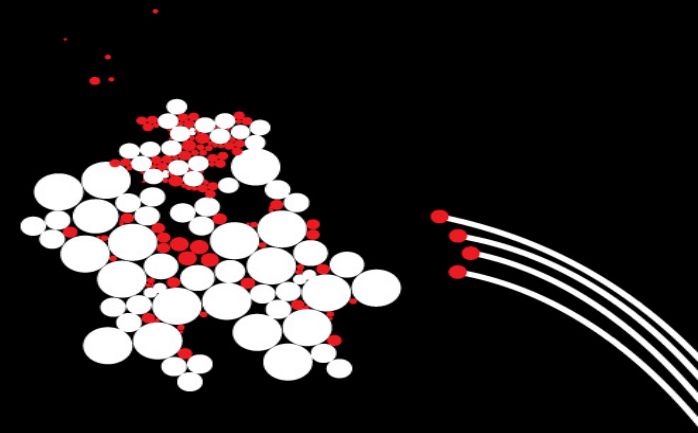
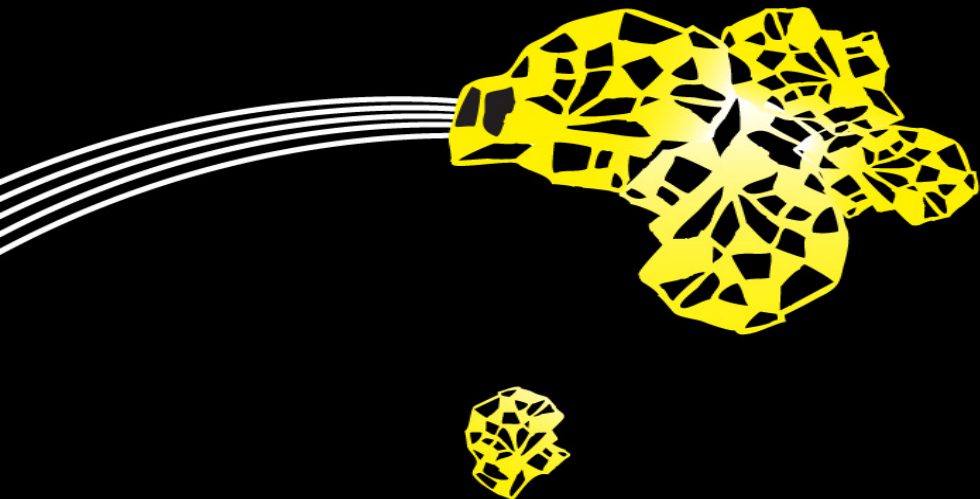


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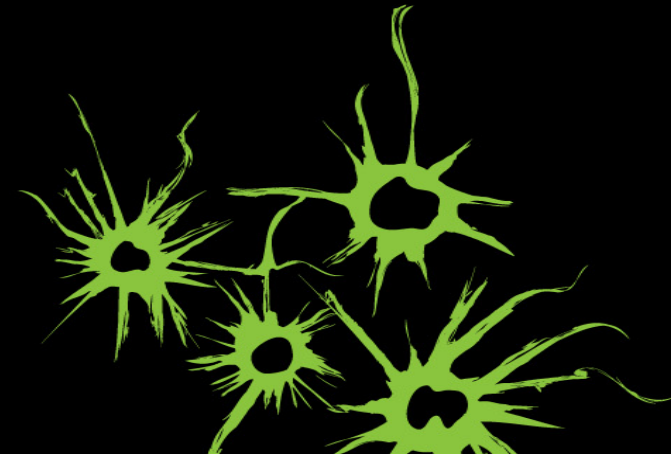


