Transport Analysis of an Aluminum/Air Battery Cell

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Introduction

An Aluminum/air battery system has the potential to be used to produce power to operate cars and other vehicles [1, 2]. In our previous paper, we provided the cell performance model equations [3]. In this paper, we have calculated the secondary current distributions in a parallel two plane and a wedge shape aluminum air cells. FEMLAB (finite element method) package was used for all the calculations [4]. Calculations were made in typical operating ranges of interest for an electric vehicle.

Mathematical Modeling

We have analyzed potential distribution and secondary current density distribution in a parallel two-plane Al/air cell and a wedge shape Al/air cell. Parameters that we studied include entrance effect, activity of the cathode, cell gap, cathode extension.

We know that the current density and potential distribution depend on [5]:

1) The geometry (the field equation);
2) The conductivity of the solution;
3) The activation overpotential;
4) The concentration overpotential;
5) Special effects in and near the electrodes.

The modified Tafel equation is used at the cathode

$i_c = a\Phi_c + b$ (linear profile).

The Butler Volmer equation is used at the anode.

$$i_a = i_{a0}\exp\left[\left(\frac{\alpha_m F}{RT}\right)\left(V_{eq} - V_{cell} - \Phi_a\right)\right]$$

Results and Discussion

Parameters used in these transport calculations are displayed in Tables 1 and 2. Losses at the anode and cathode are displayed in Table 3. Figure 1 is a typical output for a parallel plane cell. Entrance effects disappear at about one to two cell gap from the entrance. Activity of the cathode has a large effect on the local current density. Increasing the cell gap decreases the average current density, but the peak current density over average current density increases. By extending the cathode below the anode, the high local current density can be reduced. We also studied a wedge shape anode. In the cell the cathode is parallel to the anode. As the anode is consumed the planar portion of the anode enters the cell. The top portion of the anode is consumed faster because of the decreased cell gap and increased reaction rate keeping the entering anode parallel to the cathode in the cell.

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Table 1. Cathode kinetic parameters for Equation 6 [3, 6, 7].

Cathode	Kinetic parameters	
	$a/10^4$ $A/(m^2 \cdot V)$	$b/10^4$ A/m^2
Yardney		-
AC65 (Ag)	1.3106	0.4409
AC75 (CoTMPP)	1.1806	0.2832
AC78 (Pt)	1.3210	0.3342
Chan and Savinell	3.898	1.3094

Table 2. Constants used for FEMLAB modeling [5, 6].

Anode parameters	Cathode parameters	Op. conditions
α_m=0.07956	$a=3.898\times10^4$ $A/(m^2\cdot V)$	T=333 K
i_{a0}=137.1 A/m^2	$b=-1.3094\times10^4$ A/m^2	V_{cell}=0.9-1.3

F=96,500 C/equiv, R=8.314 J/(mol· K), κ_0=80 S/m, E_{eq}=2.726 V

Table 2. Cell overpotential and ohmic losses at 0.8V and 8cm/s velocity [5].

Cell gap, cm.	Current density, A/m^2	Act. loss, V Anode	Act. loss, V Cathod
0.2	5280	1.32 68.4%	0.47 24.4%
0.4	4370	1.25 64.7%	0.45 23.7%
0.6	3810	1.20 62.2%	0.43 22.2%
0.8	3380	1.16 60.1%	0.42 21.8%

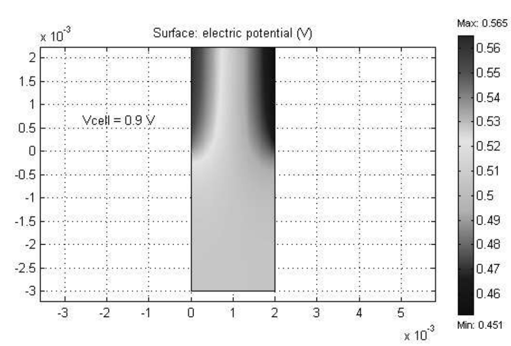

FIGURE 1. The potential distribution in the electrolyte of a parallel two-plane al/air cell. Anode and cathode are of equal size. Cell voltage is 0.9V.