WORK PACKAGE 1.2 FUEL CELLS

LOUGHBOROUGH UNIVERSITY

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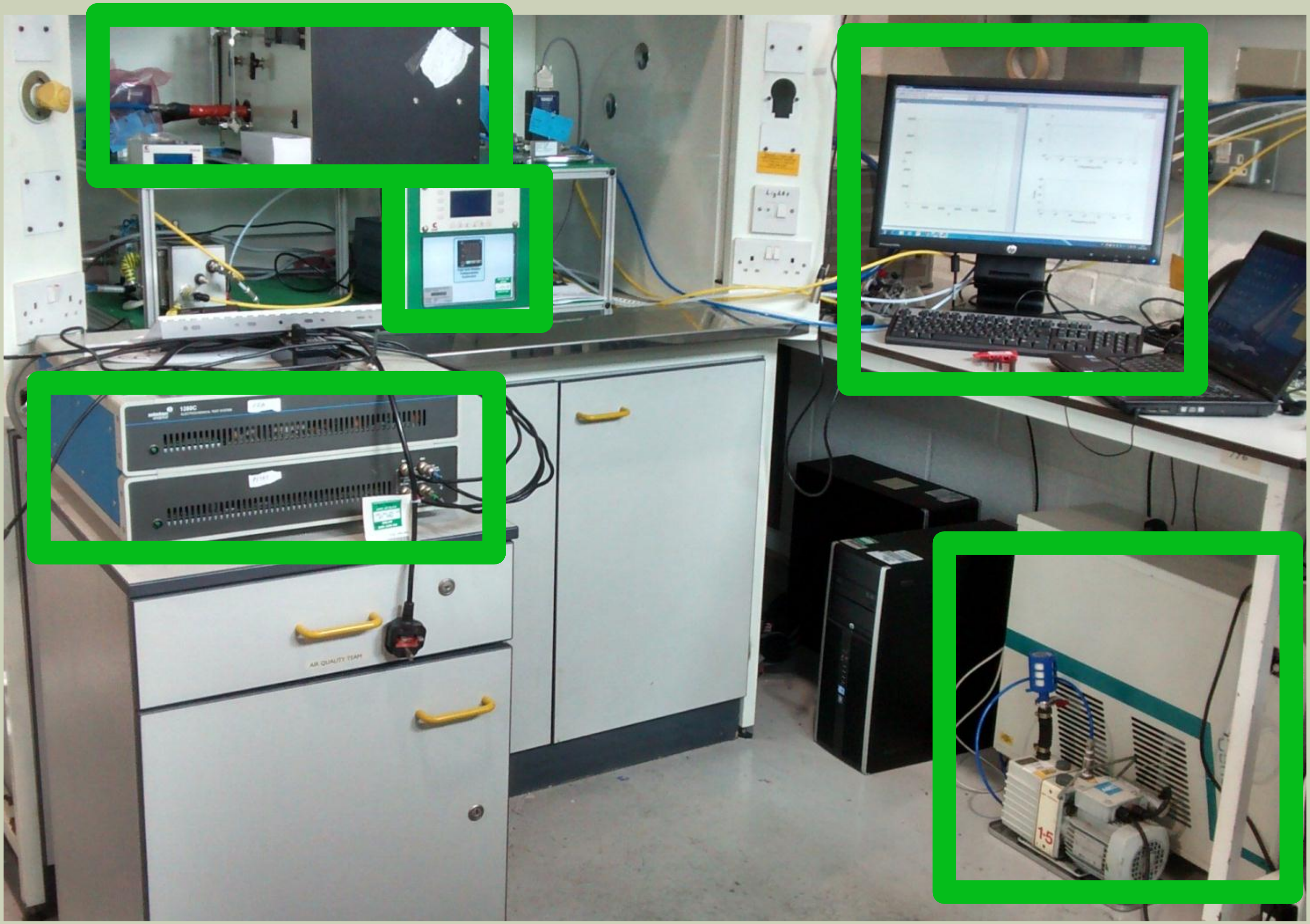
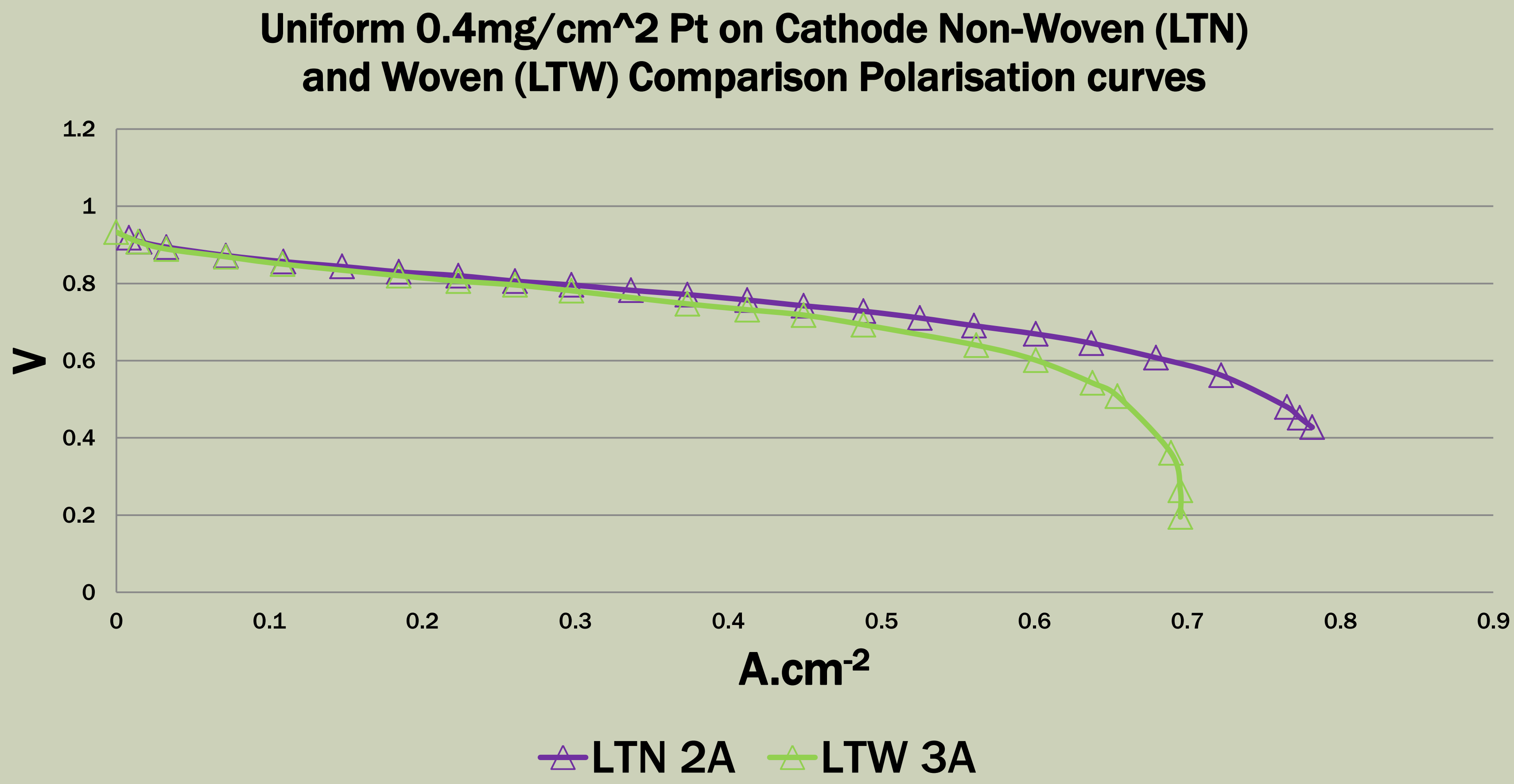
14 Jan 2015