# INTRODUCTION



B2B Session 13  
October 27, 2022

DR. AAYAN BANERJEE

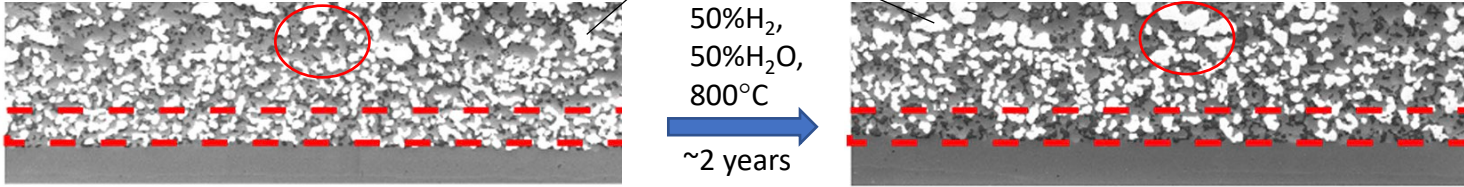


# Integrated Surface → System Digital Twins

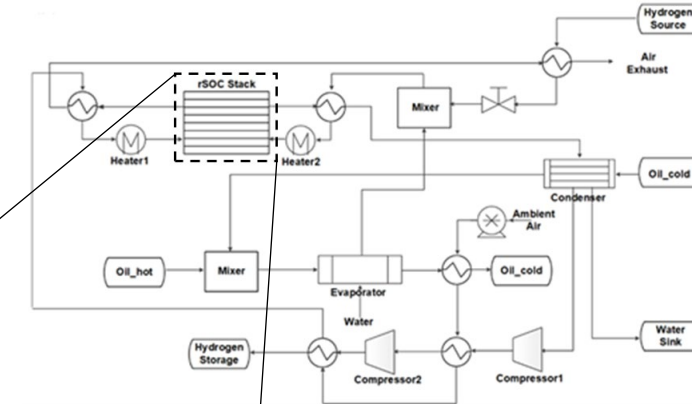
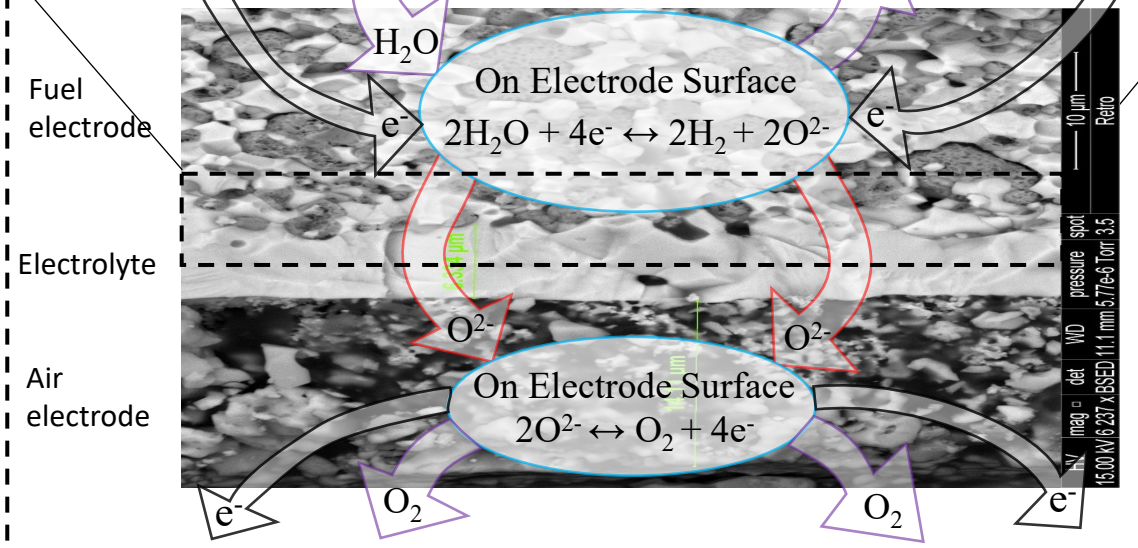
Interfacial Degradation due to mobile Nickel  
(nm - μm scale)

