72 V @ 0.2 A/cm^2 (H_2/air, 150 ^oC)
  - Implementing alloy catalyst and performance enhancing binder
  - Improving acid distribution and Pt utilization within MEA
- Cell performances analysis : *in-situ* electrochemical analysis and *ex-situ* methods

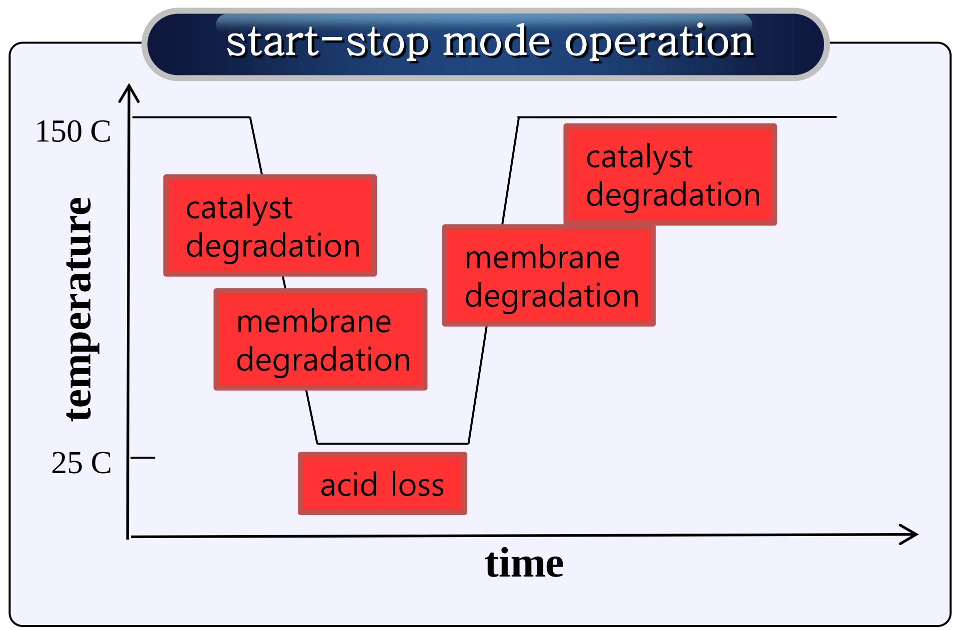




Changes within MEA during operation

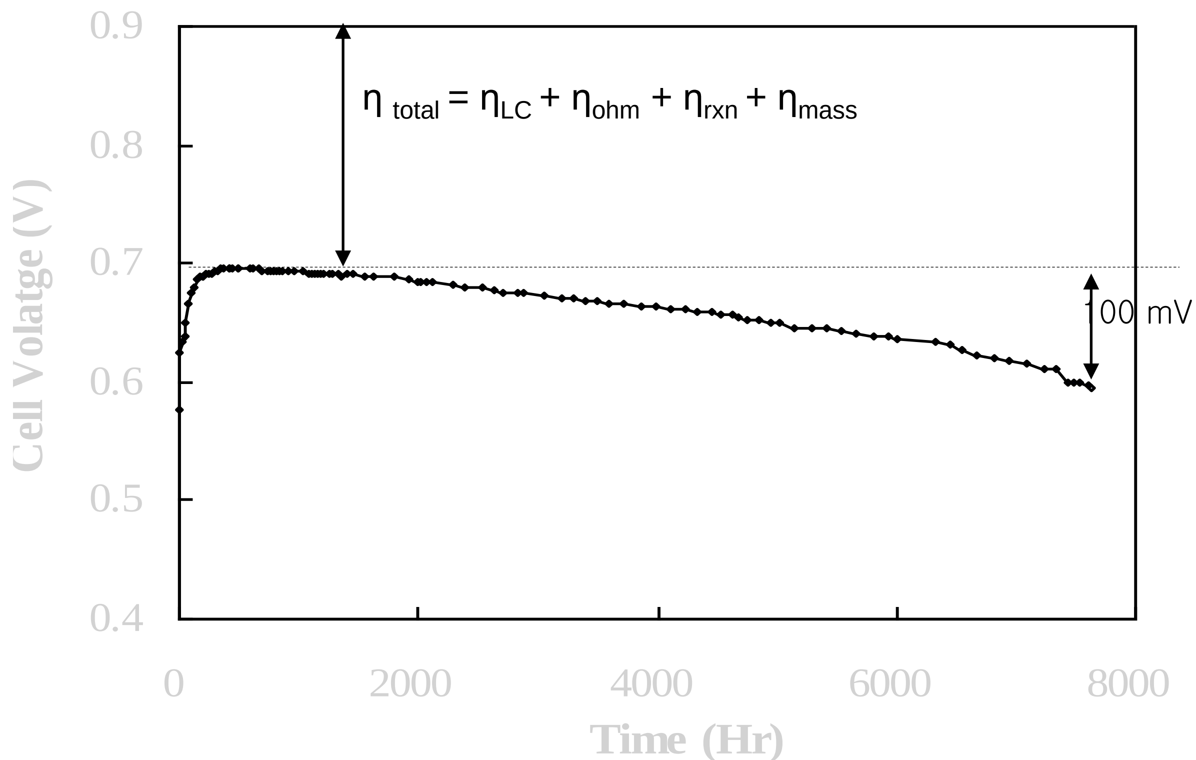






MEA Durability Analysis

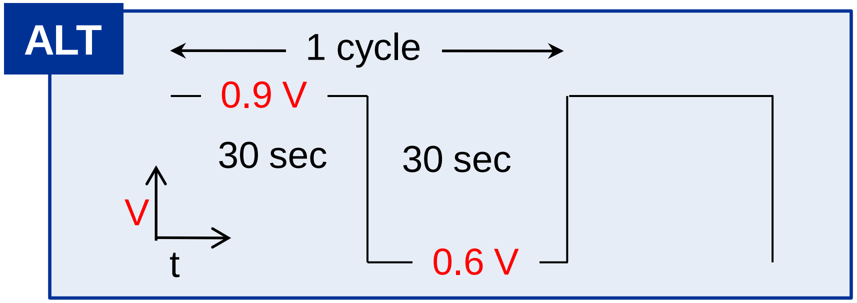
- Changes of overpotentials during operation : $\eta_{rxn} >> \eta_{ohm}, \eta_{mass} > \eta_{LC}$
- Ex situ analysis of catalyst confirm degradation

