# Modeling of Soluble lead-acid flow battery

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## Introduction

- ✓ Need of clean energy
- ✓ Emphasis on RES
- ✓ Energy storage technology
  - ❑ Flow battery

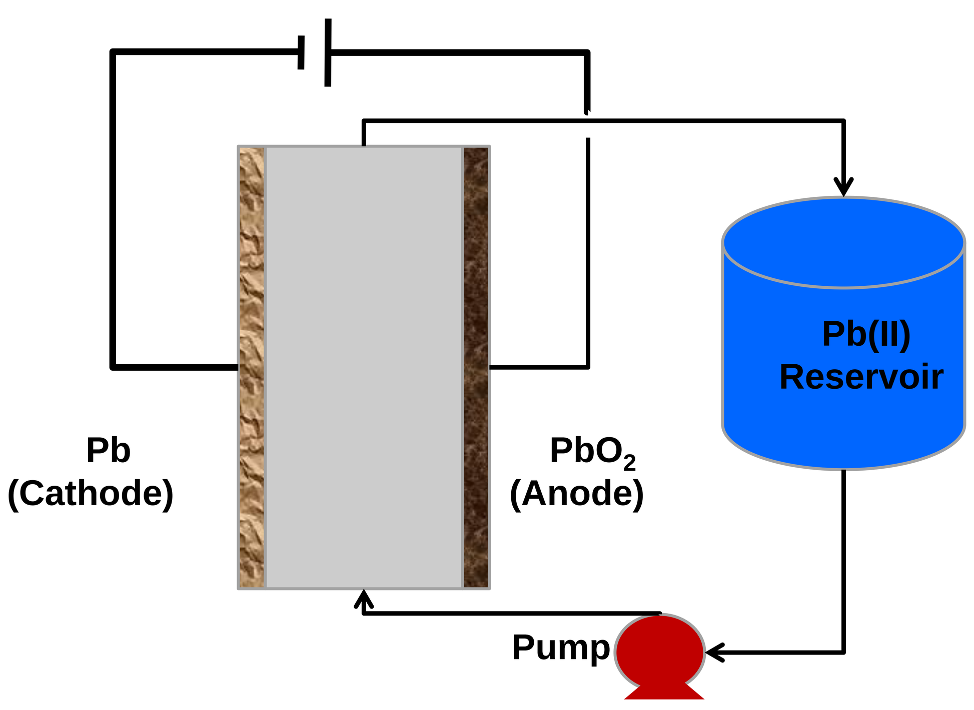


**Figure 1**. Soluble lead acid flow battery

Electrolyte: $CH_3SO_3H \rightleftharpoons CH_3SO_3^- + H^+$

$Pb(CH_3SO_3)_2 \longrightarrow Pb^{2+} + 2CH_3SO_3^-$

Cathode: $Pb^{2+} + 2e^- \rightleftharpoons Pb$

Anode: $Pb^{2+} + 2H_2O \rightleftharpoons PbO_2 + 4H^+ + 2e^-$

Overall: $2Pb^{2+} + 2H_2O \rightleftharpoons Pb_{(s)} + PbO_{2(s)} + 4H^+$

Side Reaction:

$PbO_2 + 2H^+ + 2e^- \rightleftharpoons PbO_x + H_2O$

## Computational Methods

Physics Interfaces:

a. Laminar Flow
b. Ternary Current Distribution-moving/fixed grid
c. Surface Reaction
d. Global ODE

$$\frac{dc_i^{in}}{dt} = \frac{Q}{V}\left(c_i^{out} - c_i^{in}\right)$$

$$j_{PbO_2} = nFk_{PbO_2}c_{Pb(II)}c_{H^+}\left(\exp\left(\frac{2\alpha F}{RT}\eta\right) - \exp\left(\frac{-2\beta F}{RT}\eta\right)\right)$$

$$= 0 \quad if \ C_{PbO_2} = 0$$

$$j_{Pb} = nFk_{Pb}c_{Pb(II)}\left(\exp\left(\frac{2\alpha F}{RT}\eta\right) - \exp\left(\frac{-2\beta F}{RT}\eta\right)\right)$$

$$j_{PbO_x} = nFk_0^f\left(C_{PbO_x}\right)^{1.4}\exp\left(\frac{0.9F}{RT}\eta\right) - nFk_0^b C_{PbO_2}c_{H^+}\exp\left(-\frac{0.9F}{RT}\eta\right)$$

