U.S.–China Clean Energy Research Center
中美清洁能源研究中心
Clean Vehicles Consortium

U.S.-China Clean Energy Research Center
Clean Vehicle Consortium (CVC)

Huei Peng
US Director

Ouyang Minggao
China Director

January 10, 2013

Outline

- Goals and success metrics
- Center projects and collaborative activities
- Highlights of research results
- IP
- Industry engagement
- Expected outcomes by end-of-fifth year

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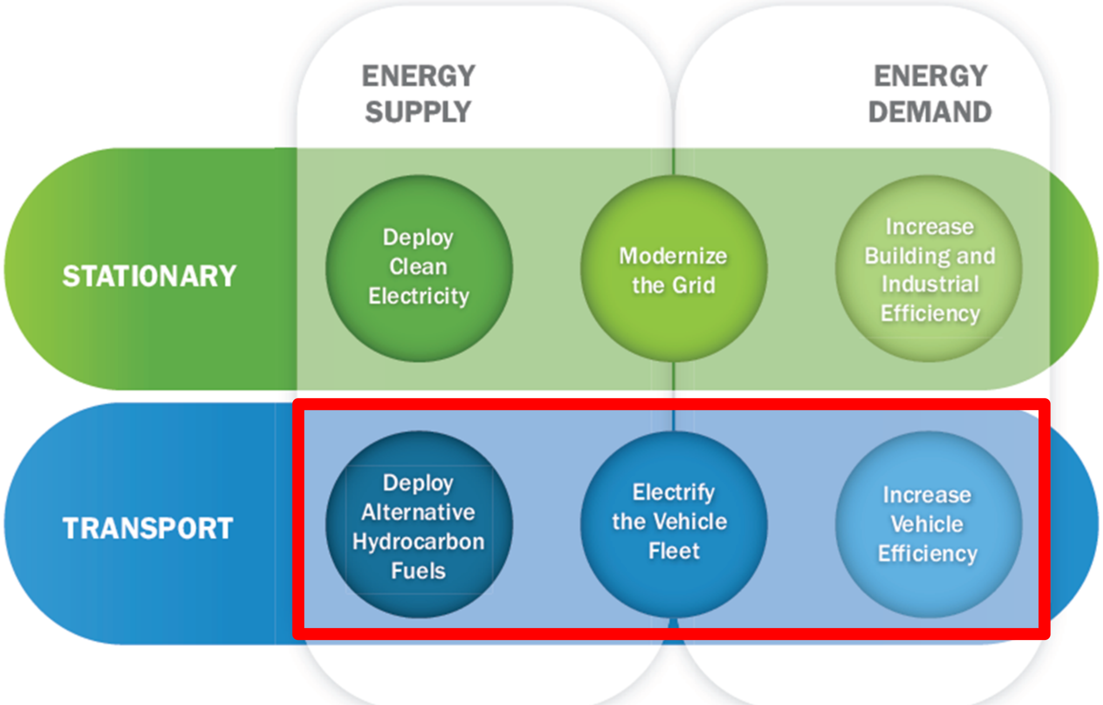
CERC-Clean Vehicle Consortium: Objective

"The objective is to contribute to technologies with the potential to reduce the dependence of vehicles on oil and/or improve vehicle fuel efficiency"

Figure ES-1. The QTR has framed six strategies to address national energy challenges.



CERC-CVC objective and projects are aligned with the three transport strategies outlined in the 1st DOE QTR

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CERC-CVC Success Metrics (defined 2011)

- Joint conferences, workshops and symposia organized
- Journal and conference papers published
- IP disclosures filed; US, China, and international patents issued
- Number, frequency, duration of personnel exchanged/collocated among organizations
- Students graduated and students hired by CERC-CVC members and affiliates
- Post-doctoral fellows trained
- Awards received (individual, team, technology)
- Prestigious lectureships/keynotes given at national and international conferences
- Commercialization of CERC-CVC IP by OEMs, suppliers and start-ups

Update on Key Metrics

- Joint conferences, workshops and symposia organized
  - 3 CERC-CVC-wide meetings, 6 EVI workshops
  - 51 Technical meetings (mostly by individual TA)
- Journal and conference papers published
  - 152 papers published or accepted, 22 are joint
- IP disclosures filed; US, China, and international patents issued
  - 12 in China, 20 in US (11 from Chinese side)
- Number, frequency, duration of personnel exchanged/collocated among organizations
  - ~ 80 short-term visits, 21 long-term (> 30 days) visits planned or executed

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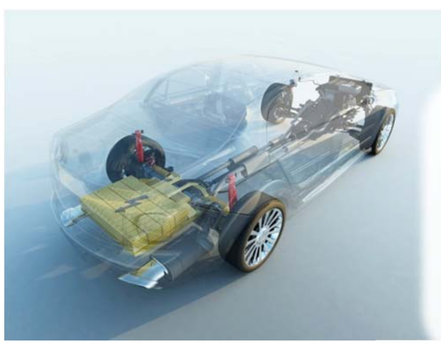
CERC-CVC Thrust Areas

1. Advanced Batteries and Energy Conversion

2. Advanced Biofuels, Clean Combustion and APU



3. Vehicle Electrification

4. Lightweight Structures

5. Vehicle-Grid Integration

6. Energy Systems Analysis, Technology Roadmaps and Policies

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Project Changes

- US side:
  - One project termination at UM (Departure of PI)
  - Four projects added in Jan 2012 (supported by industrial membership fee, research topics selected by industrial advisory board with significant industrial involvement)
  - Three more new projects planned ~Jan 2013 (to be supported by industrial membership fee, research topics selected by industrial advisory board)
- China side:
  - Addition of one project at THU (Thousand-talent candidate; Prof. He Xin at THU focus on clean combustion)

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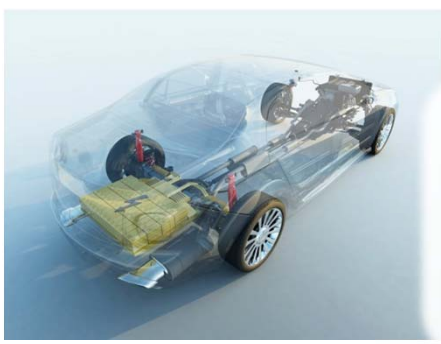
Two Thrust Areas Will be Highlighted

1. Advanced batteries and Energy Conversion

2. Advanced Biofuels, Clean Combustion and APU



3. Vehicle Electrification

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Introduction to the CERC-CVC Battery Thrust

Xinping Qiu[1] and Don Siegel[2]

Battery & Energy Conversion Thrust Co-Leaders

[1]Chemistry Department, Tsinghua University

[2]Mechanical Engineering Department, University of Michigan

CERC Steering Committee, January 10, 2013

Washington, DC

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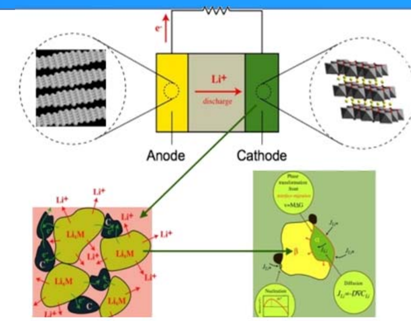
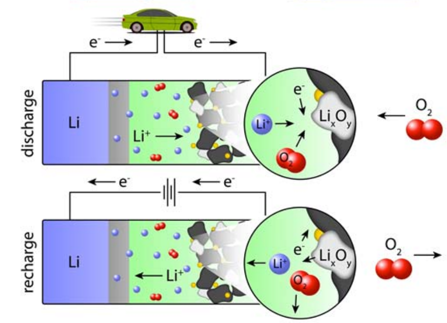
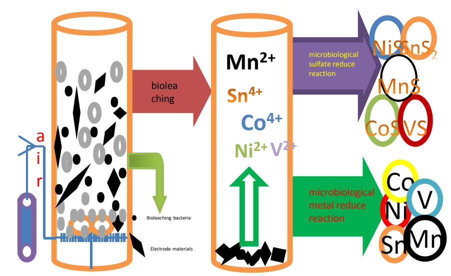
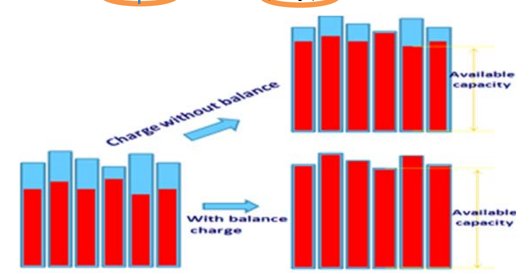
TA1 Goals

- **Degradation**: Combine modeling and advanced characterization to understand degradation mechanisms in Li-ion batteries.
- **Modeling, Controls, and Implementation**: To extend battery life, develop battery management systems with on-board balancing technologies. Review protocols for battery testing & safety. Explore pathways for reuse & recycling of batteries.
- **New Chemistries**: Advance Li-air and Li-sulfur chemistries towards commercial viability by revealing limiting phenomena and developing materials/architectures that overcome these obstacles.









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TA1 Projects and Personnel

U.S.		China
Degradation Babu (OSU) Bhushan (OSU) Conlisk (OSU) Cao & Canova (OSU) Daniel (ORNL) Leung (Sandia) Amine (ANL)	↔	**Degradation** Qiu (THU)
Modeling & Controls Bernstein & Stein (UM)	↔	**Modeling & Controls** Lu (THU)
Protocols, Recycling Bloom, Gaines, Sullivan (ANL)	↔	**Protocols, Recycling** Hua (THU)
New Chemistries Siegel (UM) Van der Ven (UM) Shao-Horn (MIT) Ceder (MIT)	↔	**New Chemistries** Wu (BIT) Kang (THU) Qui (THU) He (THU)

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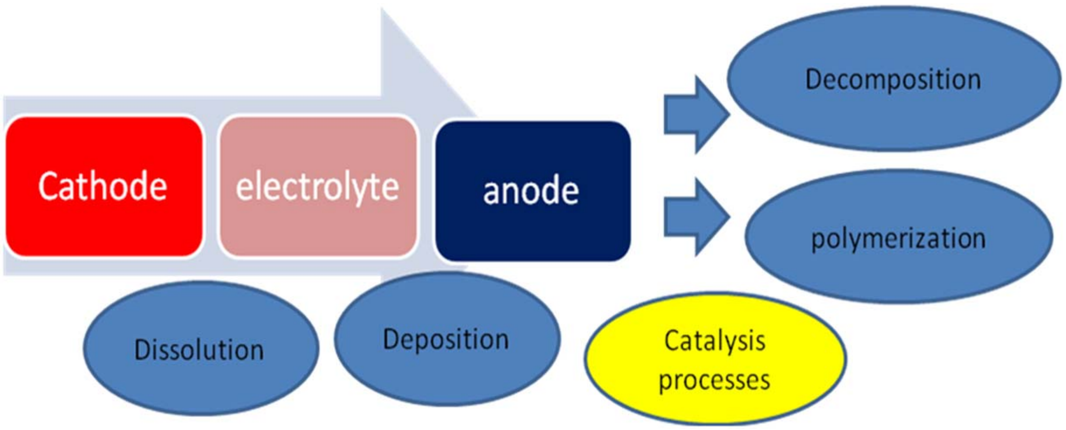
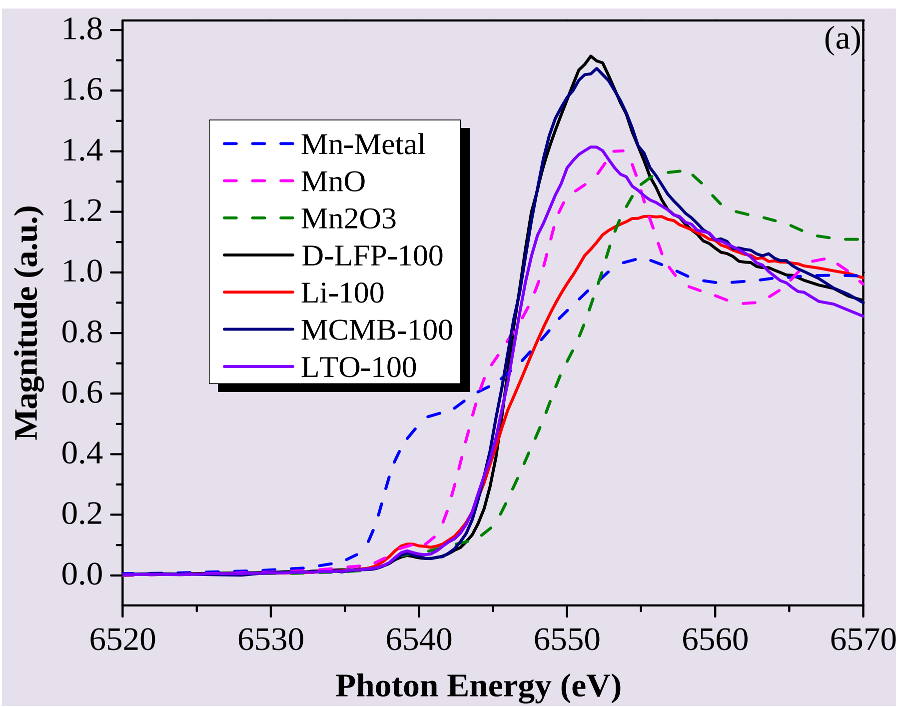
Dissolution- Deposition Processes in Li-ion Batteries





- Accumulation of Mn on Li anode can be detected after formation, and continues to increase upon cycling.
- Mn on the anode exhibits +2 oxidation state, NOT Mn(0), which is the main reason for increase in internal resistance.

Submitted to Nature Comm.

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A Comparison of US and Chinese Battery Testing Protocols

- Test protocols used:
  - USABC EV DST
  - China QC/T 743 and 846 protocols
- **Similarities in the protocols**
  - Usable DOD (energy) window, temperature, capacity measurements at RPT and EOT at 80% performance degradation
- **Differences in the protocols**
  - Constant-current cycling vs. dynamic, power-based cycling
  - Power density measurement at 50% DOD (10-s pulse) vs. peak power estimation at 80% DOD (30-s pulse)
  - RPT frequency: 24 cycles (6 days) vs. 50 cycles (10.5 days)
  - RPT duration: 18 h vs. 35 h

Early results indicate that the USABC test protocol stresses the cells more than the Chinese test protocol

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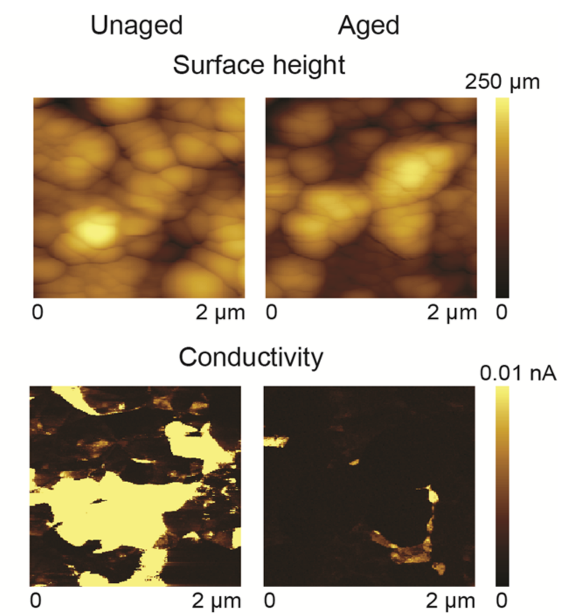
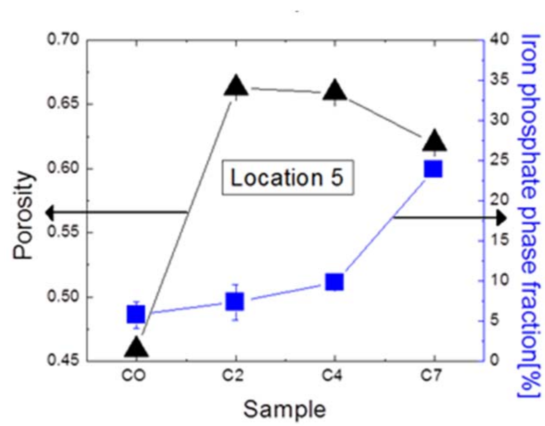
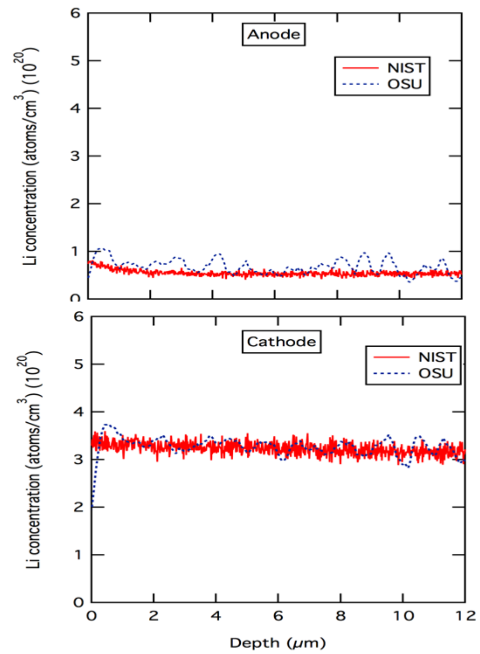
Lithium-ion Battery Degradation

