Design of PHEVs and Electrolyte Properties

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This presentation does not contain any proprietary or confidential information

Outline

- Electrolyte Properties (with Sarah Stewart)
  - Transport and thermodynamic property measurements
  - Collaborators: Vince Battaglia

- Design of PHEVs (with Paul Albertus and Jeremy Couts)
  - Collaborator: Venkat Srinivasan

Purpose of Work

- Measure transport and thermodynamic properties of electrolytic solutions
  - Use a variety of appropriate experimental techniques

- Explore how battery size and capacity usage depend on
  - Cell chemistry and design
  - Separator area and driving distance

Barriers

- Electrolyte properties
  - Poor transport properties
  - A lack of knowledge of thermodynamic properties
  - A need for improved experimental methods for characterizing physical properties

- Design of HEVs and PHEVs
  - Cost ($/system, or $/kWh)
  - Limited capacity usage, large battery size
  - A lack of simple guidelines for evaluating different chemistries

Approach

- Develop improved experimental methods for measuring transport and thermodynamic properties.
  - Restricted diffusion to measure diffusion coefficients
  - AC impedance for conductivity
  - Melting-point depression for activity coefficients

- Develop mathematical models to improve understanding of limitations in cell performance
  - A simplified, 0-D model, for basic insights
  - A detailed battery and vehicle model for examination of the complexities