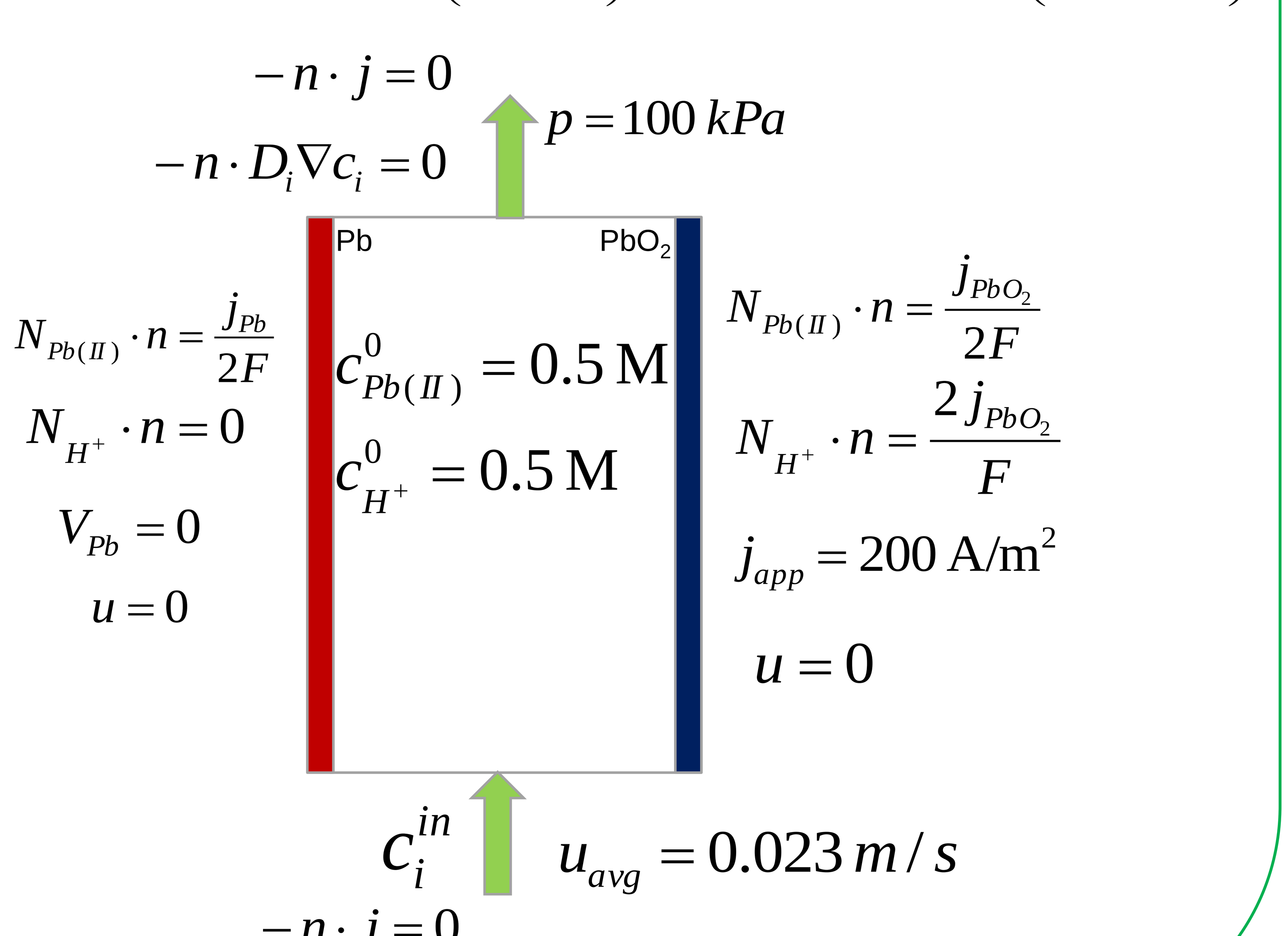


**Figure 2**. Boundary conditions

## Results (Fixed geometry)

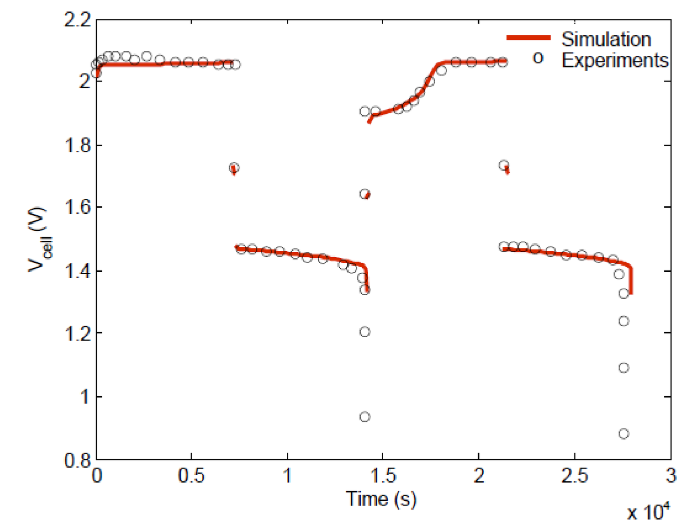


**Figure 3**. V versus Time

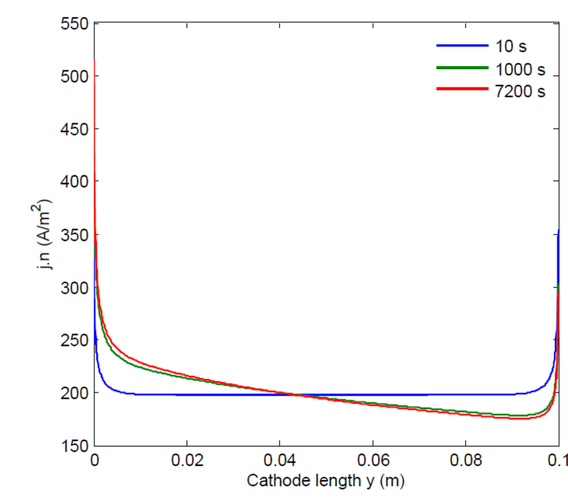


**Figure 4**. Deposits (Anode)

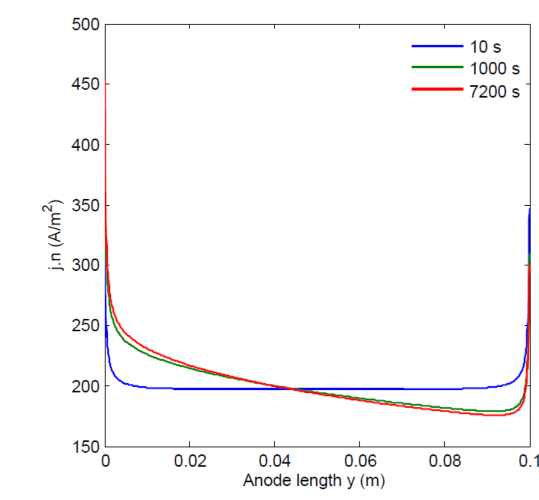


