Gas Diffusion Electrodes for Fuel Cells

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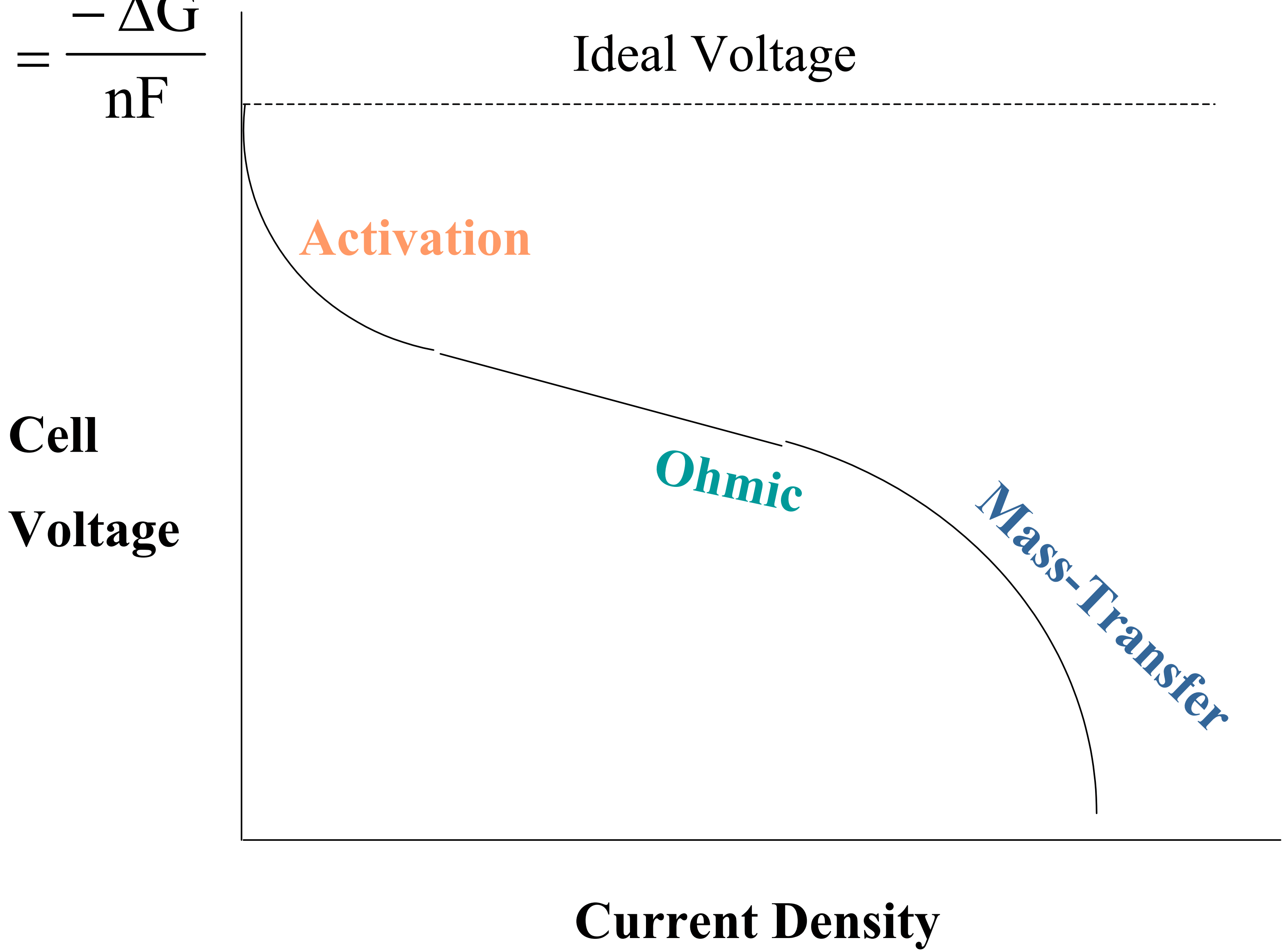
$$E = \frac{-\Delta G}{nF}$$



Sir William Grove 1839

Fuel Cells

"The chief difficulty was to obtain anything like **a notably surface for action**"

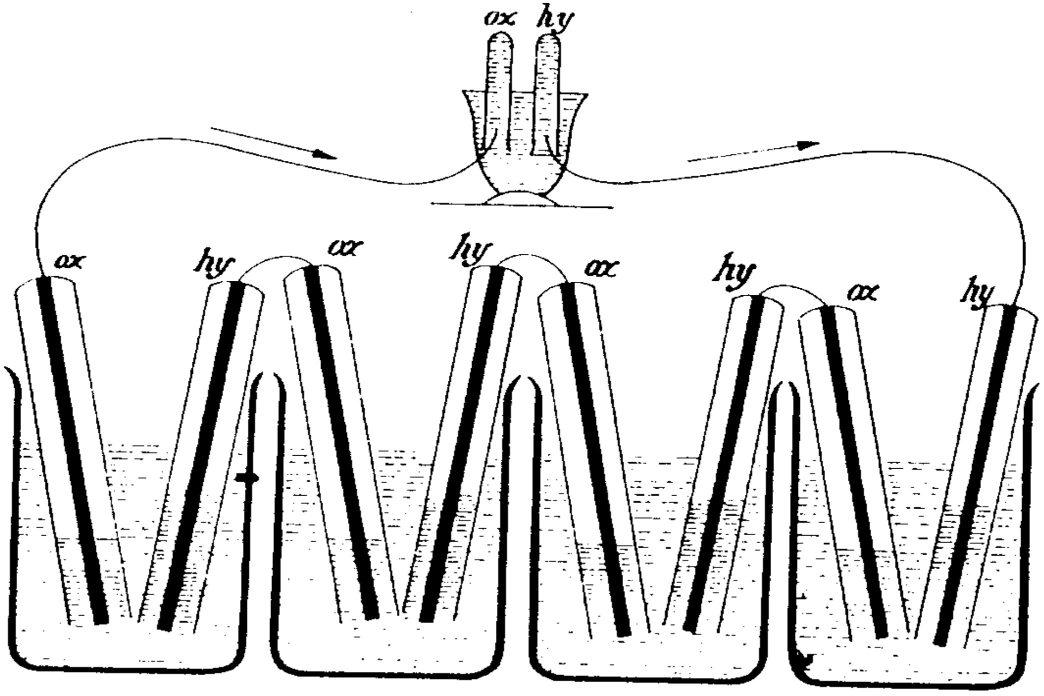


Fig. 1.5 *Four cells of Groves H_2/O_2 battery, used, in Grove's words, 'to effect the decomposition of water by means of its composition'*