A multi-scale approach to study degradation of morphology, electrical properties and chemical structure in Li-ion battery materials

Agglomeration → Leads to → Increase in Porosity → Affects → Li Migration





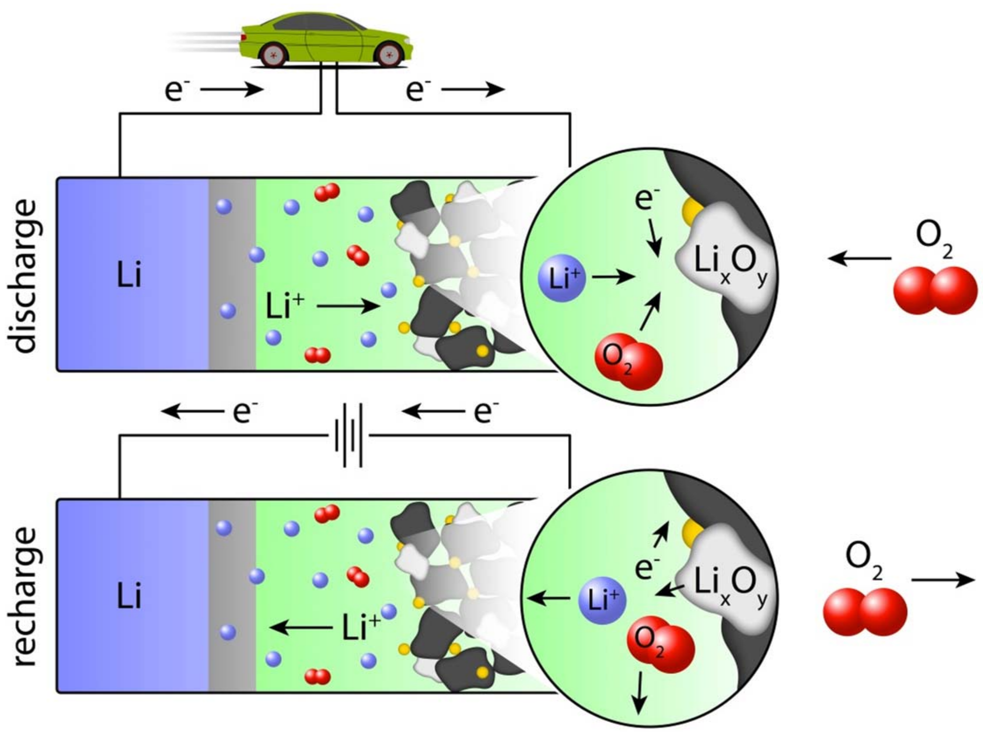


- Agglomeration of particles observed with high resolution AFM imagining
- Drop in electrical conductivity

- Porosity increase causes loss of active material and subsequent loss of capacity.

- More Li builds up on the anode surface with aging while total Li drops in cathode.

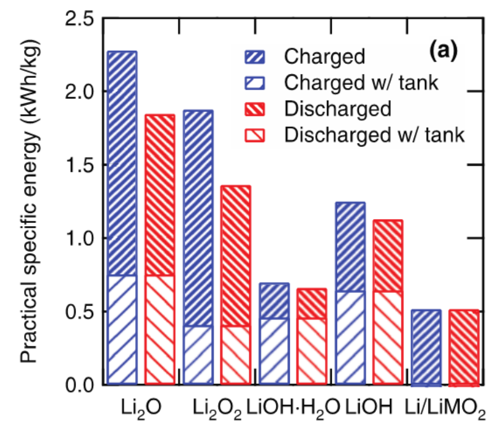
New Chemistries



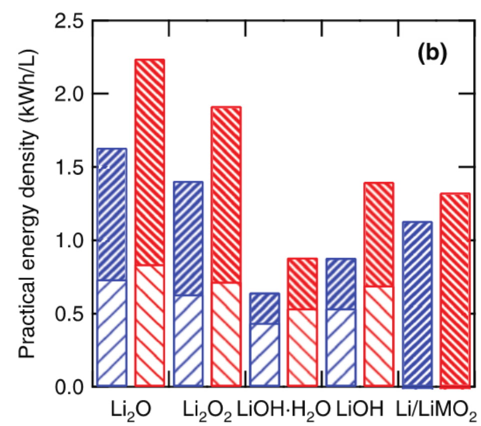
$$2Li^+ + O_{2(g)} + 2e^- \rightarrow Li_2O_{2(s)} \quad U^o = 2.96\ V$$

$$2Li^+ + \tfrac{1}{2}O_{2(g)} + 2e^- \rightarrow Li_2O_{(s)} \quad U^o = 2.92\ V$$

Estimated practical specific/volumetric energy density



300-400% vs. Li-ion



30-60% vs. Li-ion

JES **159**, 2193, R1 (2012).

Li-air projected cost:
$100/kWh[1],
$238/kWh[2]

[1]Johnson Controls, 2011 Battery Congress
[2]J. Power Sources 199 (2012) 247– 255

Understanding Cathode Phenomena

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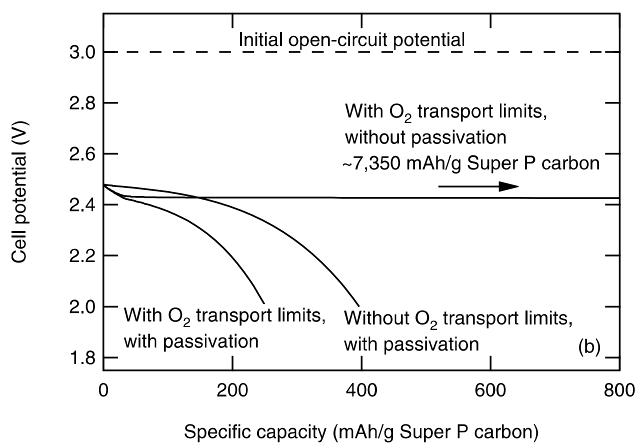
Objective: to reveal key factors that limit battery performance

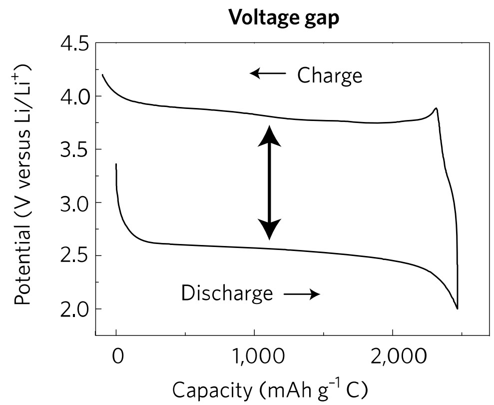
Continuum-scale models and flat-electrode experiments suggest that electrical passivation can limit capacity

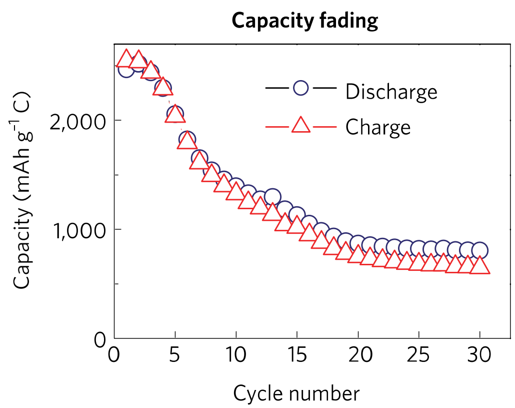


Simulated discharge curves illustrating the effects of O_2 transport or electrical passivation.

J. Electrochem. Soc. 158, A343 (2011)

High efficiency and long cycle-life are also challenges

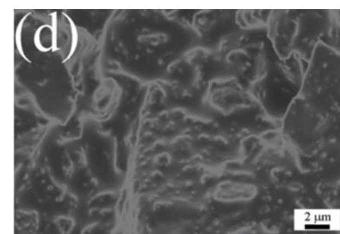


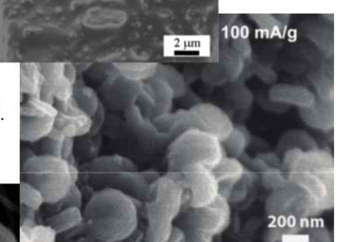


Nature Mat. 11, 19 (2012)

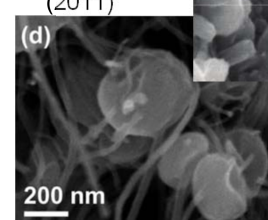
Morphology of discharge phase can vary dramatically

Energy Environ. Sci. 5, 8927 (2012)

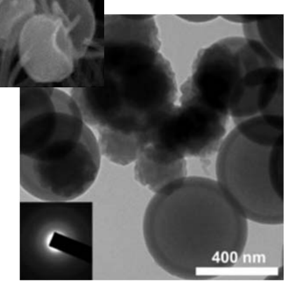




Energy Environ. Sci. **4**, 2999 (2011)



Energy Environ. Sci. 4, 2952 (2011)



Nano Lett. 12, 4333 (2012)

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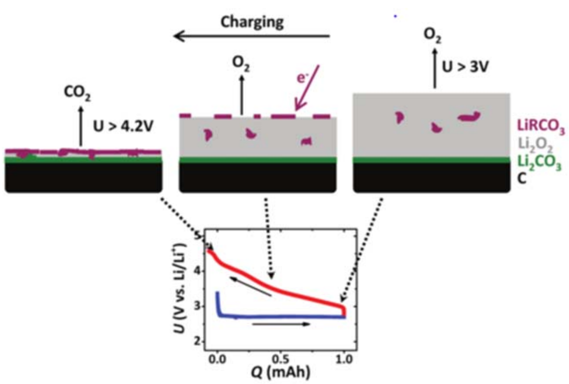
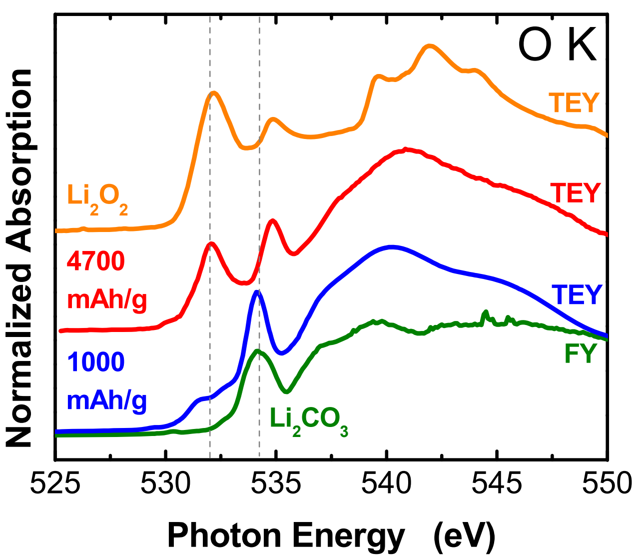
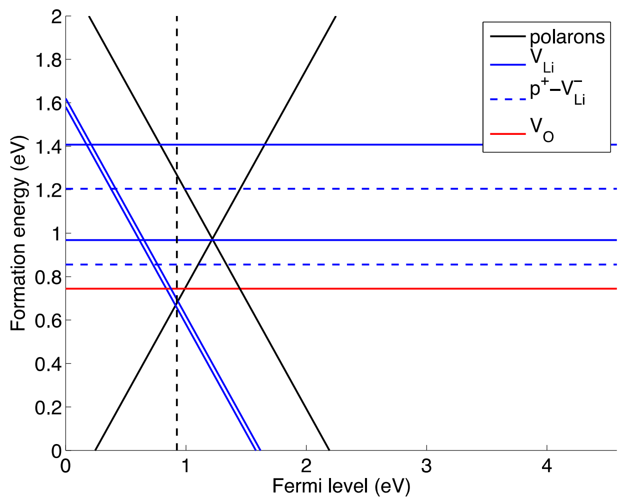
Structure and Properties of Discharge Phases

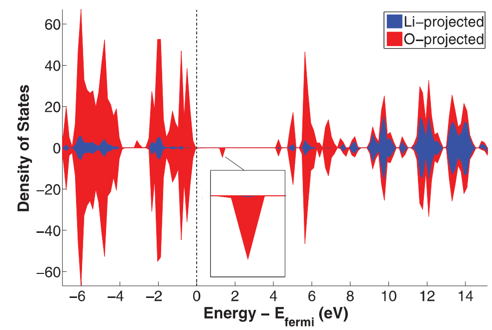
XANES Spectroscopy



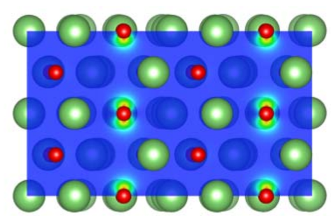


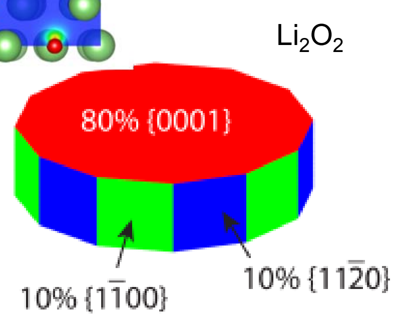
First-Principles Modeling

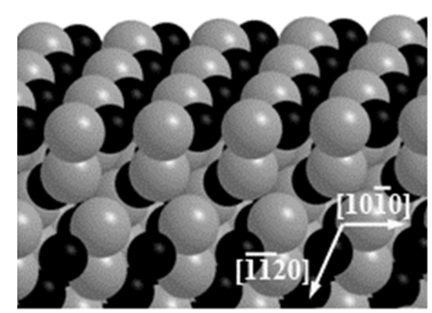




Material	σ (S/cm)
Stainless Steel 304	1.4×10^4
Vulcan carbon	4×10^{-1}
Bulk Li_2O_2	**$2 \times 10^{-7}/3 \times 10^{-8}$**
Glass	10^{-12}-10^{-16}







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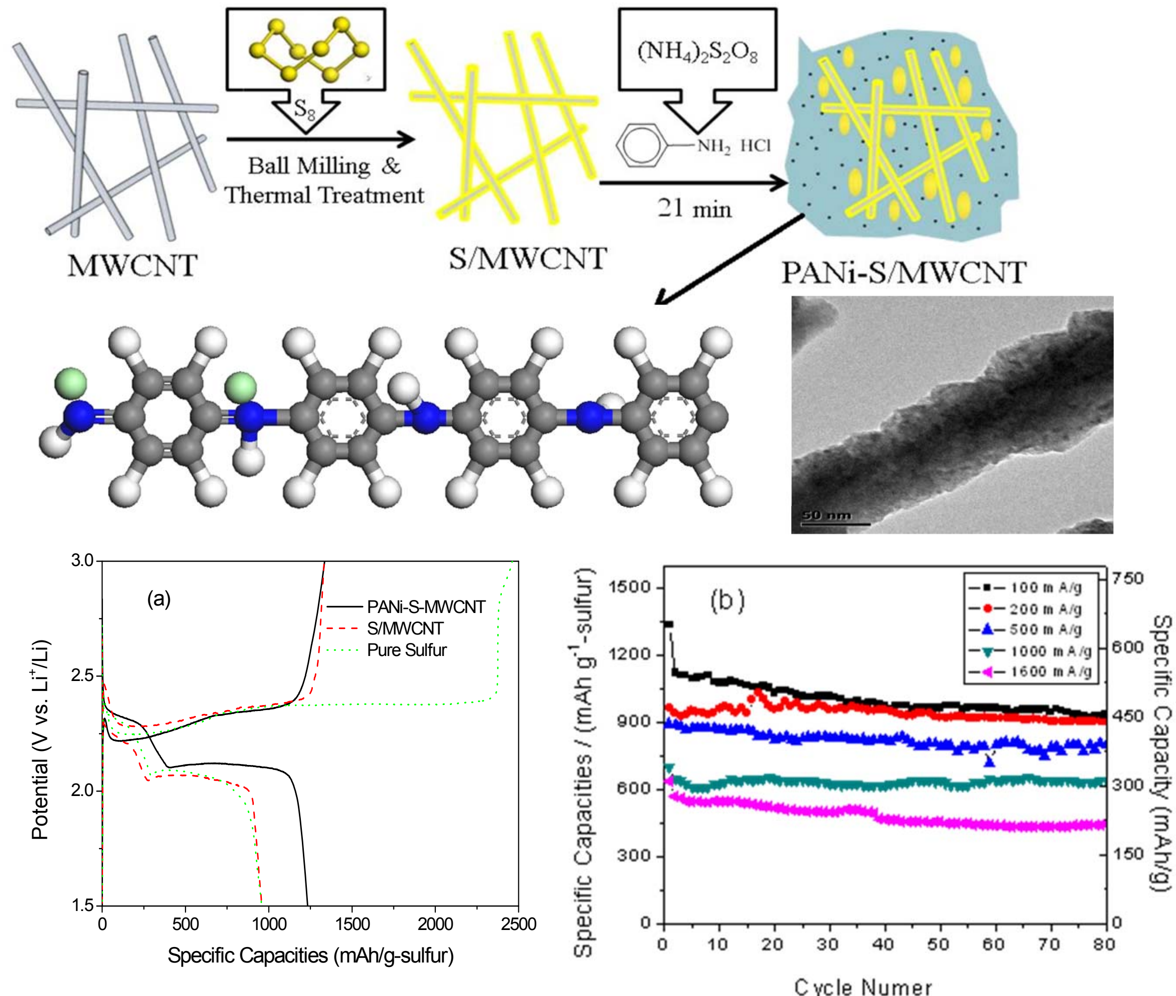
Composite S/C Material for Li-Sulfur Batteries



J. Phys. Chem. C, 2011, *115* (49),24411

- Polymerization creates a shell which prevents the Sulfur shuttle mechanism.
- **Benefits:** columbic efficiency doubled (~90%), discharge capacity maintained (1334.4 mAh g^{-1}), improved rate performance (634.1 mAh/g at 1C).

