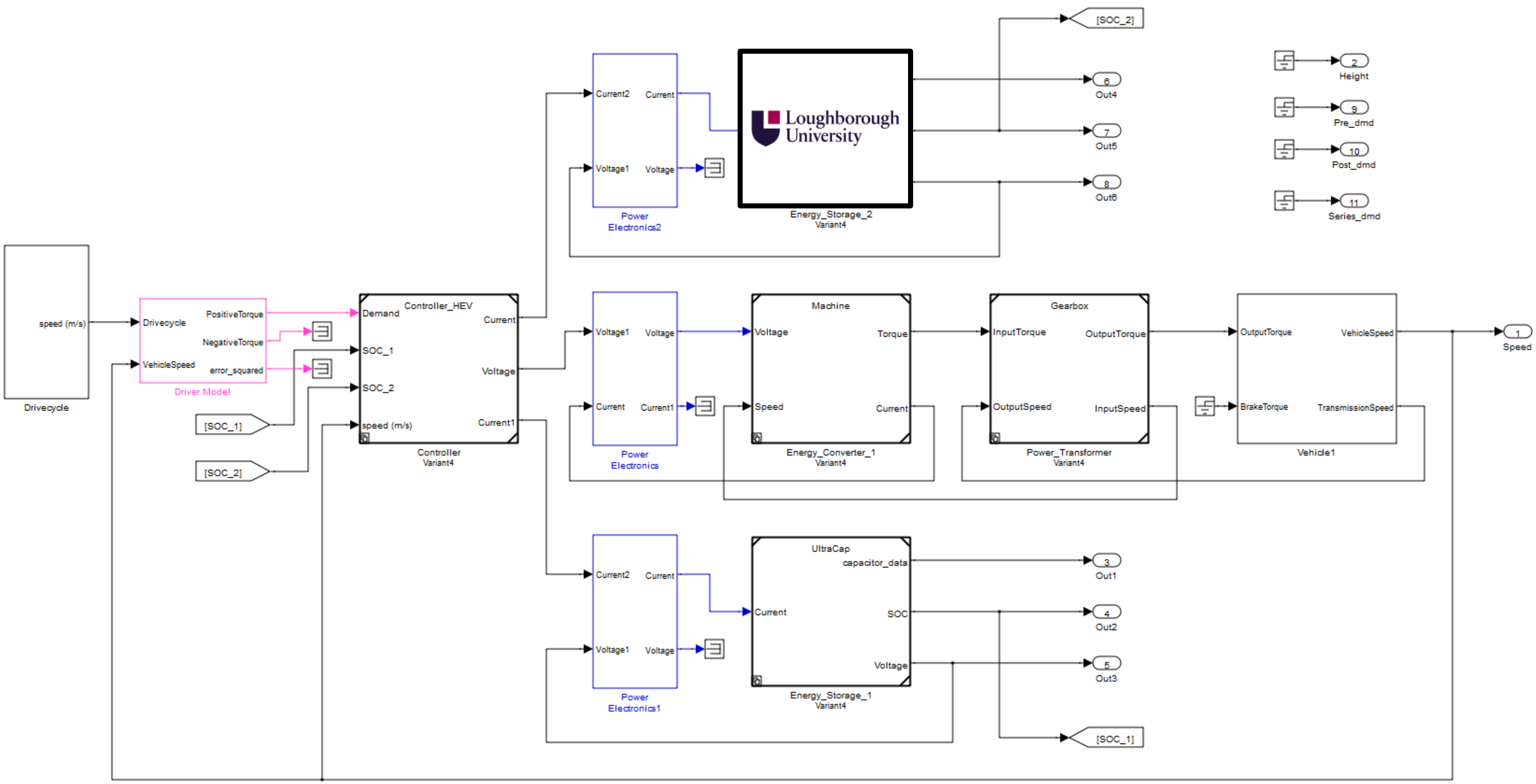
FUEL CELLS



[SOC_2]
Current2
Current
Voltage1
Voltage
Power Electronics2
Loughborough University
Energy_Storage_2
Variant4
Out4
Out5
Out6
Height
Pre_dmd
Post_dmd
Series_dmd
speed (m/s)
Drivecycle
Drivecycle
VehicleSpeed
PositiveTorque
NegativeTorque
error_squared
Driver Model
[SOC_1]
[SOC_2]
Demand
Controller_HEV
SOC_1
SOC_2
speed (m/s)
Current
Voltage
Current1
Controller
Variant4
Voltage1
Voltage
Current
Current1
Power Electronics
Machine
Voltage
Speed
Torque
Current
Energy_Converter_1
Variant4
Gearbox
InputTorque
OutputSpeed
OutputTorque
InputSpeed
Power_Transformer
Variant4
OutputTorque
BrakeTorque
VehicleSpeed
TransmissionSpeed
Vehicle1
Speed
Current2
Current
Voltage1
Voltage
Power Electronics1
UltraCap
capacitor_data
Current
SOC
Voltage
Energy_Storage_1
Variant4
Out1
Out2
Out3
[SOC_1]