Gas Diffusion Electrodes

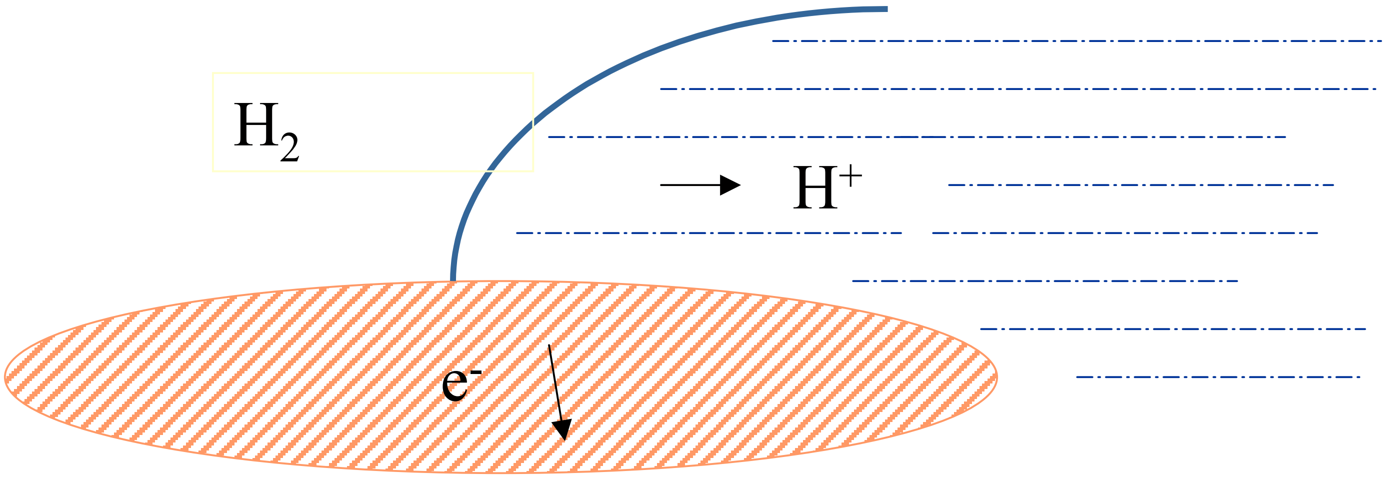
Steps:

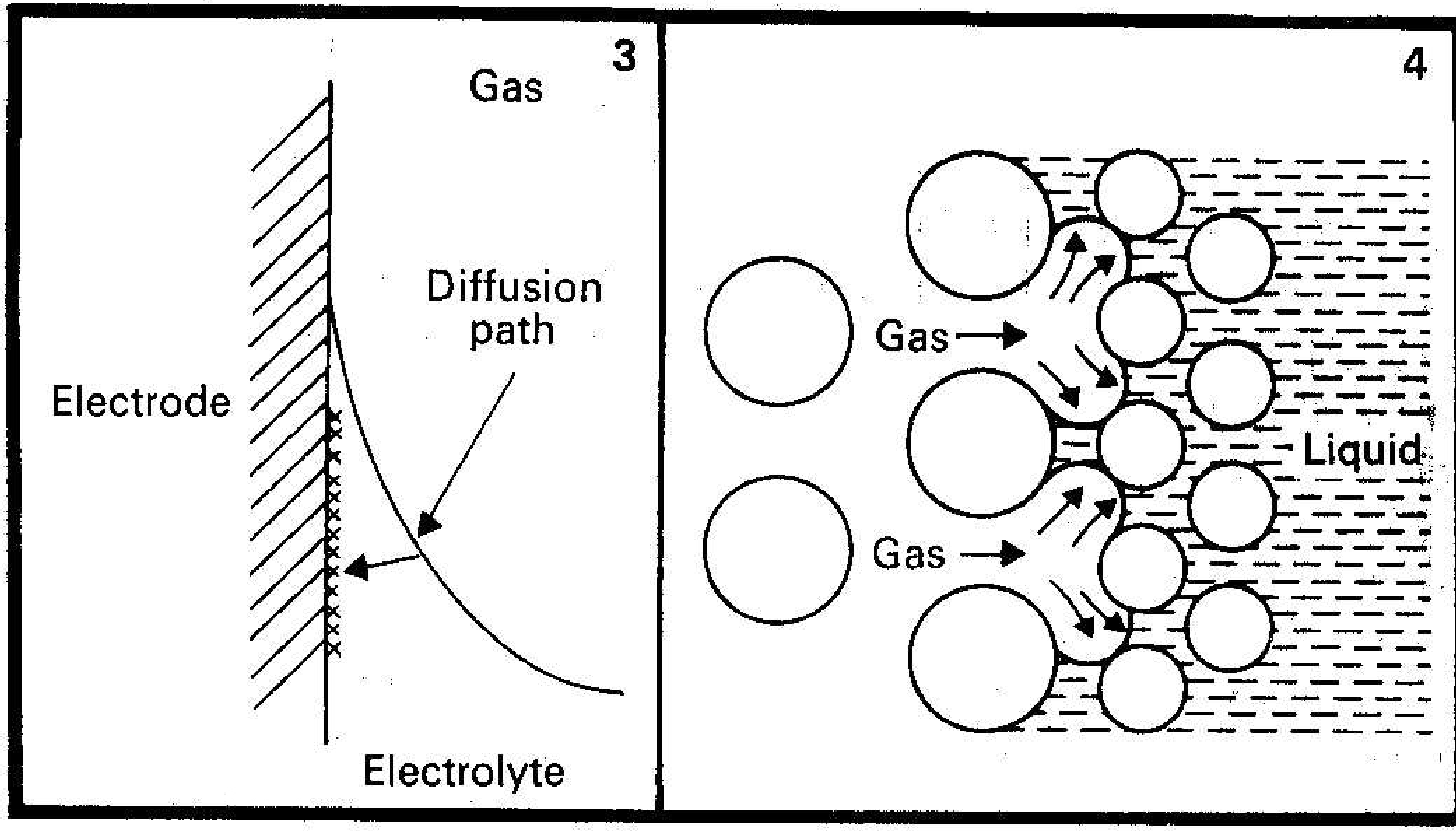
1) Convection and diffusion in gas phase   2) Dissolution at Gas-Liquid interface

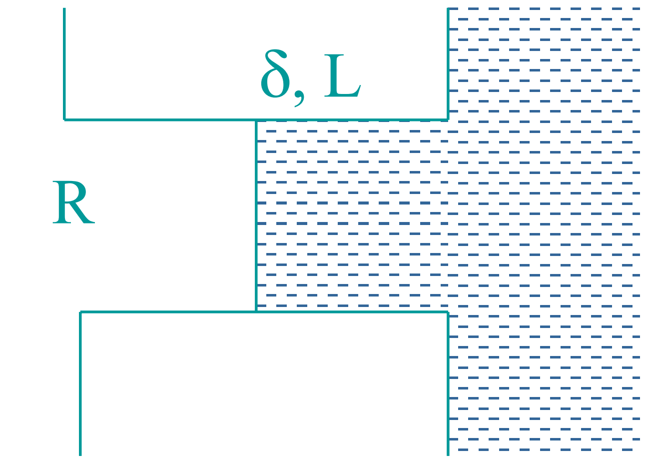
3) Diffusion to Sold-Liquid Interface   4) Electrochemical Charge Transfer Reaction

4) Diffusion of ions through electrolyte phase to opposite electrode-electrolyte interface

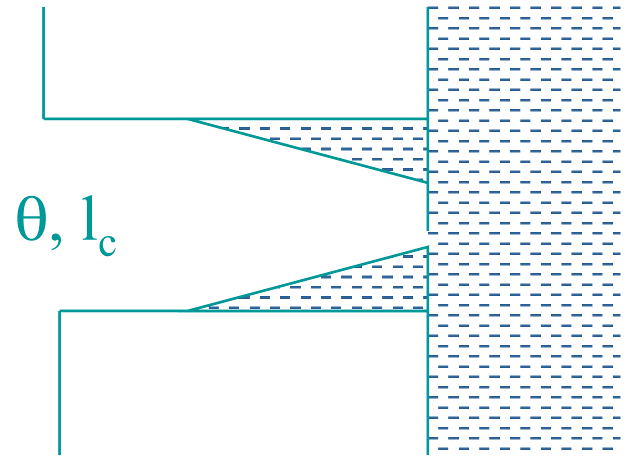
5) Simultaneous conduction of electrons through current collector