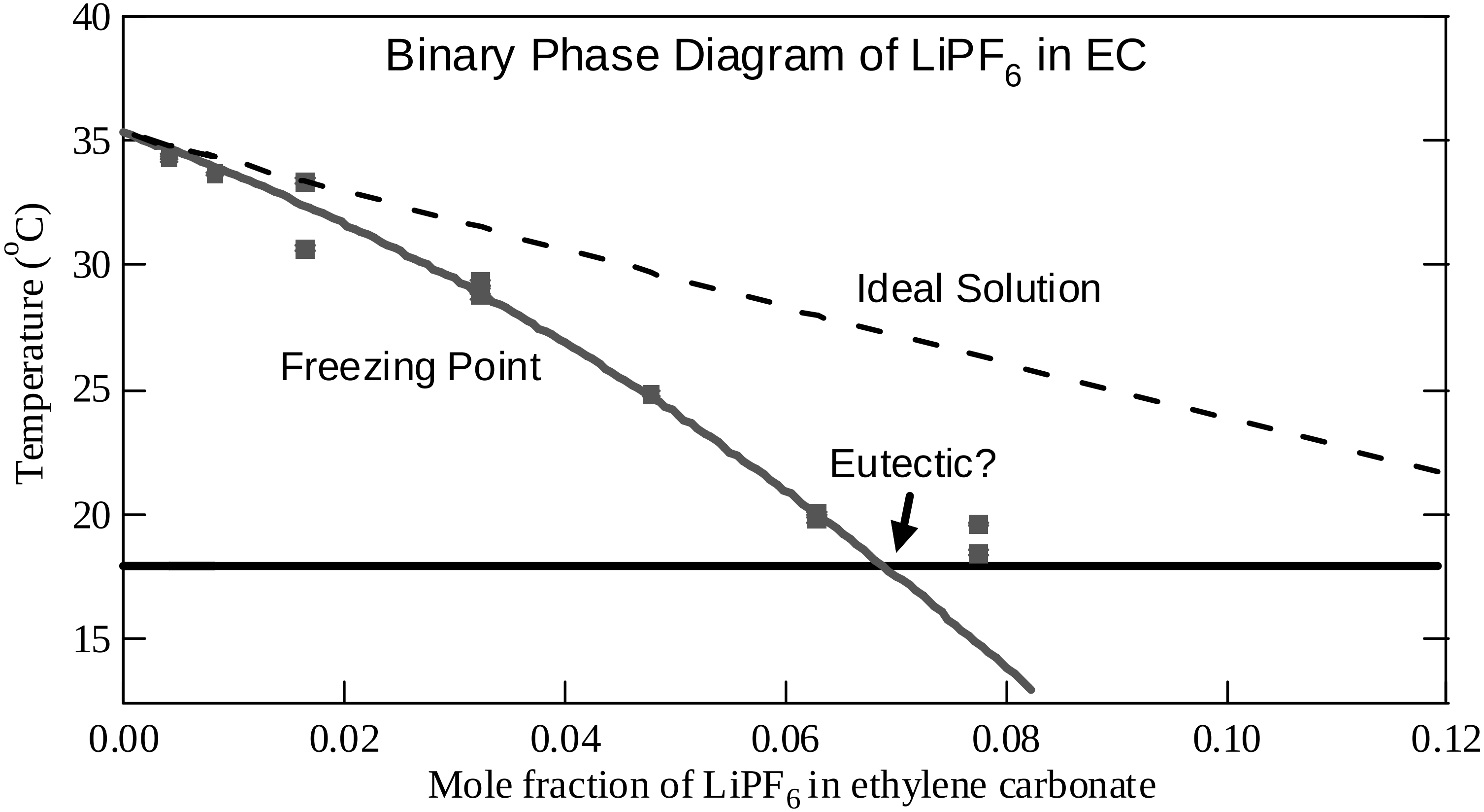
Performance Measures

- Transport and thermodynamic properties
  - Pulse discharge and regenerative power
  - Round-trip energy efficiency

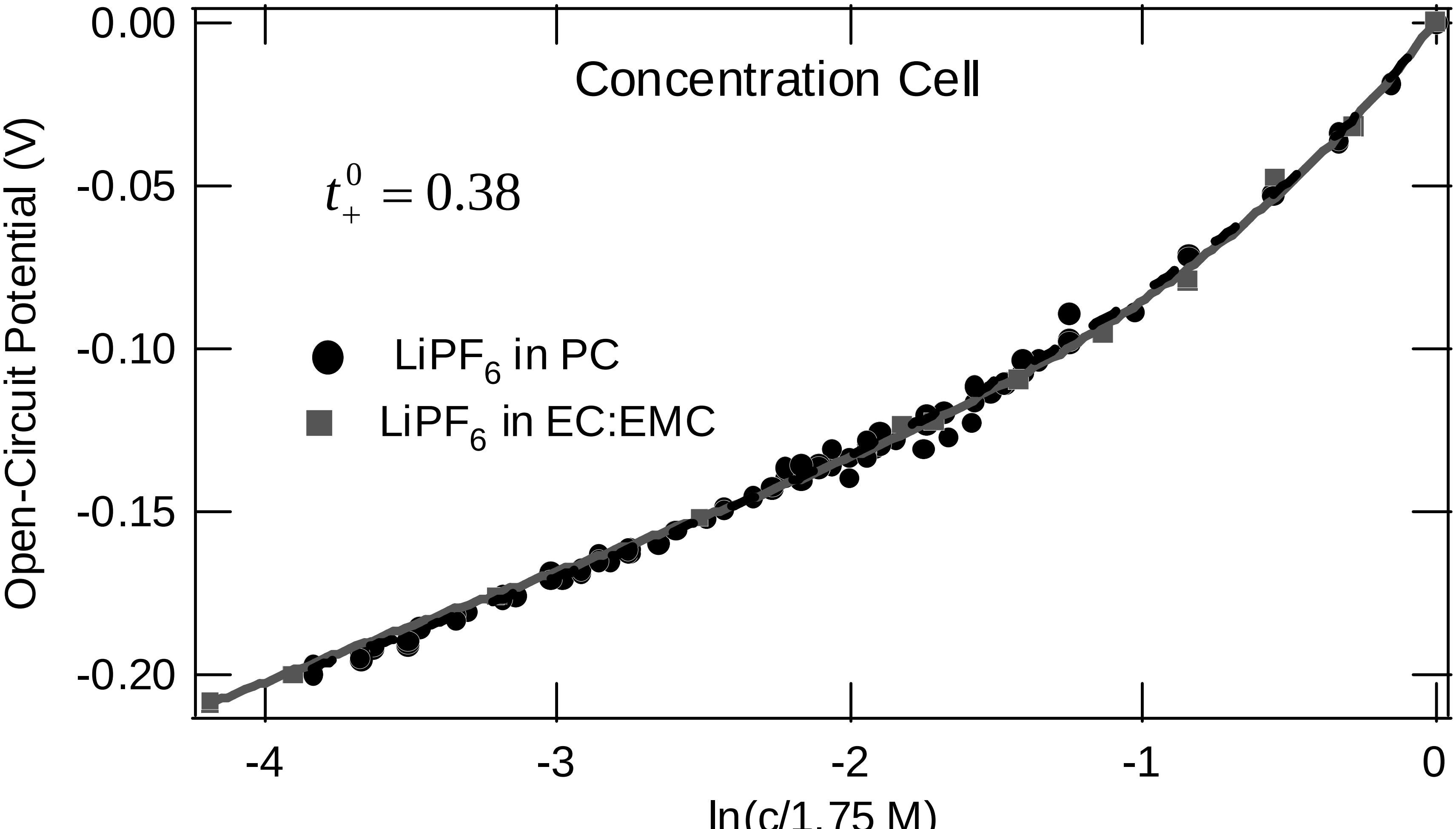
- Design of HEVs and PHEVs
  - Available energy goals
  - Discharge throughput
  - Cycle life