Nickel

50%H<sub>2</sub>,  
50%H<sub>2</sub>O,  
800°C  
~2 years

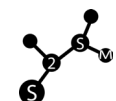
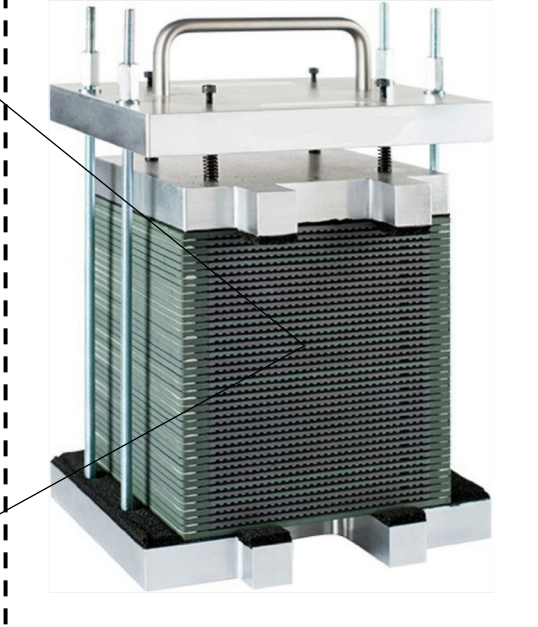


Membrane-electrode-assembly of Single Cell  
(μm - mm scale)



Digital Twin of rSOC system

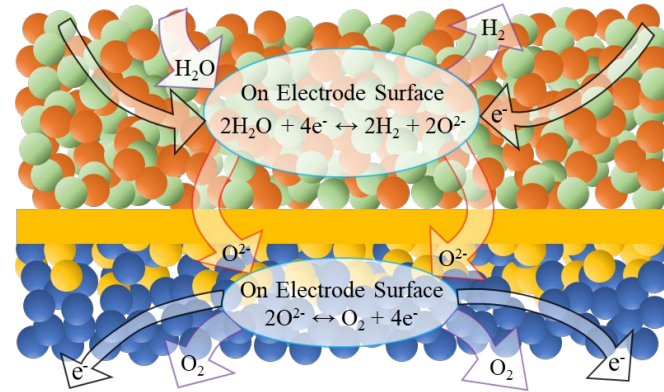
Solid Oxide Cell Stack  
(cm - m scale)



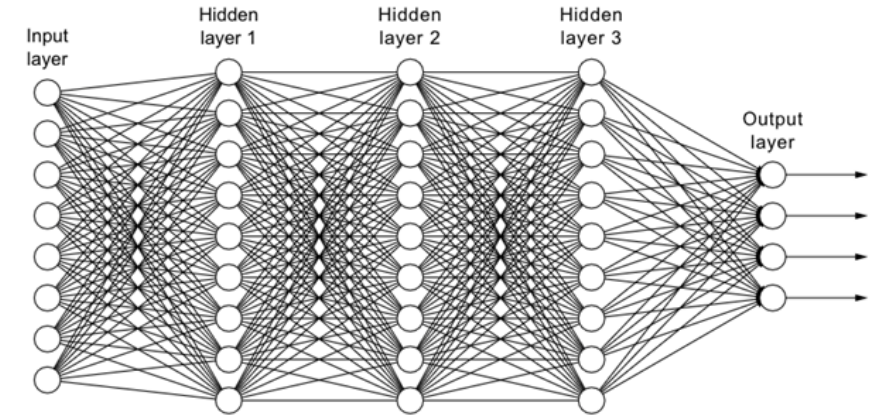
# Integrated Surface → System Digital Twins

The Integrated Surface → System Approach can be realised via NN surrogates of multi-physics models