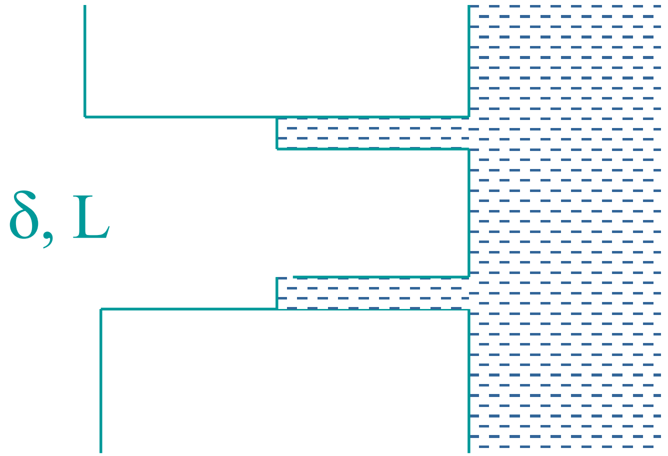

3
Gas
Diffusion path
Electrode
Electrolyte
4
Gas
Gas
Liquid



Simple Pore Model



Wedge Meniscus Model

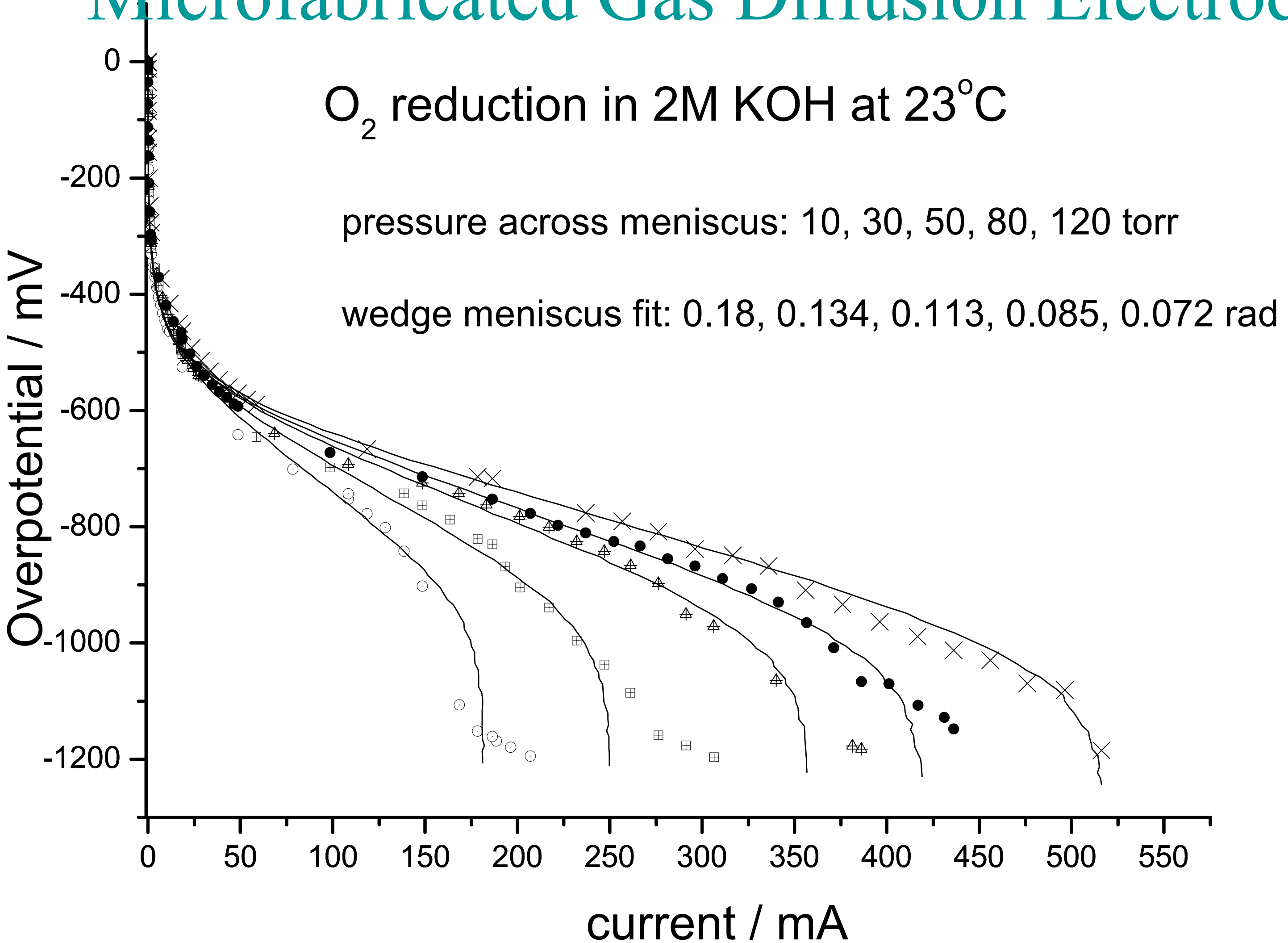


Thin Film Model

Two parameters: contact angle and three phase line length l_c

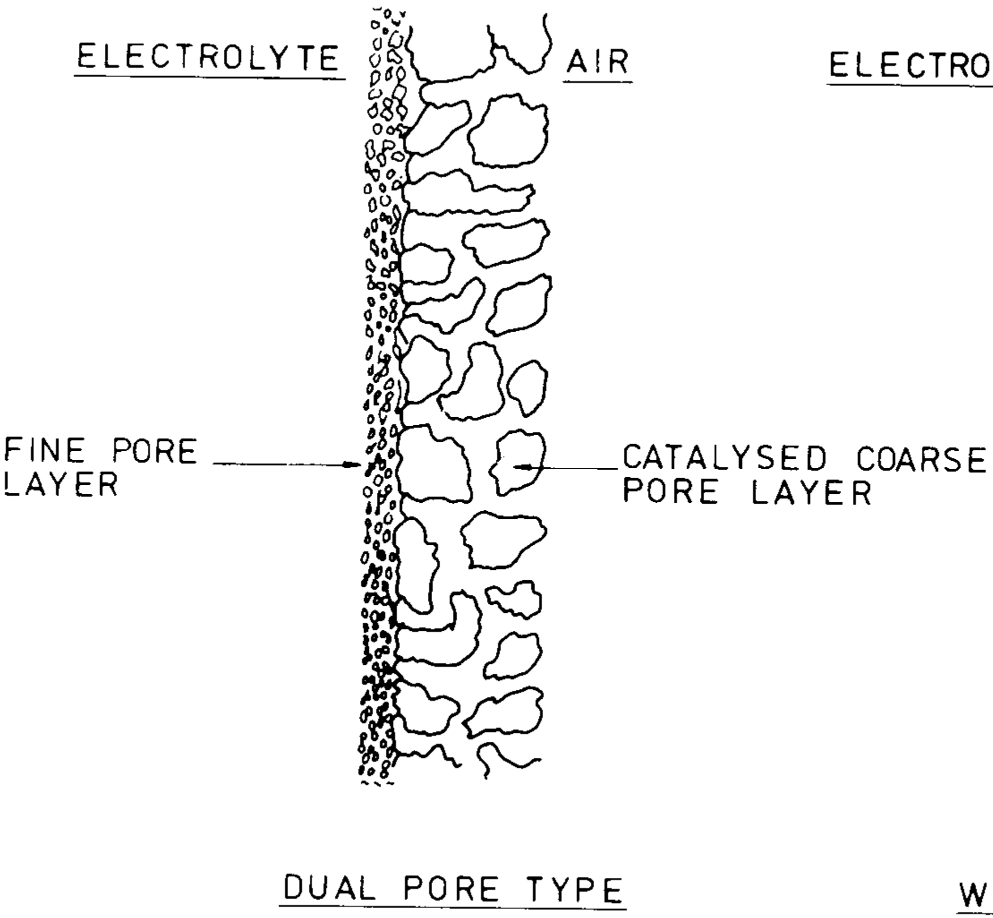
Chan et al. , Electrochimica Acta, 32 (1987), 1227;33 (1988) 1767.

