4.5 List at least four important requirements for a candidate fuel cell electrolyte. Which requirement (other than high conductivity) is often the hardest to fulfill?

Sol.

1. High ionic conductivity
2. Low electronic conductivity
3. High stabilty (in both oxidizing and reducing environments)
4. Low fuel crossover
5. Reasonable mechanical strength (if solid)
6. Ease of manufacturability

Other than the high-conductivity requirement, the electrolyte stability requirement is often the hardest to fulfill. It is difficult to find an electrolyte that is stable in both the highly reducing environment of the anode the highly oxidizing environment of the cathode.

4.6 Redraw Figure 4.4c for a SOFC, where O2- is the mobile charge carrier in the electrolyte.

Sol.

Problem 4.6 (10 points) There are two differences from the PEM case: first, the charge carrier has the opposite sign, and second, it flows in the opposite direction, from the cathode to the anode. These two effects combine to make the diagram exactly the same. The ohmic loss still decreases the output voltage of the fuel cell, and the oxygen ion is negative it flows up a potential gradient. Note that the graph is exactly the same as the figure in the text!

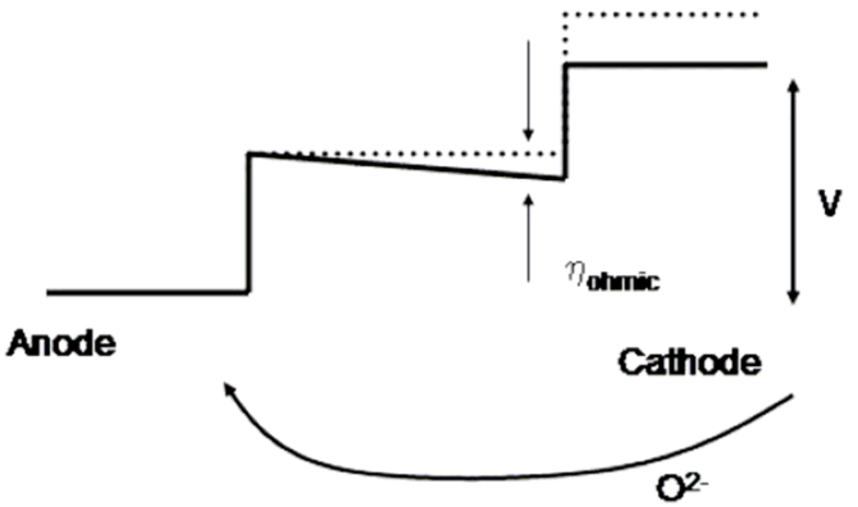
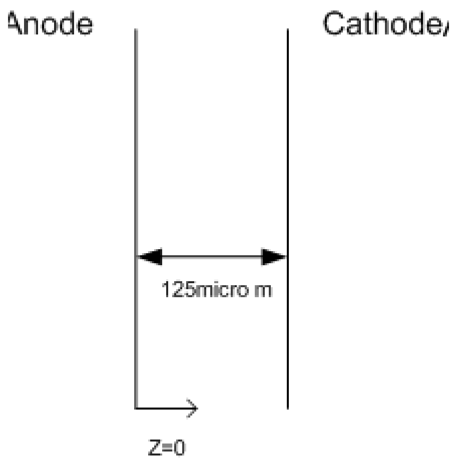


Figure 5: Voltage losses for problem 4.6.

4.13 Consider two H2-O2 PEMFCs powering an external load at 1A/cm2. The fuel cells are runnig with differently humidified gases: (a) aw,anode=1.0, aw,cathode=0.5; (b) aw,anode=0.5, aw,cathode=1.0. Estimate the ohmic overpotential for both fuel cells if they are both running at 80oC. Assume that thy both employ a 125μm-thick Nafion electrolyte. Based on your results, discuss the relative effects of humidity at the anode versus the cathode.

Sol.



Water flux balance는

$$J_{H_2O} = 2n_{drag}^{sat}\frac{j}{2F}\frac{\lambda}{22} - \frac{\rho_{dry}}{M_w}D_\lambda(\lambda)\frac{d\lambda}{dz} \quad (1)$$

이 되며, 여기서 J_{H_2O}와 N_{H_2O}의 flux 비는

$$J_{H_2O} = \alpha N_{H_2} = \alpha (j/2F) \quad (2)$$

가 된다. 여기서 식 (1)을 1계 선형 미분방정식의 형태로 나타내면

$$\frac{d\lambda}{dz} = (2n_{drag}^{sat}\frac{\lambda}{22} - \alpha)\frac{jM_m}{2F\rho_{dry}D_\lambda} \quad (3)$$

이 되고, 그 해는

$$\lambda(z) = \frac{11}{n_{drag}^{sat}}\alpha + cexp[\frac{jM_m n_{drag}^{sat}}{22F\rho_{dry}D_\lambda}z] \quad (4)$$

