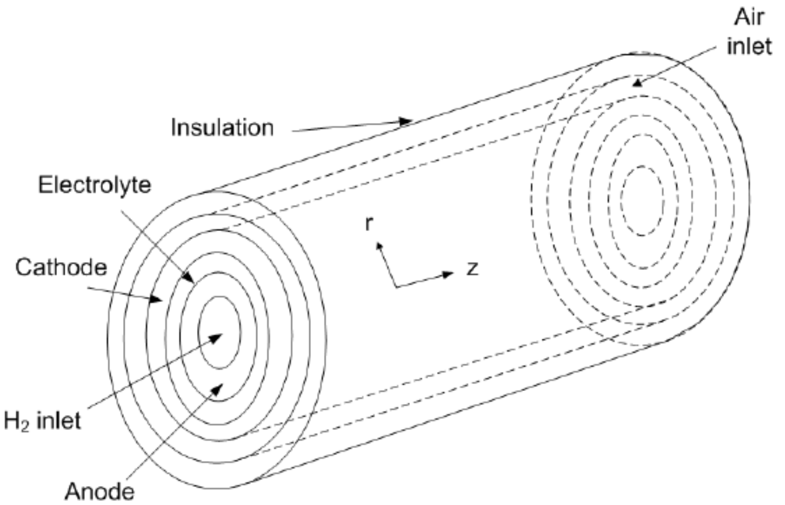
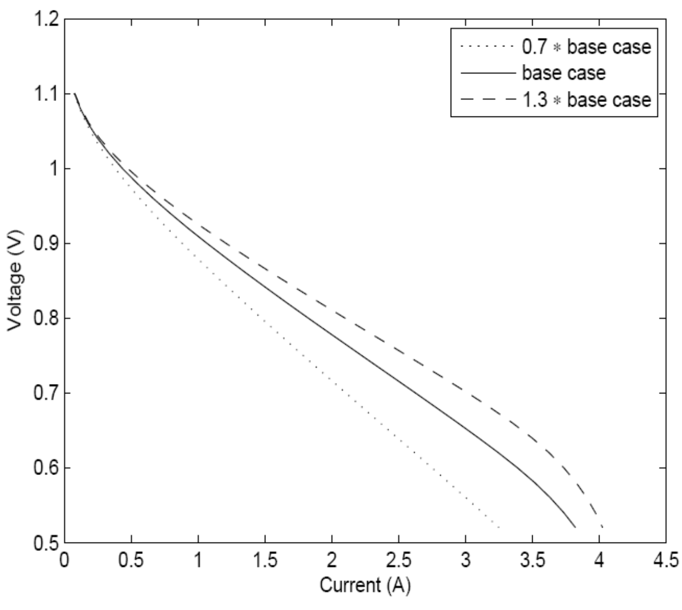
Fuel Cell Science and Technology

Final Exam

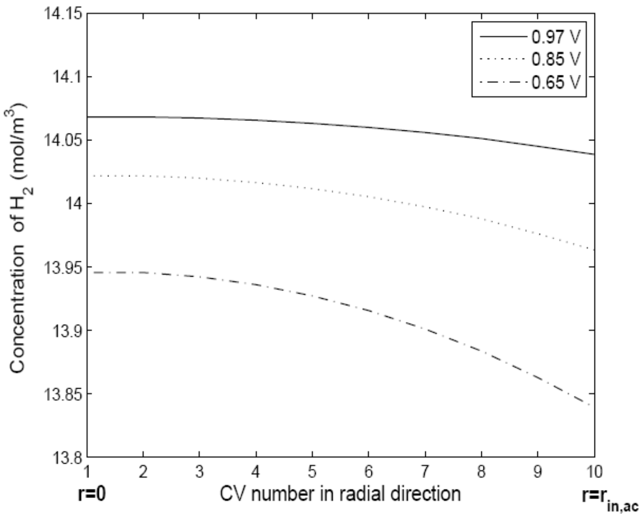
1. (10 pt)Let's consider a typical tubular SOFC design from Siemens-Westinghouse. The following figure shows the geometry of the anode supported type. We assume the cell operates under typical condition, say high temperature with enough hydrogen and air. Answer the following questions.



   a) When we change the thickness of the cathode, following IV curves were obtained. In other words, when the thickness of the cathode increases, the performance increases. Explain why.