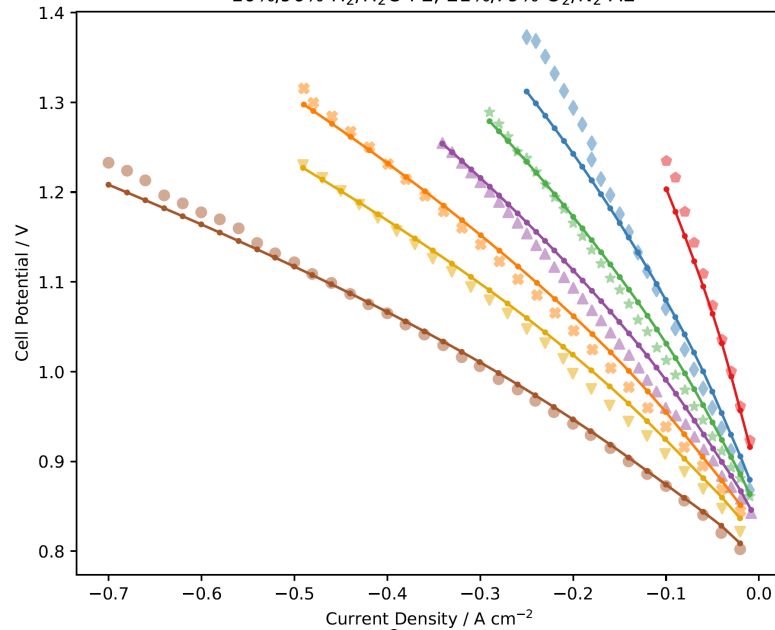
Multiphysics Model of Membrane-electrode-assembly of Single Cell (μm - mm scale)



Neural Network Model of Membrane-electrode-assembly of Single Cell



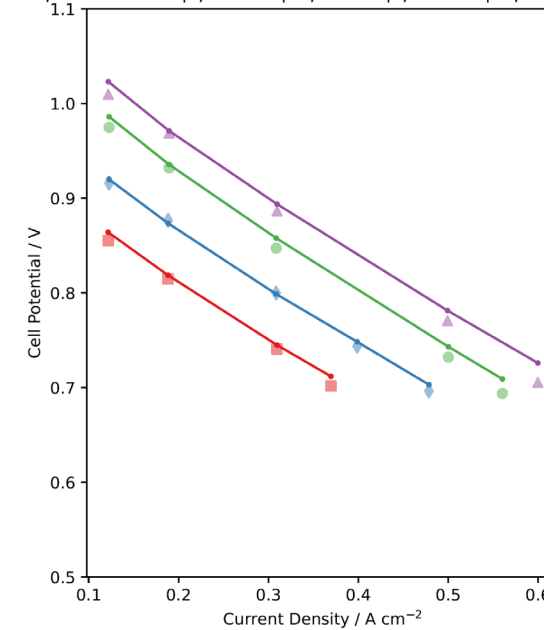
48μm LSCF|7μm CGO|81μm YSZ|7μm CGO|25μm Ni-CGO  
10%/90% H<sub>2</sub>/H<sub>2</sub>O FE, 21%/79% O<sub>2</sub>/N<sub>2</sub> AE



Solid Oxide **Electrolyser**

- data, 700 °C
- data, 750 °C
- data, 775 °C
- data, 800 °C
- data, 825 °C
- data, 850 °C
- data, 900 °C
- Machine Learnt Model

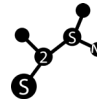
30μm LSCF-CGO|5μm CGO|82μm YSZ|2μm CGO|20μm Ni-CGO