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TA 6: ENERGY SYSTEMS ANALYSIS, TECHNOLOGY ROADMAPS AND POLICY

UNIVERSITY OF MICHIGAN

Argonne NATIONAL LABORATORY

Sandia National Laboratories

Oak Ridge National Laboratory

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Xunmin Ou
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Dawn Manley
5.麻省理工学院（MIT）
John Heywood
6. 美国环保署（EPA）
Jeff Alson

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TA 6: Goals

University of Michigan, Argonne National Laboratory

- Develop CV energy efficiency and carbon targets and evaluate life cycle performance of CV powertrain

Tsinghua University, Beihang University

University of Michigan, Sandia National Laboratories

- Identify optimal fuel mix strategies & constraints

Tsinghua University, North China Electric Power University

University of Michigan

- Develop recommendations for fuel economy and GHG standards and labels for PEVs

Tsinghua University

University of Michigan, Massachusetts Institute of Technology, Argonne National Laboratory

- Develop tech-roadmap & policy recommendations for accelerating clean vehicle deployment

Tsinghua University

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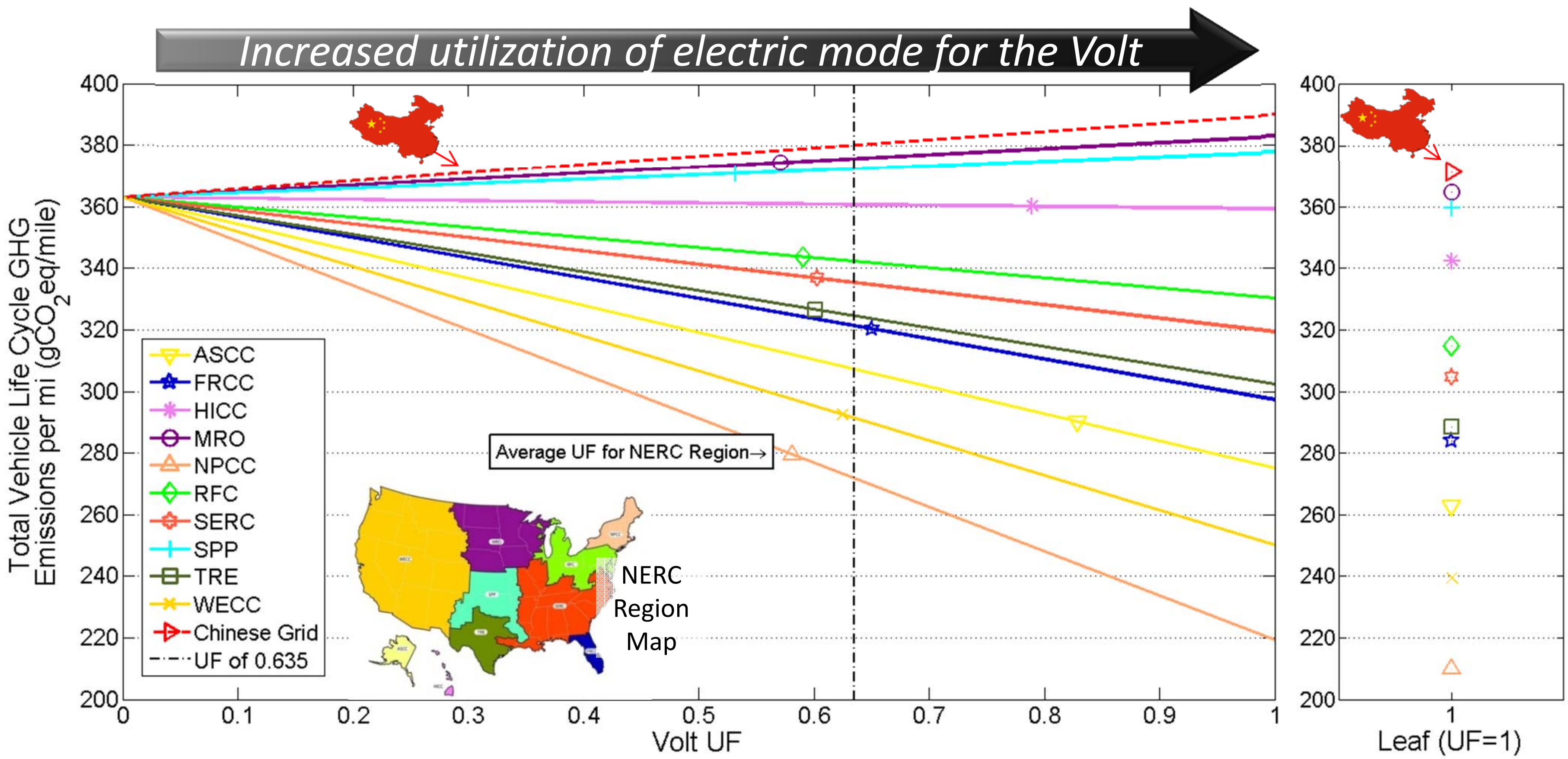
FE and GHG Emissions Labeling and Standards for EVs from LCA Perspective



Electrified vehicle emissions and labeling analysis was conducted with input from policy analysts at the EPA's National Vehicle & Fuel Emissions Laboratory

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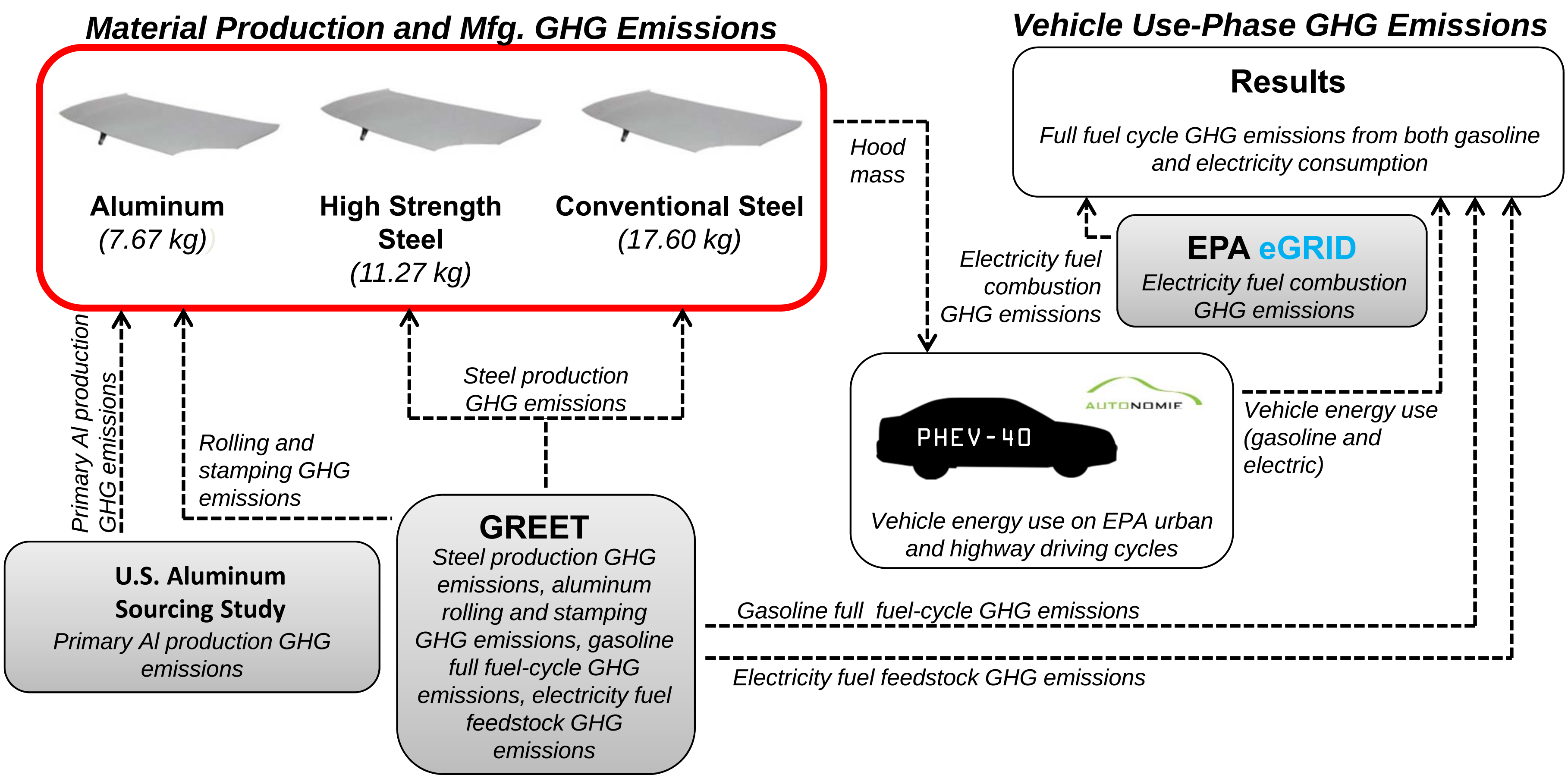
Electricity and Material Sourcing Scenario Analyses to Guide Vehicle Technology Strategies

PHEV-40 Hood Case Study

Methodology



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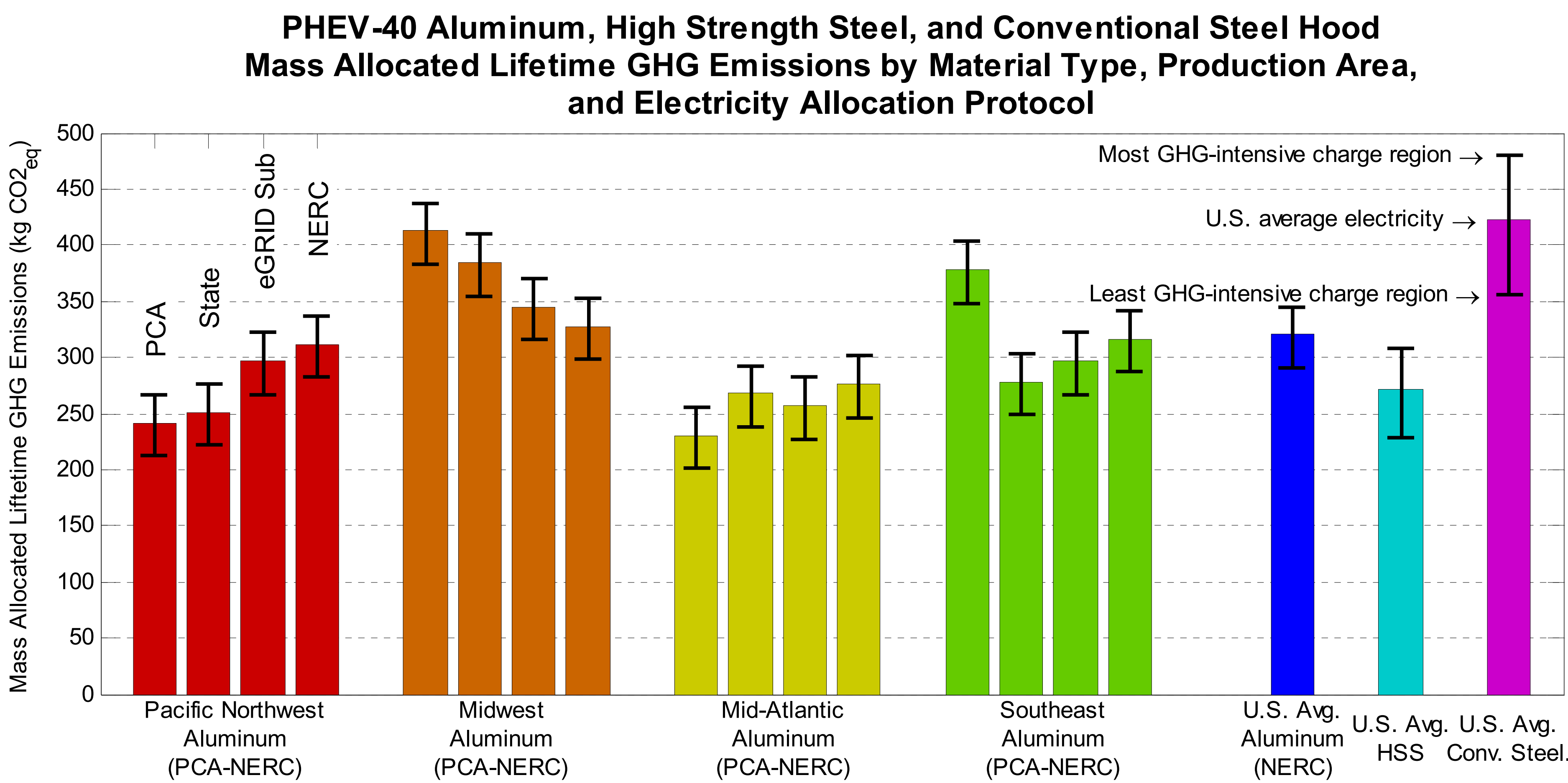
PHEV-40 HOOD CASE STUDY RESULTS



Primary aluminum production GHG emissions vary significantly based on production location and electricity allocation protocol

Driving pattern in China mega city for EV design

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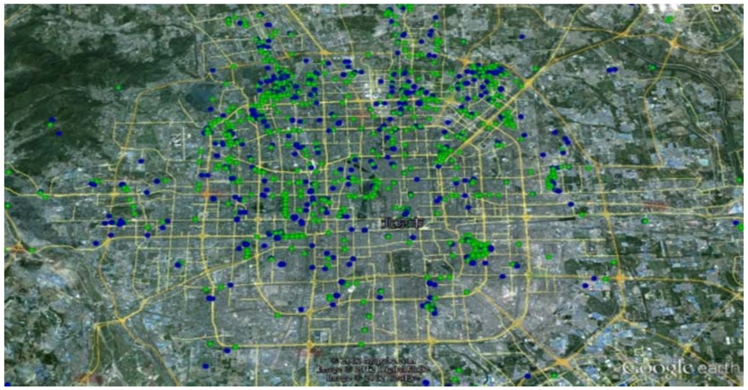
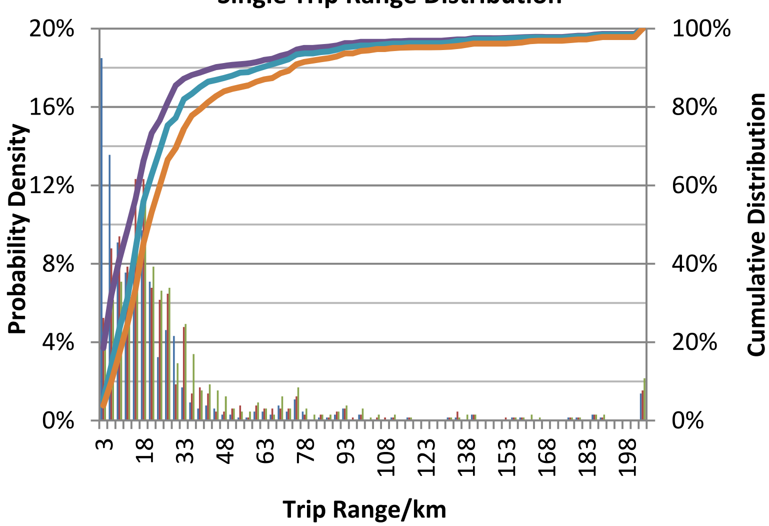