Experimental work

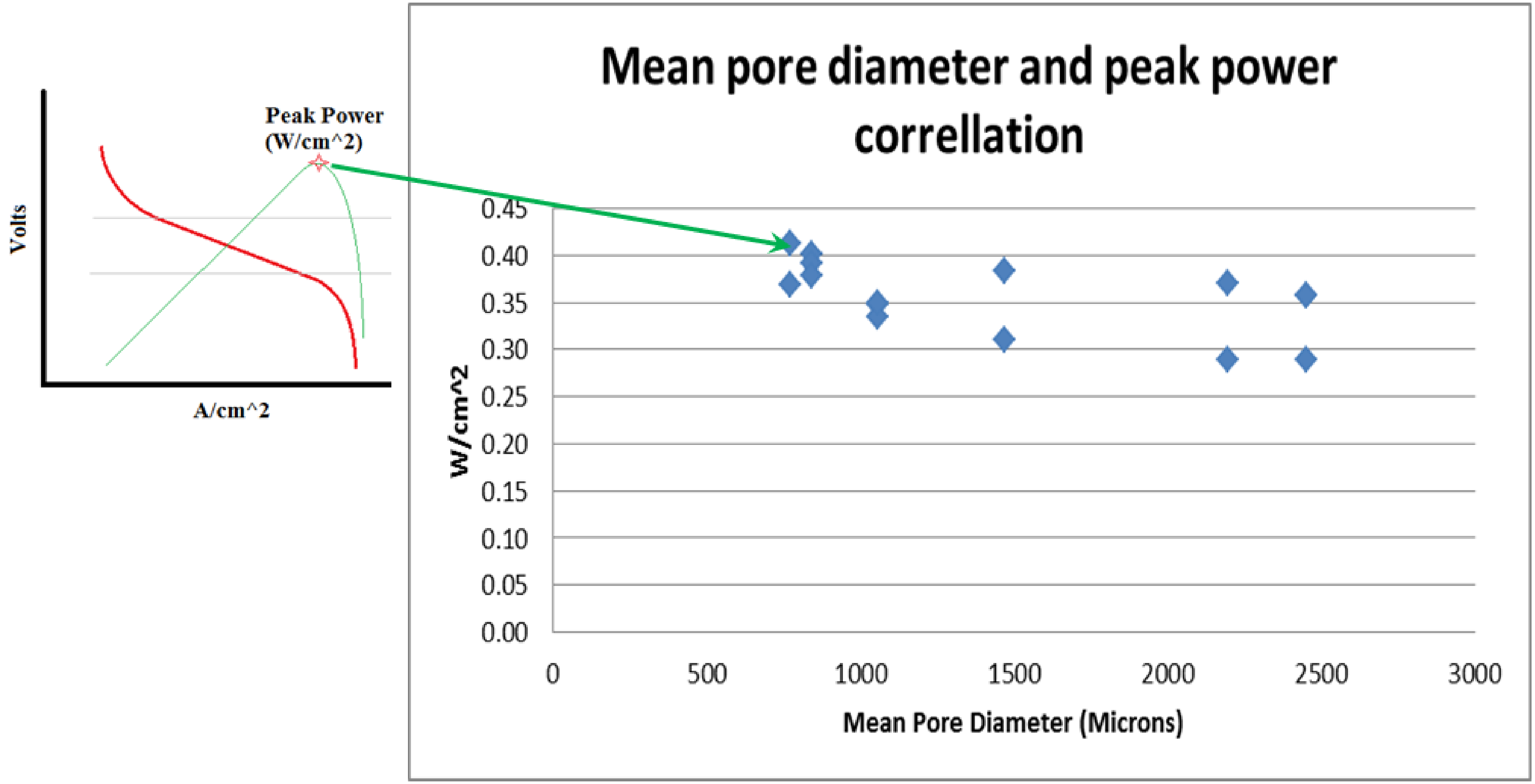
By Nick McCarthy

G.E.I.S.T. RIG AT L'BORO




Uniform 0.4mg/cm^2 Pt on Cathode Non-Woven (LTN) and Woven (LTW) Comparison Polarisation curves
V
1.2
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
A.cm-2
LTN 2A
LTW 3A