Solid Oxide **Fuel Cell**

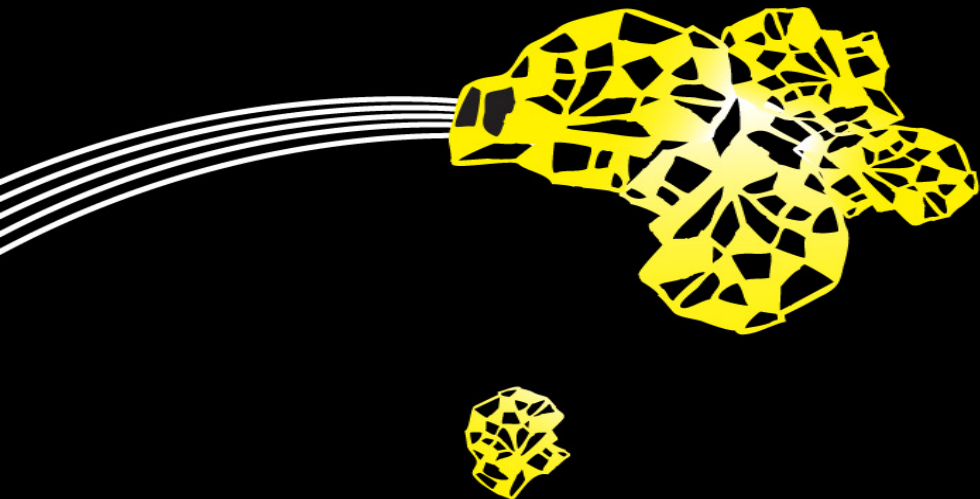
- data, 800 °C, 50%/50% H<sub>2</sub>/H<sub>2</sub>O 21%/79% O<sub>2</sub>/N<sub>2</sub>
- data, 800 °C, 80%/20% H<sub>2</sub>/H<sub>2</sub>O 21%/79% O<sub>2</sub>/N<sub>2</sub>
- data, 800 °C, 96%/4% H<sub>2</sub>/H<sub>2</sub>O 21%/79% O<sub>2</sub>/N<sub>2</sub>
- data, 800 °C, 96%/4% H<sub>2</sub>/H<sub>2</sub>O 100% O<sub>2</sub>
- Machine Learnt Model

Validation of physics-based NN model against measured cell performance data

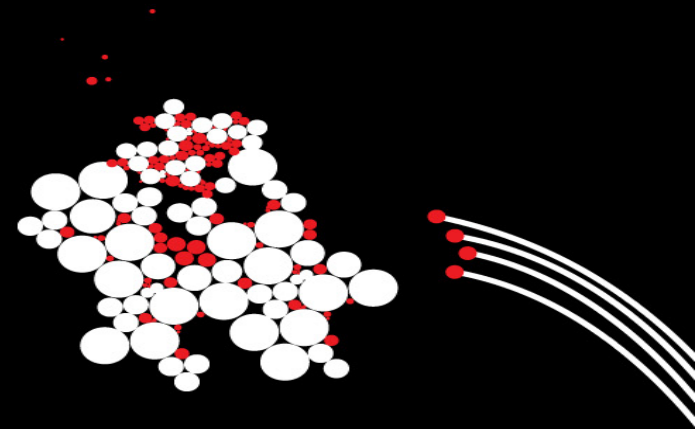


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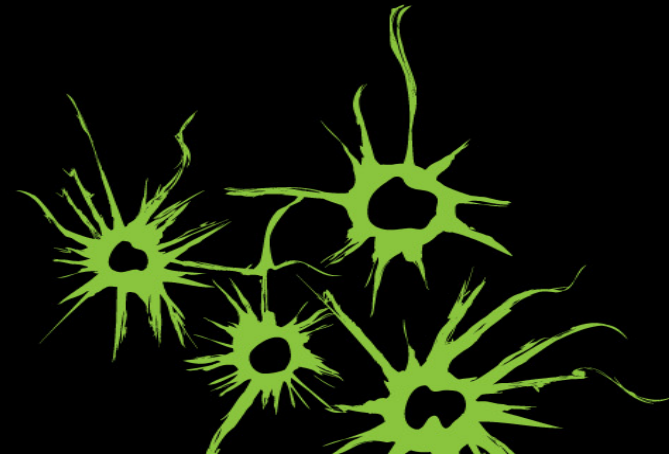
LOOKING TO THE FUTURE...