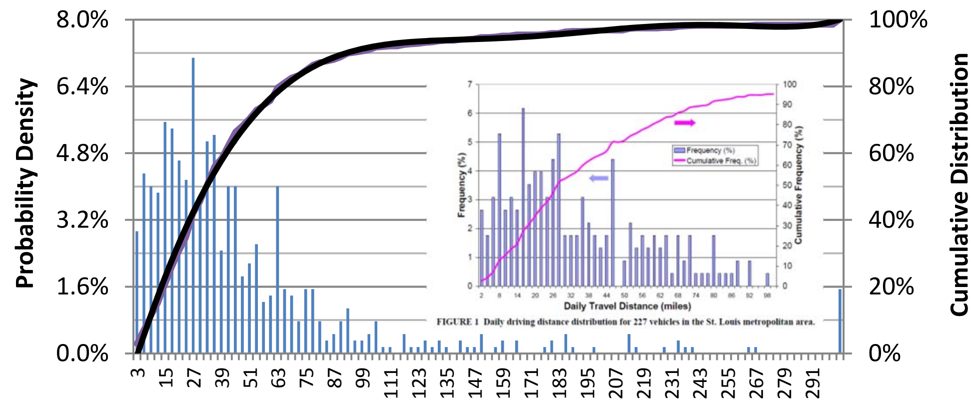
98 household, 987 vehicle-days, 4-41days, >2000 trips

	3rd Ring	4th Ring	5th Ring
Origin	26.2%	43.0%	72.8%
Destination	24.6%	43.6%	75.9%

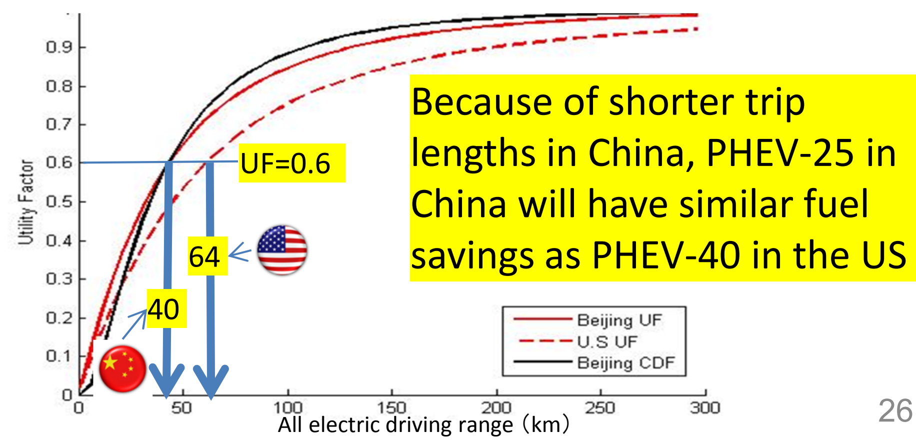
Single Trip Range Distribution



Daily Range Distribution



	Mean (km)	50% (Km)	80% (km)
Beijing survey based on GPS (2012)	**43.1**	33	60
NHTS (US, 2009)	**46.8**	-	-



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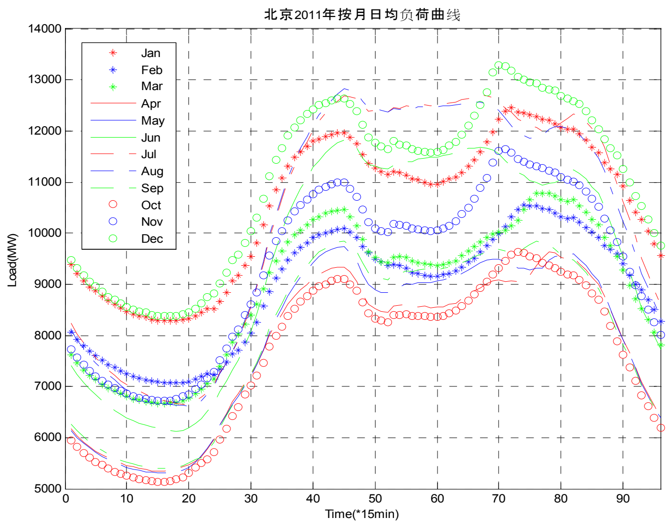
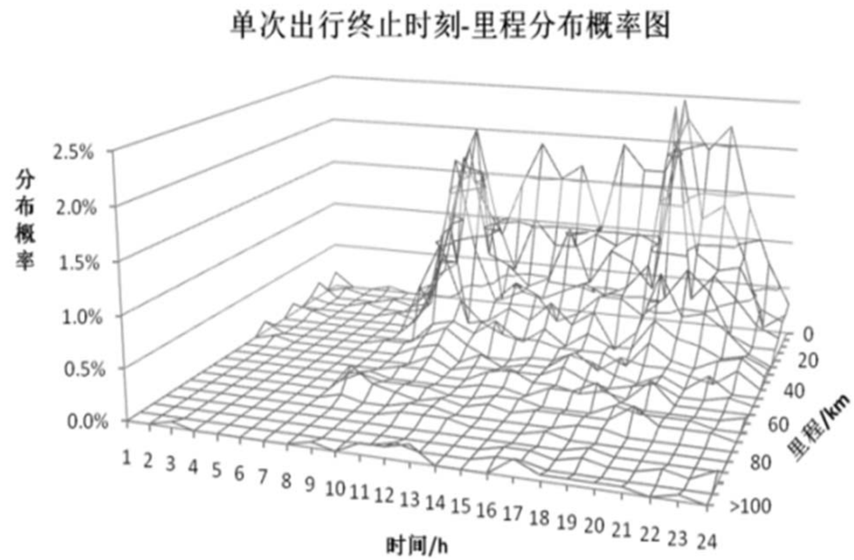
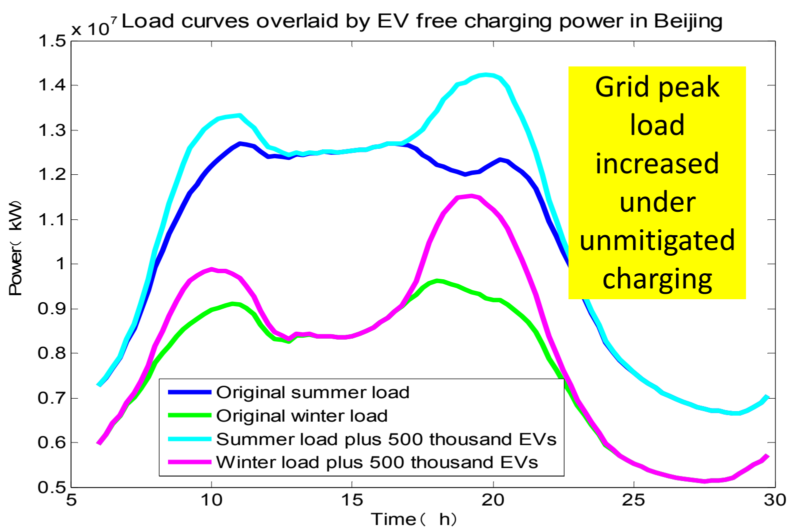
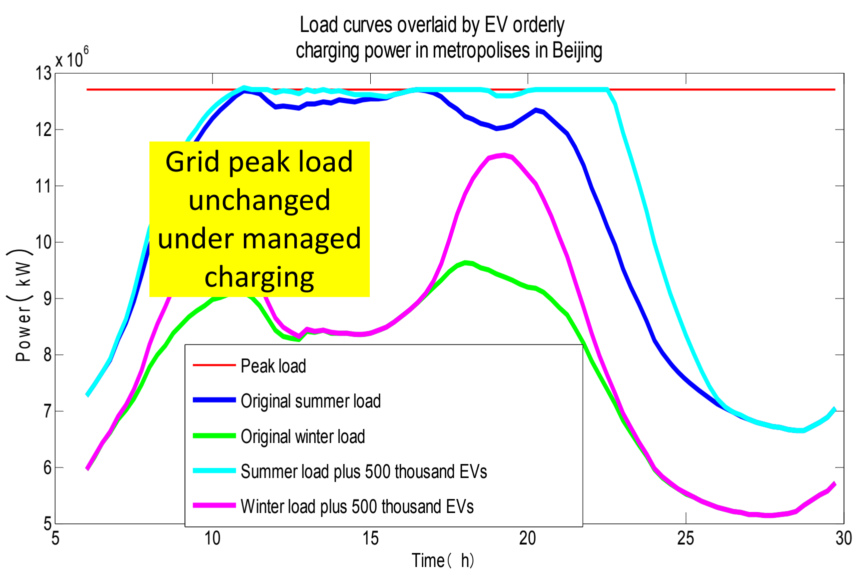
EV Charging Mode and Impact on Electric Grid





Electricity load curves in Beijing （2011）





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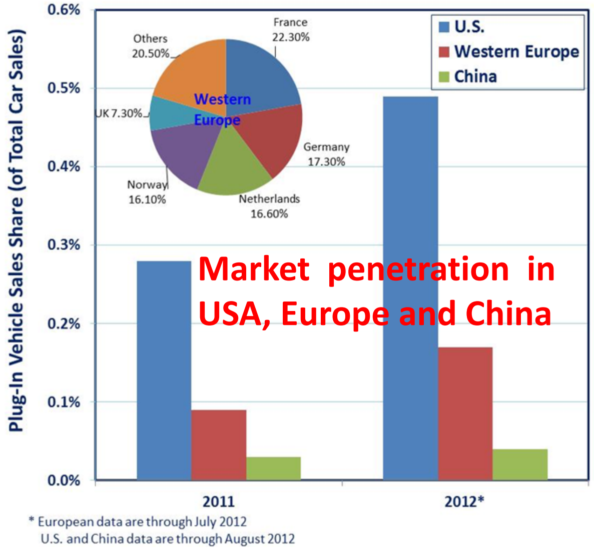
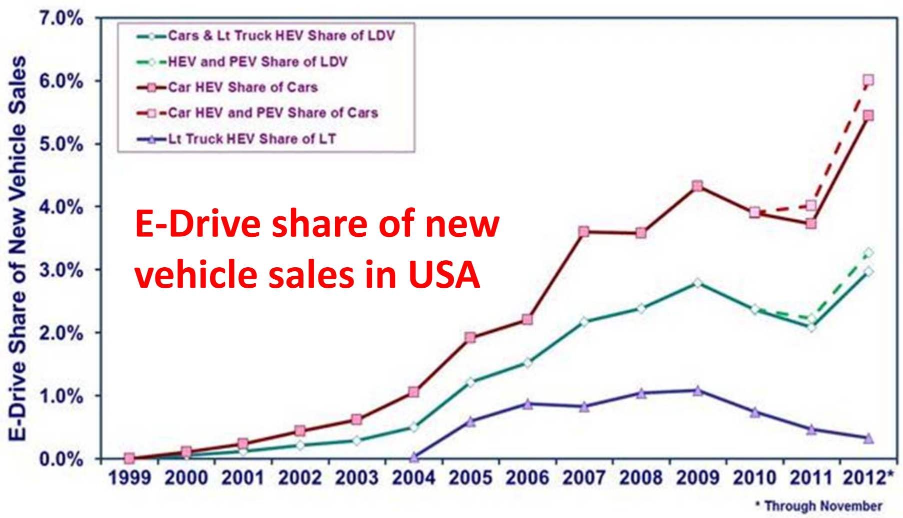
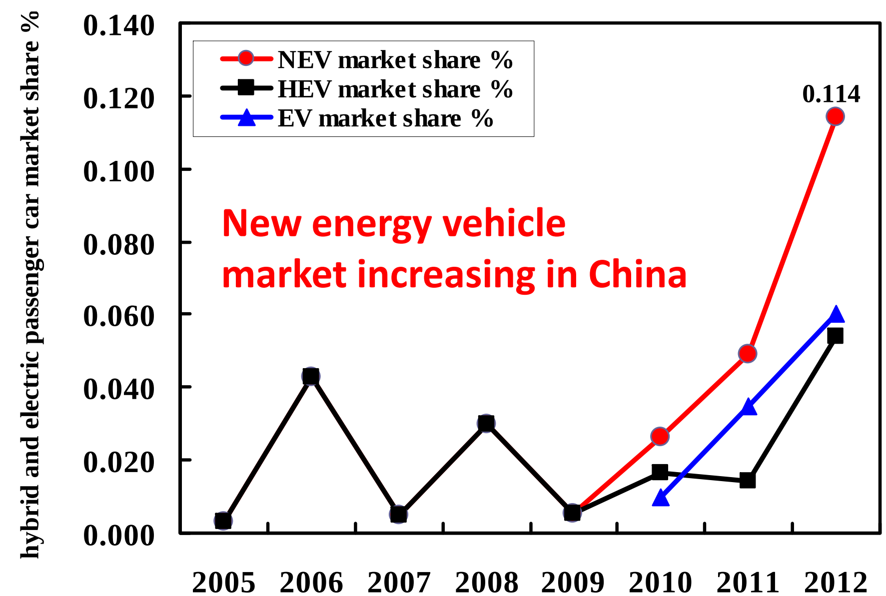
Clean Vehicle Data Analysis and Sharing

Analysis and sharing of new energy vehicle data, submitted to DOE and MOST monthly.
http://www.transportation.anl.gov
http://www.car.tsinghua.edu.cn







Data source: collected and analyzed by CERC-CVC(Tsinghua)
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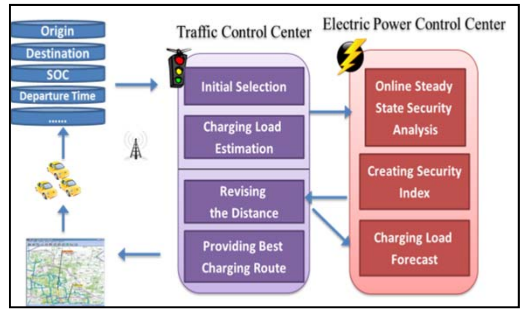
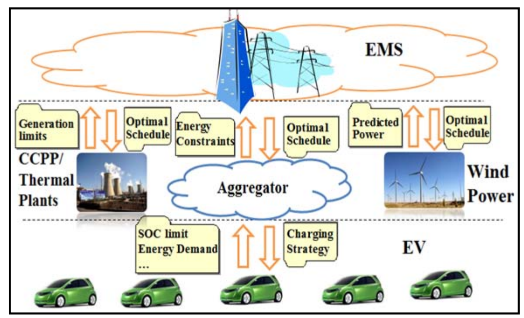
TA 5: Vehicle-Grid Interactions, Goals

Establish framework and key technologies to implement vehicle-grid systems:

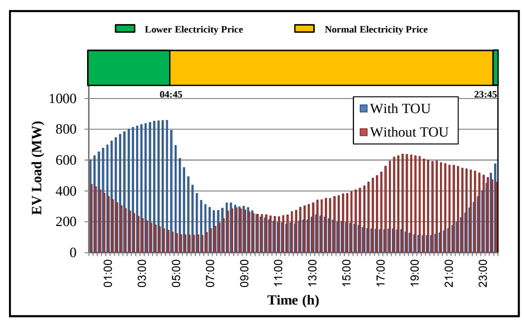
- Use of Intelligent Transportation Systems technology to optimize vehicle charging and energy use.
- Development of adaptive battery management systems, on and off the grid
- Assess the impact of large-scale deployment of PEVs on the grid and develop technology and policy recommendations to accelerate EV deployment in the U.S. and China
- Develop control strategies and protocols for vehicle-grid interactions