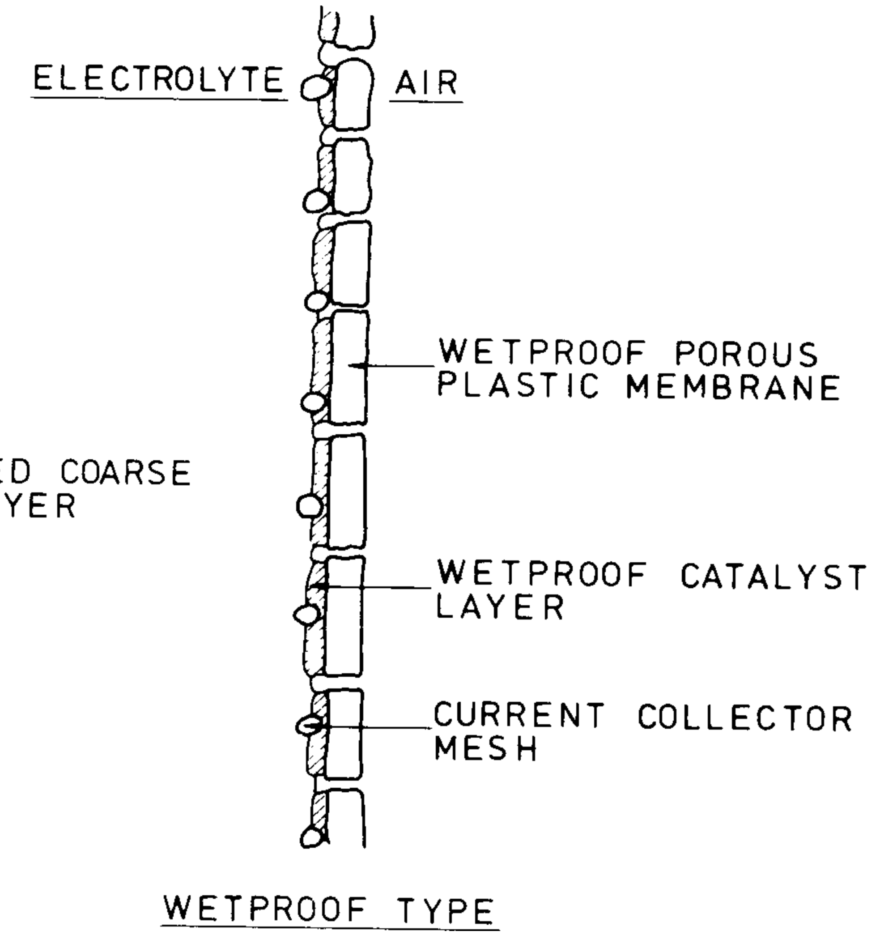
Comparison with Experiments on Microfabricated Gas Diffusion Electrodes.

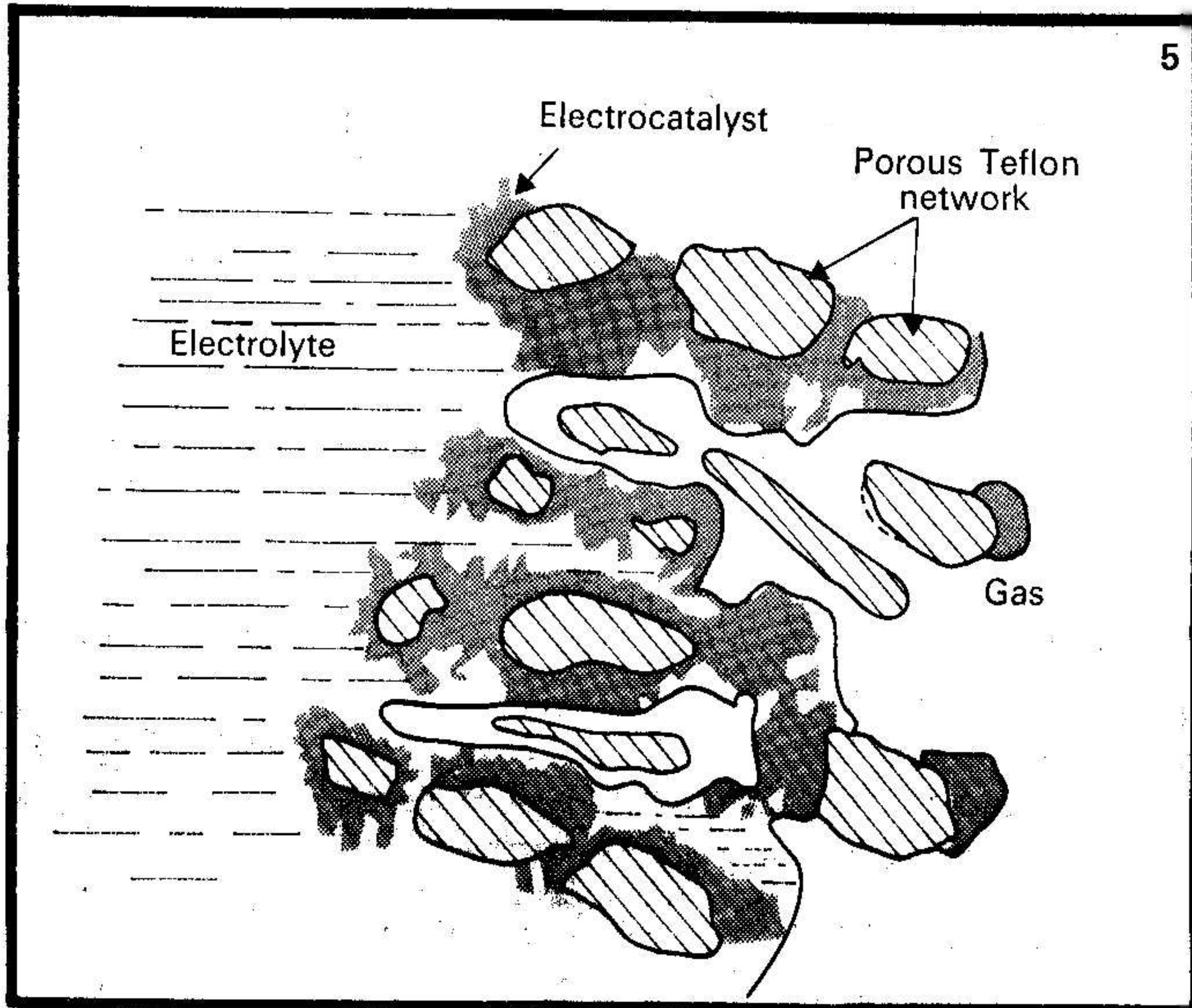


Tang and Chan, Electroanal. Chem. 334 (1992) 65.