Results – Electrolyte Properties

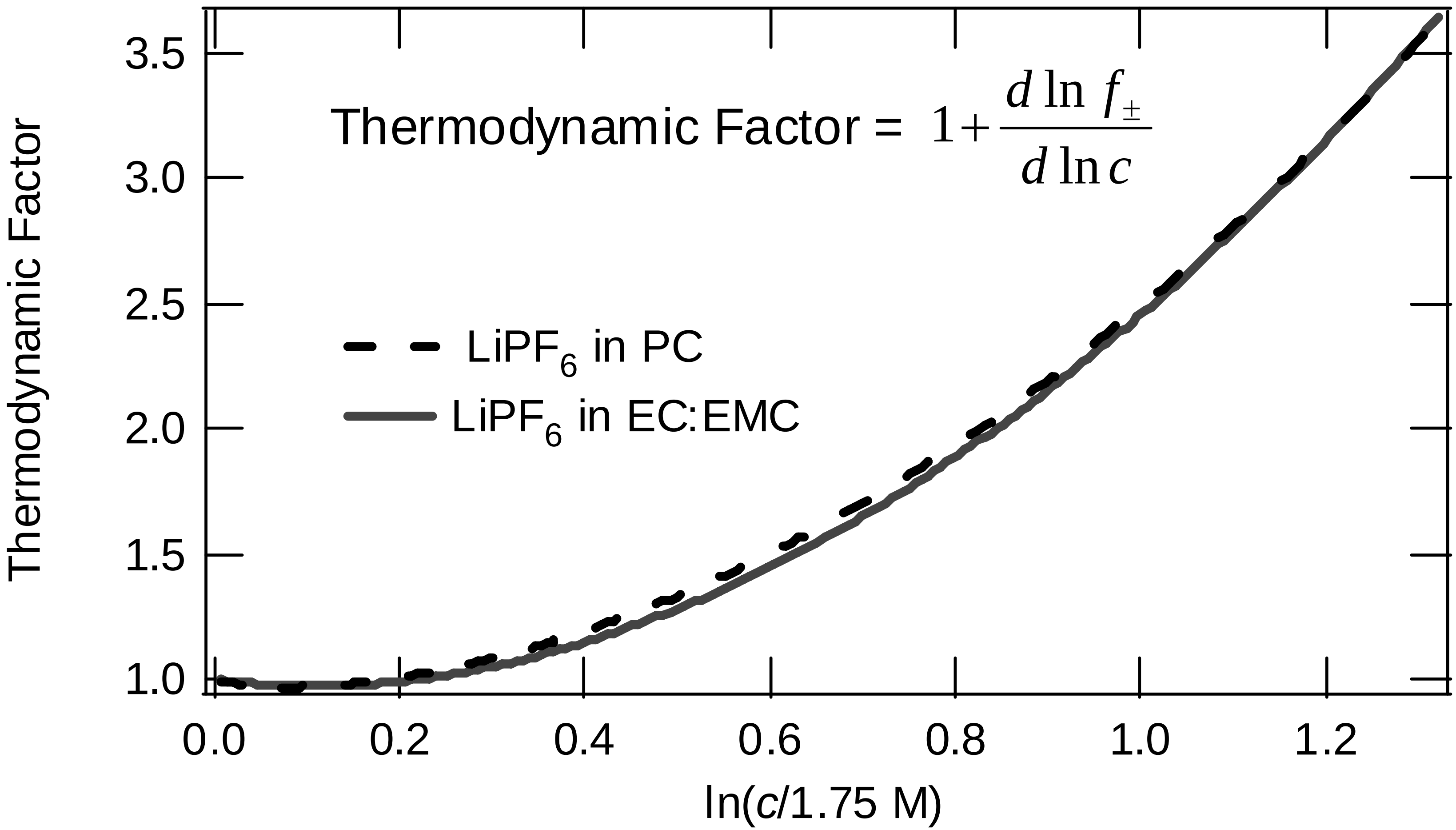
- Previous work focused on measuring diffusion coefficients using a restricted diffusion cell, and conductivity using AC impedance
- Recent work has focused on measuring the activity coefficients through the use of melting-point depression experiments