Smart Charging Guiding System (SCGS)



EV-RES Coordination



Charging load model based on transportation information

Outline

- Goals and success metrics
- Center projects and collaborative activities
- Highlights of research results
- IP
- Industry engagement
- Expected outcomes by end-of-fifth year

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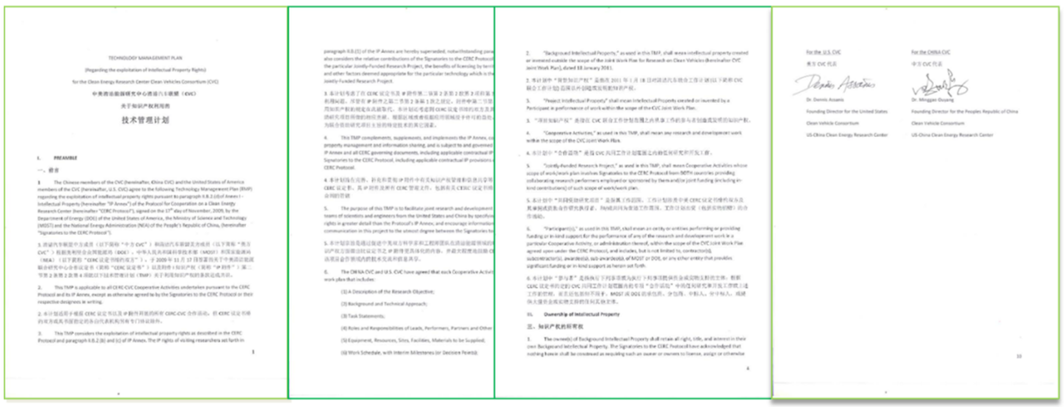
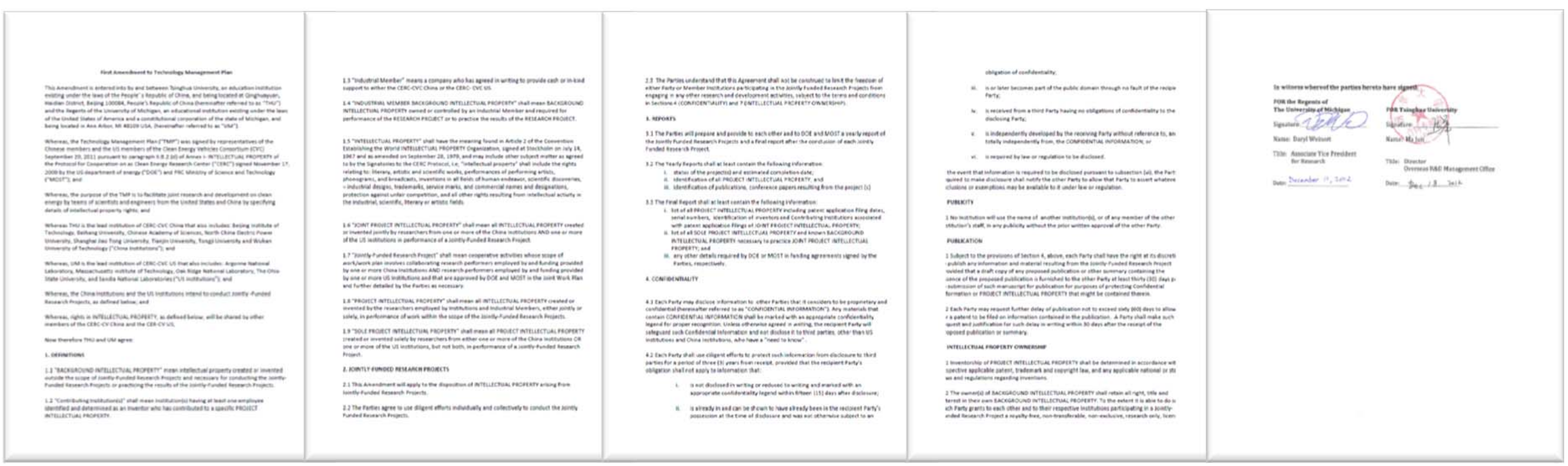
Timeline of IP Agreements

- Technology Management Plan signed in Sep 2011.



- First Amendment signed in Dec 2012.



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Outline

- Goals and success metrics
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Industrial Members

U.S. Side

China Side

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Clean Vehicles Consortium

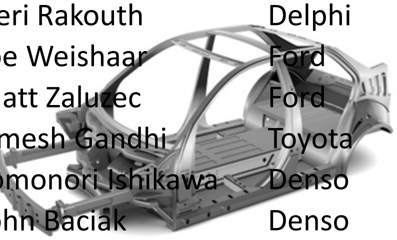
Involved Industrial Researchers

Christian Fau	Honda
Toshiaki Shimizu	Honda
Wu Bi	Honda
Andy Drews	Ford
Alvaro (Al) Masias	Ford
Ted Miller	Ford
Heri Rakouth	Delphi
Gregory Simopoulos	Delphi
Brian Denta	Delphi
John Absmeier	Delphi
Bruce Moor	Delphi
Bradley Brodie	Denso
Masaki Uchiyama	Denso
Masafumi Kurata	Denso
Mike Safoutin	EPA

Clay Maranville	Ford
Tony Phillips	Ford
Ming Kuang	Ford
John Viera	Ford
John Absmeier	Delphi
Bruce Moor	Delphi
Heri Rakouth	Delphi
Gregory Simopoulos	Delphi
Rajesh Malhan	Denso
Zhe Huang	Denso
Mike Safoutin	EPA
Clay Maranville	Ford
Tony Phillips	Ford
Ming Kuang	Ford
John Viera	Ford

Ken Labertaux	Toyota
Heri Rakouth	Delphi
Steve Briggs	First Energy
John Absmeier	Delphi
Bruce Moor	Delphi
Gregory Simopoulos	Delphi
Rajesh Malhan	Denso
Zhe Huang	Denso

James Anderson	Ford
Tim Wallington	Ford
John Kirwan	Delphi
Heri Rakouth	Delphi
Jeff White	Denso
Yujui Tomita	Denso
Dan Sweeney	Denso
Rob Cardno	Denso
Mike Safoutin	EPA



Heri Rakouth	Delphi
Joe Weishaar	Ford
Matt Zaluzec	Ford
Umesh Gandhi	Toyota
Tomonori Ishikawa	Denso
John Baciak	Denso
Javed Mapkar	Eaton
Alaa Elmoursi	Eaton

Heri Rakouth	Delphi
Mike Tamor	Ford
Tim Wallington	Ford
Sandy Winkler	Ford
Heiko Maas	Ford
Mark Mehall	Ford
Danil Prokhorov	Toyota
Gregory Simopoulos	Delphi
John Kirwan	Delphi
John Absmeier	Delphi
Bruce Moor	Delphi
Bruce Myers	Delphi
Manabu Miyata	Denso
Tomoya Tohnai	Denso
Patrick Powell	Denso
Ken Labertaux	Toyota
Jeff Alson	EPA

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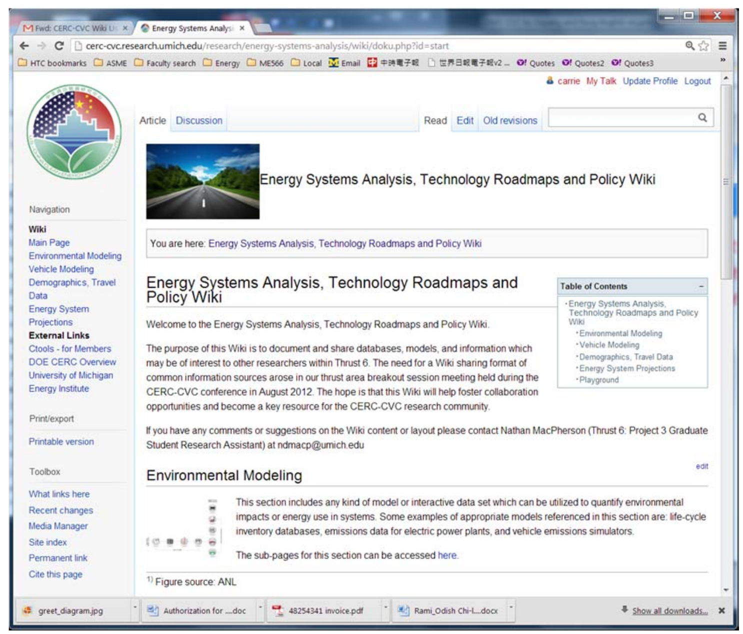
CERC Enabled Collaborations

- UM is working with government agencies and CERC industrial members to explore the possibility of creating a joint battery lab with a 5-year budget of ~7.7M
- Eaton, in collaboration with CERC researchers, plan to install data collection systems on chargers for the EVTown project (Mercy Davison, Normal, IL). The data will improve plug-in vehicle usage and charging models in CERC projects.

CERC Enabled Collaborations (cont.)

- TA6 created a wiki-style repository of datasets, including GPS travel data and grid data from China, accessible by CERC researchers, including industrial members
- On the Chinese side, significant collaboration with industrial partners on battery research



Outline

- Goals and success metrics
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- Highlights of research results
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- Expected outcomes by end-of-fifth year

Expected Outcomes

- High quality research
  - ~100 journal papers, ~200 conference papers, 60 doctoral students, ~50 IPs
- Tight US-China collaboration
  - ~ 40 Joint publications, ~10 Joint IPs
- Tight academic-Industrial partnerships
  - Battery user-facility, CV model, analysis and design tools library, battery testing standard, GHG and FE, LCA tools for next EPA label and standards, continued collaboration beyond CERC
- Technology transfer
  - Commercialization of several CERC-CVC inventions

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The Ultimate Stakeholders

3rd CERC-CVC annual meeting scheduled for Chongqing in August 2013

Appendix

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CERC-CVC Kick-Off Meeting

Ann Arbor, Michigan, Jan 20-21, 2011, 120 attendees

Initial framework of the six thrust areas of CERC-CVC defined.

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1st CERC-CVC Annual Meeting

Beijing, China, Oct 17-18, 2011, 200 attendees

20 China and US high level clean vehicle programs, followed by detailed research project reports

Joint Work Plan of 2012 discussed and formed.

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2nd CERC-CVC Annual Meeting

Ann Arbor, Michigan on August 27-28, 2012

- Project report, poster display
- Plan for 2013
- Focused discussion for industrial member participation
- Student exchange plan for 2013

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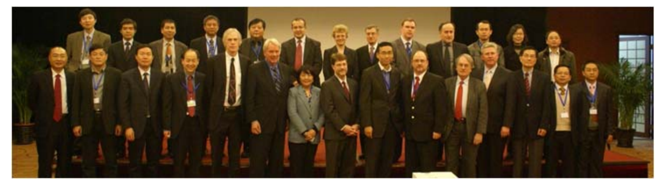
Six EVI Symposia Held

- September 2009 in Beijing, China

- September 2010 in Chicago, USA

- March 2011 in Beijing, China



- August 2011 in Chicago, USA

- April 2012 in Hangzhou, China

- August 2012 in Boston, USA

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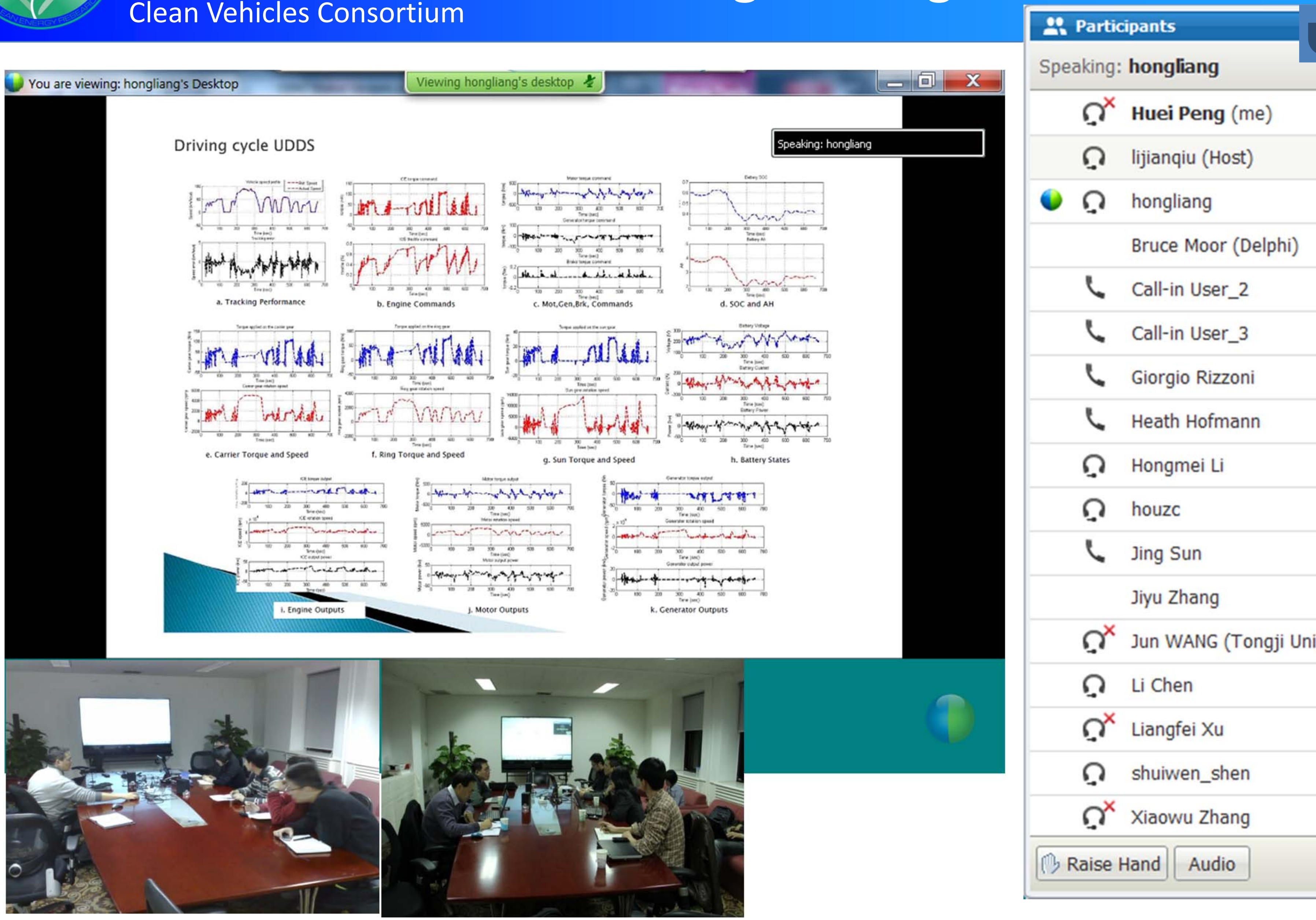
Monthly Thrust Area Technical Meetings Through WebEx



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2012 TA Meetings

2012

TA1 | TA2 | TA3 | TA4 | TA5 | TA6 | CVC

January

Mo	Tu	We	Th	Fr	Sa	Su
30	31					1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
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February

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27	28	29				

March

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April

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23	24	25	26	27	28	29

May

Mo	Tu	We	Th	Fr	Sa	Su
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28	29	30	31			

June

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25	26	27	28	29	30	

July

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August

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September

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24	25	26	27	28	29	30

October

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29	30	31				

November

Mo	Tu	We	Th	Fr	Sa	Su
			1	2	3	4
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26	27	28	29	30		

December

Mo	Tu	We	Th	Fr	Sa	Su
31					1	2
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10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Monthly TA Technical Meetings

- Examples showing TA3 presentations in 2012

No.	Date	Topic	Presenter	Affl.
1	2012-03-21	Computationally -Efficient Steady -State Solvers for Synchronous Machines.	Heath Hofmann	UM
2	2012-04-18	Electrical Variable Traction Transmission (EVTT) System Based on DMP Machine.	Longya Xu and Jin Wang	OSU
3	2012-04-18	Model-based State Estimation for Networked Systems	Xiao He	THU
4	2012-04-18	Research on a Battery Test Profile Based on Road Test Data from Hybrid Fuel Cell Buses	Xuning Fend Yang Minggao	THU
5	2012-05-16	Electric Drive Hazard Analysis	Simona Onori, Giorgio Rizzoni	OSU
6	2012-06-20	Development of a Novel Multi-mode Transmission for a HEV using a Single EM	Zhu Futang, Yin Chengliang	SJTU

TA3, 2012 (cont.)