MULTIPLE GDL TYPES (PAPER, WOVEN, NON-WOVEN) POROSITY AND PEAK POWER PERFORMANCE



EMPIRICAL LINEAR MODEL (WMAX AND GDL RELATIONSHIP)

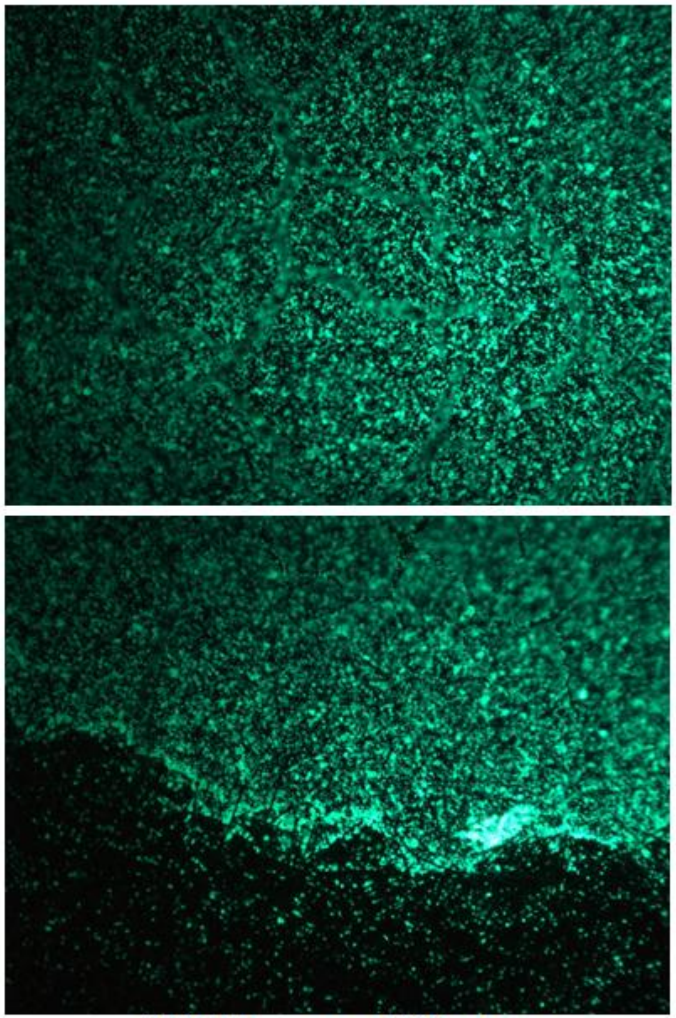
Coefficients:					
	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.4922468	0.0527059	9.339	5.55E-14	***
H_2Oangle	-0.0003779	0.0002174	-1.739	0.08644	.
MPL Mod'	0.0398119	0.0103118	3.861	0.000247	***
PTFE wt%	-0.2254306	0.0731867	-3.08	0.002942	**
RH%	-0.0011252	0.0004949	-2.274	0.026019	*
Structure Mod	-0.0141882	0.0083572	-1.698	0.093942	.
% pores	-0.0014299	0.0003463	-4.129	9.81E-05	***