Results – Electrolyte Properties



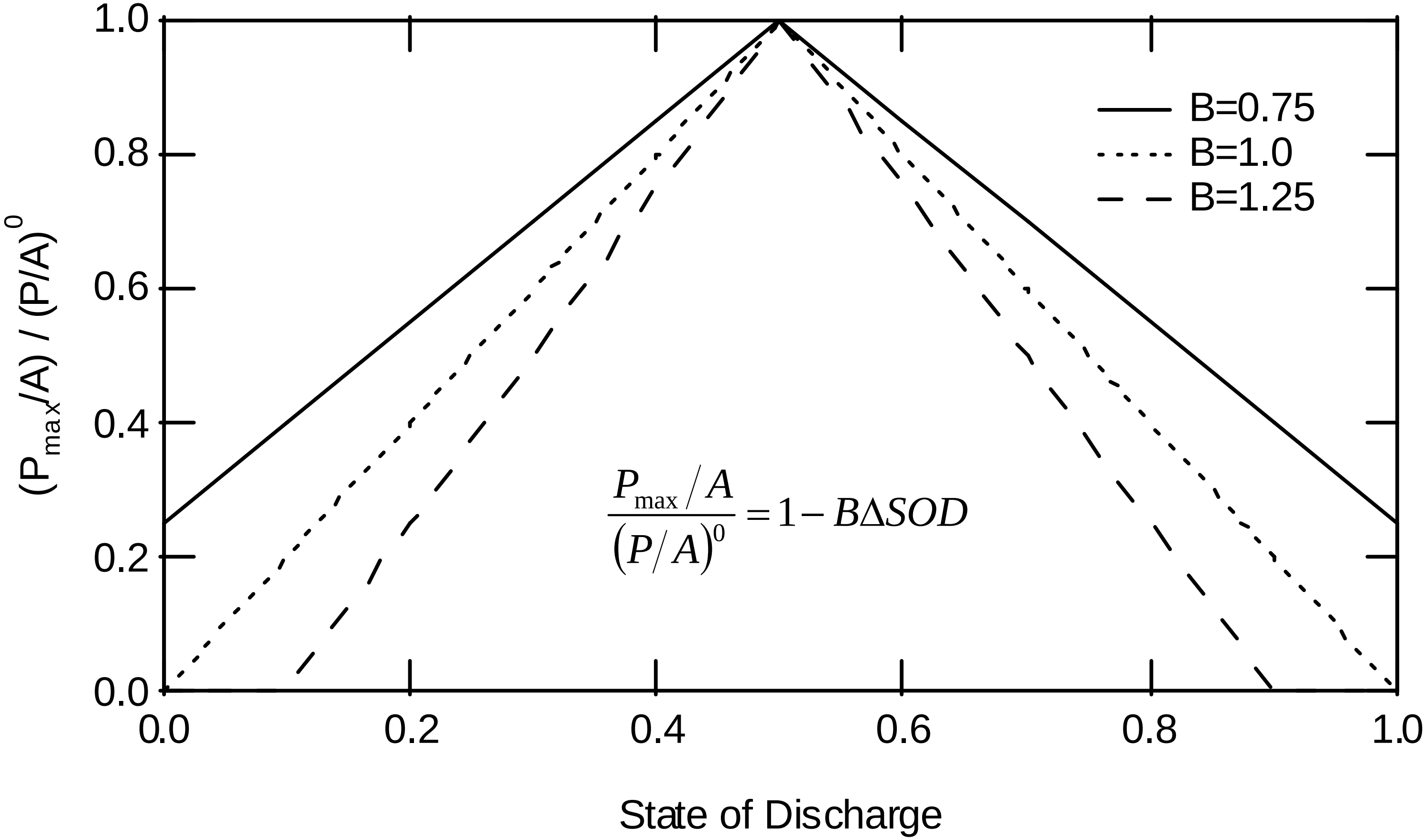
Results – Electrolyte Properties



- The thermodynamic factor is a measure of solution nonideality

Results – Design of PHEVs

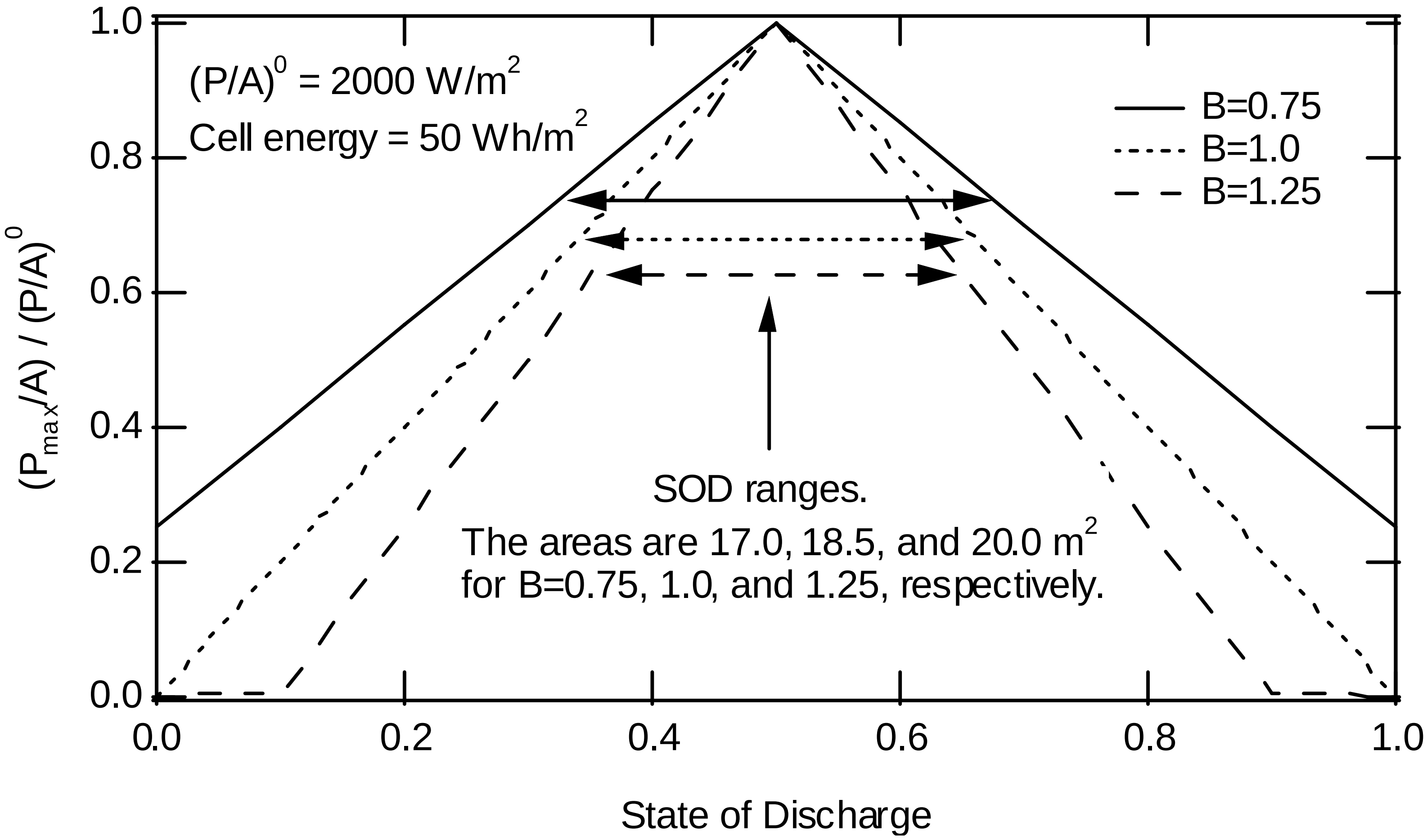
- Develop a simplified model to characterize performance in HEVs and PHEVs



P_{max} is the maximum-power requirement
B is a parameter to describe the shape of the pulse-power capability

Results – Design of HEVs

- HEV battery with a power requirement of 25 kW and an energy requirement of 300 Wh ($P/E = 83\ h^{-1}$)