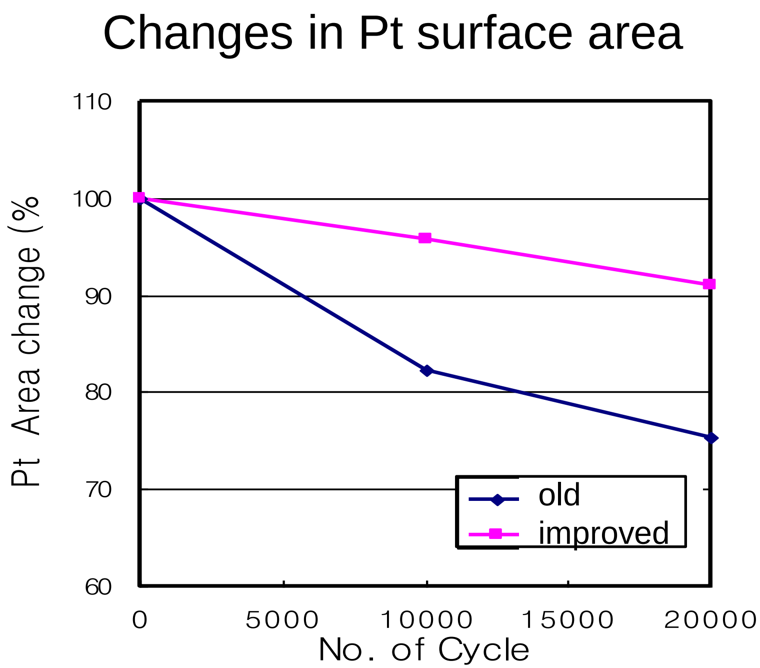


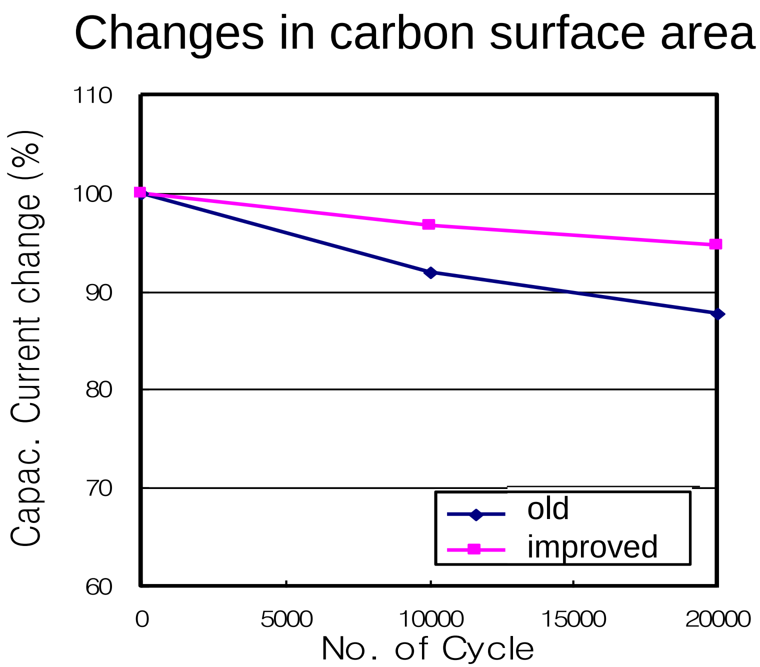
$+\Delta\ \eta_{LC}$ = 10 mV $+\Delta\ \eta_{ohm}$ = 15 mV	membrane
$+\Delta\ \eta_{rxn}$ = 60 mV $+\Delta\ \eta_{mass}$ = 15 mV	electrode

MEA Durability Improvement : Durable Catalyst ①

- Catalyst screening : Accelerated Life Time test (ALT)
- Evaluation criteria : $\Delta\ Pt_{S.A}$ and $\Delta\ C_{S.A}$