**Figure 5**. Deposits (Cathode)

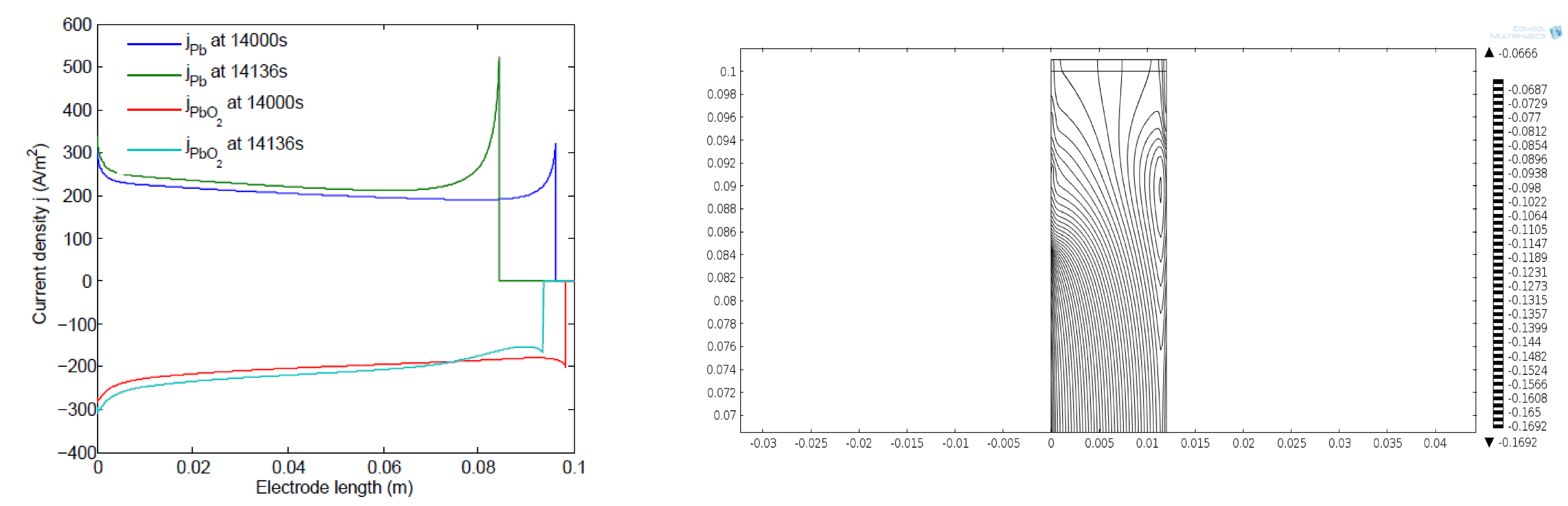


**Figure 6**. Deposits and potential profile during discharge (Anode)

## Results (Moving grid, reduced domain)

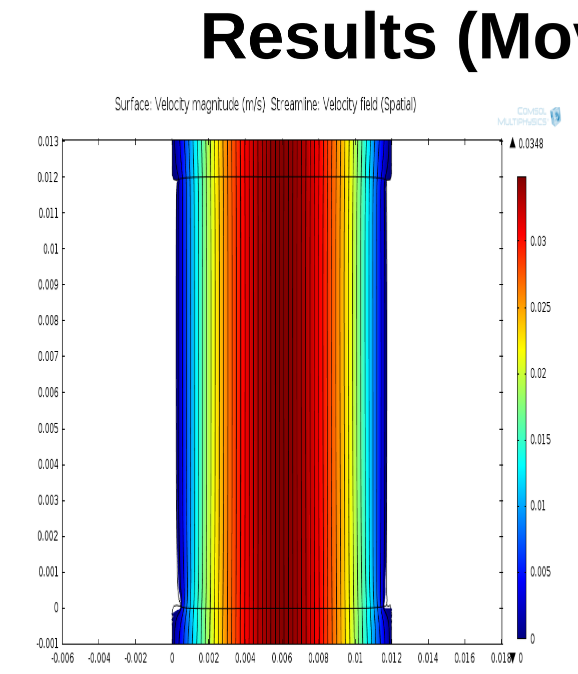

**Figure 7**. Velocity profile

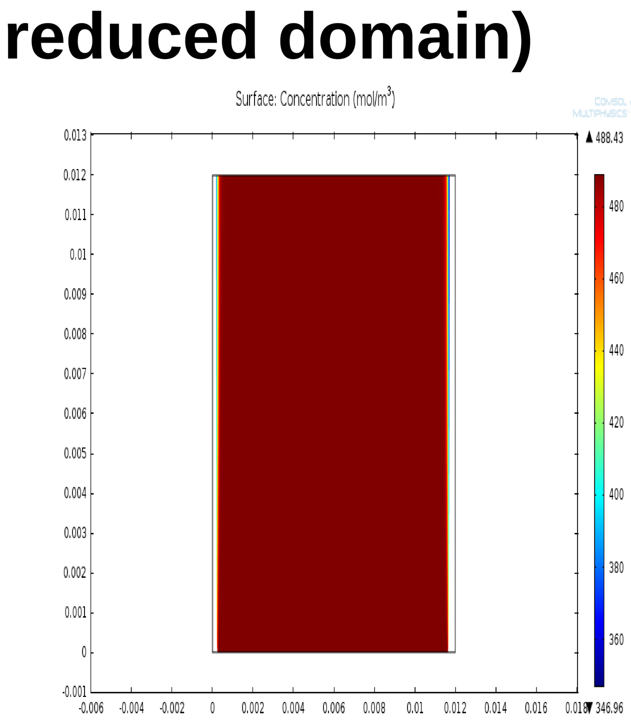

**Figure 8**. Concentration profile

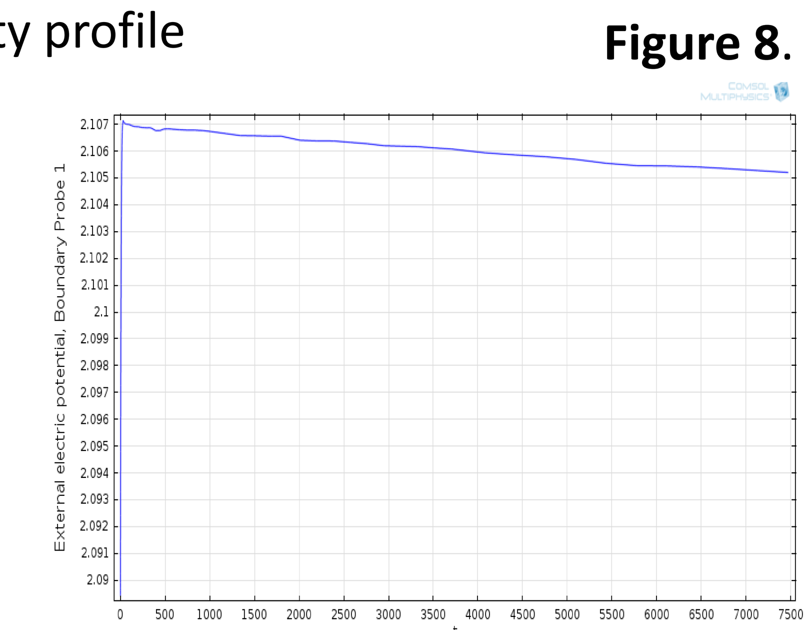

**Figure 9**. V versus time during charging

## Conclusions

1. Voltage versus time profile obtained
2. Current density is not uniform
3. Peak current at edge of reaction zone
4. Changing geometry may have influence

## References

1. A. A. Shah, X. Li, R. Wills and F. C. Walsh, A mathematical model for soluble lead acid flow battery, Journal of The electrochemical Society, 157(5), A589-A599 (2010)
2. John Collins et al, A novel flow battery: A lead acid battery based on an electrolyte with soluble lead(II) Part VIII. The cycling of a 10cmX 10cm flow cell, Journal of Power Sources, 195, 1731-1738 (2010)