Results – Design of PHEVs

Power capability

$$\frac{P_{\max}/A}{(P/A)^0} = 1 - B\Delta SOD$$

Energy requirement

$$E = E'L = A < V > Q\Delta SOD$$

Combine and solve

$$B\Delta SOD = \frac{x}{1+x}$$

$$\frac{A}{P_{\max}/(P/A)^0} = 1 + x$$

$$x = \frac{E' LB(P/A)^0}{P_{\max} Q < V >}$$

x is a dimensionless energy-to-power ratio

Results – Design of PHEVs

Power capability

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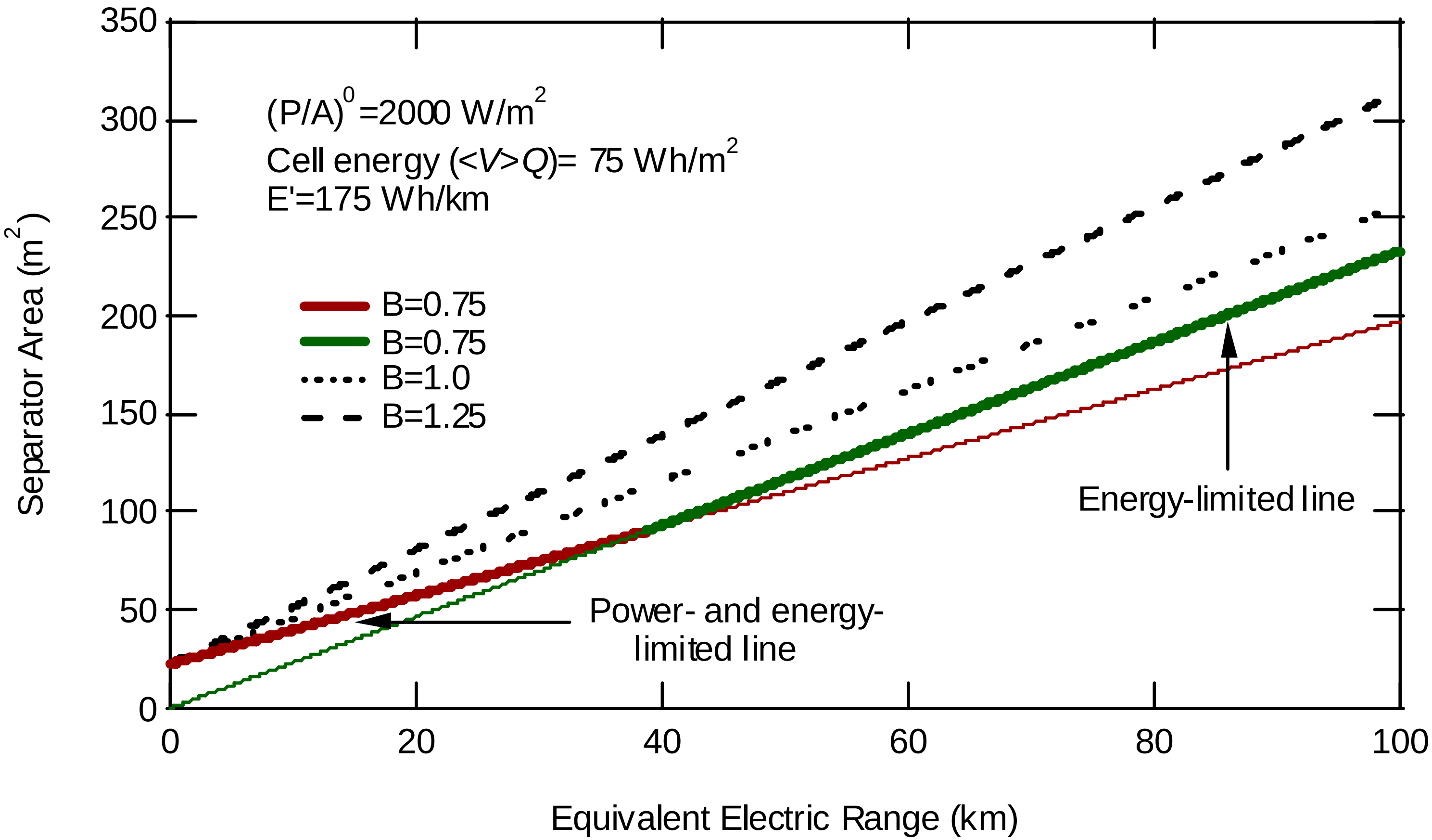
Energy requirement