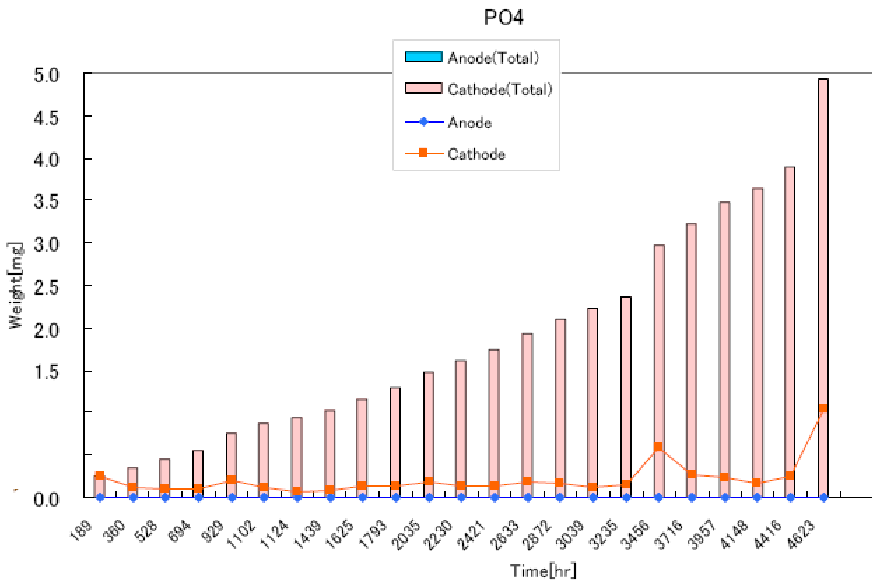




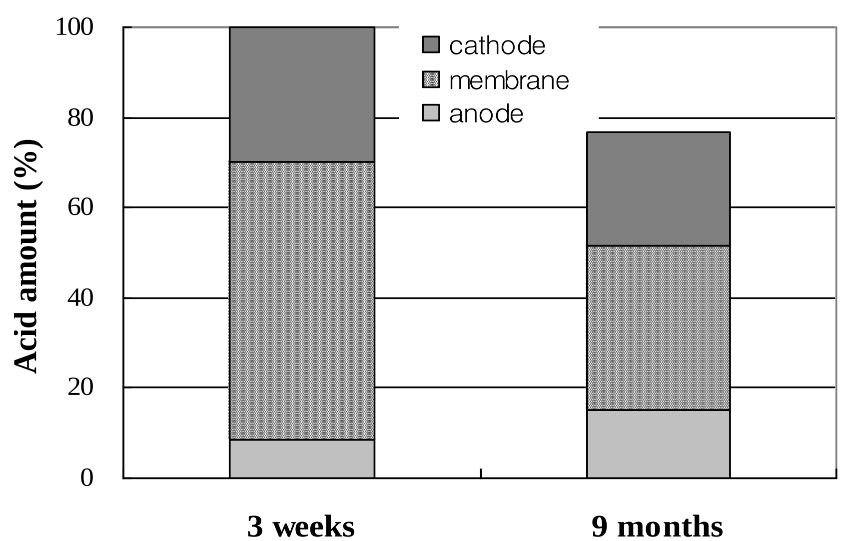
MEA Durability Improvement : Acid Loss

- Quantification of acid losses
  - during MEA operation : analysis of acid content in anode and cathode gas outlet
    → ~0.8 ug/hr (1.3 mg/cm^2 acid loss in 40,000 hr)
  - after MEA operation : actual acid loss is larger.
- MEA optimization under progress