B2B Session 13  
October 27, 2022



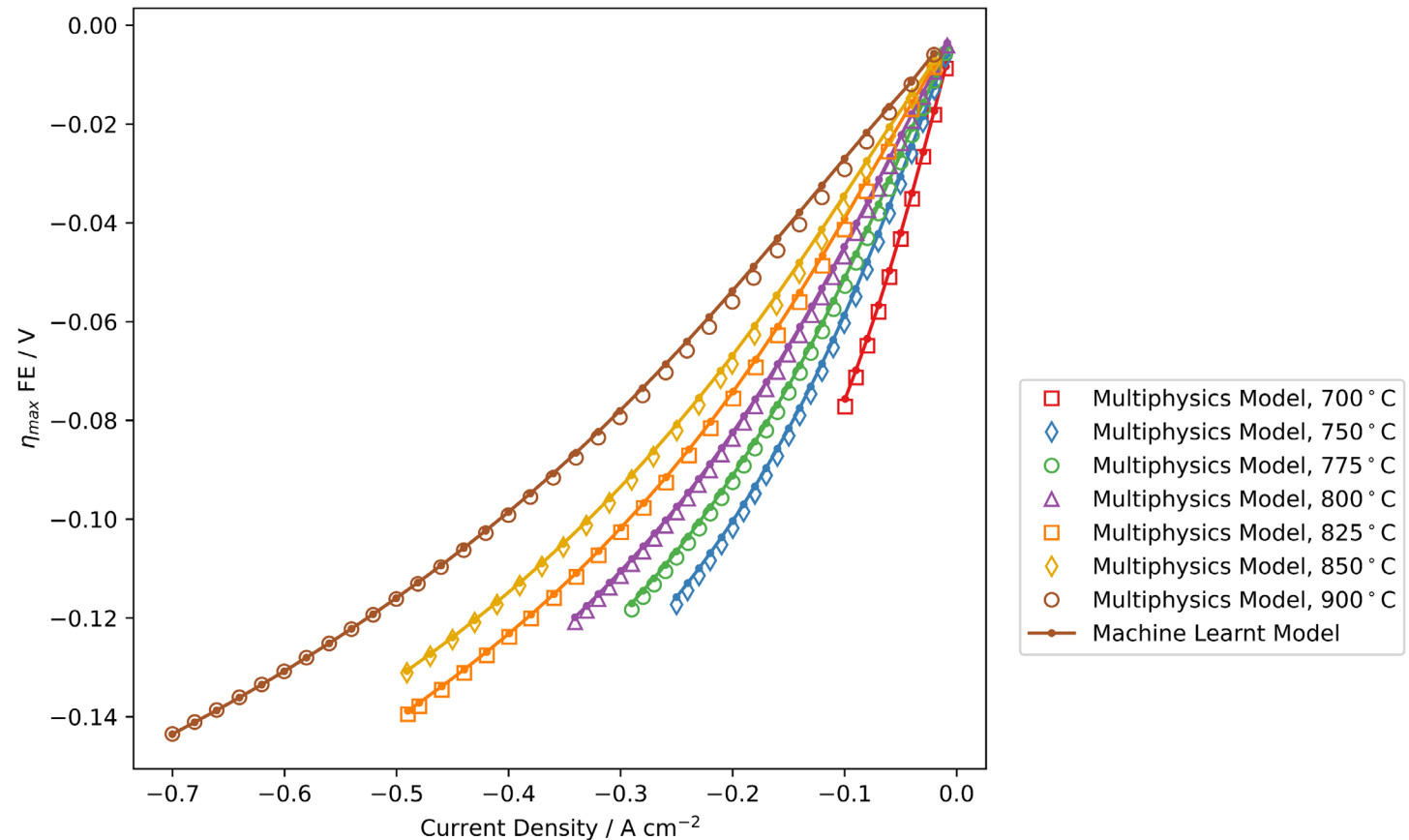
DR. AAYAN BANERJEE



# Model-Predictive Control for Lifetime

Physics-based NN model provides **real-time** access to unmeasurable internal states enabling in-depth online state-of-health analysis and new control strategies to maximize lifetime

48 $\mu\text{m}$  LSCF|7 $\mu\text{m}$  CGO|81 $\mu\text{m}$  YSZ|7 $\mu\text{m}$  CGO|25 $\mu\text{m}$  Ni-CGO  
10%/90% H<sub>2</sub>/H<sub>2</sub>O FE, 21%/79% O<sub>2</sub>/N<sub>2</sub> AE



Maximum potential difference at the Ni-CGO interface inside the fuel electrode  
(A key parameter driving Ni depletion)

