Reducing Platinum Content in Proton Exchange Membrane Fuel Cells

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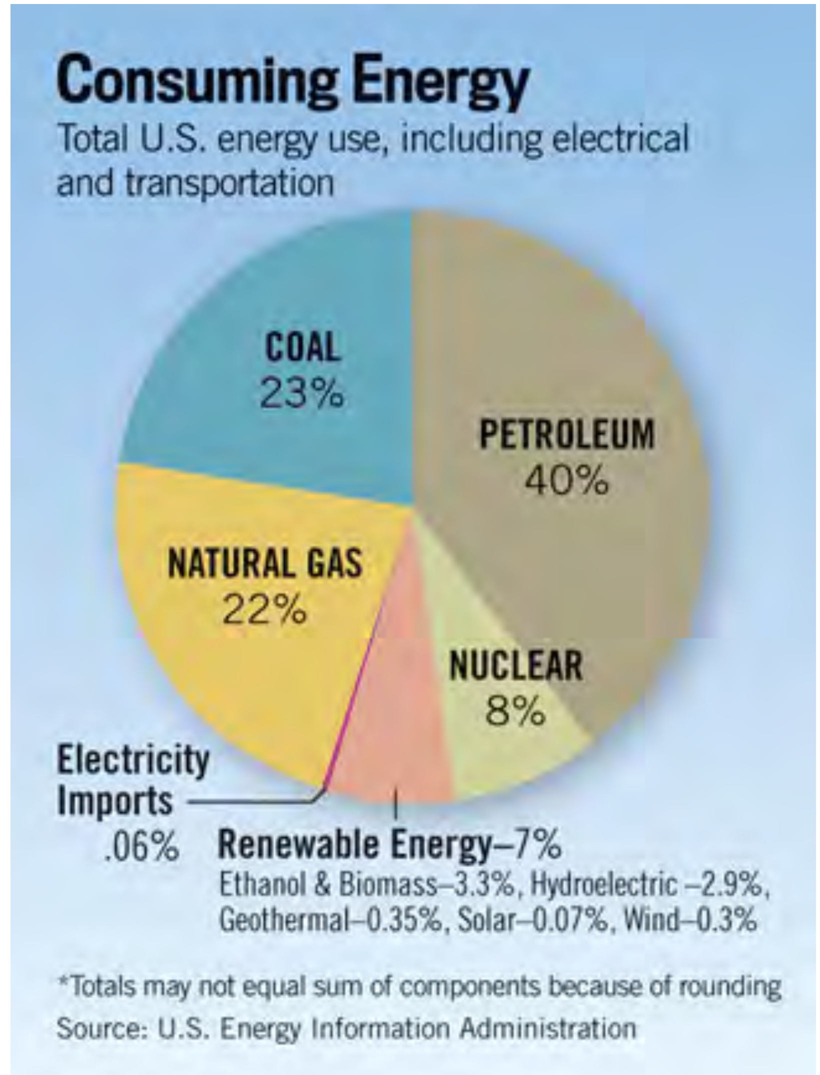
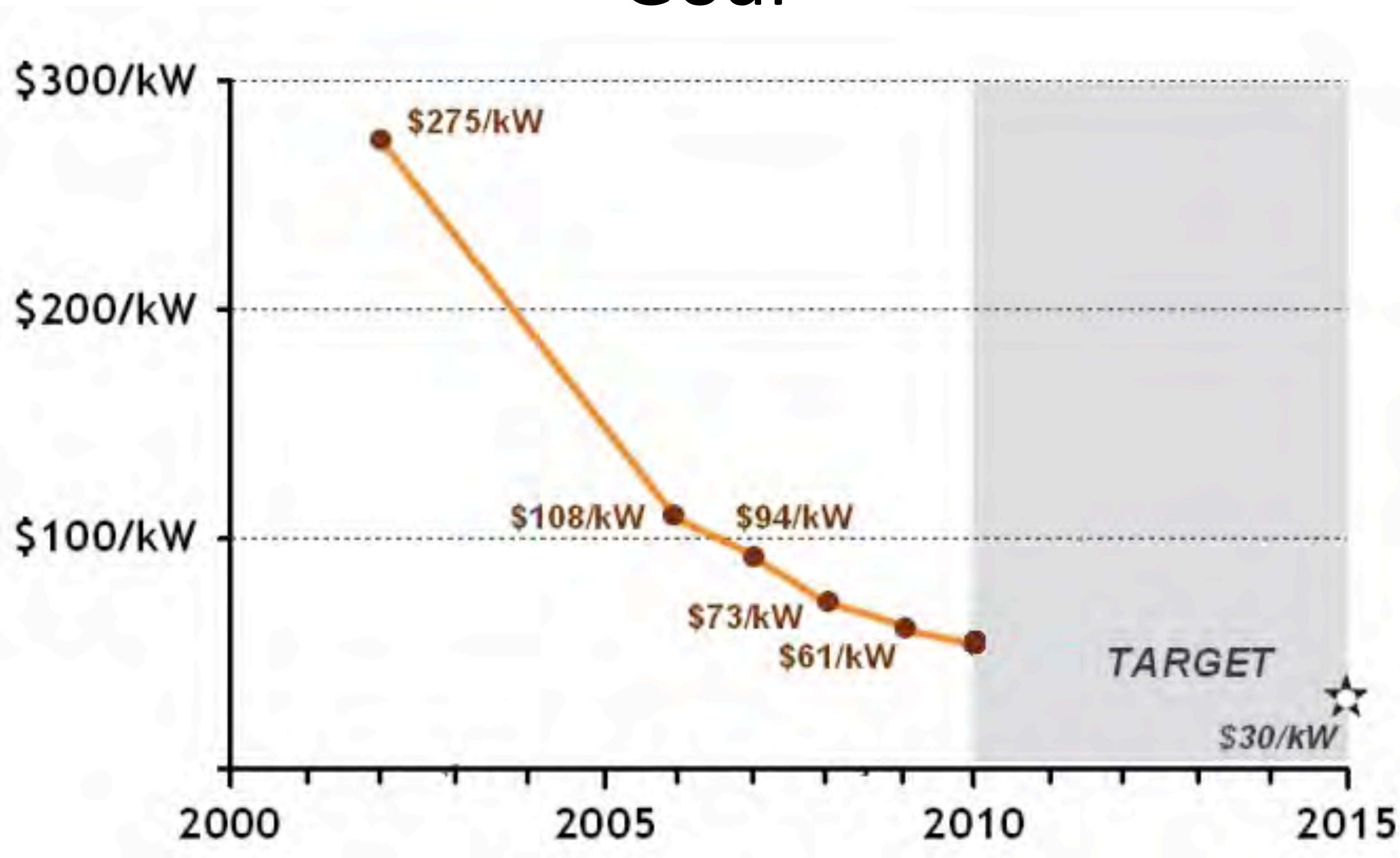
Introduction to Fuel Cells