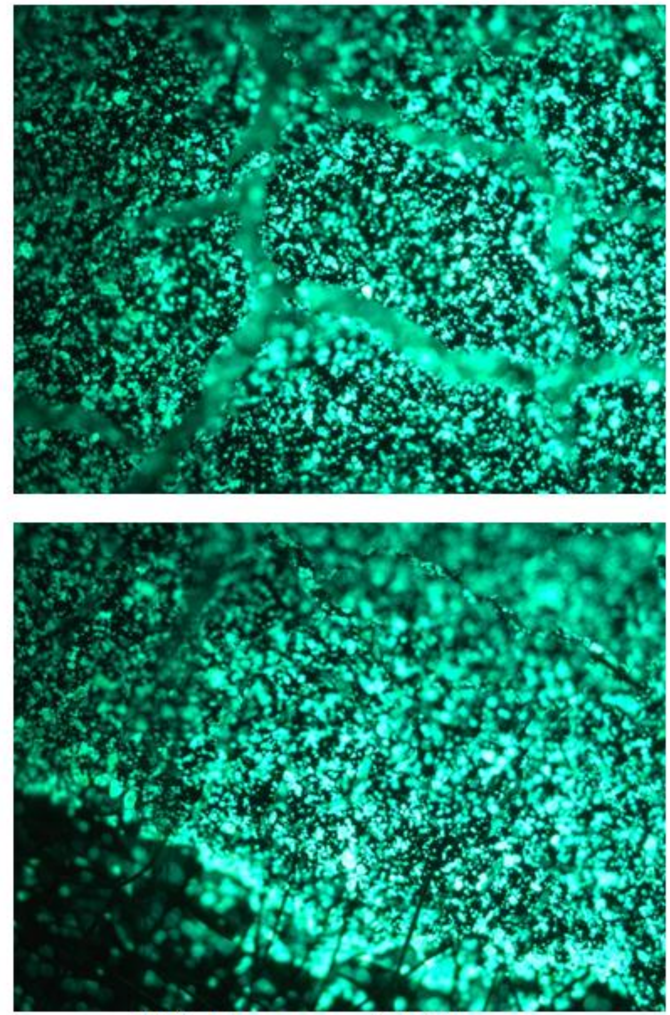
Which we can simplify to

$$W_{MAX} = 0.492 + 0.040k_{MPL} - 0.225PTFE_{(wt\%)} - 0.001_{\%\ porosity}$$

Where
k_{MPL} = 0 for no MPL and 1 for fuel cells that include an MPL

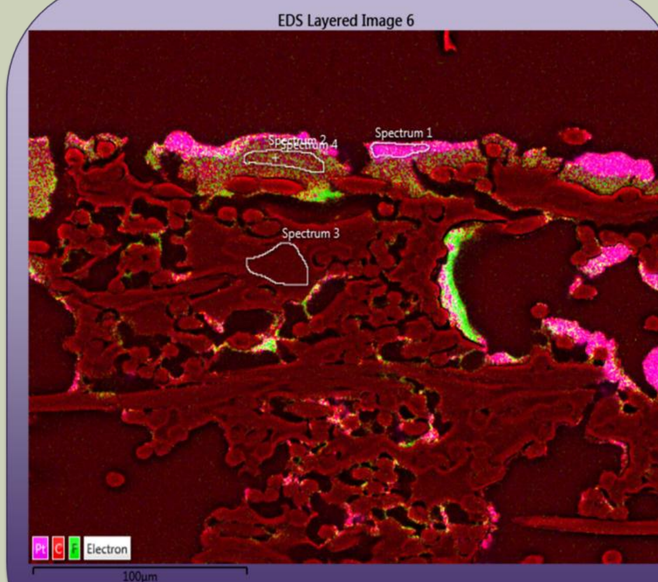
FLUORESCENT DOPING OF PT AND INK DISTRIBUTION


1% Fl-cene 50*mag

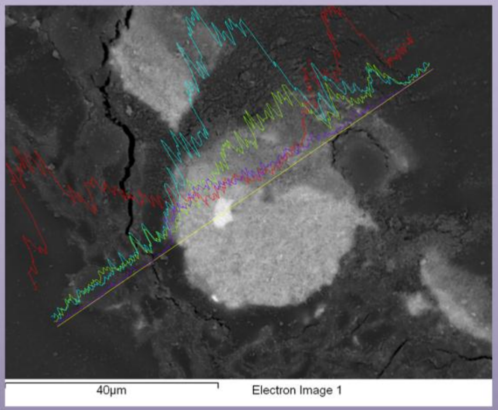

1% Fl-cene 100*mag

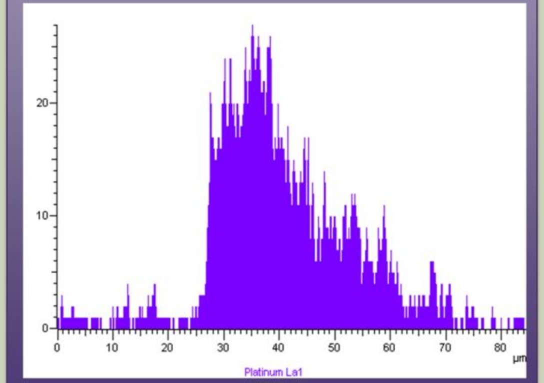
MODELLED VS ACTUAL PT DISTRIBUTION IN LAYERED CATALYSTS

Proposed distribution in [1]