Gas Diffusion Electrodes





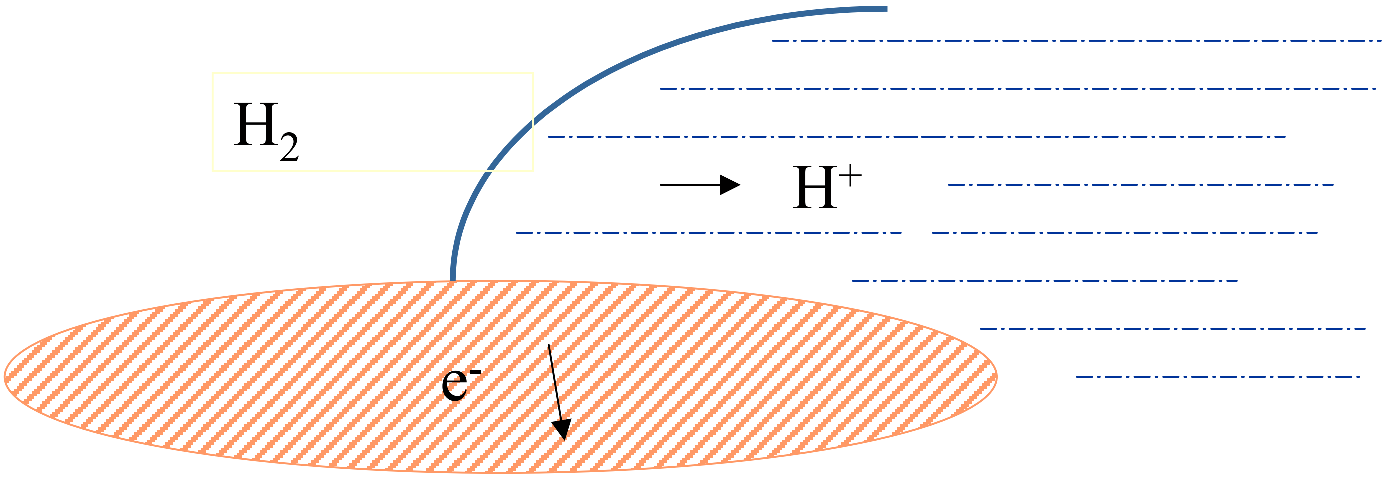

5
Electrocatalyst
Porous Teflon
network
Electrolyte
Gas

Gas Diffusion Electrodes

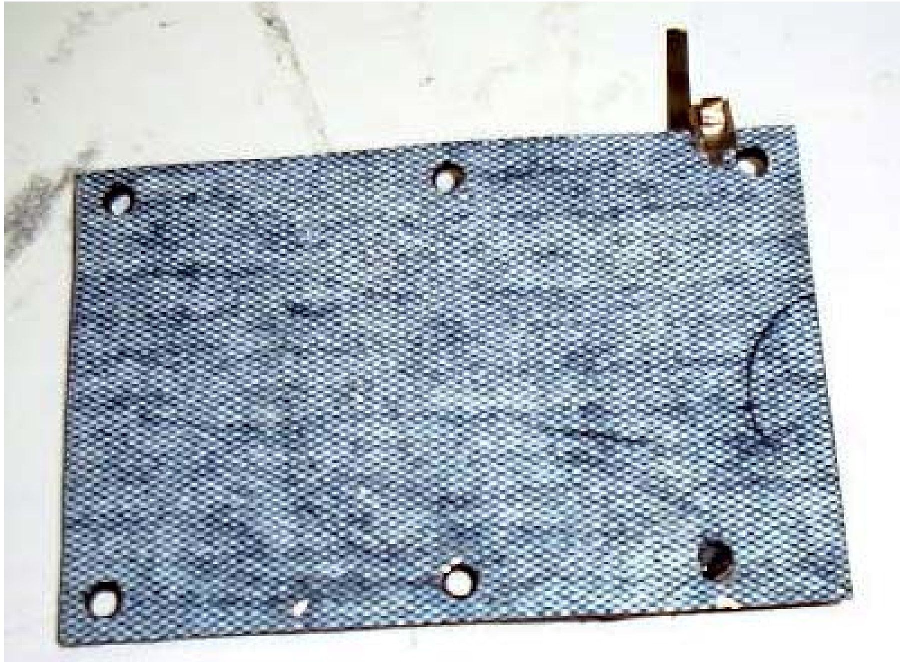
Electronic circuit: continuous solid phase

Ionic circuit: Continuous electrolyte phase

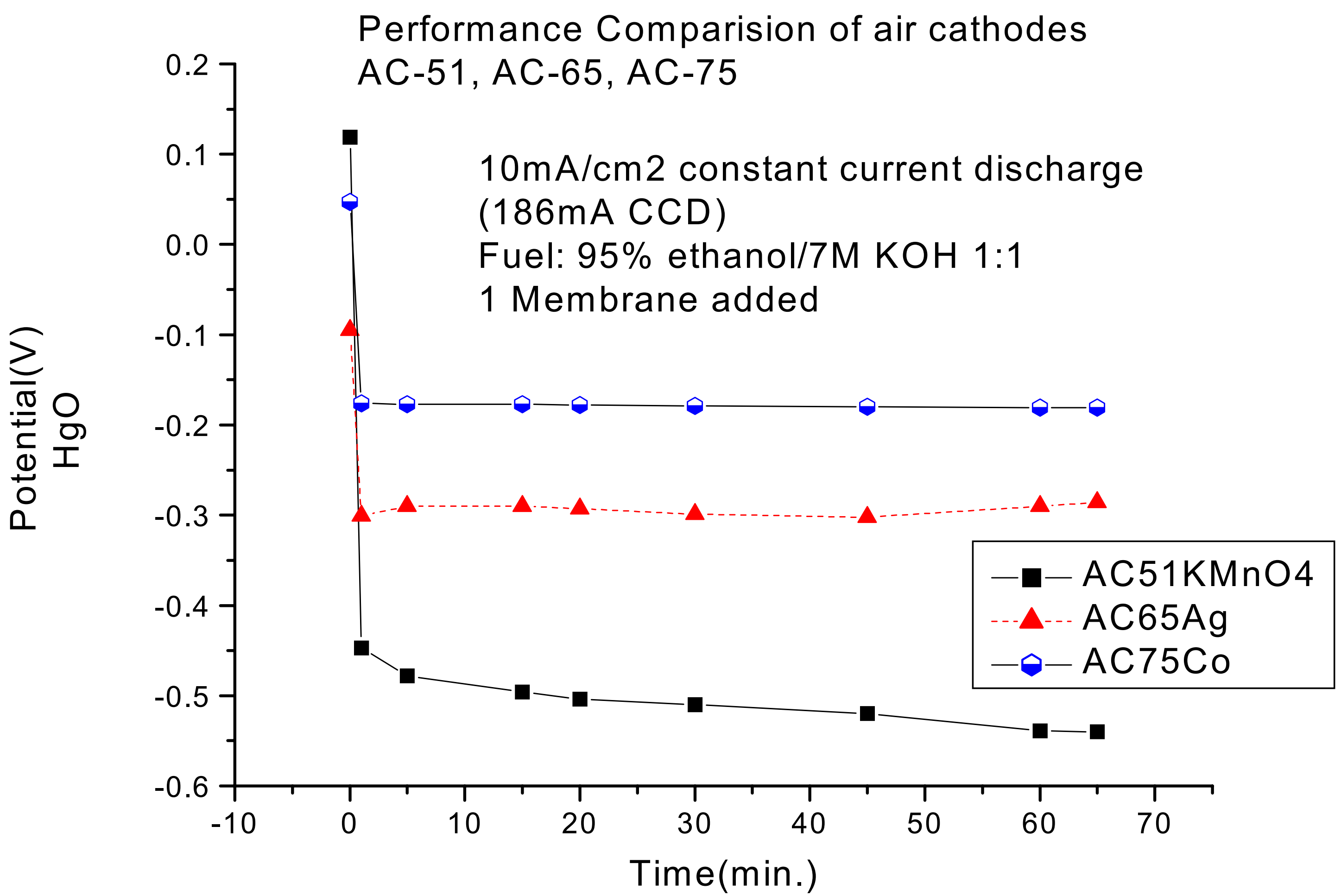
Materials flow circuit: feed of reactancts