- current energy: fuel and nuclear power

- fuel cells as "clean" source of energy

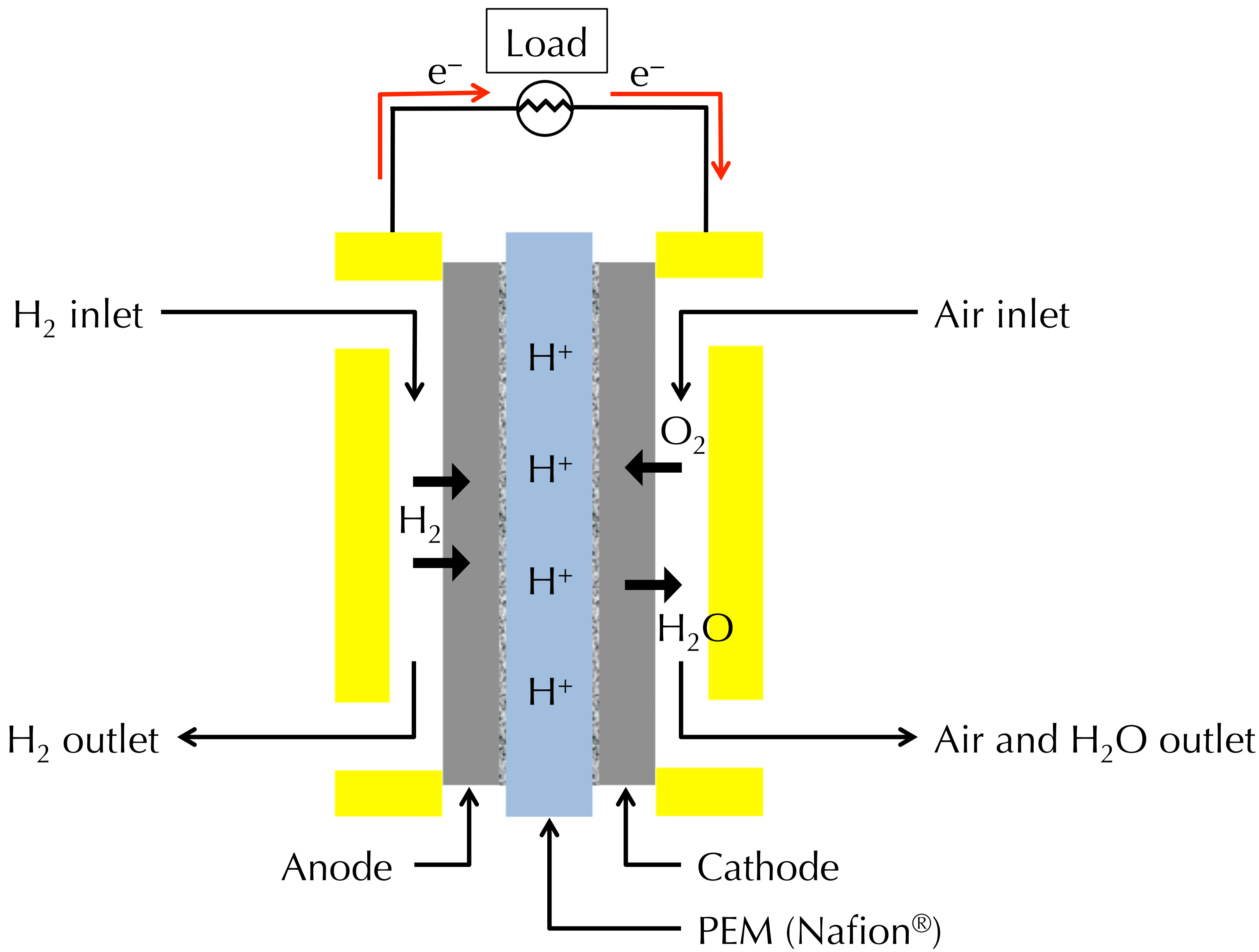


Current Challenge: DOE Fuel Cell Cost Goal



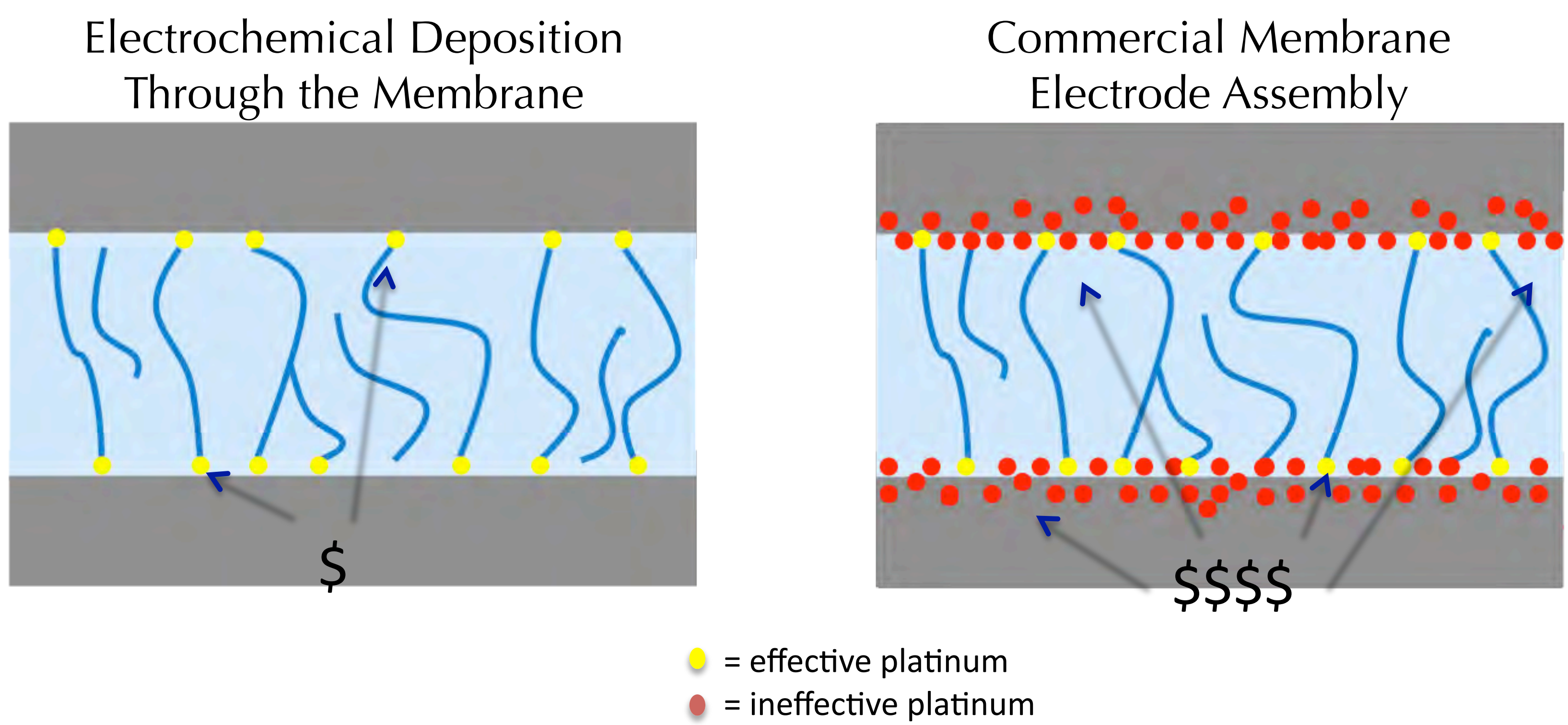
J. S. Spendelow and D. C. Papageorgopoulos. (2011).