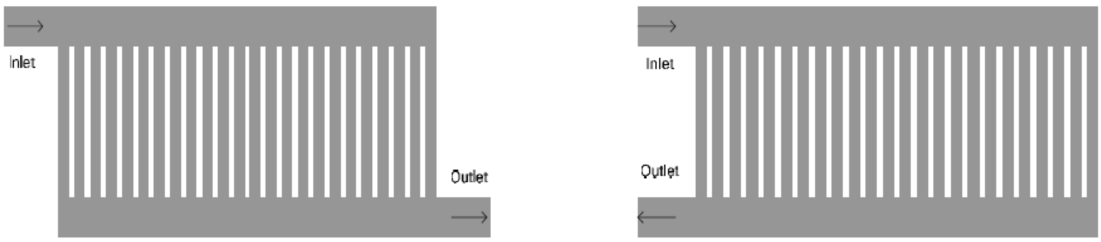


b) The hydrogen concentration profile in radial direction is shown like the following figure.



According to Fick’s law, the concentration profile is linear which is not true in this observation. Explain why. (Assume the thickness of the anode is much smaller than the radius of the tube.)

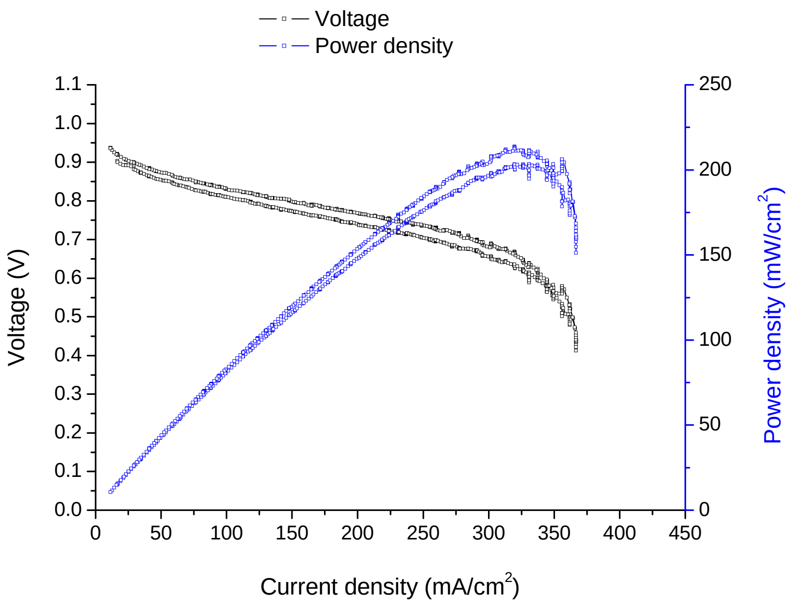
2. (10 pt) Consider following two parallel flow channel configuration for bipolar plate.



(A) (B)

Which one is more desirable for typical PEMFC? Explain why.

3. (20 pts)The following jV curve is obtained from the an **air-breathing** planar PEMFC operating under ambient condition supplied with **dry** hydrogen.

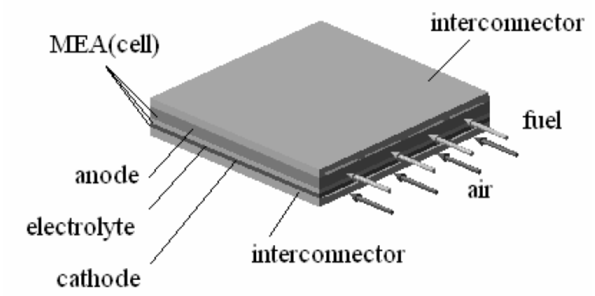


The voltage of the cell is monitored while the current slowly changes from 0 A/cm^2 to 370mA/cm^2 then back to 0 A/cm^2. The two jV curves in the figure are obtained from these **incremental current sweep** and **decremental current sweep** process, respectively. Answer the following questions.