$$E = E'L = A < V > Q\Delta SOD$$



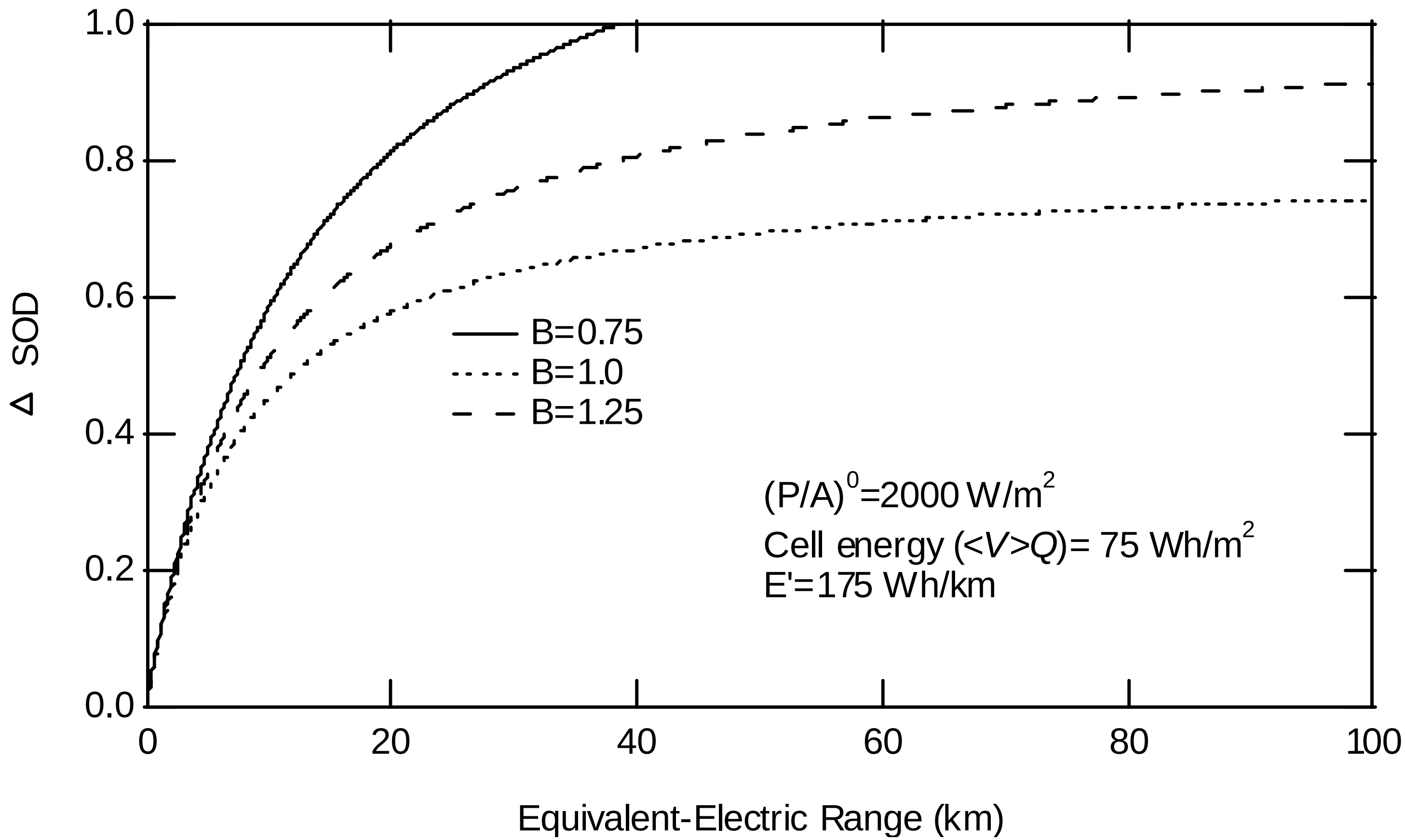
Results – Design of PHEVs

Power capability

$$\frac{P_{max}/A}{(P/A)^0} = 1 - B\Delta SOD$$

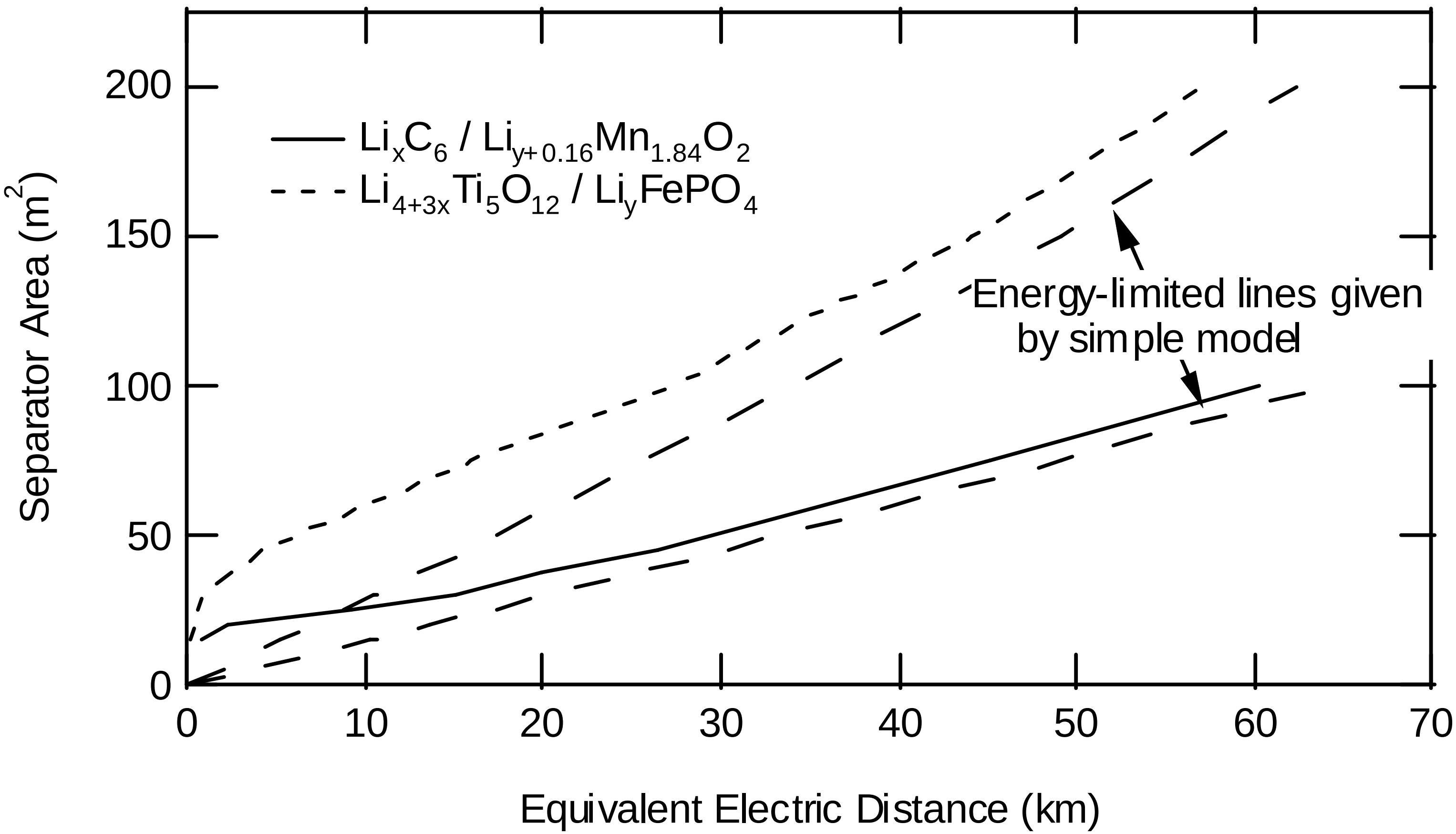
Energy requirement

$$E = E'L = A < V > \Delta SODQ$$



Results – Design of PHEVs

Detailed Model (Dualfoil and Vehicle)



- Combined model captures complexities of real chemistries

Future Work

- Finalize modeling work and finish write-up of the HEV and PHEV work

- Modeling spurious lithium deposition
  - Lithium deposition at the edges of electrodes
  - Use 1-D and 2-D models to understand the conditions in which deposition may occur

Summary

- Measurements of the transport and thermodynamic properties of $LiPF_6$ in several solvents have been carried out
- A simplified model has been developed to provide insights on the design of HEVs and PHEVs
- A combined battery and vehicle model has been used to provide accurate and comprehensive prediction of behavior in HEVs and PHEVs, for design

Publications

- Stewart, S., Newman, J., "The Use of UV/vis Absorption to Measure Diffusion Coefficients in $LiPF_6$ Electrolytic Solutions," J. Electrochem. Soc., 155 (1) F13-F16.

- Stewart, S., Newman, J. "Measuring the Salt Activity Coefficient in Lithium-Battery Electrolytes," J. Electrochem. Soc., Accepted.

- Stewart, S. "Determination of Transport Properties and Optimization of Lithium-Ion Batteries." Ph.D. Dissertation, University of California, Berkeley, 2007

- Albertus, P., Newman, J.. "I. A Simplified Model for Determining Capacity Usage and Battery Size for HEVs and PHEVs," In preparation.

- Albertus, P., Couts, J., Srinivasan, V., Newman, J. "II. A Combined Model for Determining Battery Size and Capacity Usage of the Li_xC_6 / $Li_{y+0.16}Mn_{1.84}O_4$ and $Li_{4+3x}Ti_5O_{12}$ / Li_yFePO_4 Chemistries for HEV and PHEV Applications," In preparation.