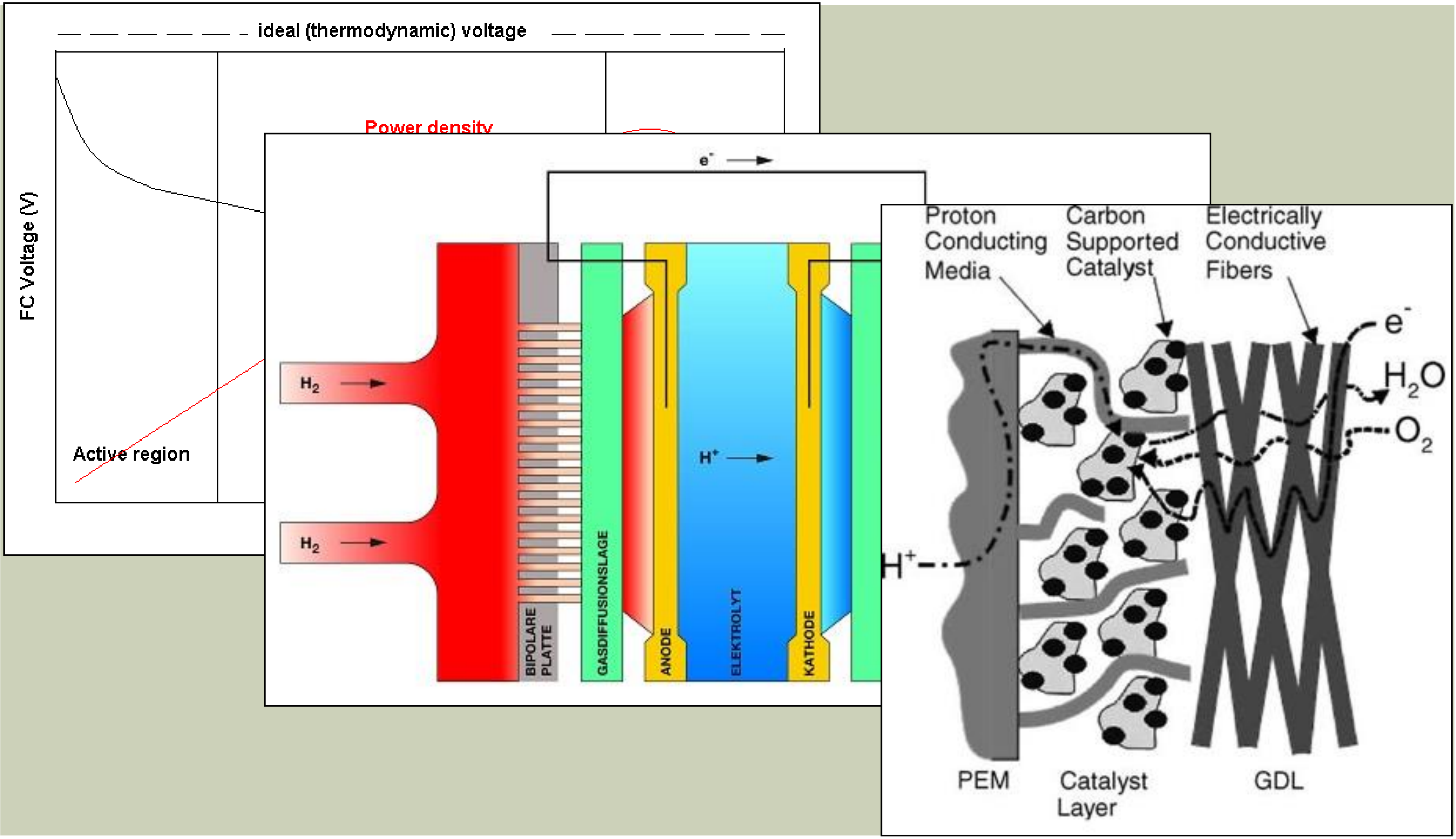
INTRODUCTION

- Basic of fuel cells
- Basics of fuel cell degradation
- Upgraded test facilities
- Fundamental knowledge
  - Layered catalyst structures & degradation
  - Fluorescence doping of PTFE layers
  - Period and duration of short circuit in fuel cells
- CO and CO_2 models
  - Segmented cells

BASIC OF FUEL CELLS

- Polarisation curves and peak power
- $2H + O_2 = 2 H_2O$
- Structure
  - Bipolar plates, Flow channels, (GDL+MPL+Pt-on-C+Nafion =) MEA

BASIC OF FUEL CELLS



BASICS OF FUEL CELL DEGRADATION

- Recall the polarisation curve
- Not all degradation is permanent
- Activation loss
  - ECSA
    - CO, CO_2, NOx, H_2SO_4
    - Pt migration
    - Pt loss
- Ohmic Loss
  - Compression changes during operation
  - Loss of carbon catalyst support structures
  - Hydration management
- Mass transport/kinetic losses
  - Porosity changes
  - Porosity ‘collapse’
  - Hydration management

PERIOD / DURATION OF SHORT CIRCUITS AND DEGRADATION

- WIP
- ECSA
  - Poisoning of surface structures
  - Sudden potential drop caused by ‘short circuits
  - Changes the chemistry at the catalyst surface
  - CO evolves to CO2 and is removed from the catalyst surface
  - What else though?
  - Experiments are ongoing and will be reported before the end of the project in May 2016.
- Collaboration project with Simon Howroyd (Loughborough) and Gaurav Gupta (Imperial)

G.E.I.S.T. RIG

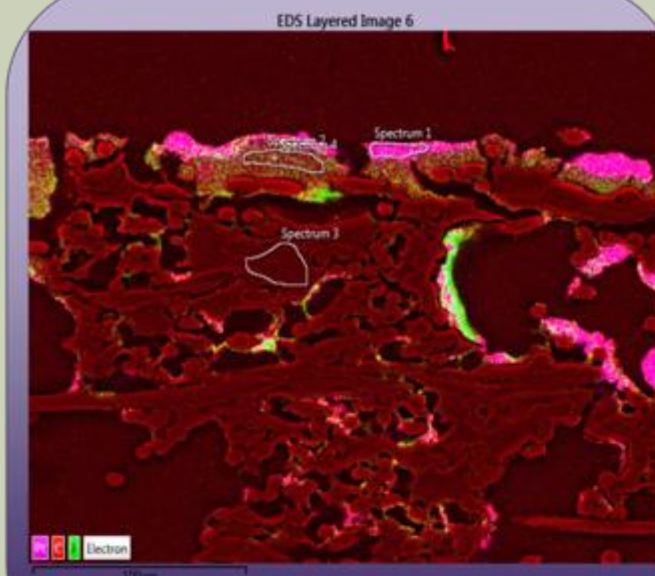
- Demetri Bourilis designed system
  - Supports the FCCA capabilities with EIS and Gas Mass Spectroscopy