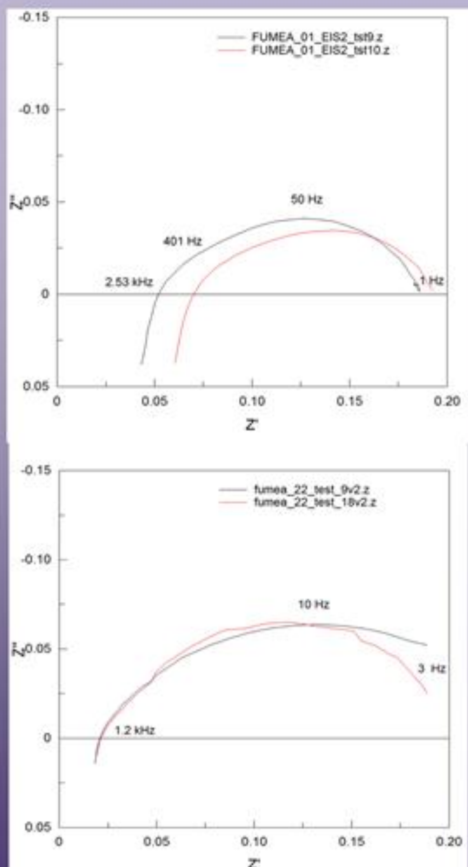
Distribution Achieved at LU



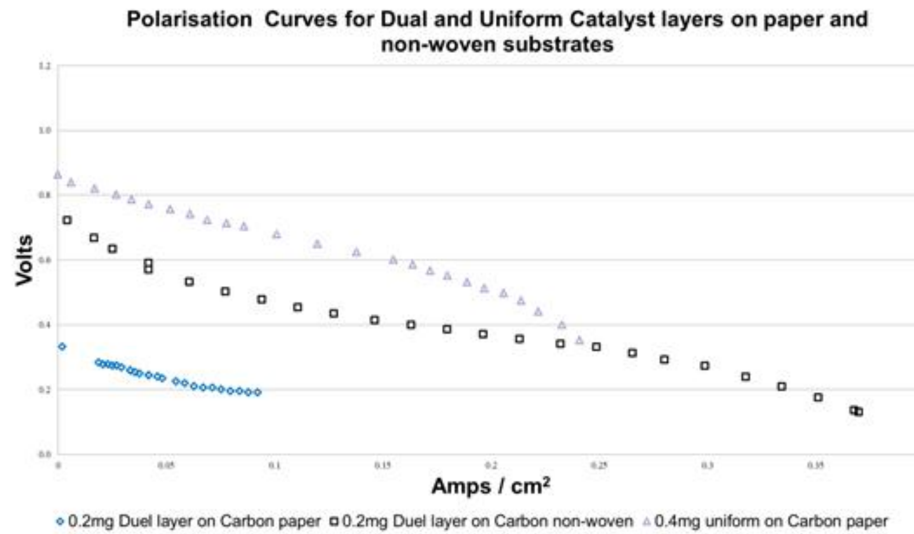


Pt distribution at surfaces achieved at LU

INITIAL DUEL LAYER RESULTS AND MASS LIMITING ISSUES



Dehydration of duel layer (FUMEA_01) system during EIS



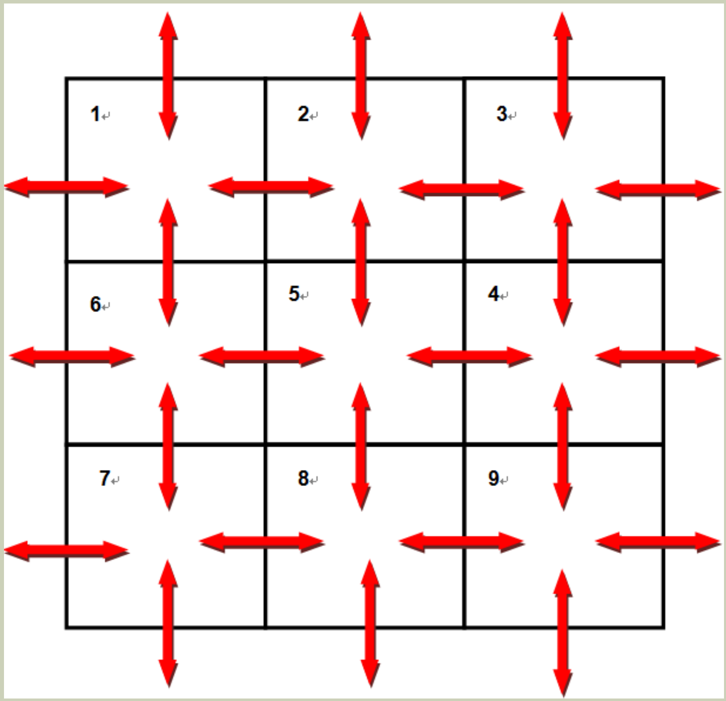
REFERENCES

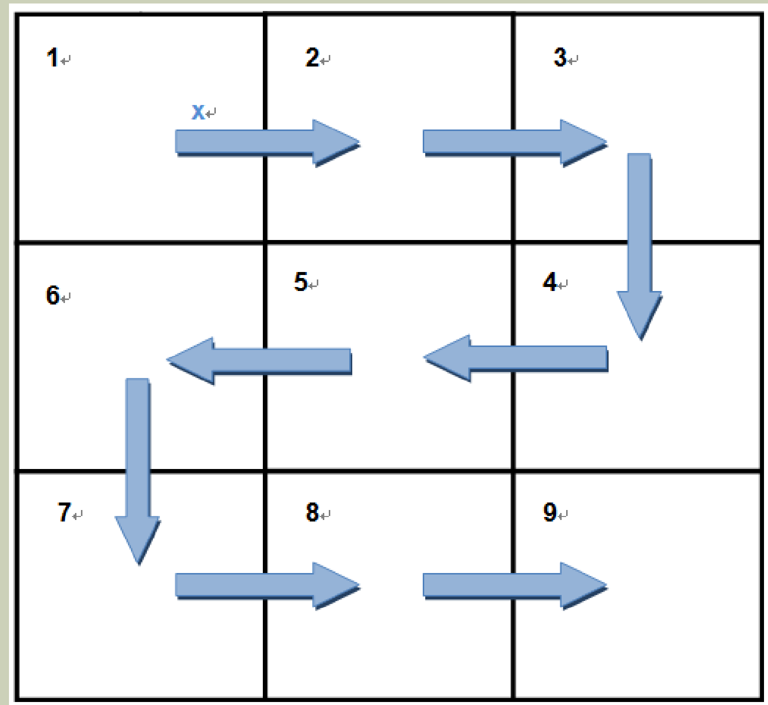
[1] Xie etal.;2005; Functionally Graded Cathode Catalyst Layers for Polymer Electrolyte Fuel Cells: II. Experimental Study of the Effect of Nafion Distribution; Journal of the Electrochemical Society, 152(6), pp. A1171-A1179

Modelling work

By Jiayi Gu

MODELLING PHILOSOPHY





Annode: $\frac{d[H_2][CO][H_2O][N_2]}{dX_a}$

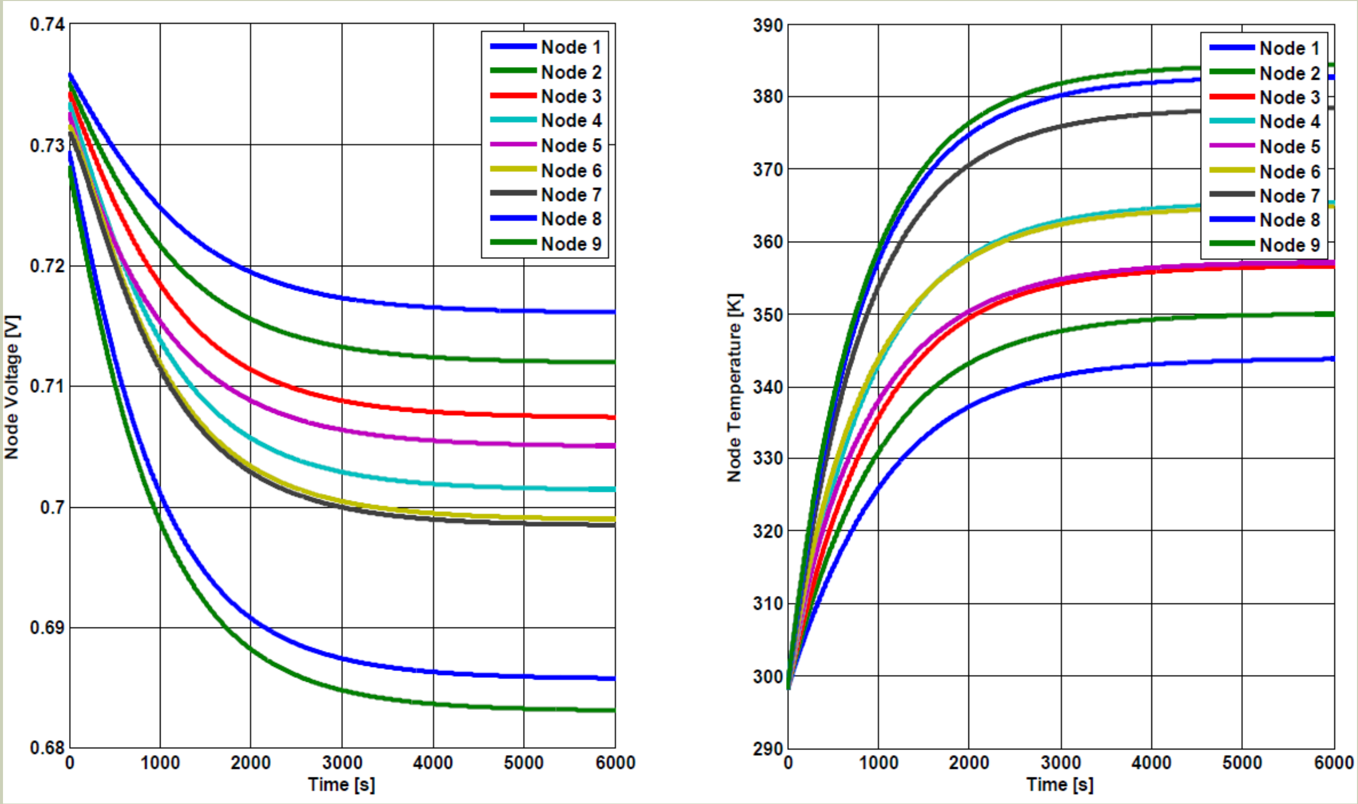
Cathode: $\frac{d[O_2][H_2O][N_2]}{dX_c}$