Fuel Cell


Load
e⁻
e⁻
H_2 inlet
Air inlet
H^+
H^+
H^+
H^+
O_2
H_2
H_2O
H_2 outlet
Air and H_2O outlet
Anode
Cathode
PEM (Nafion®)

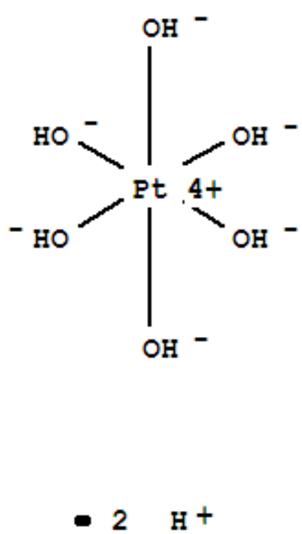
Our Goal

- Reduce Platinum content by depositing Platinum through the membrane



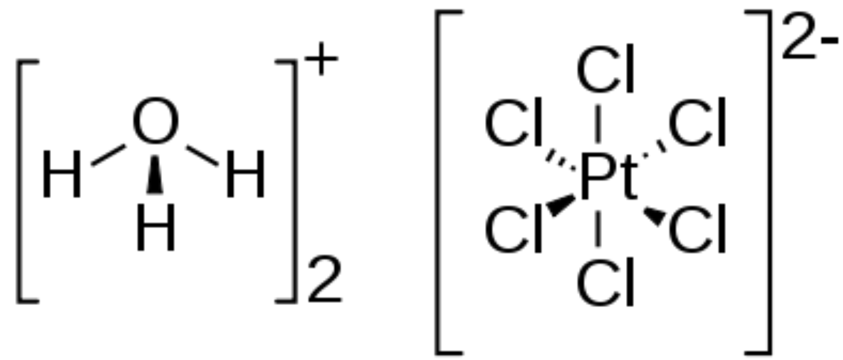
This Summer's Focus

- Platinic Acid



http://www.guidechem.com/products/51850-20-5.html

- Chloroplatinic Acid



http://en.wikipedia.org/wiki/Chloroplatinic_acid

This Summer's Focus

- **Platinic Acid** plating solution

Cathodic Process:

$H_2Pt(OH)_6 + 4\,H^+_{(aq)} + 4e^- \rightleftharpoons Pt_{(s)} + 6\,H_2O_{(l)} \qquad E°_c = 0.928V^*$

Anodic Process:

$O_{2(g)} + 4\,H^+_{(aq)} + 4e^- \rightleftharpoons 2\,H_2O_{(l)} \qquad E°_a = 1.032V$

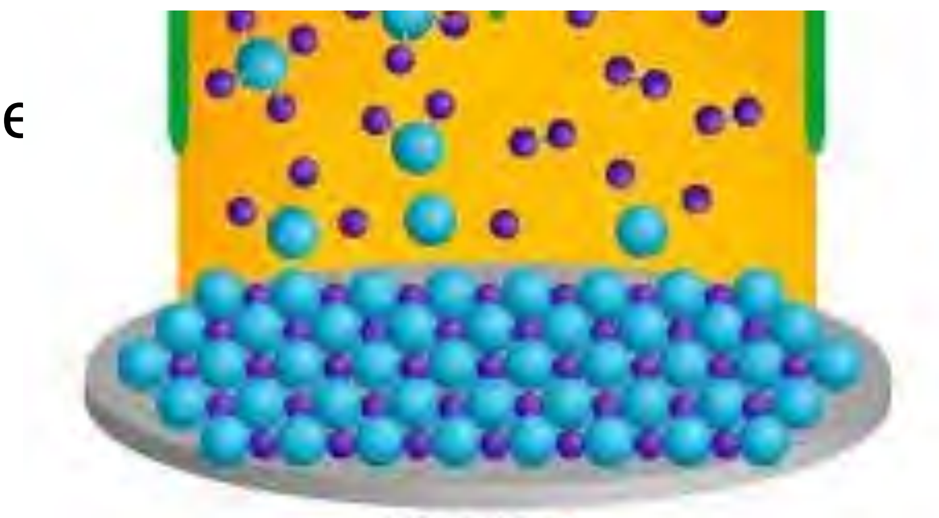
$H_2Pt(OH)_6 \rightleftharpoons Pt_{(s)} + 4H_2O_{(l)} + O_{2(g)} \qquad E°_{cell} = -0.104V$

$\mathbf{\Delta G°_{cell} = -nFE°_{cell} \Rightarrow \Delta G°_{cell} > 0}$

*Nagano Y. et al. *J. Chem. Thermodynamics* **2002**, *34*, 409-412.