LAYERED CATALYST STRUCTURES AND DEGRADATION

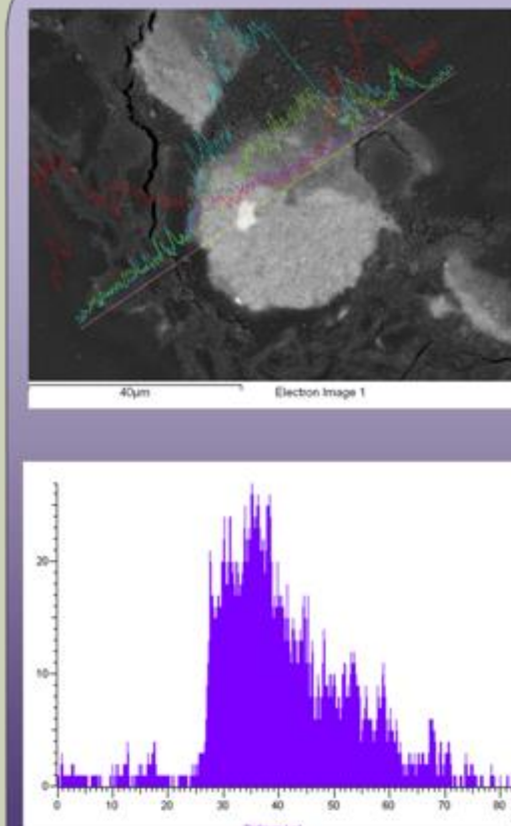
- Catalyst coated substrates
- Importance of GDL structure
- Results
  - CCS PEM fuel cell degradation rate strongly dependant on the type of 'GDM' used – poster presentation for more details
  - 'Felt'
    - High concentration duel layer catalyst degrade at a slower rate in the steady state
  - 'Paper'
    - High concentration duel layers degrade far more rapidly under a square wave duty cycle

MODELLED VS ACTUAL PT DISTRIBUTION IN LAYERED CATALYSTS

Proposed distribution in [1]