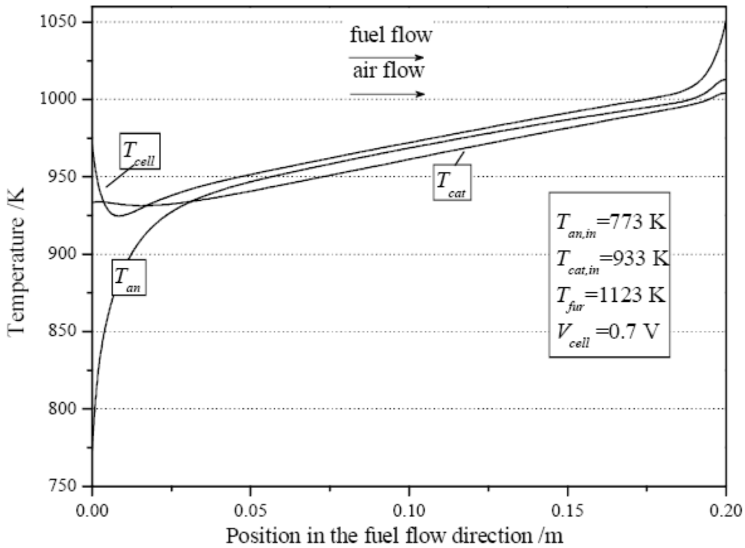
a) If the low jV curve is obtained during incremental current sweep (from 0 A/cm^2 to 370 mA/cm^2), explain why the performance of the cell is **low** during the **incremental sweep** and high during the decremental sweep (from 370 mA/cm^2 to 0 mA/cm^2) .

b) If the high jV curve is obtained during incremental current sweep (from 0 A/cm^2 to 370 mA/cm^2), explain why the performance of the cell is **high** during **the incremental sweep** and low during the decremental sweep (from 370m A/cm^2 to 0 mA/cm^2) .

4. (10 pt)In a typical planar SOFC, we can think of a few flow channel configuration. The following figure shows the so-called co-flow configuration where fuel and air is supplied from same inlet direction. In the case, the temperature distribution along the cathode and anode channel (T_{cat}, T_{an} respectively) is shown in the next figure.

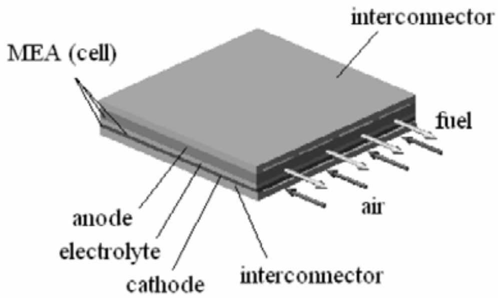


(a)



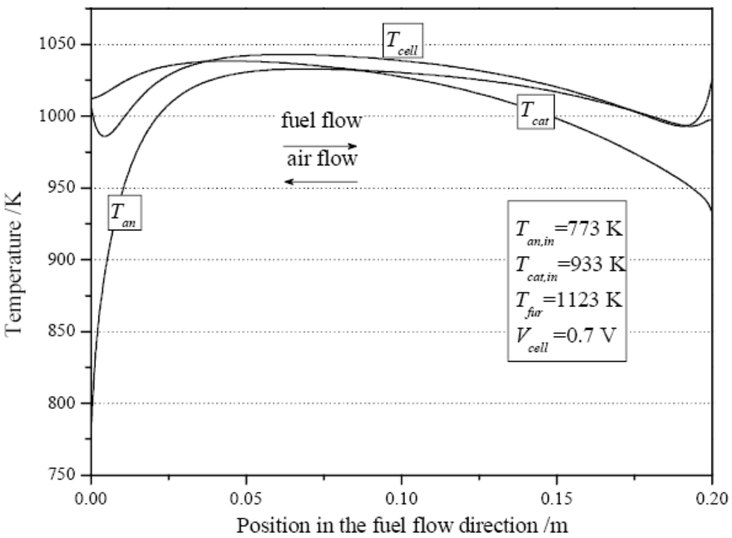
(a)