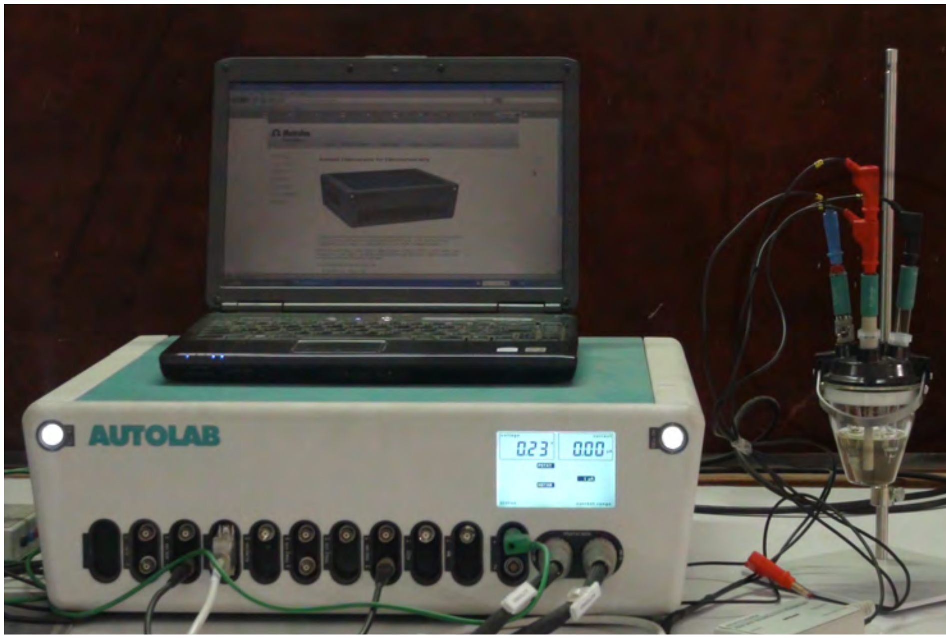
Characterizing the Solution

- Qualitative Data
  - Relationship betwee i_p and scan rate

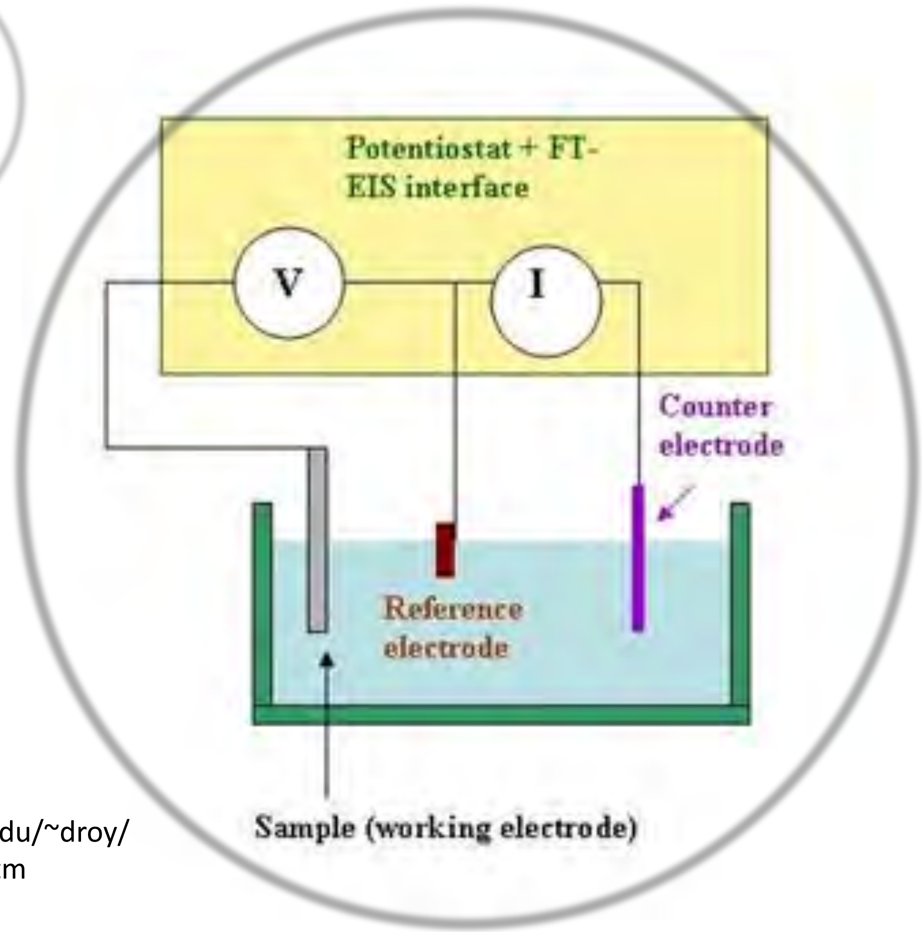


- Quantitative Data
  - Charge transfer coefficient- $\alpha\eta_\alpha$
  - Diffusion coefficient- D_0

Characterizing the Solution: Cyclic Voltammetry

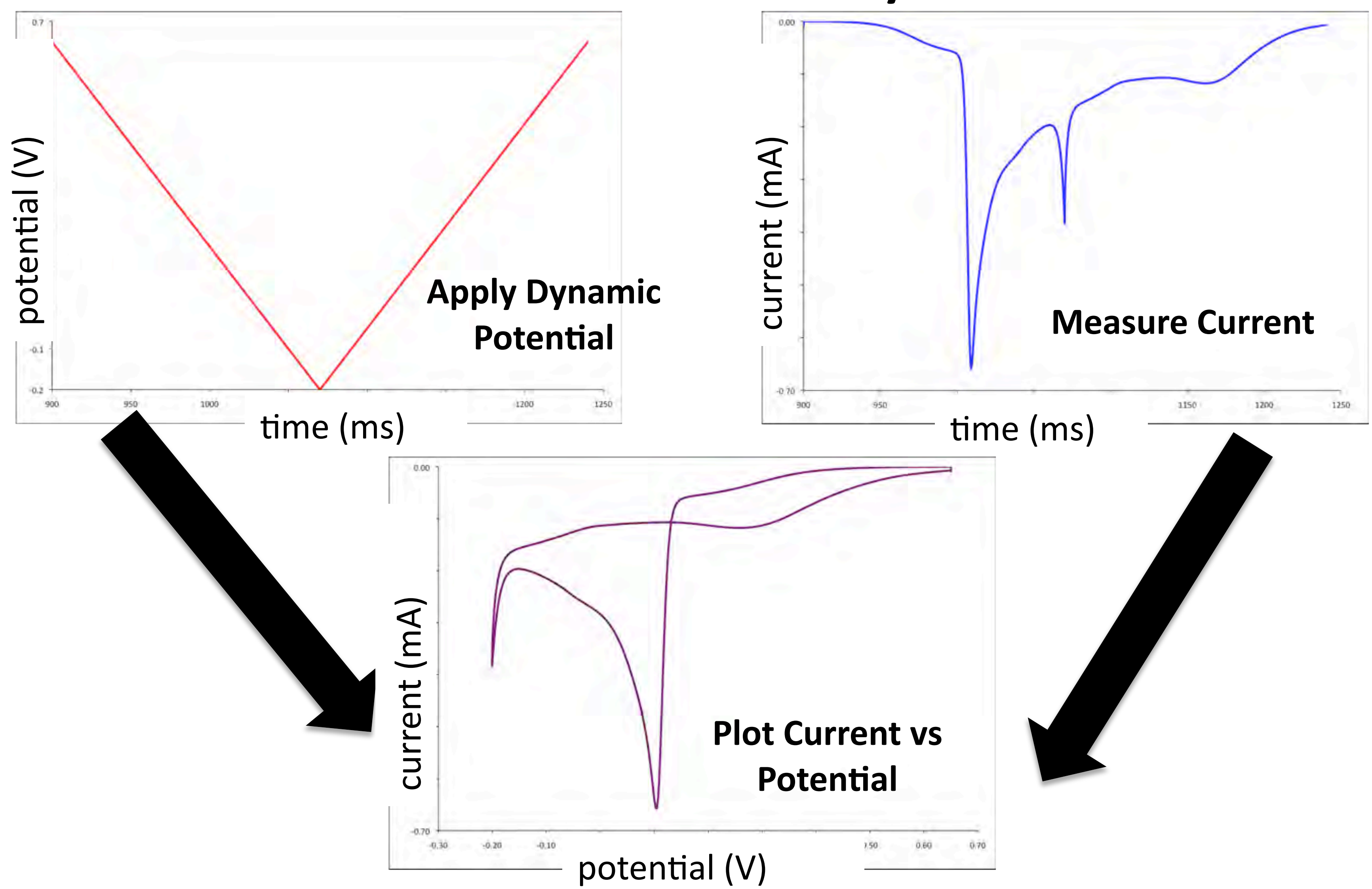


http://webcache.googleusercontent.com/search?q=cache:http://220.227.100.58/Experiments/onlineExperiments/Experiment1/setup.aspx



http://people.clarkson.edu/~droy/Corrosion_EIS.htm

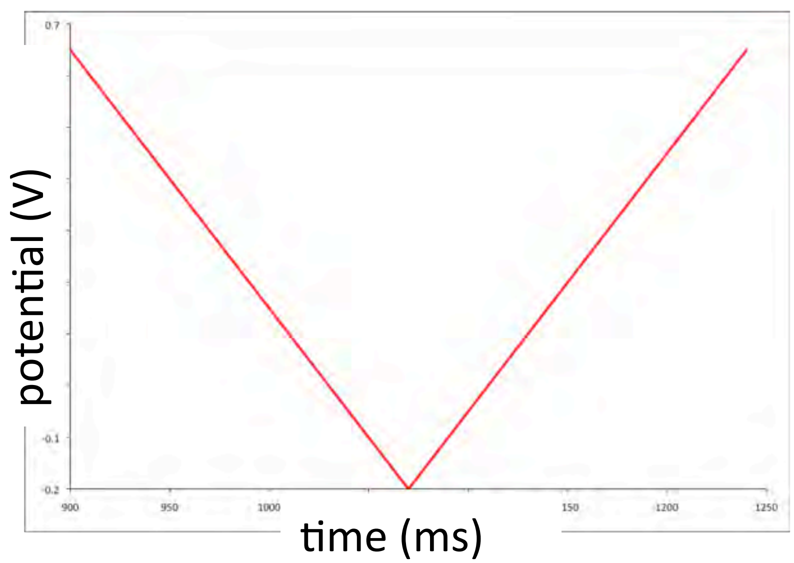
Characterizing the Solution: Cyclic Voltammetry