Single air cathode



Performances of different air cathode



Multi-Scale Structured Electrode:

- Catalyst Support: High Surface Carbon
- Size Effects of Catalysts
- Controlled Porosity
- Controlled Wetting
- Maxinum Gas-Liquid-Solid Interface
- Minimize ohmic resistance
- Minimize ionic resistance

Catalysts

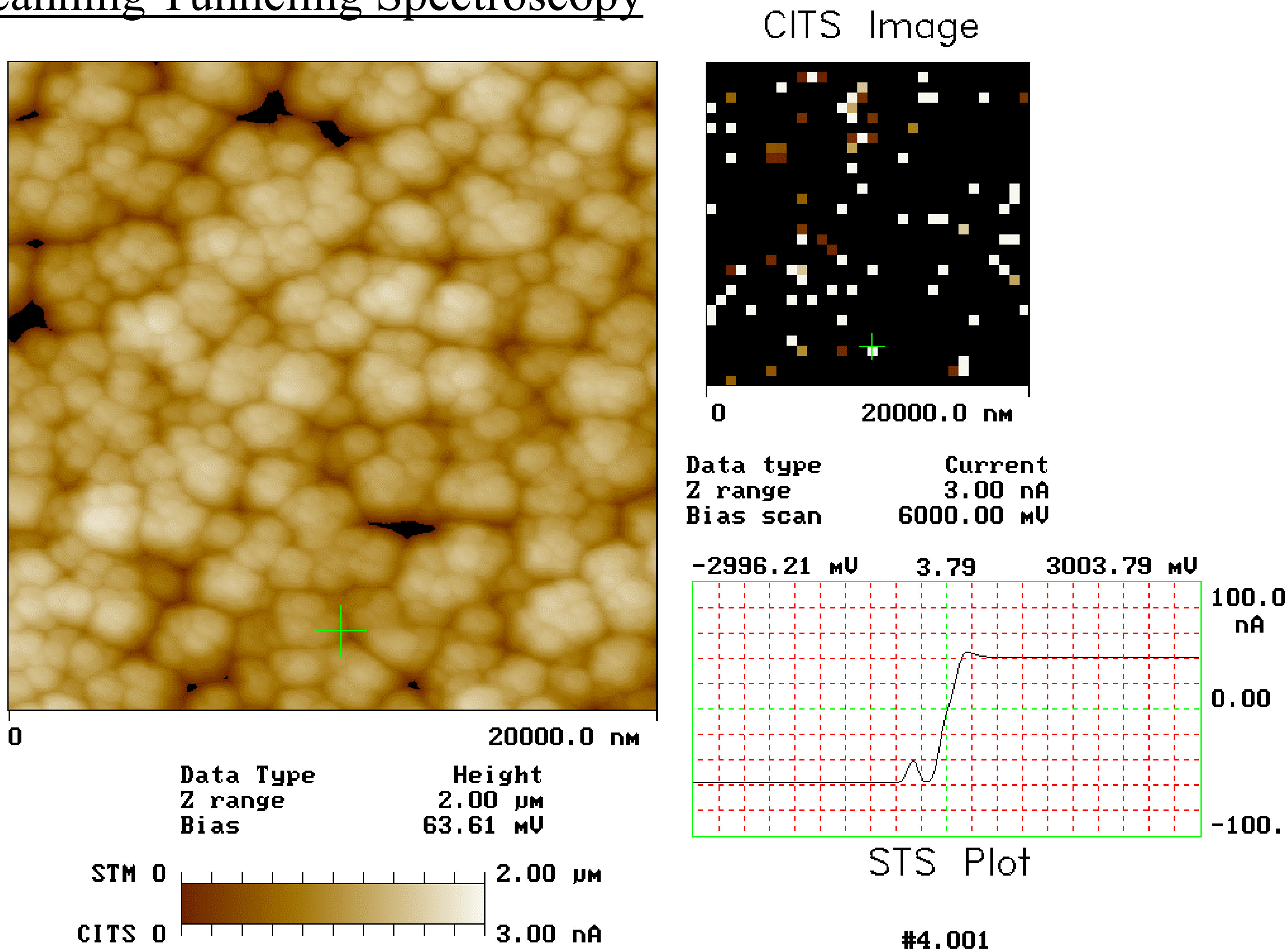
- Platinum is the most important for both anode and cathode
- Platinum can be replaced by Ag, Mn, Co, only for oxygen reduction in alkaline medium
- Platinum subject to CO poisoning (impure H_2)
- Binary/Ternary system, macrocycle, bifunctional
- Stability/Life of nanometals

Catalysts

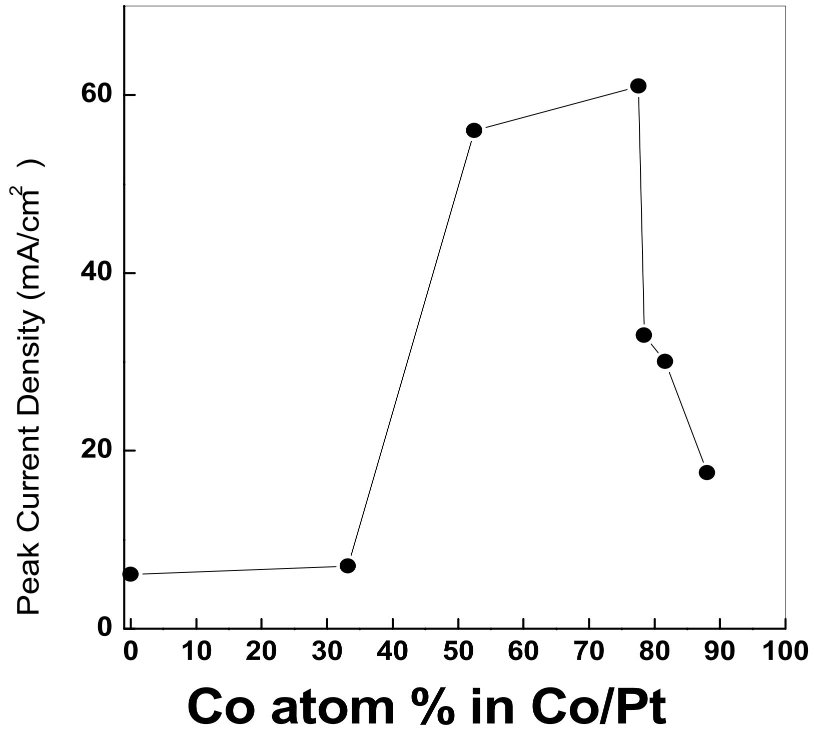
- Oxygen Cathode is most limiting and is present in most fuel cells
- Non-platinum cathode catalyst can tolerant cross over effect.