Another configuration is counter-flow configuration where fuel and air is supplied from opposite inlets as shown in the next figure.



(b)

In this case, the temperature profile along the anode and cathode channel is shown like this.

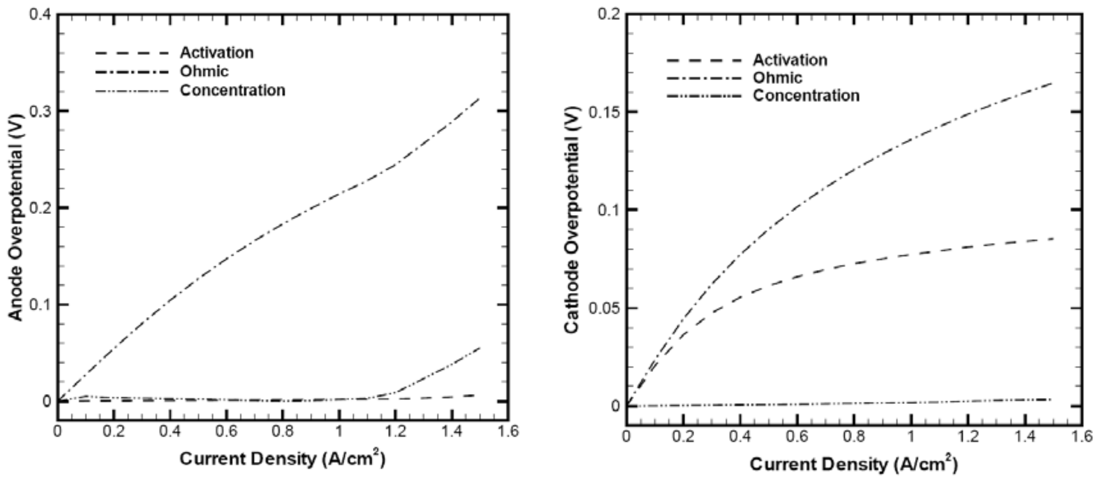


(b)

A. Explain why two configurations show different temperature distribution. Especially, discuss why the temperature peaks at the middle of channels in case of counter flow configuration.

B. Which type will be preferred for large scale fuel cells considering the cell temperature (T_{cell})? Explain why.

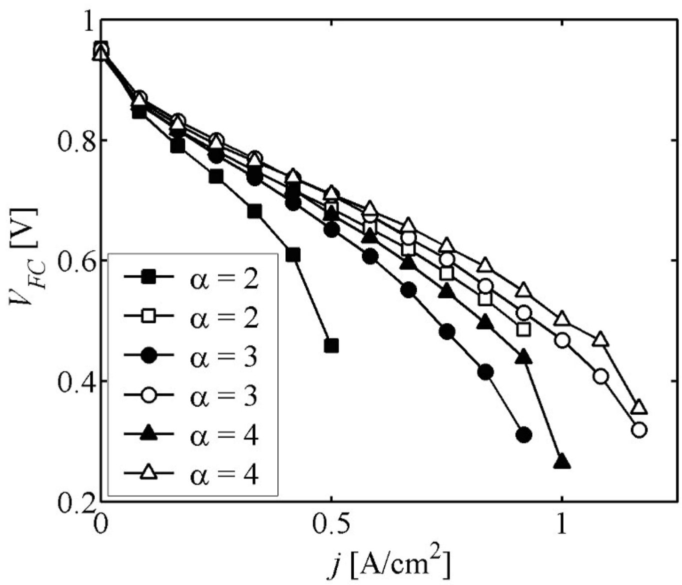
5. (15 pt)The following overvoltages were obtained from a SOFC. Each figure represents the overpotentials of the anode and the cathode. Please note that the ohmic overpotential in the figure describe the voltage loss due to the ionic conduction in the electrode. Answer the following question.