PO4 loss through gas outlet



Changes in MEA acid content

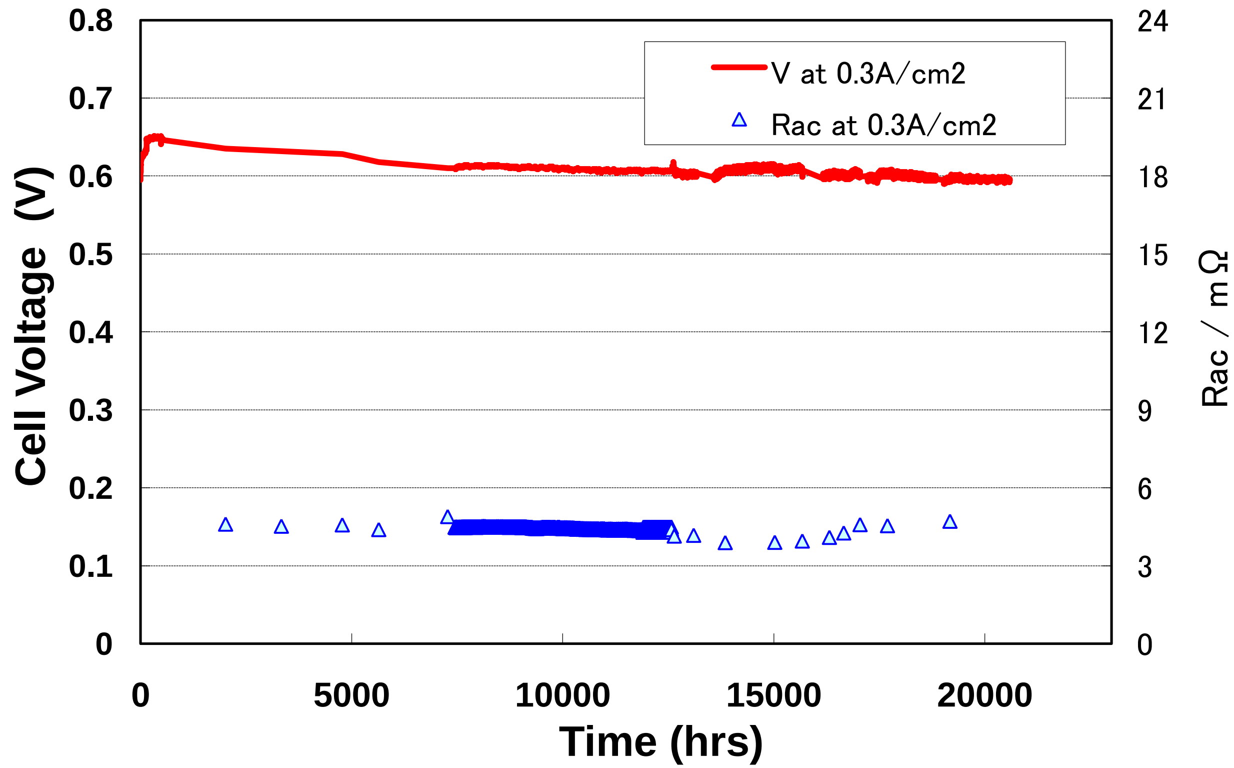


25 cm^2 cell, 150 ^{o}C, operated at 0.3A/cm^2

0.66 ~ 0.95 μg/hr phosphoric acid loss

MEA Durability : Continuous Operation

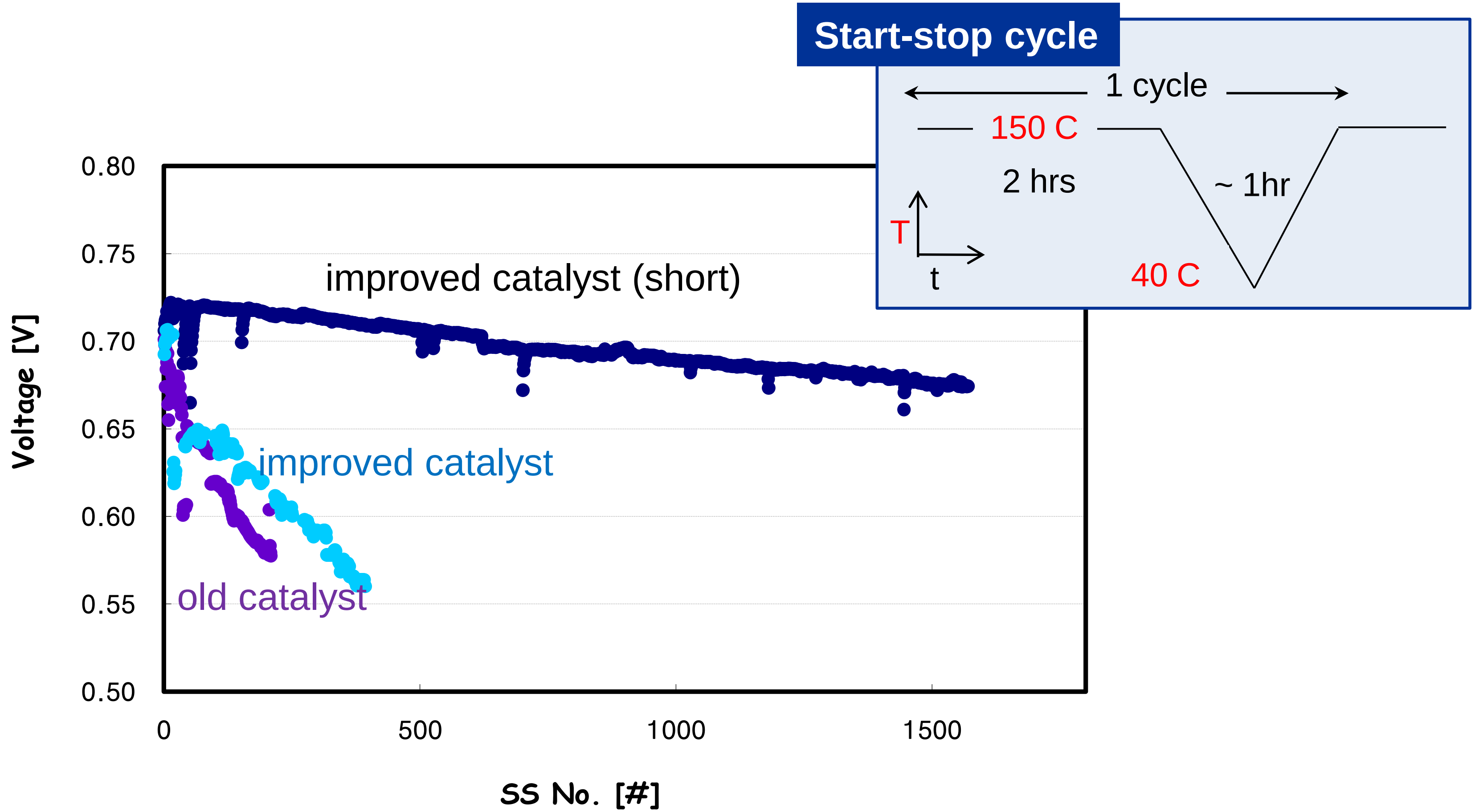
- Measured life time : 20,000 hrs, 2 uV/hr decay rate
- Improvements
  - mechanical property of membrane
  - oxidation resistance of catalyst



25 cm^2 cell, 150 ^oC, H_2/air, operated at 0.3A/cm^2

MEA Durability : start-stop Operation

- SS operation life time : 80% improvement
- By shorting the cell : > 1500 start-stop cycle



8 cm^2 cell, 150 ^oC, operated at 0.2A/cm^2

Conclusions

- Development of High temperature PEMFC at SAIT

  - High performance (0.72 V @ 0.2 A/cm^2) and durable (20,000 hrs+) MEA
  - in-situ and ex-situ analysis techniques
  - ALT methods to screen membrane, catalyst and GDL materials

- Future Development Plans

  - Cost reduction by lowering Pt loading and using cost saving materials.
  - Simplification of MEA manufacturing processes
  - Verification of MEA performance at system level

Acknowledgements

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Thank you for your attention !