- At high temperature, no precious metal or no catalysts is needed in MCFC and SOFC

Scanning Tunneling Spectroscopy



Maximum peak current density at 52.5~77.6% Co, one order of magnitude higher than that of pure Pt particles. One possible role of cobalt in promoting the catalysis of platinum, is the removal of CO_{ad} $COOH_{ad}$ intermediates.



$$HCOOH \rightarrow COOH_{ad} + H^{+} + e^{-} \qquad (2)$$

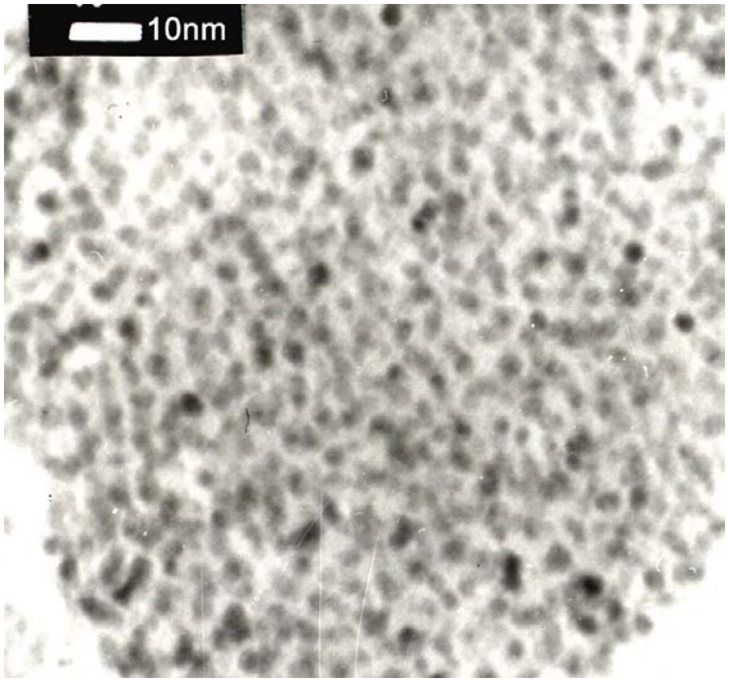
$$HCOOH + COOH_{ad} \rightarrow CO_{ad} + CO_{2} + H_{2}O + H^{+} + e^{-} \qquad (3)$$

$$COOH_{ad} \rightarrow CO_{2} + H^{+} + e^{-} \qquad (4)$$

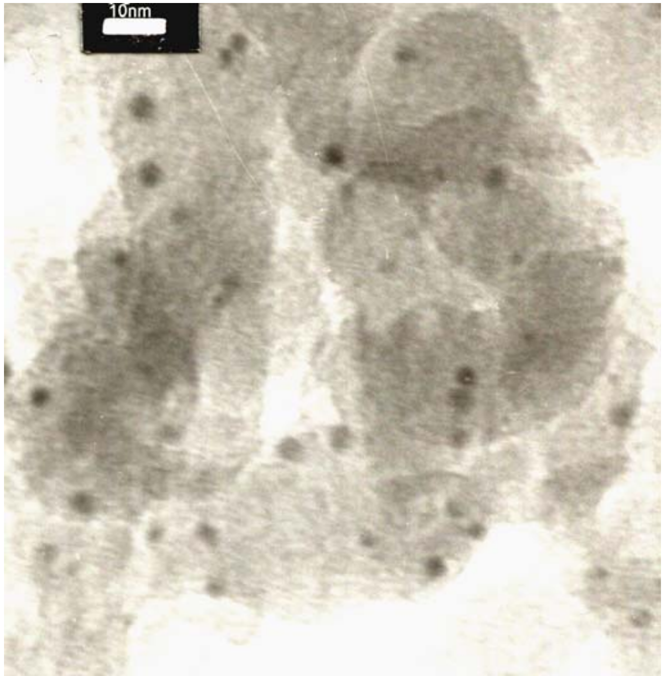
$$CO_{ad} + OH_{ad} \rightarrow CO_{2} + H^{+} + e^{-} \qquad (5)$$

Chi et al., Catalysis Letters, 71 (2001) 21.

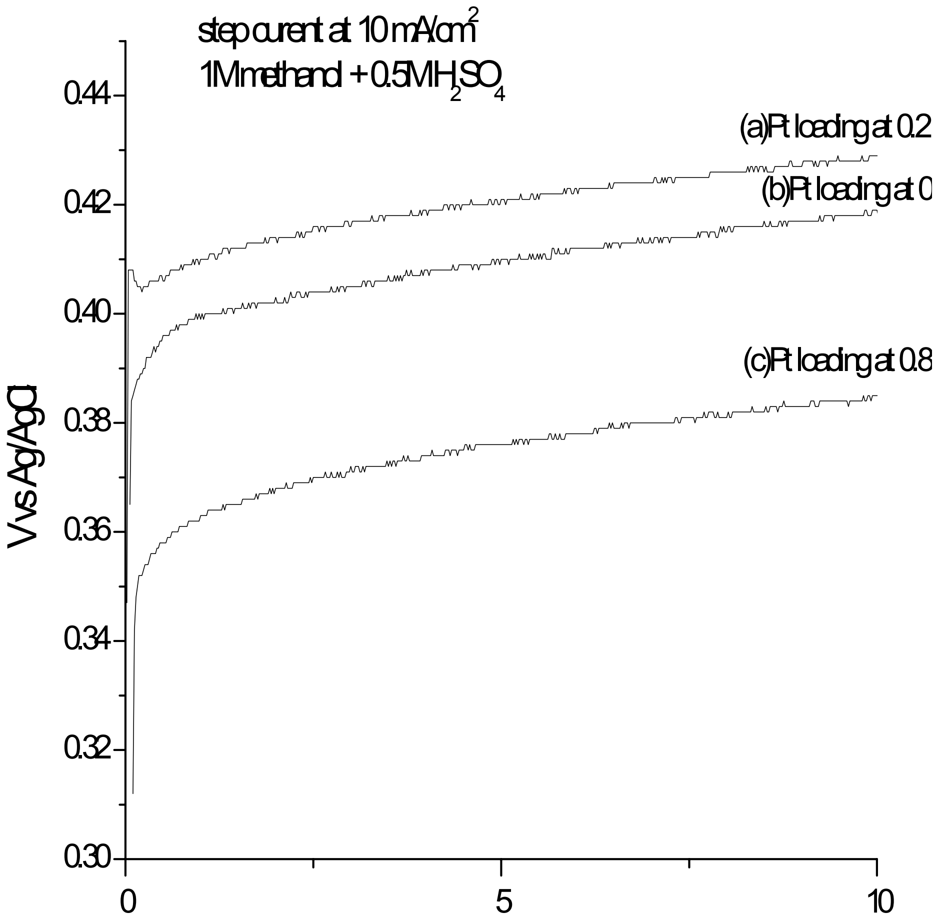
Nanometal particles prepared by microemulsion