이 된다. 여기서, D_λ는

$$D_\lambda = 10^{-6}\exp[2416(\frac{1}{303} - \frac{1}{353}) \times (2.563 - 0.33 \times 10 + 0.0264 \times 10^2 - 0.000671 \times 10^3)$$

$$= 3.81 \times 10^{-6} cm^2/s \quad (5)$$

이며, 식 (5)를 식(4)에 대입하면,

$$\lambda(z) = 4.4\alpha + cexp(156.9z) \quad (6)$$

이 된다.

a) B.C

$$\lambda(z=0) = 14$$

$$\lambda(z=L) = 3.45 \quad (7)$$

식(6)에 식(7)을 대입하면,

$$\lambda(0) = 4.4\alpha + c = 14 \quad (8)$$

$$\lambda(0.0125) = 4.4\alpha + cexp(1.96) = 3.45 \quad (9)$$

가 된다. 여기서 식이 두개, 미지수 가 두개 이므로 각각의 미지수를 구할 수 있다. 여기서 미지수는

$$\alpha = \frac{3.45 - 14\exp(1.96)}{4.4 - 4.4\exp(1.96)} = 3.57 \quad (10)$$

$$c = -1.708 \quad (11)$$

이 된다.

식 (4)에 미지수 (10),(11)을 대입하면,

$$\lambda = 15.7 - 1.7\exp(156.9z) \quad (12)$$

가 된다. 위 식을 이용하여 conductivity를 구하면,

$$\sigma_{303K} = 0.005193(15.7 - 1.7\exp(156.9z)) - 0.00326$$

$$= 0.078 - 8.83\times 10^{-3}\exp(156.9z) \quad (13)$$

$$\sigma(T,\lambda) = [0.078 - 8.83\times 10^{-3}\exp(156.9z)]\times \exp(1268(\frac{1}{303} - \frac{1}{353}))$$

$$= 0.14 - 0.016\exp(156.9z) \quad (14)$$

이 되며, ohmic loss는

$$R_m = \int_0^L \frac{dz}{\sigma(\lambda(z))} \quad (15)$$

$$R_m = \int_0^{0.0125} \frac{dz}{0.14 - 0.016\exp(156.9z)} \quad (16)$$

이 된다.

(참고) $$\int \frac{dz}{a + bexp(cz)} = \frac{z}{a} - \frac{1}{ac} ln(a + bexp(cz)) \quad (17)$$

여기서 식(16)을 풀게 되면

$$R_m = [\frac{0.0125}{0.14} - \frac{1}{0.14\times 156.9} ln(0.14 - 0.016\exp(156.9\times 0.0125)] + [\frac{1}{0.14\times 156.9} ln(0.14 - 0.016)]$$

$$= 0.160\Omega cm^2 \quad (18)$$

이 된다.

b) B.C

$$\lambda(z=0) = 3.45$$

$$\lambda(z=L) = 14 \quad (19)$$

식(6)에 식(19)을 대입하면,

$$\lambda(0) = 4.4\alpha + c = 3.5 \quad (20)$$

$$\lambda(0.0125) = 4.4\alpha + cexp(1.96) = 14 \quad (21)$$

가 된다. 여기서 식이 두개, 미지수 가 두개 이므로 각각의 미지수를 구

할 수 있다. 여기서 미지수는

$$\alpha = \frac{3.45 - 14\exp(1.96)}{4.4 - 4.4\exp(1.96)} = 0.39 \tag{22}$$

$$c = 1.734 \tag{23}$$

이 된다.

식 (4)에 미지수 (22),(23)을 대입하면,

$$\lambda = 1.716 + 1.734\exp(156.9z) \tag{24}$$

가 된다. 위 식을 이용하여 conductivity를 구하면,

$$\sigma_{303K} = 0.005193(1.716 + 1.734\exp(156.9z)) - 0.00326$$

$$= 5.65\times10^{-3} + 9\times10^{-3}\exp(156.9z) \tag{25}$$

$$\sigma(T,\lambda) = [5.65\times10^{-3} + 9\times10^{-3}\exp(156.9z)]\times\exp(1268(\frac{1}{303} - \frac{1}{353}))$$

$$= 0.012 + 0.016\exp(156.9z) \tag{26}$$

이 되며, ohmic loss는

$$R_m = \int_0^L \frac{dz}{\sigma(\lambda(z))} \tag{27}$$

$$R_m = \int_0^{0.0125} \frac{dz}{0.012 + 0.016\exp(156.9z)} \tag{28}$$

이 된다.

(참고) $$\int \frac{dz}{a + b exp(cz)} = \frac{z}{a} - \frac{1}{ac} ln(a + b exp(cz)) \tag{29}$$

여기서 식(16)을 풀게 되면

$$R_m = [\frac{0.0125}{0.012} - \frac{1}{0.012\times156.9} ln(0.012 + 0.016\exp(156.9\times0.0125)] + [\frac{1}{0.012\times156.9} ln(0.012 + 0.016)]$$

$$= 0.24\Omega cm^2 \tag{30}$$

이 된다.

식(18)과 (30)의 결과에서 알 수 있듯이 스택 운전 시 anode측 가습의 영향이 더 중요하게 된다.