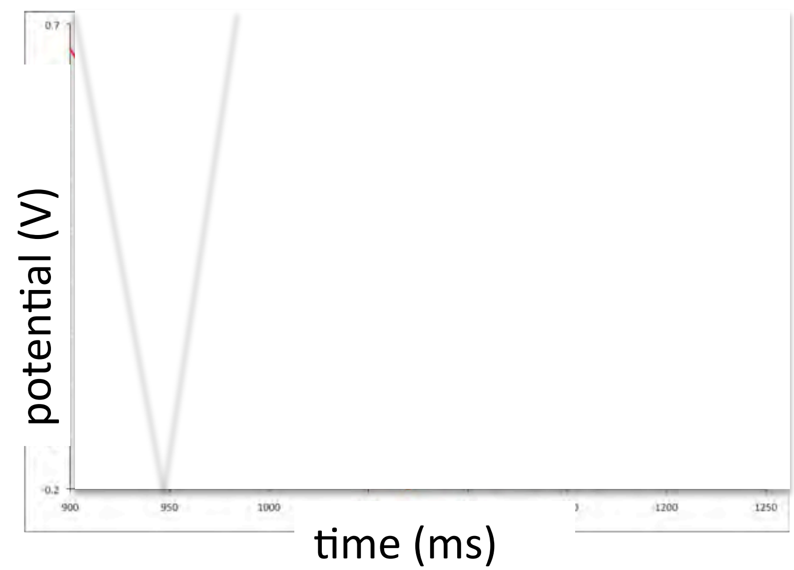
Characterizing the Solution: Cyclic Voltammetry

Scan Rate

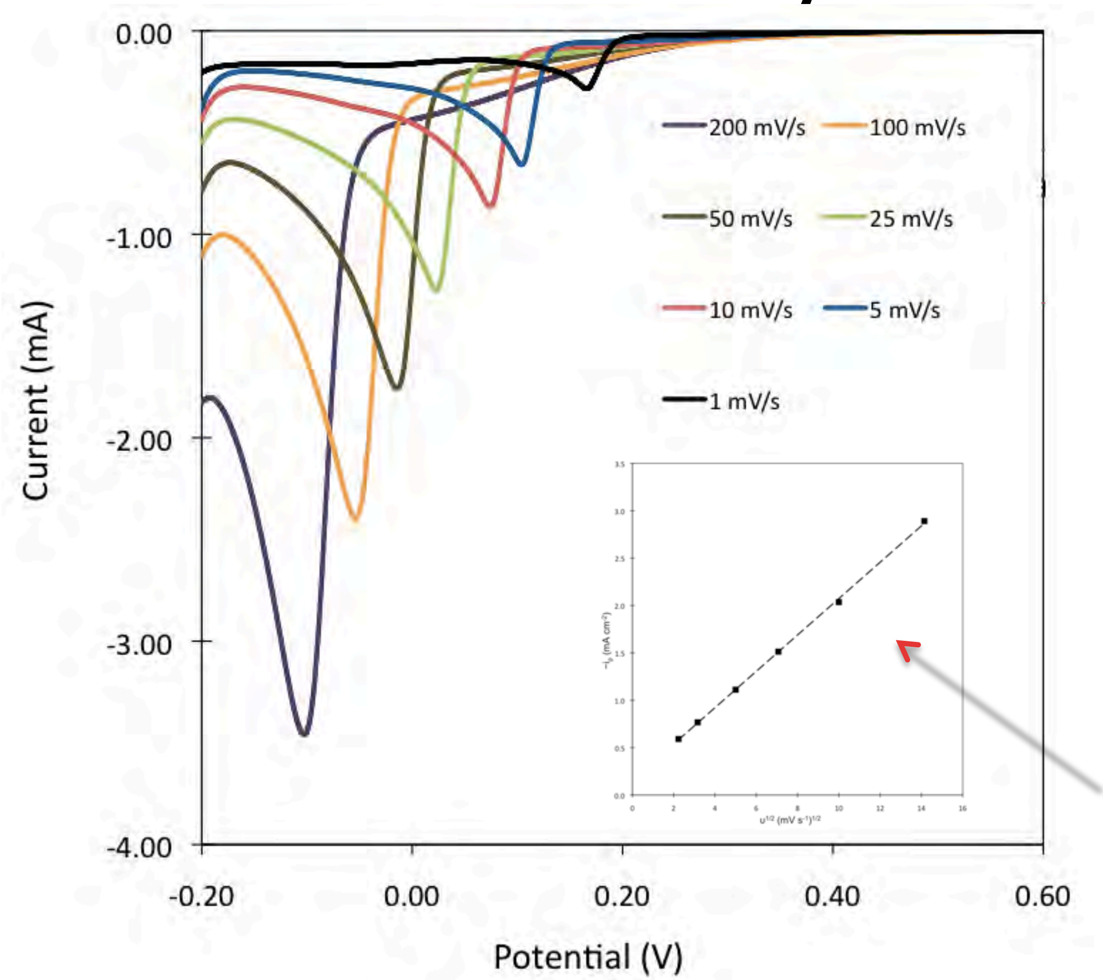
Slow Scan Rate (1 mV/s)



Fast Scan Rate (100 mV/s)