Membrane: $\frac{d[H_2O]}{d\delta_m}$

- *To reveal the distributed characteristics of PEM fuel cells.*
- *1-D fuel cell model discretised along the gas channel.*
- *Single serpentine gas channel.*
- *Thermal connections: internal + external.*

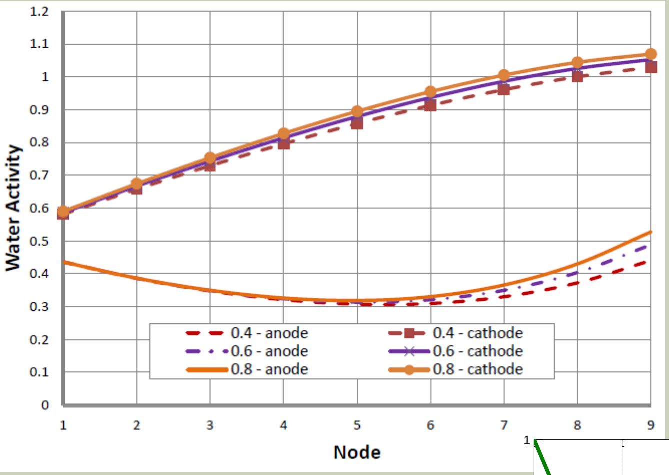
NODAL THERMAL PROPERTIES

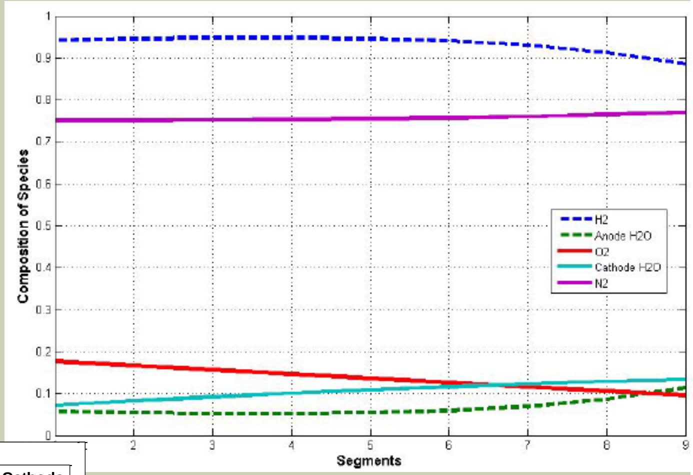
- Open cathode + dead-ended anode
- Cooling is provided by cathode air flow.

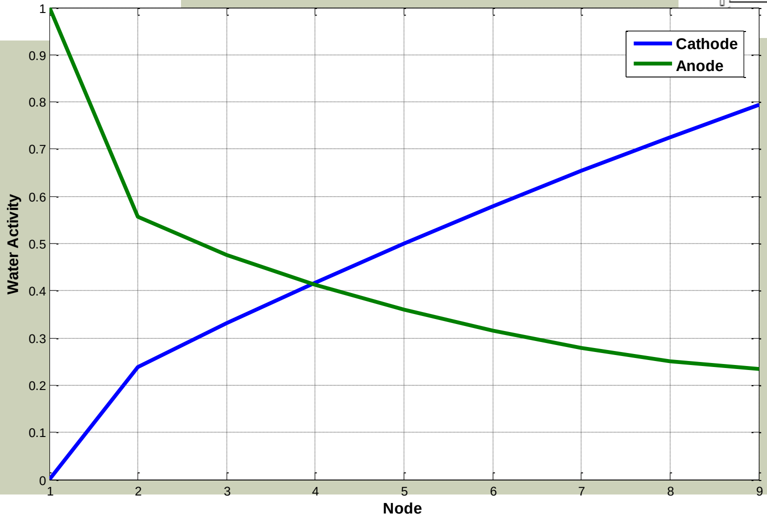


WATER MANAGEMENT

- Through-membrane water transport: Electro-osmotic drag and Back-diffusion.