No.	Date	Topic	Presenter	Affl.
7	2012-06-20	Design Methodology for Single Planetary Gear Power Split Hybrid Vehicles	Zhangxiao Wu Peng Huei Jing Sun	UM
8	2012-09-19	Modeling, Control, and Simulations for A Power-split Hybrid Electric Vehicle	Hongliang Yuan Jun Wang	TJU
9	2012-10-17	Full-automatic Code Generation Platform in VCU Development	Geng Peng, Li Jianqiu	THU
10	2012-11-21	Torque Coordination Control During Mode Transition for a Series Parallel Hybrid Electric Vehicle	Li Chen, Chengliang Yin	SJTU
11	2012-11-21	Study on Motor/Vehicle Suspension for Better NVH Performance of Electric Vehicle Driven by In-wheel Motors	Tong Wei, HOU Zhichao	THU

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Papers (red indicate joint papers)

- 1. Zhu Lei; Cheung C. S.; Zhang W. G.; Huang Zhen; Effect of charge dilution on gaseous and particulate emissions fro a diesel engine fueled with biodiesel and biodiesel blended with methanol and ethanol. APPLIED THERMAL ENGINEERING, 2011, 31(14-15):2271-2278.
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- 3. Haoyue Zhu, Stanislav V. Bohac, Kohei Nakashima, Luke M. Hagen, Zhen Huang, Dennis N. Assanis. Effect of biodiesel and ethanol on load limits of high efficiency premixed low temperature combustion in a diesel engine. Fuel (2012), http://dx.doi.org/10.1016/j.fuel.2012.10.073.
- 4. Dong Han, Andrew M. Ickes, Stanislav V. Bohac, Zhen Huang, Dennis N. Assanis. HC and CO emissions of premixed low-temperature combustion fueled by blends of diesel and gasoline. Fuel, 2012, 99: 13-19.
- 5. Ying Huang, Fuyuan Yang, Minggao Ouyang, Lin Chen, Xueqing Yang. Optimal Feedback Control with in-Cylinder Pressure Sensor under Engine Start Conditions, SAE2011-01-1422. EI: 20112714118883
- 6. Wu X., Yang F., Lu L., Ouyang M. Dynamic control for low cost auxiliary power unit of electric bus. 2011 International Conference on Electronic and Mechanical Engineering and Information Technology, EMEIT 2011. EI:20114014403139.
- 7. Li Wang, Xiangming He, Jianjun Li, Min Chen, Jian Gao, Changyin Jiang, Charge/Discharge Characteristics of Sulfurized Polyacrylonitrile Composite with Different Sulfur Content in Carbonate Based Electrolyte for Lithium Batteries, Electrochimica Acta, In Press, Available online, 7 April 2012.
- 8. Li Wang, Ning Li, Xiangming He, Chunrong Wan, Changyin Jiang, Macromolecule plasticized interpenetrating structure solid state polymer electrolyte for lithium ion batteries, Electrochimica Acta, Volume 68, 30 April 2012, Pages 214-219.
- 9. Li Wang, Wenting Sun, Jiangjun Li, Jian Gao, Xiangming He*,Changyin Jiang, Synthesis of Electrochemically Active $LiMnPO_4$ via $MnPO_4 \cdot H_2O$ with Different Morphology Prepared By Facile Precipitation, Int. J. Electrochem. Sci., 7, 2012, 3591-3600.

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Papers

- 10. Li Wang, Liwu Zhang, Jianjun Li, Jian Gao, Changyin Jiang, Xiangming He*, First-Principles Study of Doping in LiMnPO4, Int. J. Electrochem. Sci., 7 (2012) 3362-3370.
- 11. Keqiang Ding, Li Wang, Jianjun Li, Haitao Jia, Xiangming He, Influence of Carbon Sources on the Preparation of Li5Fe0.8Co0.2O4 and its Electrochemical Performance, Int. J. Electrochem. Sci., 7 (2012) 1611-1619.
- 12. Li Wang, Jishi Zhao, Xiangming He, Jianguo Ren, Haipeng Zhao, Jian Gao, Jianjun Li, Chunrong Wan, Changyin Jiang, Investigation of Modified Nature Graphite Anodes by Electrochemical Impedance Spectroscopy, Int. J. Electrochem. Sci., 7(2012)554-560.
- 13. Li Wang, Jishi Zhao, Xiangming He, Jian Gao, Jianjun Li, Chunrong Wan, Changyin Jiang, Electrochemical Impedance Spectroscopy (EIS) Study of LiNi1/3Co1/3Mn1/3O2 for Li-ion Batteries, Int. J. Electrochem. Sci., 7(2012) 345-353.
- 14. Ming Wang, Jianjun Li, Xiangming He, Han Wu, Chunrong Wan, The effect of local current density on electrode design for lithium-ion batteries, Journal of Power Sources, Volume 207, 1 June 2012, Pages 127-133.
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- 17. Yang G, Jiang CY, He XM, Ying JR, Gao J, Wan CR. Synthesis of Size-controllable LiFePO4/C Cathode Material by Controlled Crystallization. Journal of New Materials for Electrochemical Systems 2012; 15:75.
- 18. Ye YH, Shi YX, Cai NS, Lee J, He XM. Electro-thermal modeling and experimental validation for lithium ion battery. Journal of Power Sources 2012; 199:227.
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Papers (red indicate joint papers)

- 21. Wang L, Zhao JS, He XM, Wan CR. Kinetic investigation of sulfurized polyacrylonitrile cathode material by electrochemical impedance spectroscopy. Electrochimica Acta, 2011; 56:5252.
- 22. Huang JJ, Wang XF, Liu JF, Sun XM, Wang L, He XM. Flexible Free-Standing VO(2)(B) Nanobelt Films as Additive-Free Cathode for Lithium-Ion Batteries. International Journal of Electrochemical Science 2011; 6:1709.
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- 29. Wu Feng, Chen Rejie, Xiang Jin,, et.al. Physicochemical properties of new binary protic ionic liquids based on 2-Imidazolidone and trifluoroacetic acid. Journal of The Electrochemical Society. 2011, v.11; G227-G230.
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Papers

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- 33. Wu Feng, Xiang Jin,ChenRenjie et.al. The Structure-Activity Relationship and Physicochemical Properties of Acetamide-Based Bronsted Acid Ionic Liquids. J. Phys. Chem. C.2010, v.114: 20007-20015.
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Papers

- 42. Wu Feng，Chen Rejie，Xiang Jin,, et.al. Physicochemical properties of new binary protic ionic liquids based on 2-Imidazolidone and trifluoroacetic acid. Journal of The Electrochemical Society. 2011, v.11: G227-G230.
- 43. Wu Feng, Tan Guoqiang, Chen RenJie et.al. Novel Solid-State Li/LiFePO4 Battery Configuration with a Ternary Nanocomposite Electrolyte for Practical Applications. Advanced Materials. 2011, v.23: 5081-5085.
- 44. XinBaoping, Chen Bing et.al. Extraction of manganese from electrolytic manganese residue by bioleaching. Bioresource Technology. 2011, v.102: 1683-1687.
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Invention Disclosure and Patents (U.S. side)

TA	Project	Inventor	Org	Disclosure Number	Title
3	1	Hofmann	UM	5115	A voltage-driven, two-dimensional steady-state finite-element solver for the analysis of synchronous machines.
1	2	Siegel	UM	5597	Improved Performance in Rechargeable Metal-air Batteries via Fermi-Level Tuning
3	3	Peng/Sun	UM	5521	New configurations of power split hybrid vehicles using a single planetary gear
5	6	Sun/Peng	UM	5519	On-board State of Health Monitoring of Lithium-ion Batteries Using Incremental Capacity Analysis with Support Vector Regression
4	4	Saitou	UM	5536	A Tool to Assist in the Manipulation of a Vehicle FE model without Editable CAD Models
2	4	Wang	OSU	2013-098	Engine onboard fuel property identification method using common rail pressure signal
2	8	Heremans	OSU	2013-086	Aluminum as a resonant level in p-type CoSb3
1	2	Van der Ven	UM	-	New concept for a rechargeable metal air battery
4	2	Ni	UM	-	Hybrid Friction Stir Welding for dissimilar materials through Electro-Plastic Effect

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Personnel Exchange

- ~40 short-term visits in 2011
- ~40 short-term visits in 2012
- Long-term exchange started in 2011

	Name	Status	Research interests	Date
1	Caihao Wang	PhD Candidate (UM)	Battery management system	05/11-06/11
2	Xiankun Huang	PhD Candidate (THU)	Battery Chemistries	07/11-08/12
3	Hongmei Li	Professor (Hefei)	Diagnosis and Prognosis	05/12-11/12
4	Xiaowu Zhang	PhD Candidate (UM)	Power-split hybrid vehicles	06/12-06/12
5	Xianli Su	PhD Candidate (WUT)	Thermalelectric materials	09/10-07/12
6	Lily Zhang	Assistant Prof. (WUT)	Thermalelectric materials	02/11-01/12
7	Xuerei Ma	PhD Candidate (SJTU)	Configuration of power-split hybrid vehicles	12/12-12/13
8	Mingxuan Zhang	Pre-admission (THU)	Powertrain control	01/13-02/13
9	Cong Hou	PhD Candidate (THU)	Component size optimization for parallel PHEV	06/13-08/13
10	Yugong Luo	Associate Prof. (THU)	Vehicle-Grid Integration	08/13-08/14
11	Xuning Feng	PhD Candidate (THU)	Battery safety	12/13-12/14
12	Ziyou Song	PhD Candidate (THU)	Auxiliary energy capacitor	12/13-12/14

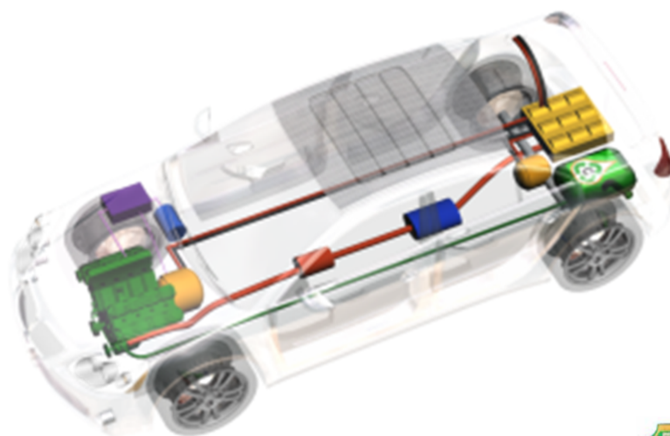
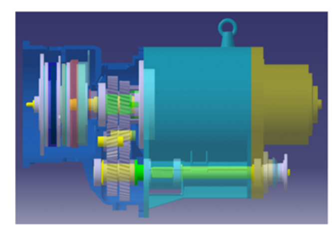
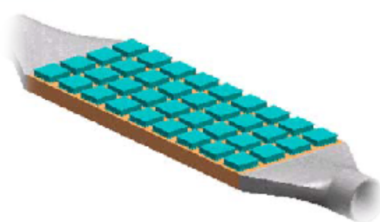
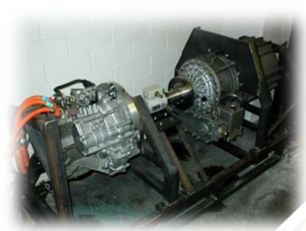
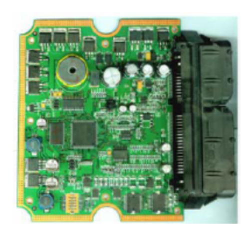
Personnel Exchange

	Name	Status	Research interests	Date
13	**HeWu Wang**	Associate Prof. (THU)	Energy Policy	2011.9-2012.9
14	**Ingrid Bonde Akerlind**	Master student (MIT)	Chinese auto market and policy	1month at THU
15	**Valerie Karplus**	Researcher (MIT)	Energy and climate, visited THU	
16	**Xunming Ou**	Assistant Prof. (THU)	Energy policy, visited MIT	
17	**Dawn Manley**	Researcher (SNL)	Energy policy, visited THU	
18	**Hong Huo**	Associate Prof. (THU)	Energy Policy, visited ANL for 4 months	
19	**Lei Zhu**	Ph.D. student (CAS)	EV/HEV motor drive, visited OSU	2011.12-2012.5
20	**Li Chen**	Associate Prof. (SJTU)	Modeling of Li-ion battery packs, visited OSU	2012.04-2012.11
21	**Jianqiang Kang**	Assistant Prof. (WUT)	Thermal and electrochemical modeling of Li-ion batteries, visited OSU	2012.09-

Research Highlights—TA3

Vehicle Electrification Goal

- To develop new concepts, models, methodologies, and tools to construct, analyze, design and simulate key components of electrified vehicles, and to study their controls and integrations.

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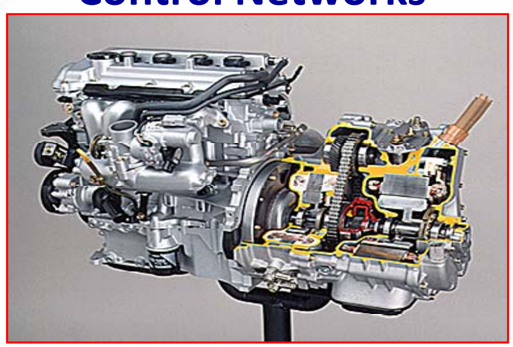
Projects and Participations

US	
Jing Sun	UM
Heath Hofmann	UM
Huei Peng	UM
Giorgio Rizzoni	OSU
Jin Wang	OSU
Longya Xu	OSU
Simona Onori	OSU

China	
Jianqiu Li	THU
Minggao Ouyang	THU
Zhichao Hou	THU
Jun Wang	TJU
Liangfei Xu	THU
Geng Yang	THU
Chengliang Yin	SJTU
Zaimin Zhong	TJU
Xuhui Wen	CAS-IEE
William CAI	JJE

Components Design and Optimization

Powertrain Control and Distributed Vehicle Control Networks



System Integration Technologies

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Collaborations and Interactions

- Collaboration/Exchange activities:
  - Visits/seminars
  - Student exchanges
- Industrial collaborations
  - Monthly WebEx meeting participation
  - Exchange/training of design tools
  - Annual conference presentations:
    - Presentations from Ford and Delphi

TA#3 Project 1: Efficient and high-power density electric powertrain

Collaborators: Xu, Wan (OSU), Hofmann (UM), Wen, Fan (CAS)

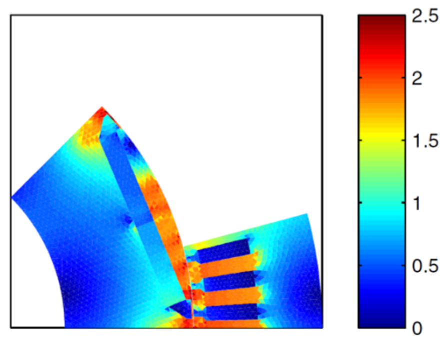
Research Objectives

- Develop innovative and optimized electric machines and drives to achieve electrified powertrain with significantly higher power density and efficiency.