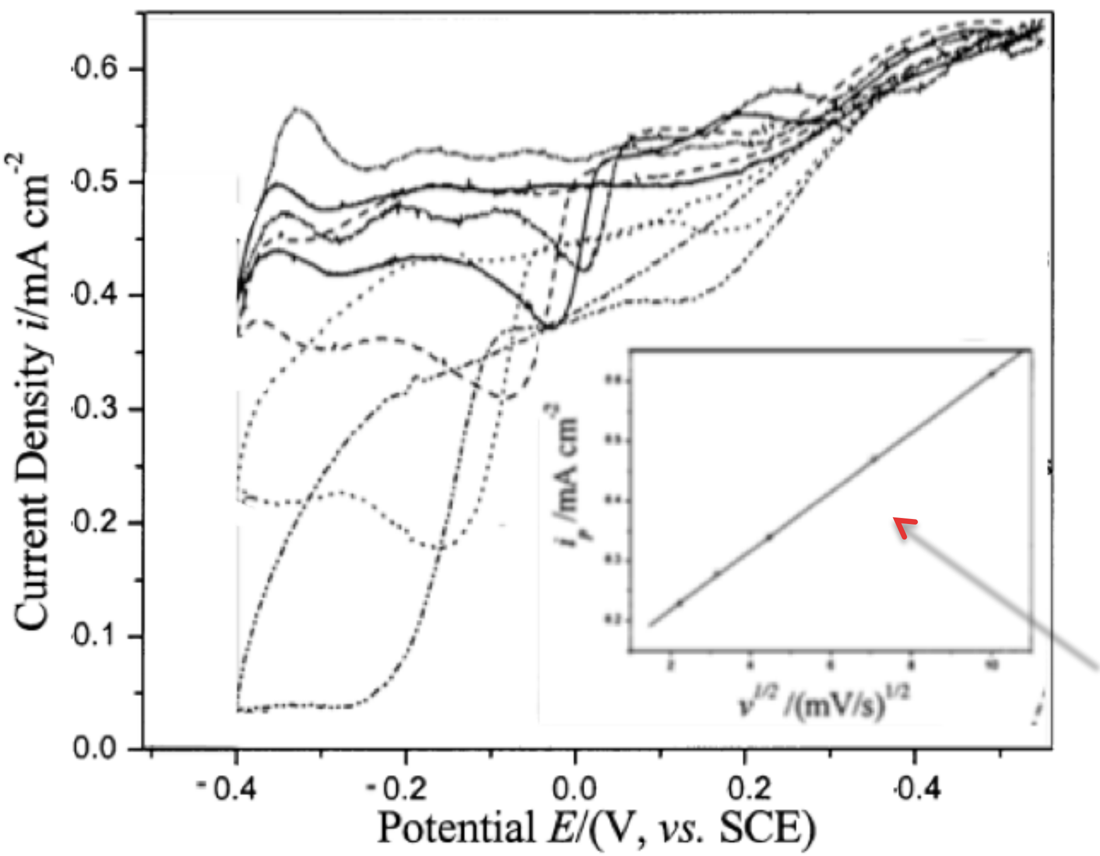


Characterizing the Solution: Cyclic Voltammetry



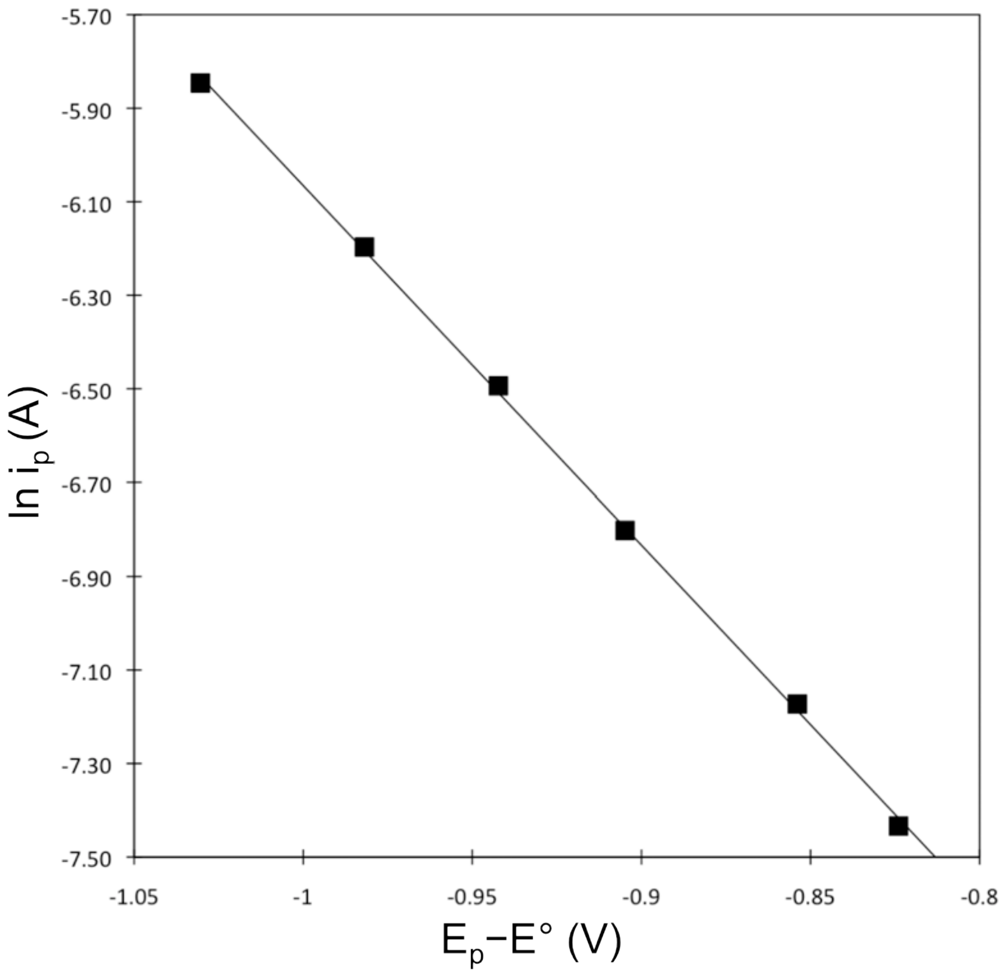
i_p is directly proportional to $\upsilon^{½}$ => diffusion limited

Lu et al.



i_p is directly proportional to $\upsilon^{½}$ = diffusion limited

Characterizing the Solution: Finding $\alpha\eta_\alpha$



$$i_p = 0.227 nFAC_o^* k^o \exp\left[\frac{-\alpha\eta_\alpha F(E_p - E^{o'})}{RT}\right]$$

i_p= peak current (A)

n=number of electrons, 4

F= Faraday's constant, 96485 C/mol

A=area of the electrode, $1cm^2$

C_o =concentration of solution 5.0×10^{-6} mol/cm^3

k^o= rate constant (cm/s)

$\alpha\eta_\alpha$= charge transfer coefficient

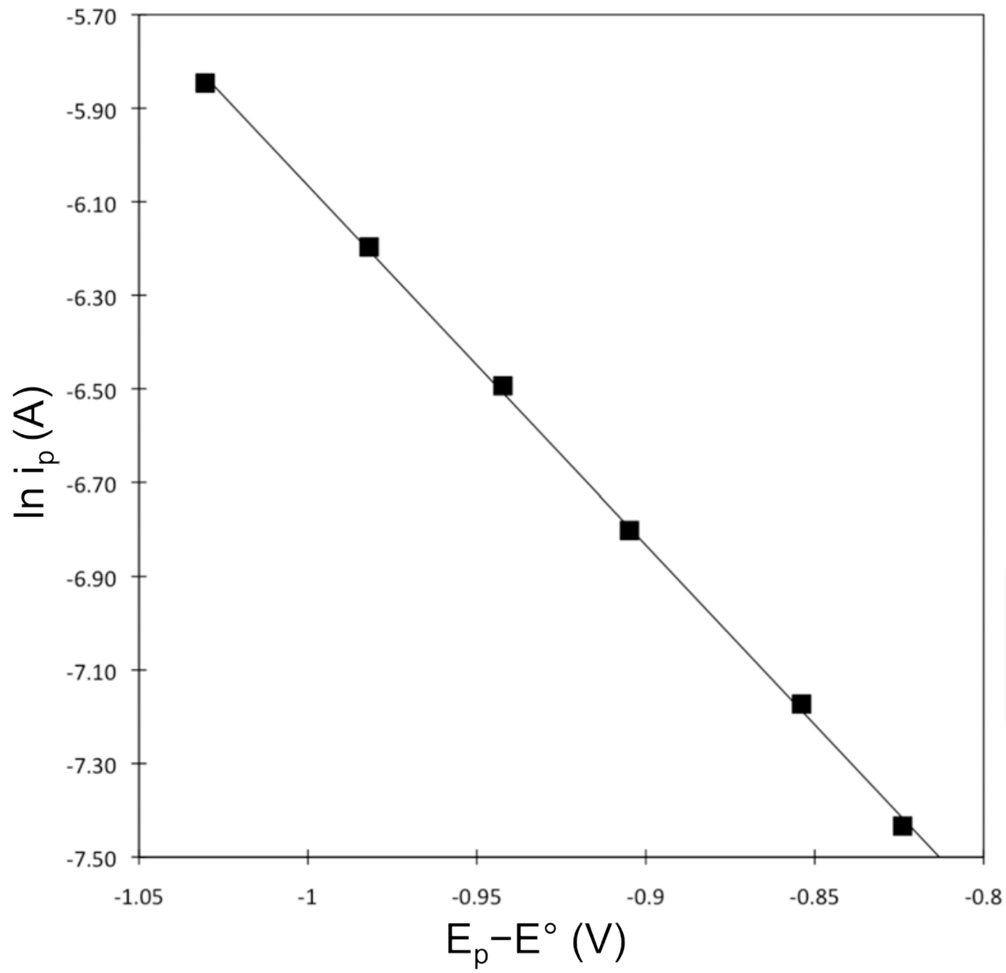
E_p= potential at i_p, (V)

$E^{o'}$= equilibrium potential (V)