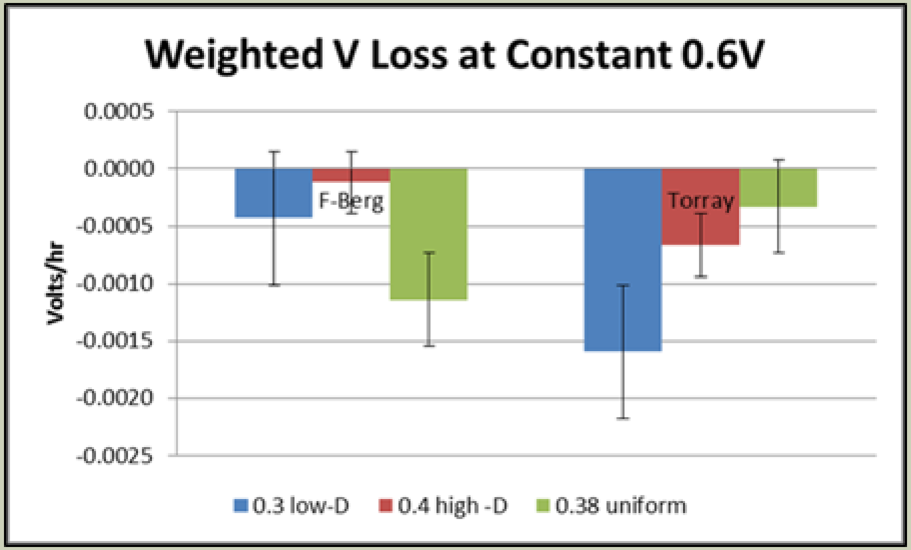
Distribution Achieved at LU

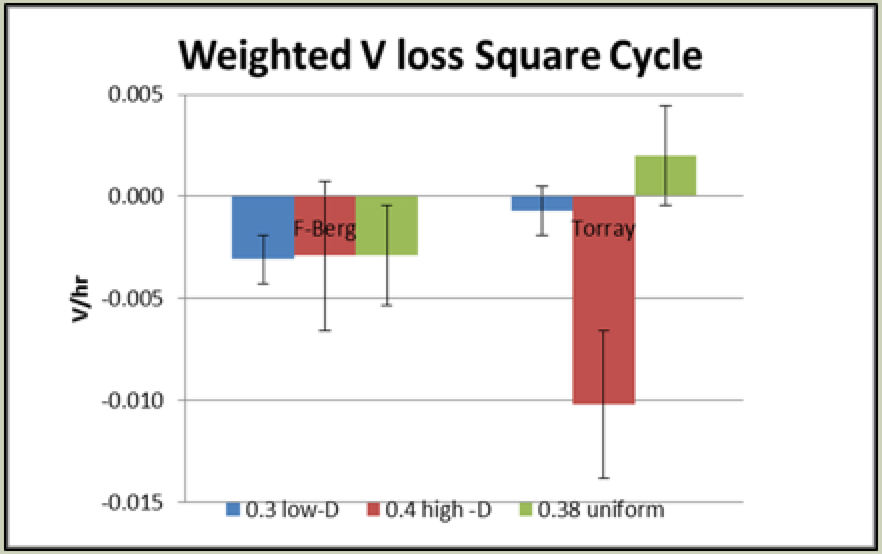


Pt distribution at surfaces achieved at LU

LAYERED CATALYST STRUCTURES AND DEGRADATION

Test	Volts/hour loss
Square: 0.15-0.8 Volts	1.28×10^{-3}
Steady state 0.6 Volts	13.6×10^{-3}