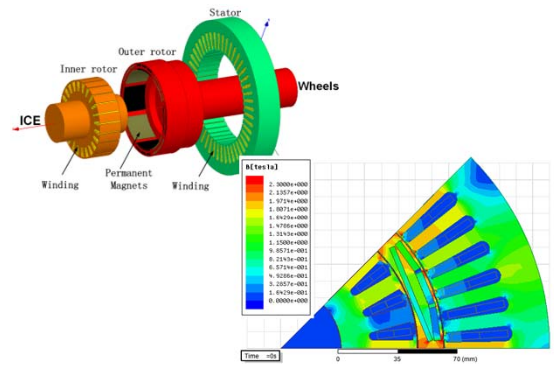
Technical Approach

- Development of computationally-efficient finite element tools for the steady-state analysis of electric machines (UM)
- Development of EVTT dual-mechanical port electric machine concept for electric vehicle and hybrid electric vehicle applications. (OSU)
- Model the unique features in amorphous alloy such as saturation, non-sinusoidal excitation and high-frequency eddy current effect (CAS)
- Design optimal permanent magnet machine using the above magnetics models (CAS)

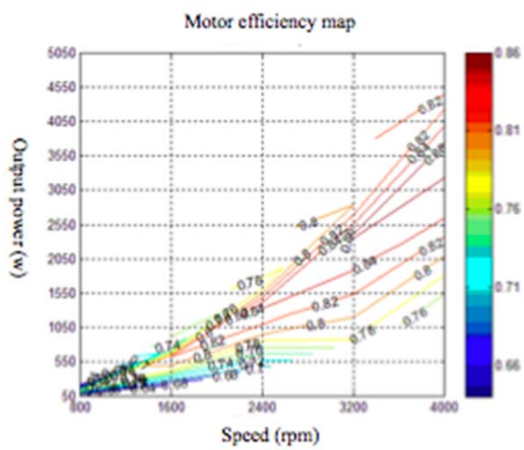
Initial Results

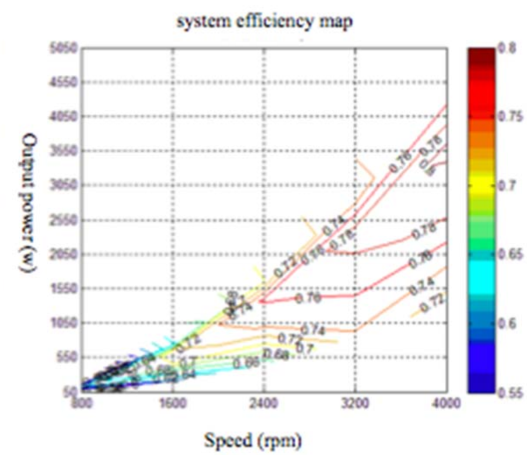


Computationally-efficient 2-D FEA steady-state solver



Simulation of EVTT machine and drive.





Permanent magnet motor with amorphous alloy laminations has been built and tested.

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TA#3 Project 2: Control and optimization of distributed vehicle network

Collaborators: Li, Xu (Tsinghua), Wang, Zhong (Tongji), Yin (SJTU), Peng (UM)

Research Objectives

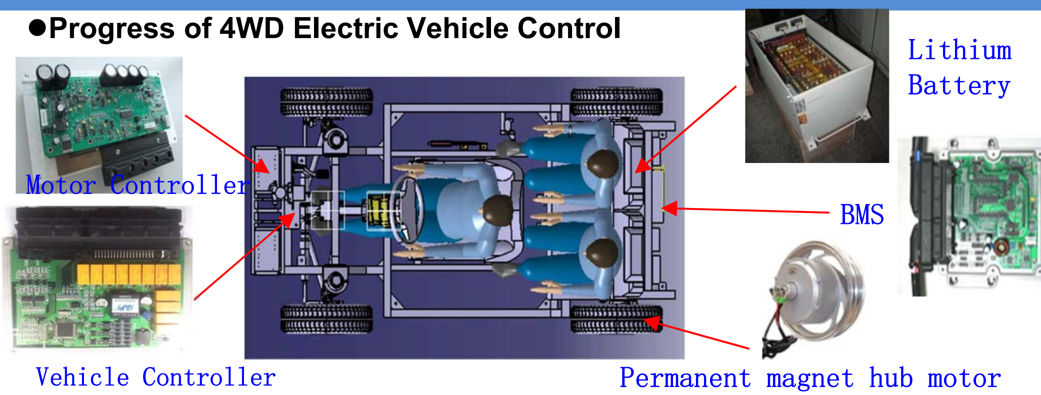
Develop hardware solutions, design tools, and control strategies to optimize distributed vehicle network architecture and information management system for electrified vehicles.

Technical Approach

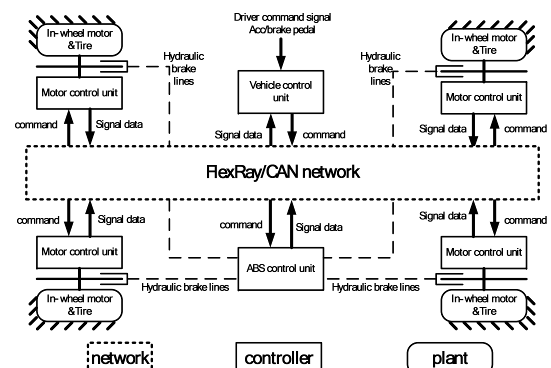
- Develop advanced hardware/software platforms, in-vehicle network control systems, and inter-vehicle communication and monitoring systems.
- Develop optimal cooperative control among multiple power sources for the driving and braking processes
- Develop optimal power management for power-train systems with global positioning systems (GPS) and inertial navigator systems (INS), targeting 10% fuel economy improvements.
- This project will be led by Chinese partners, in collaboration with U.S. CERC members.

Initial Results

● **Progress of 4WD Electric Vehicle Control**



Initial development completed for :four-wheel independent driving control, vehicle control system evaluation, hub motor drive control, and battery management system development



- FlexRay communication system design completed and prototype built
- Software architecture for automatic code generation from Matlab/Simulink model completed
- Initial design of a new generation vehicle controller unit based on MPC5644

TA#3 Project 3: System integration technologies for improved efficiency, safety, reliability and NVH performance

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Collaborators: UM (Peng, Sun); OSU (Rizzoni, Onori); Tsinghua (Li, Xu ,Yang, Hou); SJTU (Yin, Zhu, Chen)

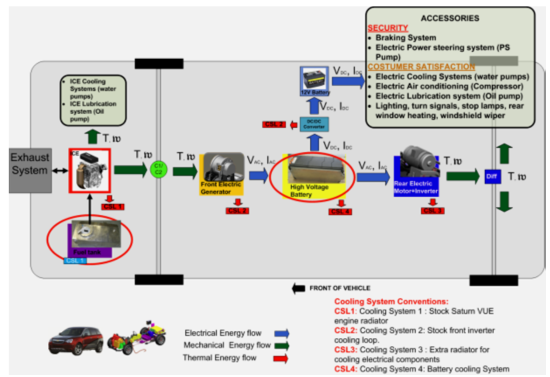
Research Objectives

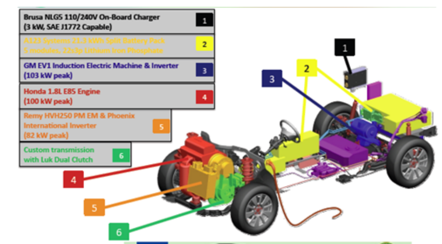
Develop new concepts and tools for modeling, design and analysis for control and diagnosis of electric power-trains to enable rapid integration and optimization.

Technical Approach

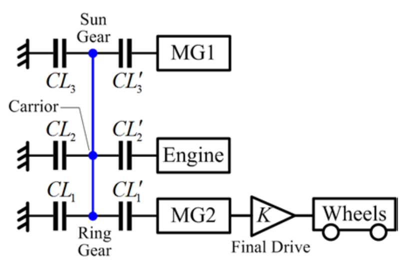
- Develop a systematic, top-down design and analysis framework for conceptual design, analysis, and evaluation.
- Development of a modular and hierarchical model structure to facilitate configuration optimization and trade-off analysis.
- Combined model-based investigation and experimental verification for intelligent diagnosis and prognosis.
- NVH and safety analysis for components and subsystems.
- Identify key vehicle operating modes
- Development of a state machine diagram
- Case study on the control and diagnosis of vehicles

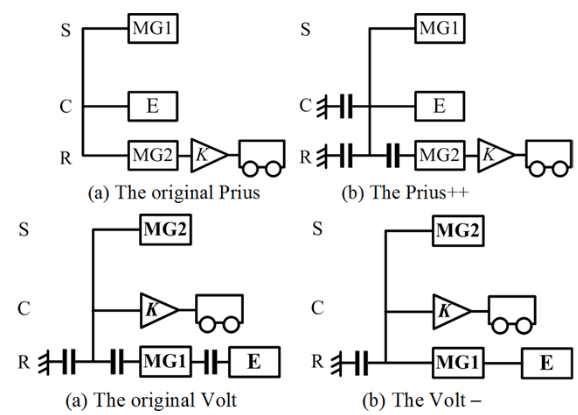
Initial Results





A complete Hazard Analysis along with Failure Mode and Effects Analysis (FMEA) and Failure Tree Analysis (FTA) for clean vehicles powertrains





Thorough analysis of all possible configurations of power-split hybrid powertrain that use a single planetary gear. Dynamic Programming to identify best execution

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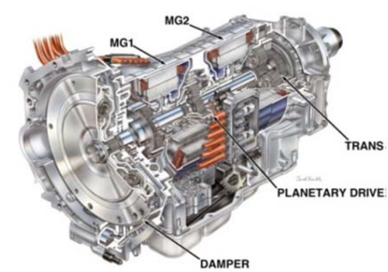
Deep Dive: Configuration optimization and component sizing

Methodology Development

- Needs: Multiple design decisions on component sizes and subsystem selections
- State-of-the-art: DP (Dynamic Programming) used for hybrid vehicle sizing, but it is computationally expensive and subject to “curse of dimensionality”
- PEARS (Power-weighted Efficiency Analysis for Rapid Sizing):
  - Combines statistical information in optimization and efficiency analysis
  - Highlights sensitivities of overall cycle efficiencies to size parameters
  - Provides a much faster method for sizing: over **5000** times faster without compromising optimality!
  - Deals with several design variables such as MG sizes, Final drive and R:S



Procedure

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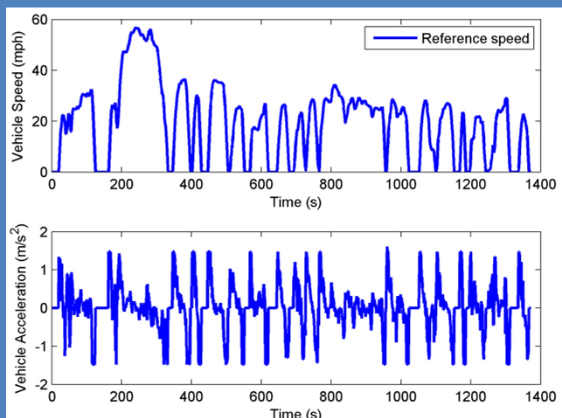
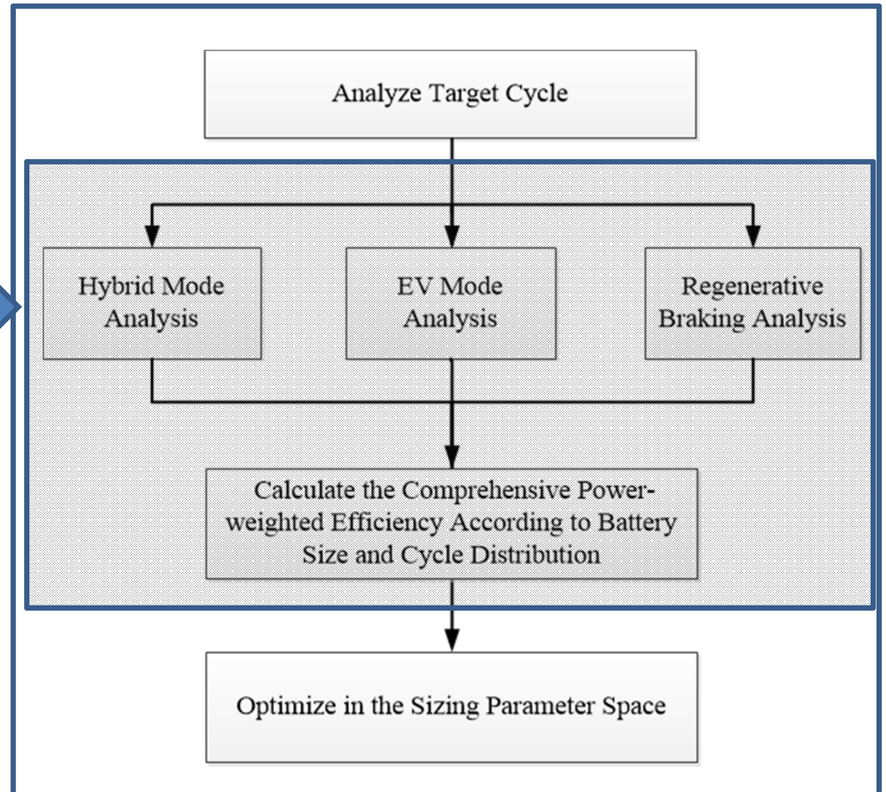
Deep Dive: Configuration optimization and component sizing

Vehicle Parameters

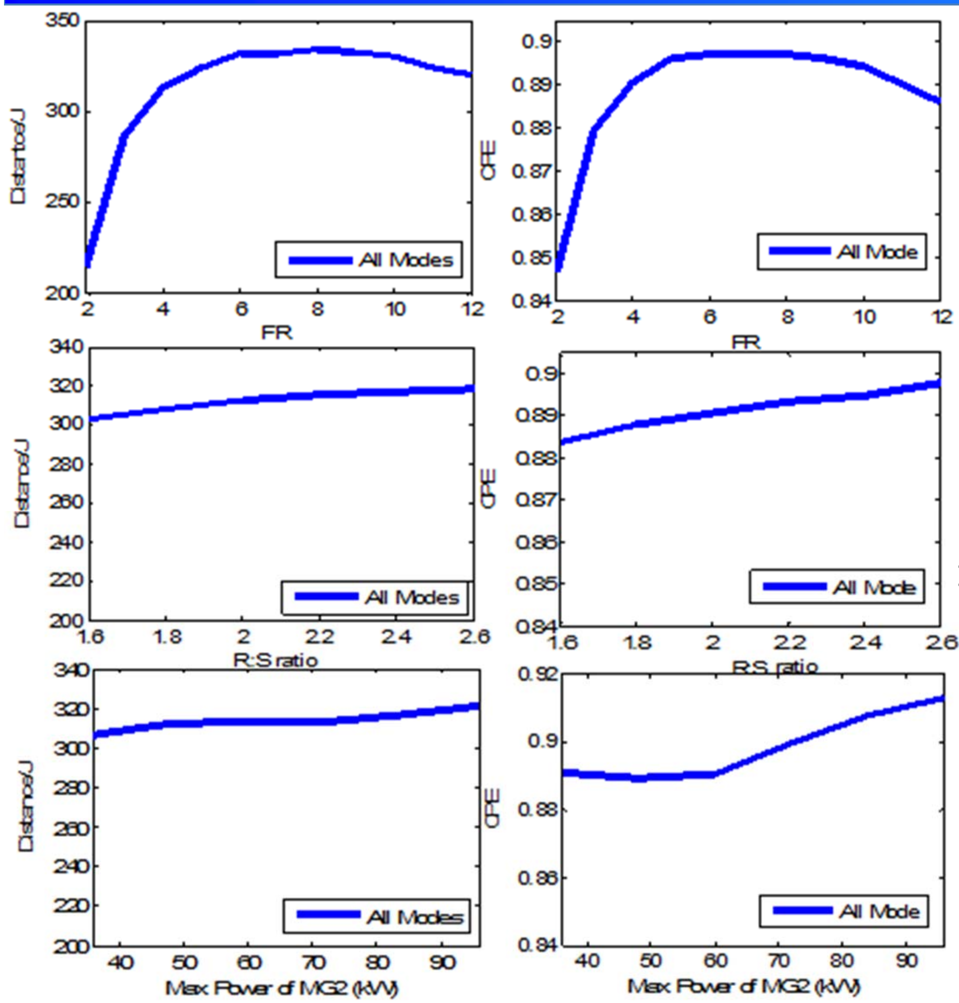


Cycle Information



Optimized Sizing Parameters

Deep Dive: Configuration optimization and component sizing

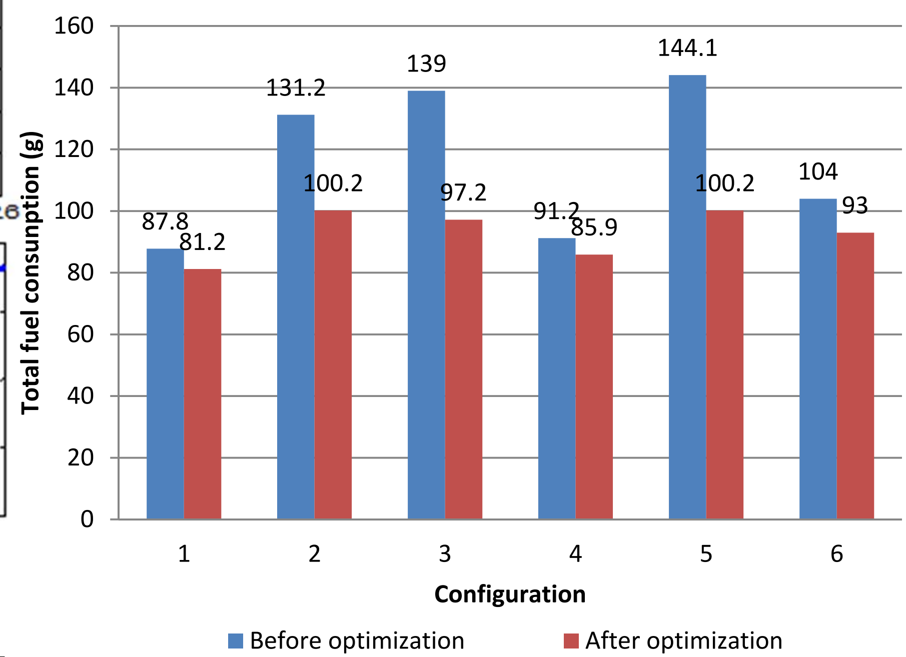


DP PEARS

DP v.s. PEARS verification is performed along 3 design dimensions

The Prius parameter is used as the baseline for each configuration study. After executing PEARS, best designs are identified and the corresponding fuel consumptions are calculated by DP.