A. Is this fuel cell is anode supported type or cathode supported type? Justify your answer.
B. Which catalytic activity is better? Cathode or anode? Justify your answer.
C. What is the most serious loss in these electrodes? How can you improve it?

6. (10 pts)Scientists invented a new material that can replace graphite to be used for PEMFC flow channels. The new material has high electrical conductivity, high chemical resistance, high mechanical strength and excellent gas tightness. Even better, the new material can *instantly absorb infinite amount of liquid water.*

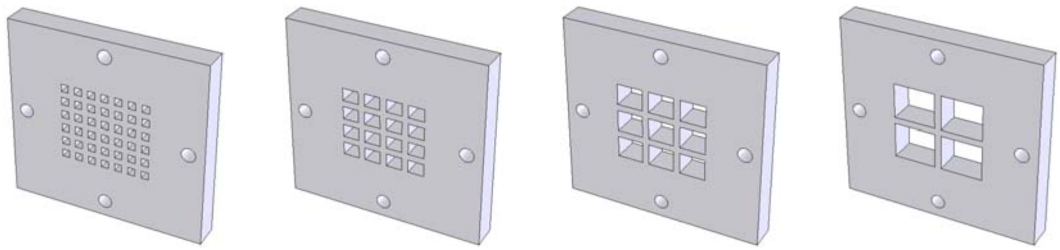
   The following figure compares the IV curves of PEMFC's using flow channels made of graphite (filled markers) and the new material (empty markers). Both fuel cells were operating with *fully humidified hydrogen and air* at 50C. The hydrogen stoichiometric number was 2 and the oxygen stoichiometric number was varied between 2 and 4 (α stands for oxygen stoichiometric number in Fig 2.). Answer the following questions



a) Based on the IV curves, qualitatively explain why new material improves the fuel cell performance.

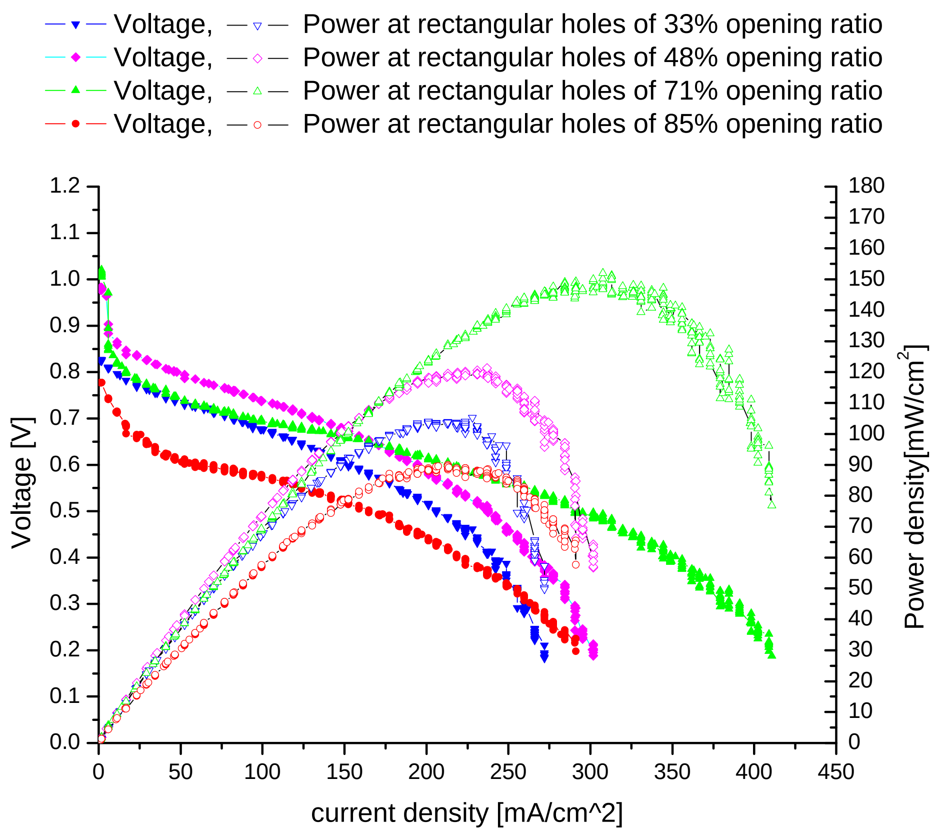
b) Explain why the performance improvement of fuel cells at low stoichiometric number(say α =2) is higher than that of high stoichiometric number(α =4).