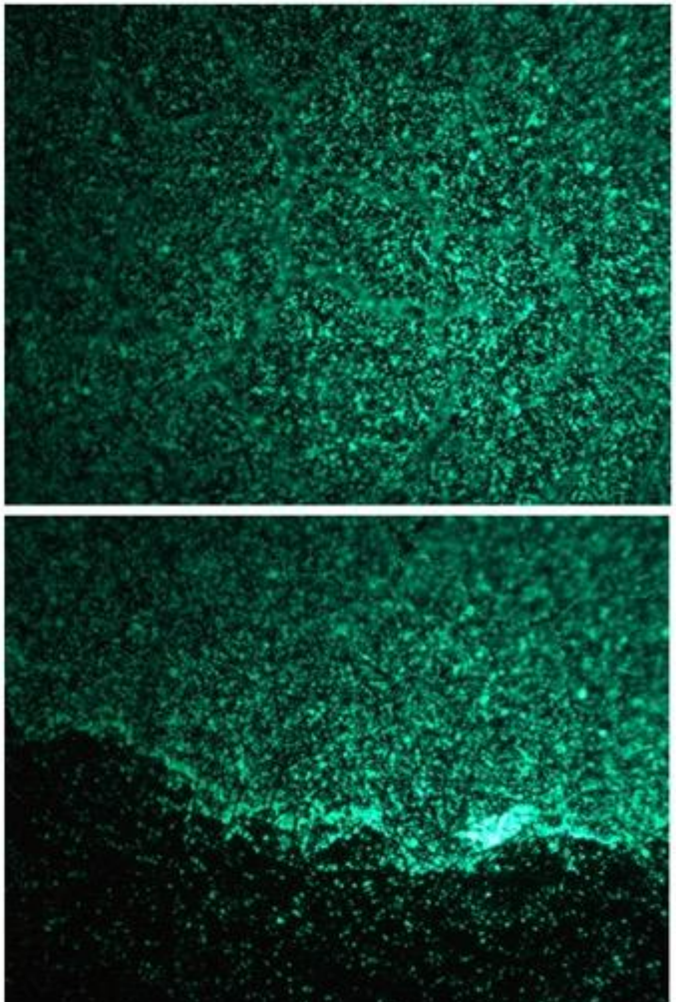




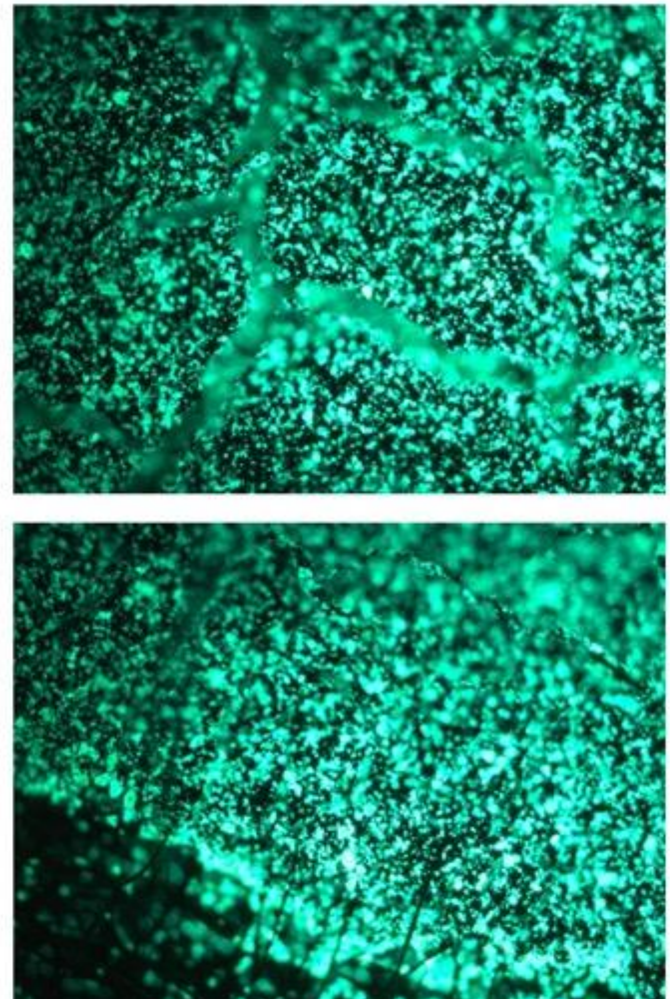
FLUORESCENCE DOPING OF PTFE LAYERS

- Multiple uses of PTFE in MEAs
  - Nafion membrane
  - Hydrophobicity coating on carbon fibres
  - Binding of Nafion, Pt-on-Carbon and MPL structures
- Until now no way to differentiate easily between them
- Fluorescence microscopy method developed to assess distribution of PTFE in the MEA