R= gas constant 8.314 J/mol K

T= temperature 298.15K

Characterizing the Solution: Finding $\alpha\eta_\alpha$



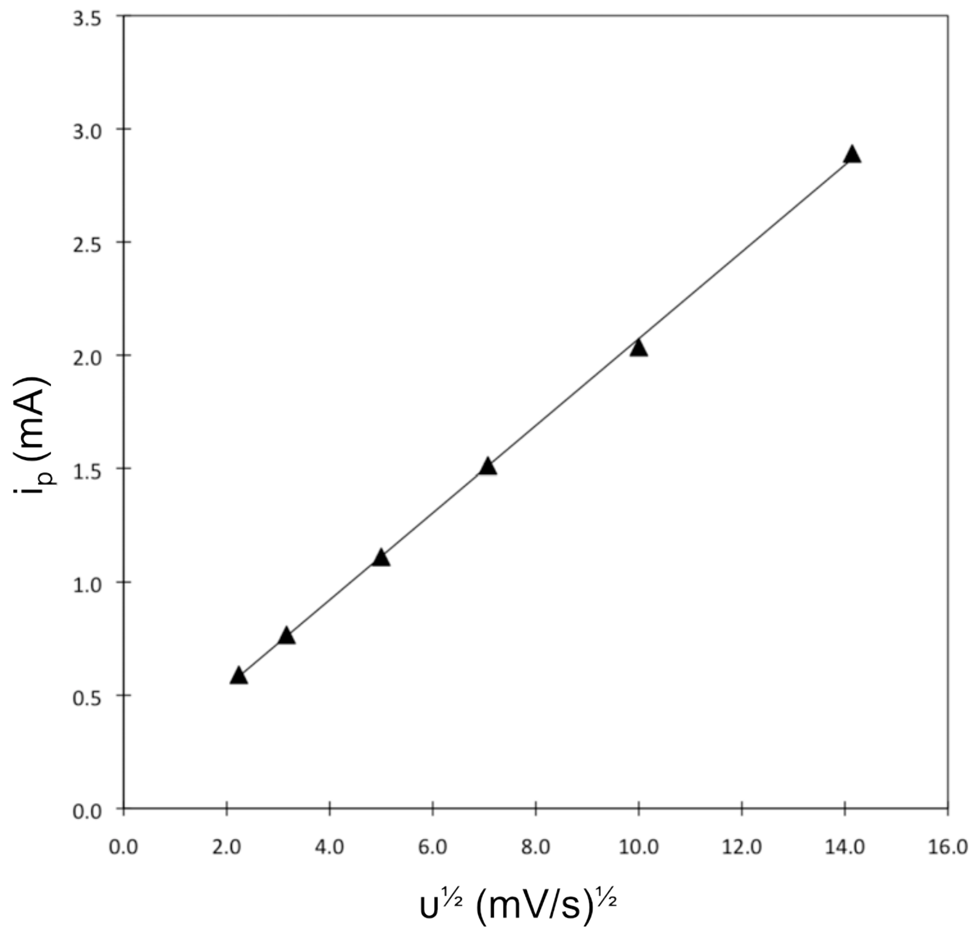
$$i_p = 0.227 nFAC_o^* k^o \exp\left[\frac{-\alpha\eta_\alpha F(E_p - E^{o'})}{RT}\right]$$

Plot ln i_p vs $(E_p - E^{o'})$

$$slope = \frac{\alpha\eta_\alpha F}{RT}$$

$\alpha\eta_\alpha = 0.197286$

Characterizing the Solution: Finding D_o



$$i_p = 2.99x10^5 n(\alpha\eta_\alpha)^{1/2} AD_o^{1/2} C_o v^{1/2}$$

i_p= peak current (A)

n=number of electrons, 4

$\alpha\eta_\alpha$= charge transfer coefficient

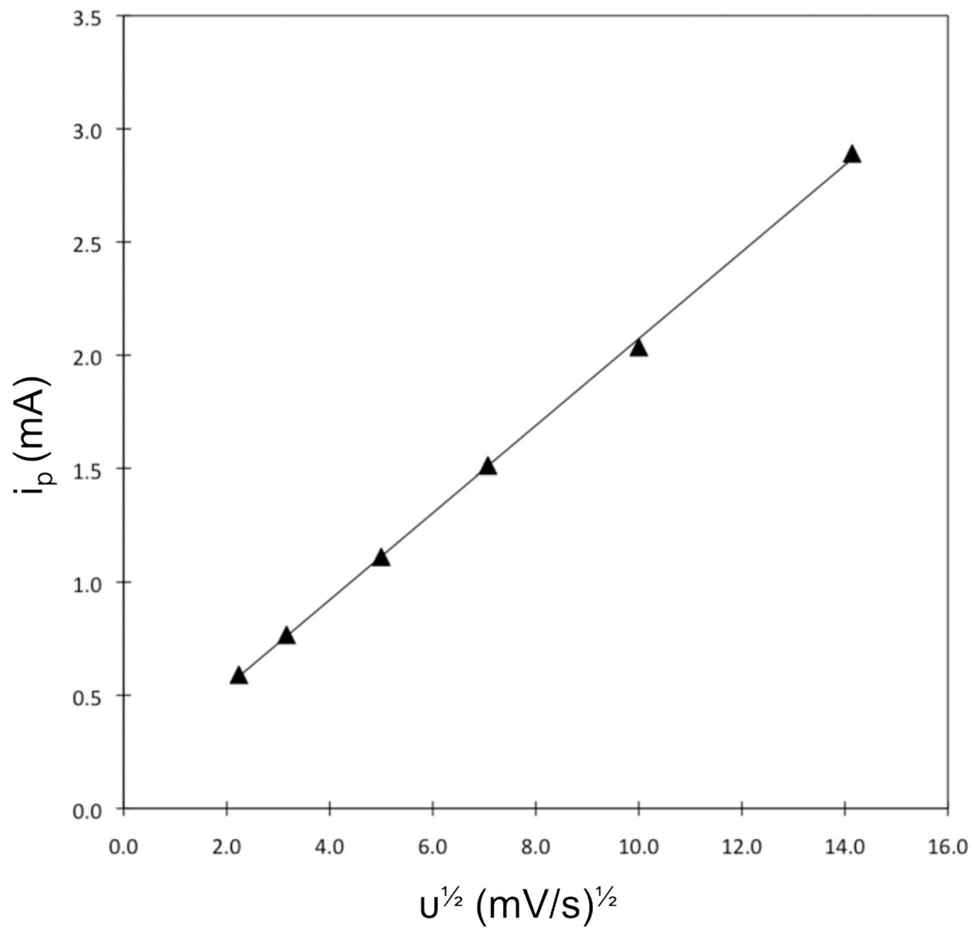
A=area of the electrode, $1cm^2$

D_o= diffusion coefficient, cm^2/s

C_o =concentration of solution 5.0×10^{-6} mol/cm^3

v= scan rate, V/s

Characterizing the Solution: Finding D_o



$$i_p = 2.99x10^5 n(\alpha\eta_\alpha)^{1/2} A D_o^{1/2} C_o v^{1/2}$$

Plot $v^{1/2}$ vs i_p

slope=$2.99x10^5 n(\alpha n_\alpha)^{1/2} A D_o^{½} C_o$

D_o= $5.217x10^{-9}$ cm^2/s

Characterizing the Solution: Conclusions

- Qualitative Data
  - Linear relationship between i_p and $\upsilon^{1/2}$ indicates reaction is diffusion – limited