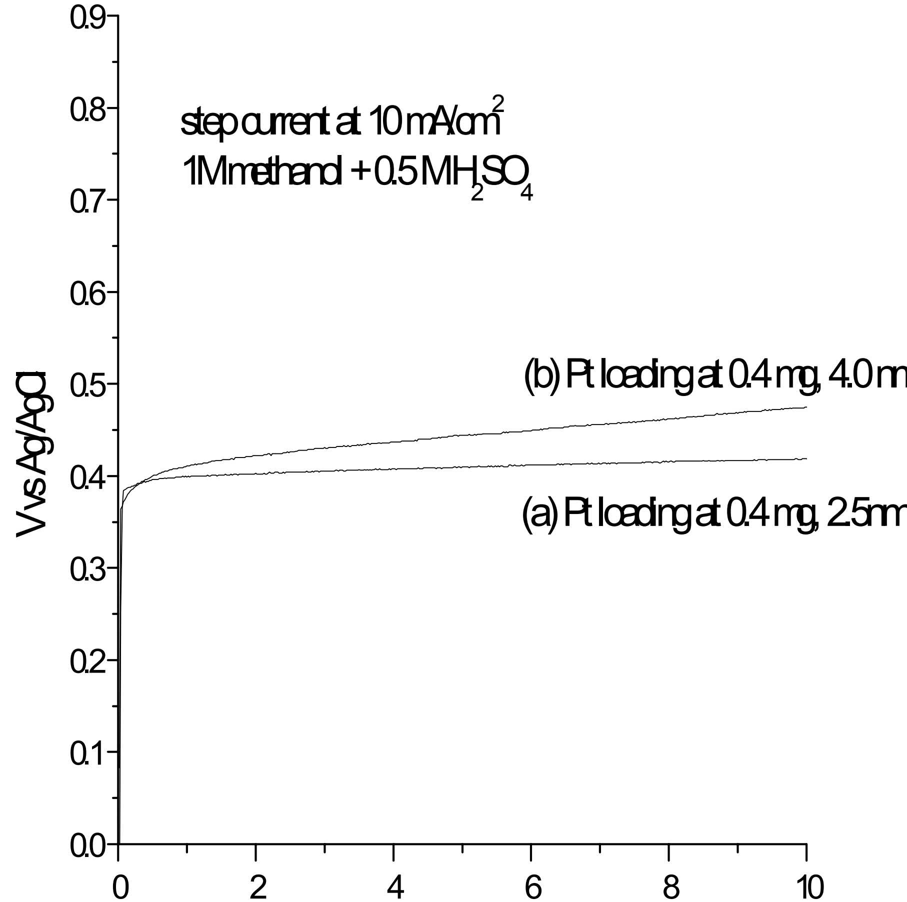


Nanometal particles adsorbed in carbon



Zhang and Chan, J. Mater. Chem. 12 (2002) 1203.

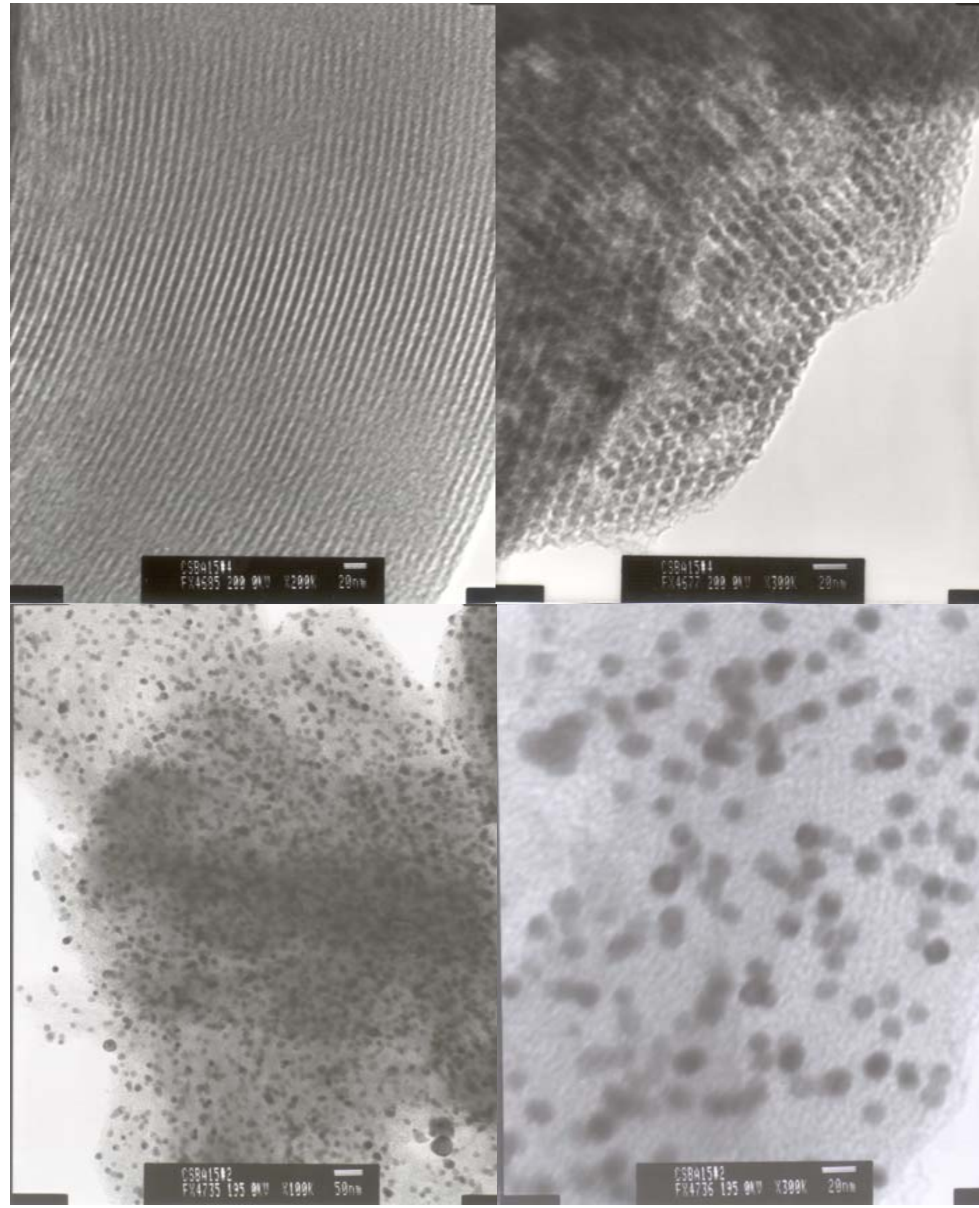




Pt/Ru nanoparticles on carbon

TEM images of Meosoporous Carbon synthesized from SBA 15 Template

carbon(a and b) and supporting Pt nanoparticles(c and d).



Current Collector and Binder

- Metal Mesh, Metal Foam can use used as current collector and mechanical support for the carbon powder
- Platinum mesh or Carbon cloth will be needed for acid electrolyte including PEM
- Binder will hold loose powder together and also be attached to current collector: PVA, glue, PTFE (heat at > 300 ºC), CMC, etc.

Membrane-Electrolyte Assmebly

- For PEM fuel cell, anode and cathode are made of carbon cloth and are pressed together with a Nafion membrane sandwiched under temperature > 100 ºC. A special hot press is required.
- For wet fuel cells, electrode can be made by heating inside an furnace without mechanical press.