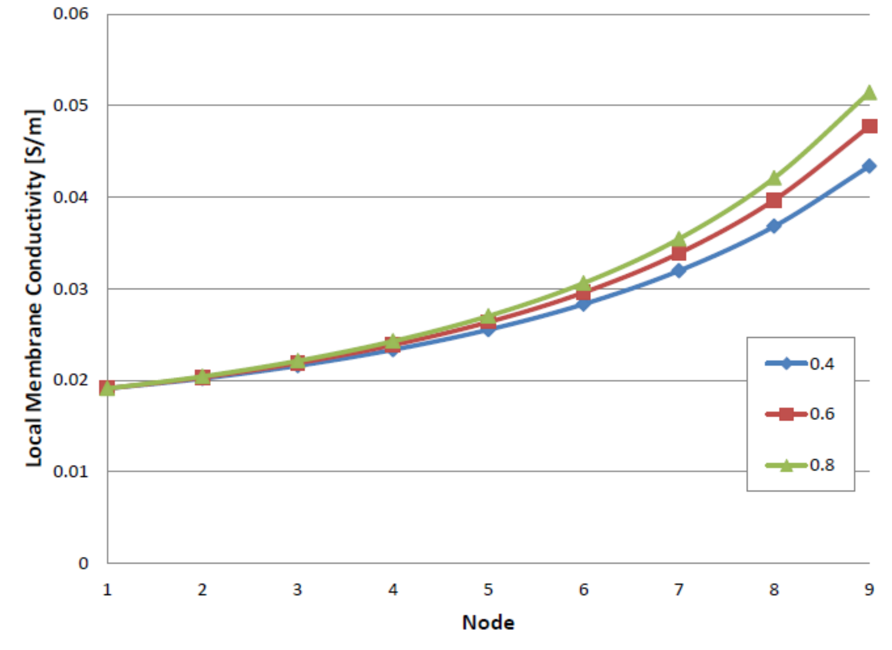


[Above] Nodal humidity variations at different loads.

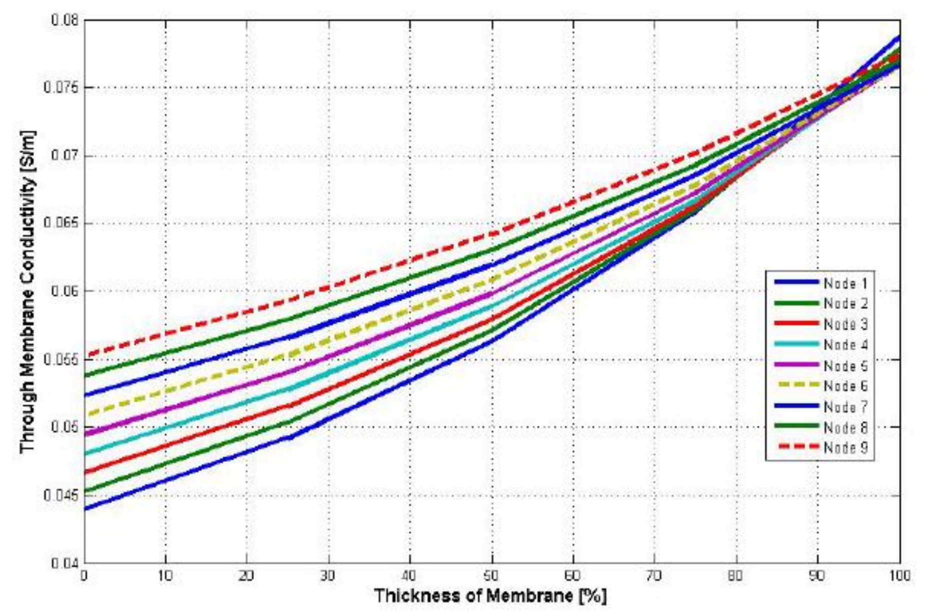
[Above] Species variations at 0.8A/cm^2.

[Left] Extreme case: Fully humidified anode and dry cathode input.

LOCAL MEMBRANE CONDUCTIVITY



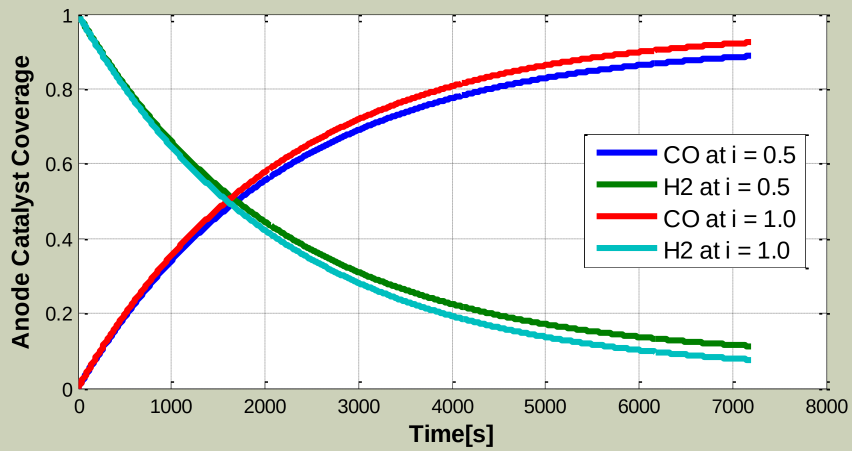
[Left] Local conductivity is a function of membrane water content.



[Right] Through-membrane conductivity is lower at anode surface and higher at cathode surface.

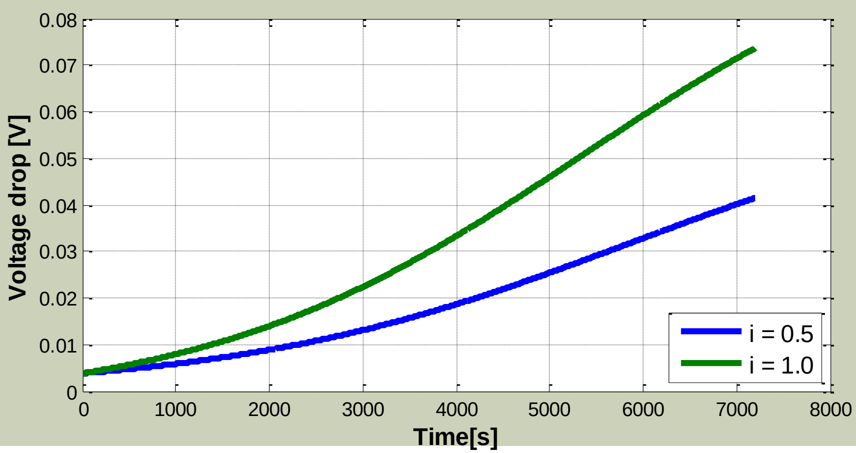
DEGRADATION 1

Carbon-monoxide Poisoning



•The adsorption, desorption and electro-oxidation of hydrogen and CO on the catalyst surface are described by a 6-reaction set[2].