FLUORESCENT DOPING

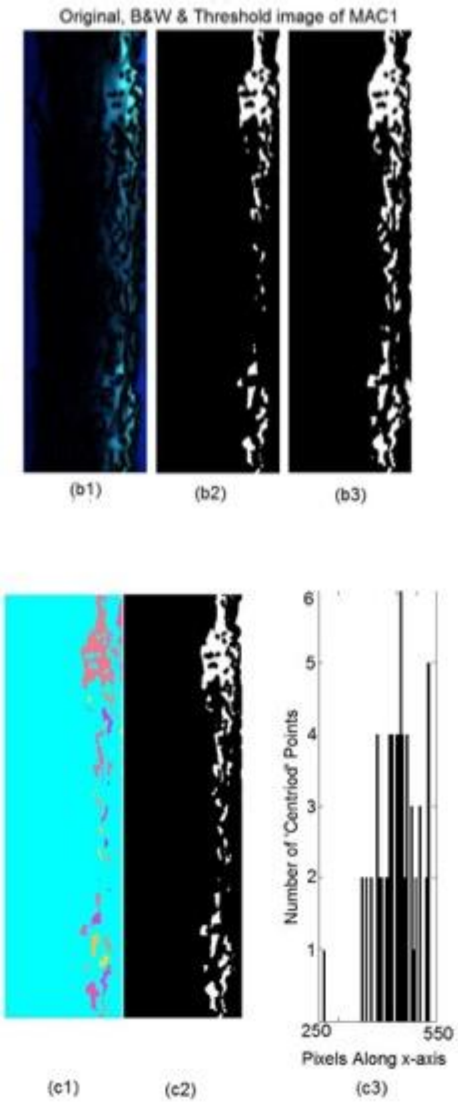


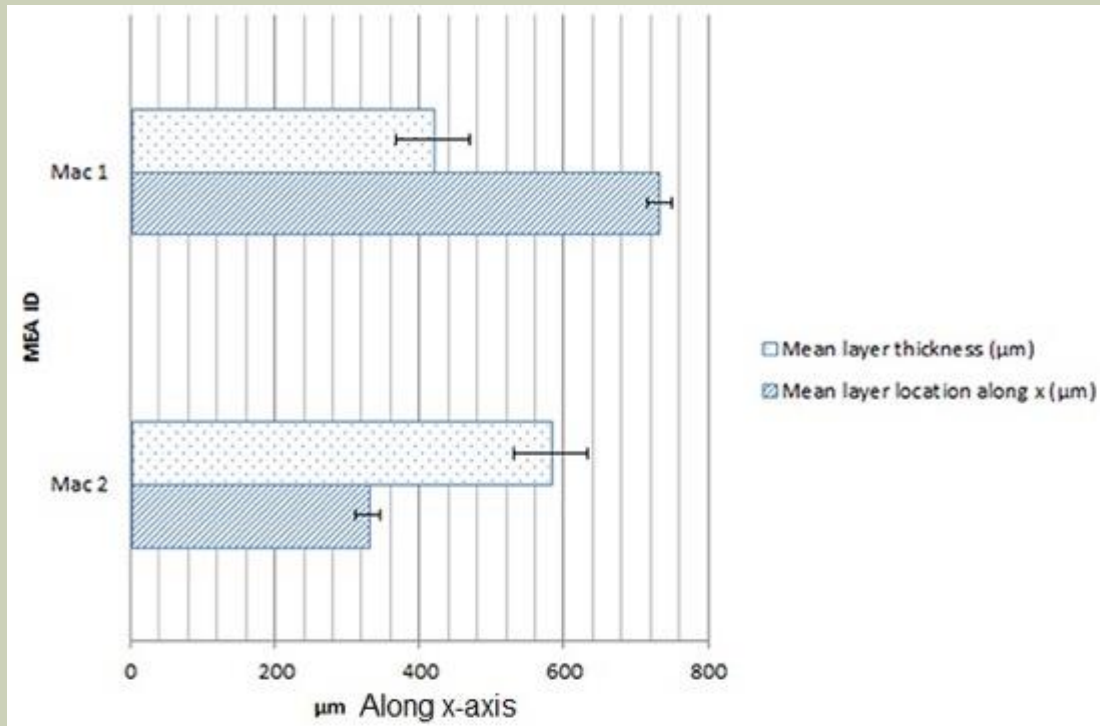
1% Fl-cene 50*mag



1% Fl-cene 100*mag

FLUORESCENCE DOPING OF PTFE LAYERS

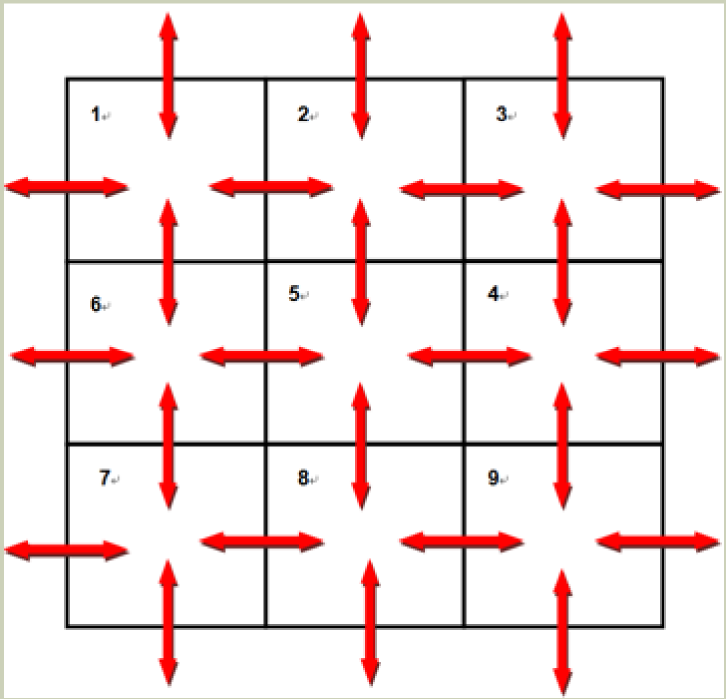


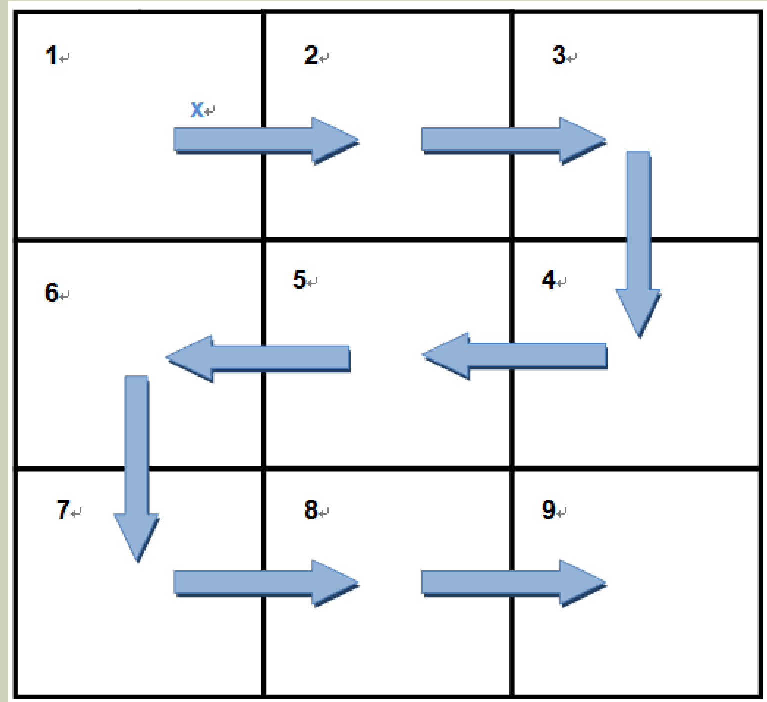


CO AND CO_2 MODELLING IN SEGMENTED FUEL CELLS

- **Jiai Gu**
  - **Details**
  - Concentration variation of reactant gasses along channel length

RECAP OF MODELLING PHILOSOPHY