7. (10 pts) Mr. Fuel Cell designed an air-breathing PEMFC operating with hydrogen. He designed several cathode flow plate with graphite as shown in the following figures.



(a) 33 % (b) 48 % (c) 71 % (d) 85 %

In this air-breathing fuel cell, air is transported through the holes at the cathode plate. The numbers for each cover design represents the ratio between open area and total cathode area. Thus, the cover with higher number may provide more air to the fuel cell. The cover also serves as a current collector of the cathode. Following figure represent the performance of the fuel cell with each cathode cover.



The best performance of the fuel cell is obtained for 71% opening ratio. Explain why.

8. (15 pts) The following figure represents the impedance measurement from a PEMFC

supplied with either humidified hydrogen or oxygen for two electrodes. In other words, same gas is supplied to the fuel cell at a time. The humidity of each gas is 45%. Answer the following questions.

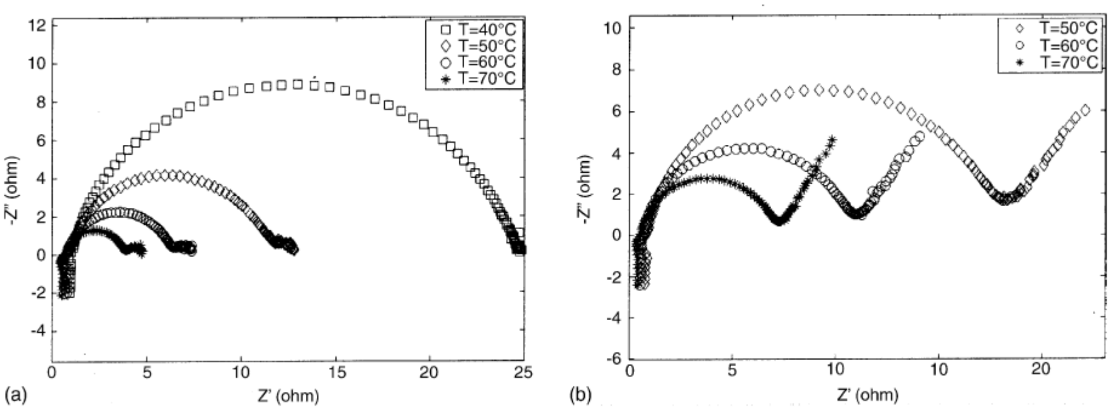


Fig. 3. Impedance plots for PEMFC working in "symmetrical mode" with (a) H_2/H_2 and (b) O_2/O_2 at 45 ± 5% RH.

a) When the temperature increases, the size of the half circle decreases. Explain why.

b) Can you tell which gas (hydrogen or oxygen) is more reactive from the impedance plot? Explain why based on the observation from the figure.

c) Each half circles in the plot meets real axis at high frequency. The meeting points shift to left when the temperature increases. Explain why.