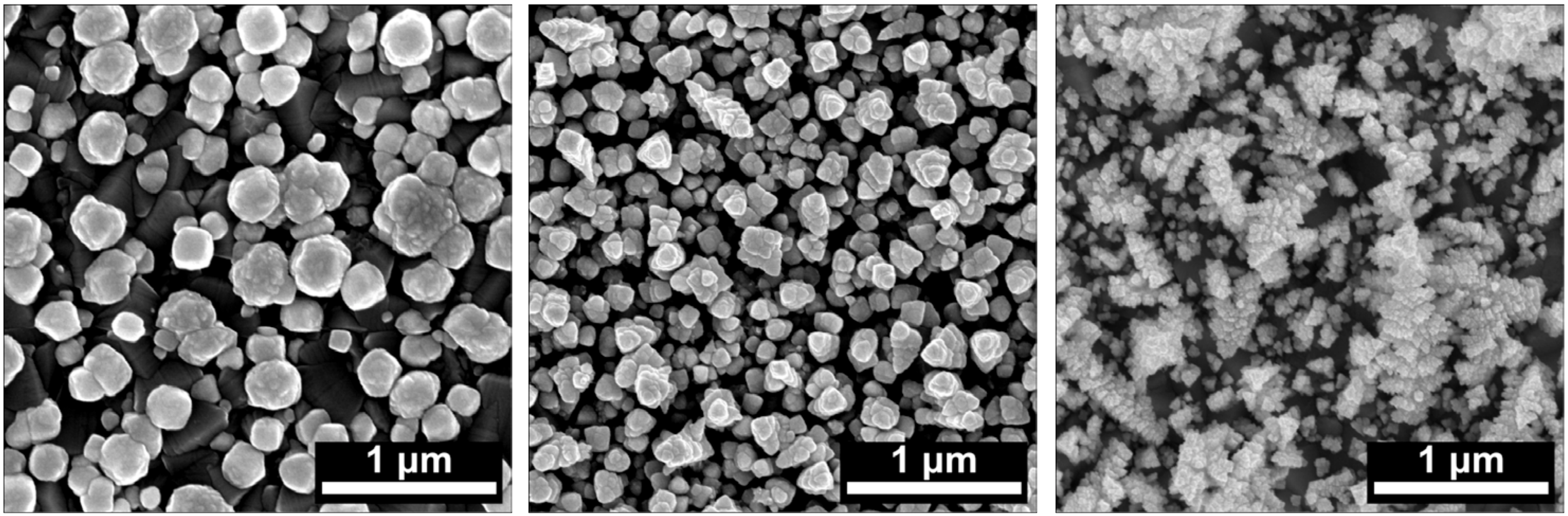
- Quantitative Data
  - Charge transfer coefficient-α_{η_α} = 0.197286
  - Diffusion coefficient- D_0 = 5.217×10^{-9} cm^2/s

Why does D_o make sense?

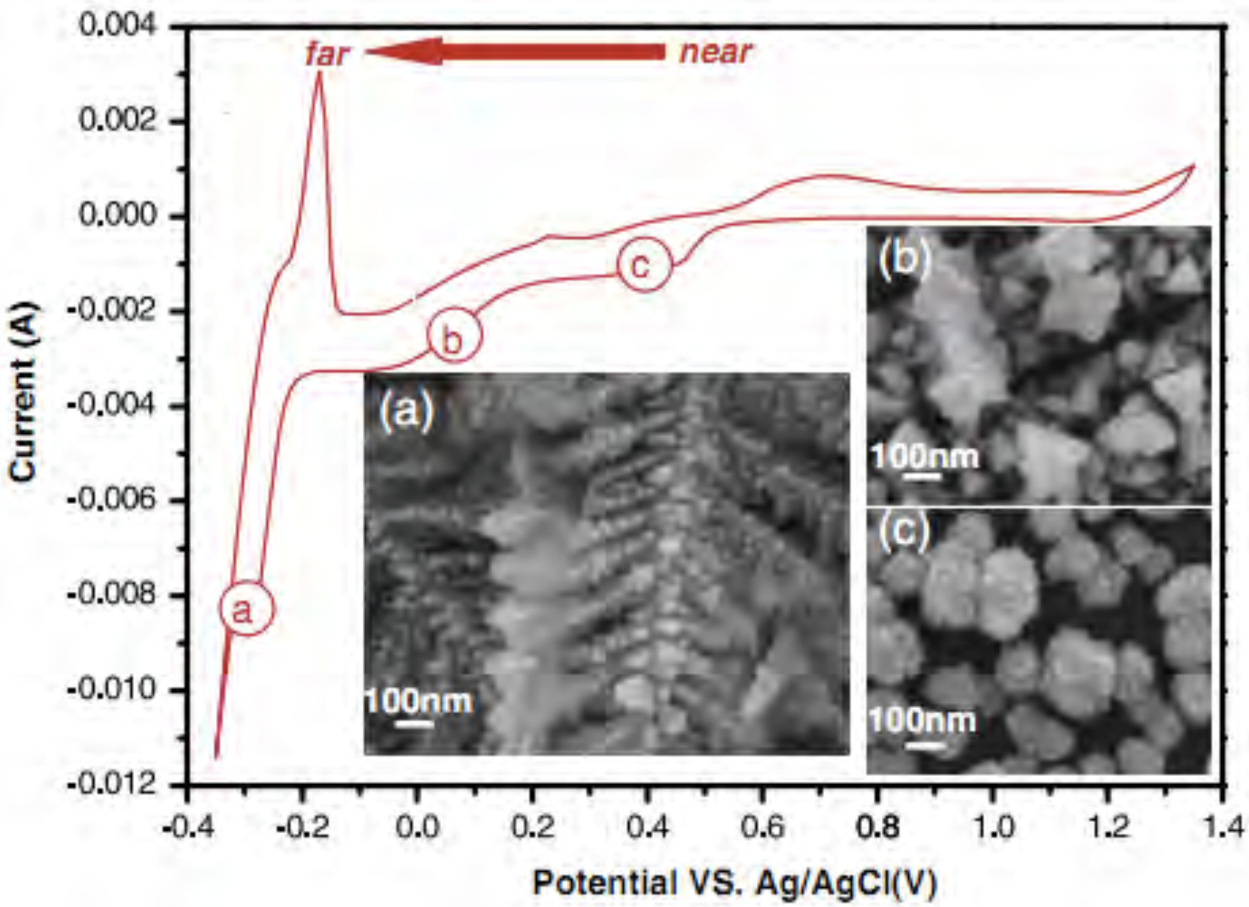
Small (E_p – E°')

Large (E_p – E°')

>



Why does D_o make sense?

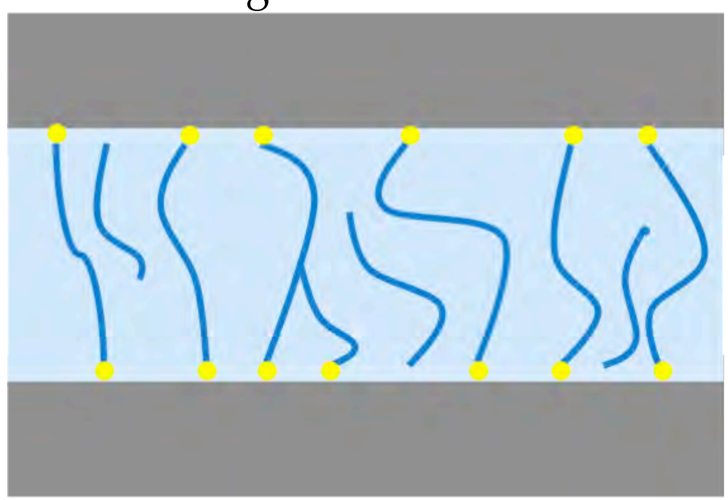


Yu et al. 2010

Next Steps

- Use Platinic Acid solution to deposit Platinum through the membrane.

Electrochemical Deposition
Through the Membrane



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