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

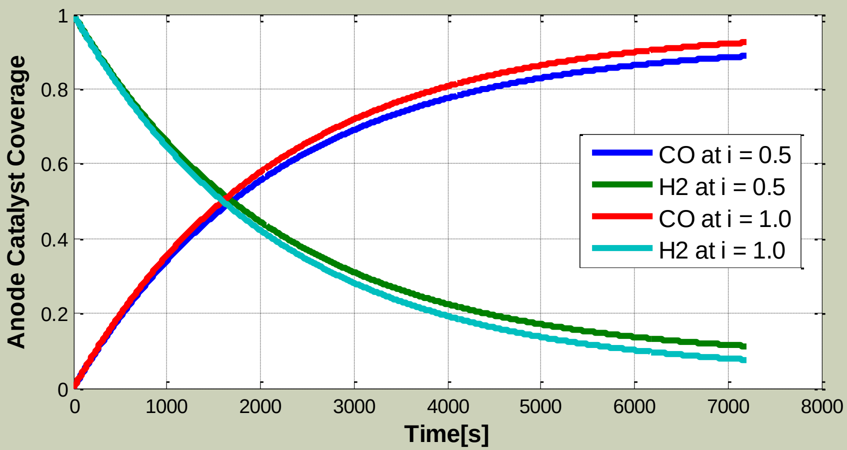
Cathode: $\frac{d[O_2][H_2O][N_2]}{dX_c}$

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

- *1-D fuel cell model discretised along the gas channel.*
- *Thermal connections: internal + external.*
- *Pressure drop along channel: frictional loss (done) + concentration loss (done).*

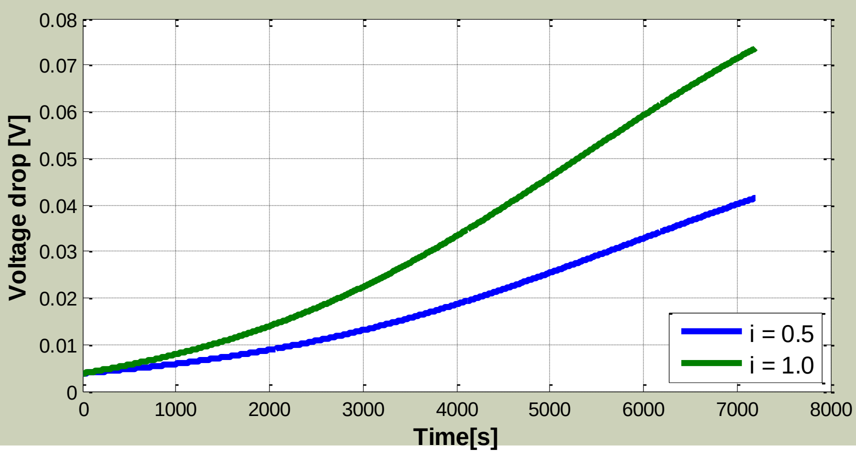
DEGRADATION 1

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.



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

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

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

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

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

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

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

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