•The rate of change of coverage by hydrogen and CO is calculated by a set of kinetic equations in the of the Butler-Volmer equation.



$$H_2 + 2M \xrightarrow{k_{fh}} 2\,(M - H)$$

$$H_2 + 2M \xleftarrow{b_{fh}k_{fh}} 2\,(M - H)$$

$$CO + M \xrightarrow{k_{fc}} M - CO$$

$$CO + M \xleftarrow{b_{fc}k_{fc}} M - CO$$

$$(M - H) \xrightarrow{k_{eh}} H^+ + e^- + M$$

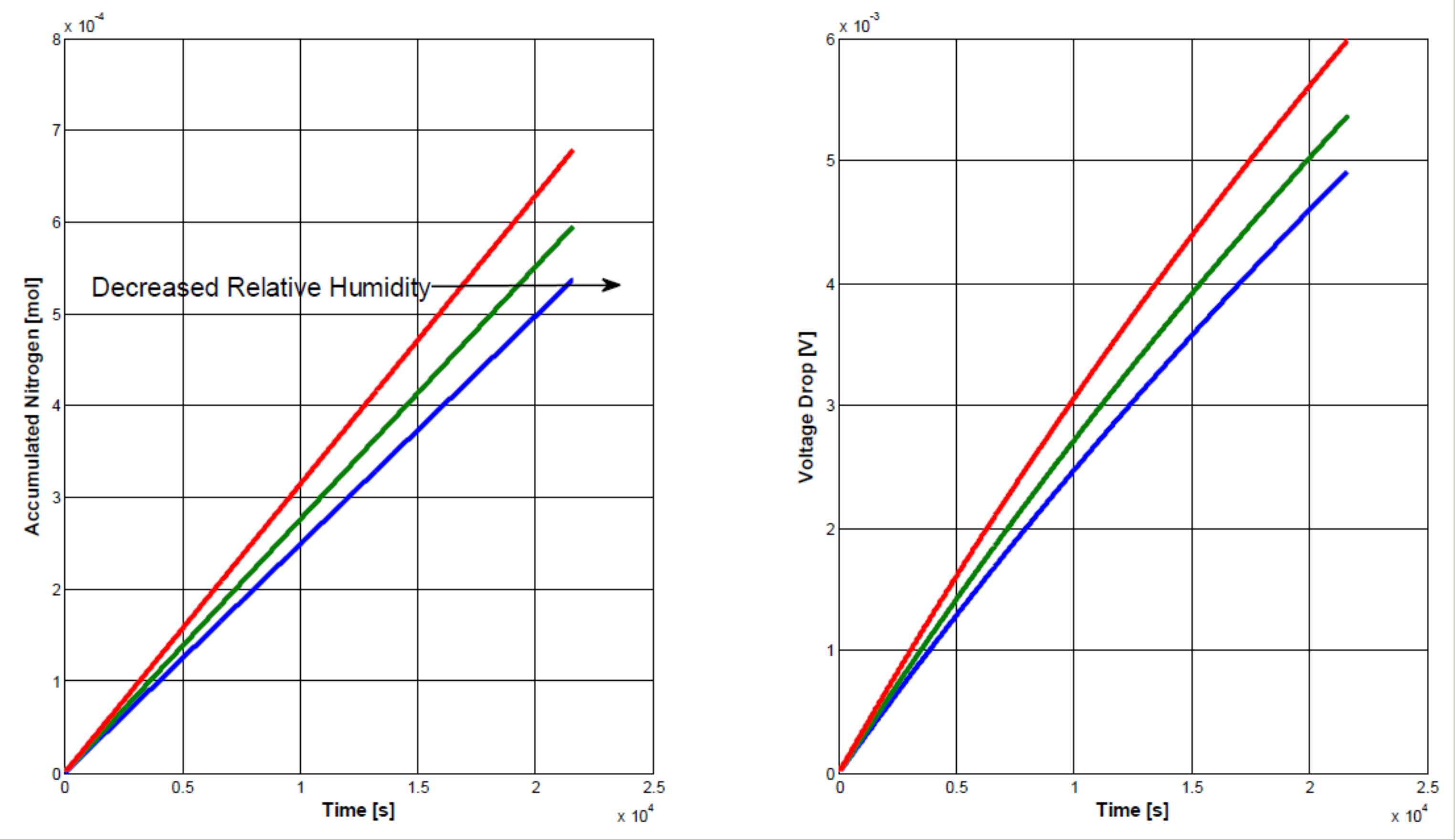
$$H_2O + (M - CO) \xrightarrow{k_{ec}} M + CO_2 + 2H^+ + 2e^-$$

$$\rho\frac{d\theta_h}{dt} = k_{fh}x_h P(1 - \theta_h - \theta_c) - b_{fh}k_{fh}\theta_h - 2k_{eh}\theta_h \sinh\left(\frac{\eta_a}{RT/\alpha F}\right)$$

$$\rho\frac{d\theta_c}{dt} = k_{fc}x_c P(1 - \theta_h - \theta_c) - b_{fc}k_{fc}\theta_c - 2k_{ec}\theta_c \sinh\left(\frac{\eta_a}{RT/\alpha F}\right)$$

DEGRADATION 2

- N_2 permeability in water is up to two magnitude higher than in Nafion.



THANK YOU FOR YOUR TIME!

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