Optimization Results in FUDS32



Research Highlights—TA4

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TA#4 LIGHTWEIGHT STRUCTURES
MULTI-MATERIAL LIGHTWEIGHT BODY SUBSYSTEM OPTIMIZATION

Karim Hamza (UM); Kazuhiro Saitou (UM)

Research Objectives

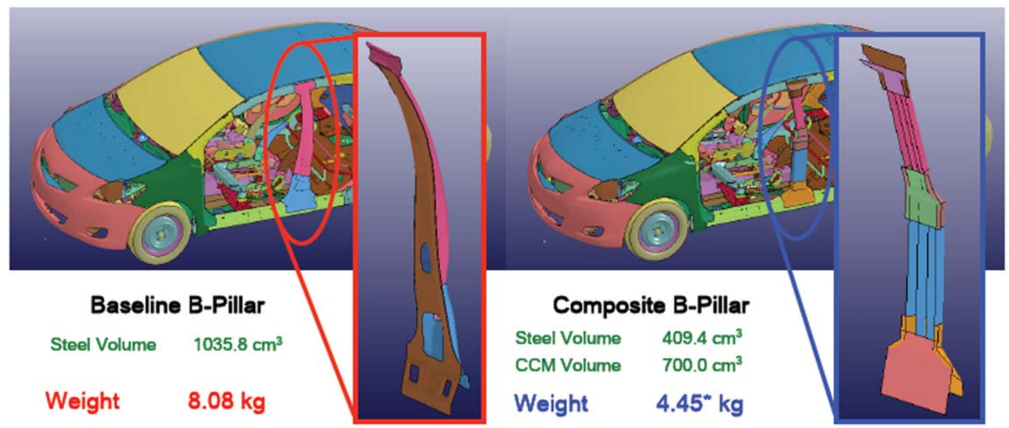
- Develop a methodology for economically integrating components made of lightweight materials in vehicle structure with maximum weight reduction benefit

Technical Approach

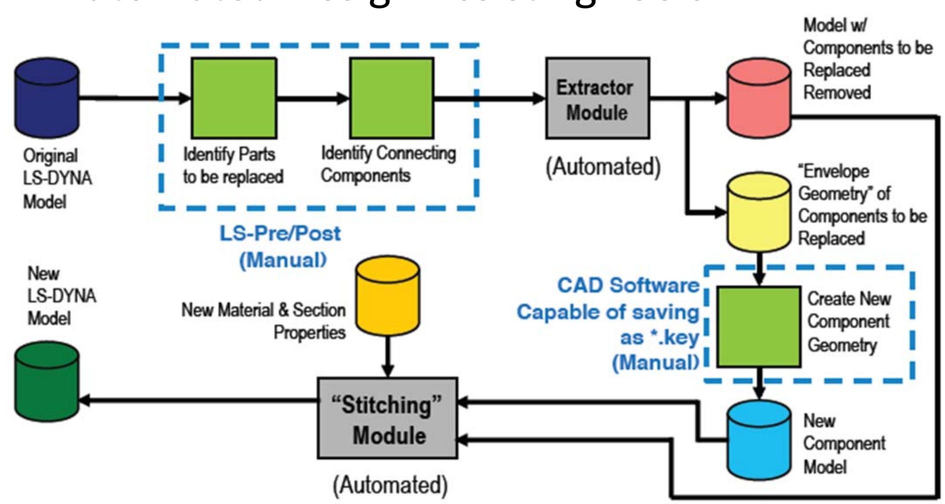
- Applying lightweight materials in key structural subsystems while maintaining crash performance.
- Optimize under constraints imposed by manufacturing and joining processes
- Benchmark with a public-domain Finite Element model of 2010 Toyota Yaris
- Initial focus: carbon fiber-reinforced composite B-pillar

Achievements

Design Modifications



Semi-Automated Design Assisting Tools



TA#4 LIGHTWEIGHT STRUCTURES
JOINING MULTI-MATERIAL VEHICLE STRUCTURES WITH HYBRID FRICTION STIR WELDING PROCESS

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Jun Ni (UM); LAI Xinmin (SJTU)

Research Objectives

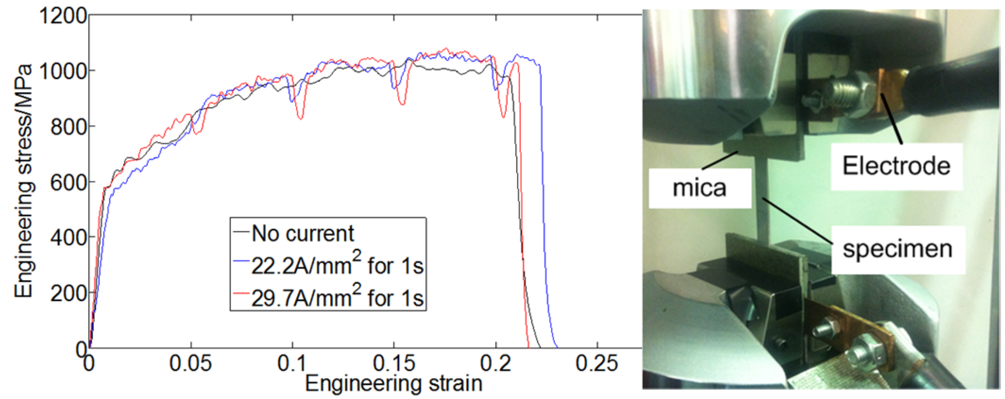
- Development of a hybrid Friction Stir Welding process to enhance joint quality for dissimilar materials, enlarge processing window and increase tool life

Technical Approach

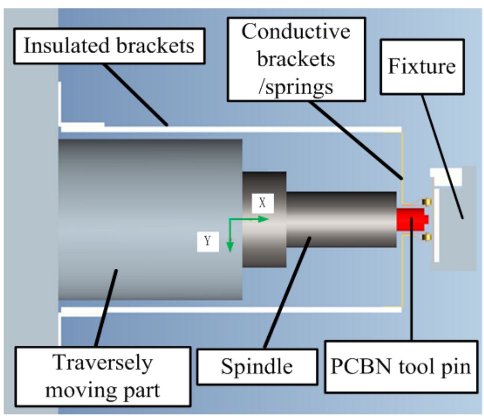
- Investigate the effectiveness of Electro-Plastic Effect on various types of light weight materials
- Develop constitutive material model for Electro-Plastic Effect
- Integrate Electro-Plastic Effect into Friction Stir Welding process
- Develop Finite Element Model considering the electrical energy based on the material model developed before
- Optimize process parameters

Achievements

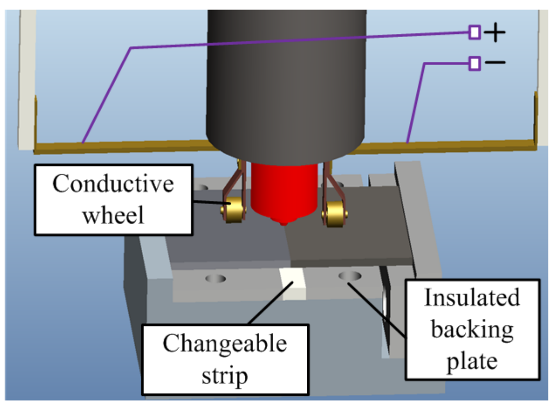
Material behavior test on Electro-Plastic Effect



Hybrid Friction Stir Welding based on Electro-Plastic Effect



Overview of the CAD model



Partially magnified view

TA#4 LIGHTWEIGHT STRUCTURES
STRUCTURAL CONFORMAL INTERFERENCE JOINING FOR MULTI-MATERIAL VEHICLE STRUCTURES

Nolan Windholtz (OSU), Geoff Taber (OSU), Andrew Sattler (OSU), Anthony Luscher (OSU), Glenn Daehn (OSU)

Research Objectives

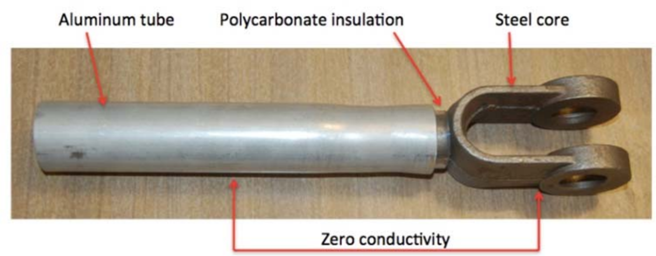
- Use high-speed conformal interference joining to assemble dissimilar metals
- Develop the engineering science both behind the manufacturing process and the assembly performance

Technical Approach

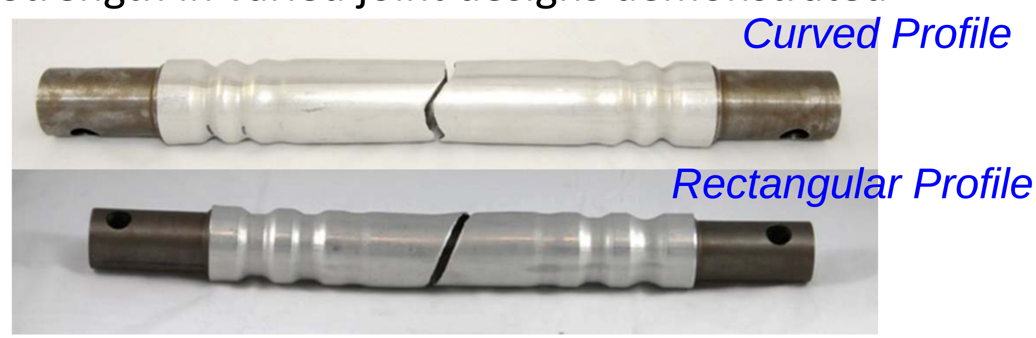
- Use insulating layer between dissimilar metals.
- Explore axial and torsional strength in static loading and fatigue for round geometries with insulation.
- Explore development of non-axis symmetric shapes.
- Develop clear design methodology

Achievements

Introduced galvanically isolating polycarbonate layer between dissimilar metals. Maintains insulating properties without cutting. Layers can be as little as 0.005” thick and appear to give great mechanical properties.



Strength in varied joint designs demonstrated



Design of joints with torsional and axial strength properties

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TA#4 LIGHTWEIGHT STRUCTURES
AERODYNAMIC STYLING DESIGN FOR ELECTRIC-VEHICLE

YANG Zhigang (TJU), ZHU Hui (TJU), WANG Yigang (TJU), LI Qiliang(TJU)

Research Objectives

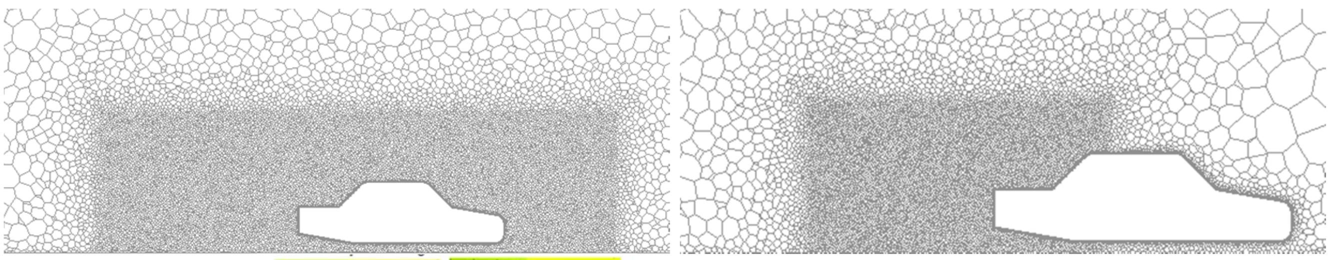
- Significant reductions in aerodynamic drag of EV
- Aesthetic design of EV
- A new style with low CD and fine appearance

Technical Approach

- CFD
- Drawing
- CAD

Achievements

Grid independence and scheme research for simulating aerodynamic drag of notchback MIRA model



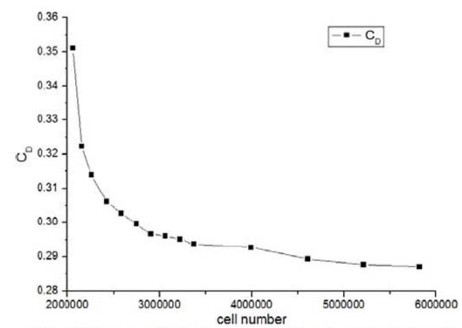


Fig. 9 Drag coefficient curve of refined polyhedral mesh around the model

Numerical Analysis on Effect of Vehicle Length on Automotive Aerodynamic Drag

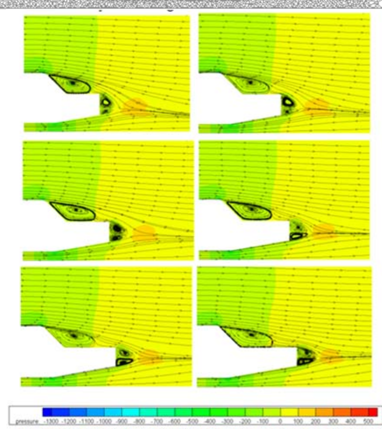


Fig. 8 Contors and streamlines of six models at y=0 plane

Numerical Analysis on Effect of Back/Front Windshield and Hood angle on Automotive Aerodynamic Drag

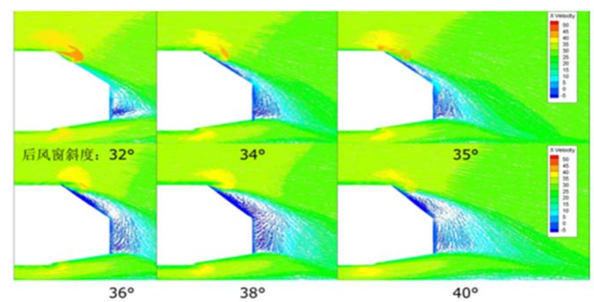


Fig. 6 .middle section velocity vector contour

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TA#4 LIGHTWEIGHT STRUCTURES STUDY OF CRASH SAFETY OF SMALL LIGHTWEIGHT EV

ZHOU Qing (THU), XIA Yong (THU), TANG Liang (THU)

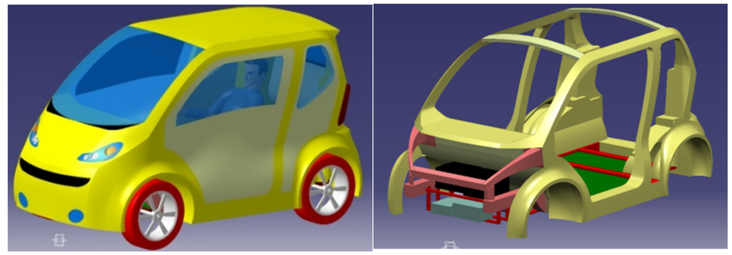
Research Objectives

Study of influence of structural design parameters and applications of lightweight materials for crash safety of small lightweight EV

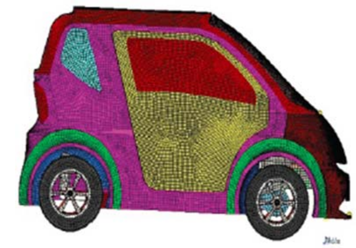
Technical Approach

- Define parameters of a study vehicle
- Build parameterized finite element model for crash analysis
- Crash simulations and analyses
- Material selection for small lightweight EV body
- Deformation and failure modeling methods for lightweight materials and structures and design countermeasures
- Preliminary study of crashworthiness of EV battery

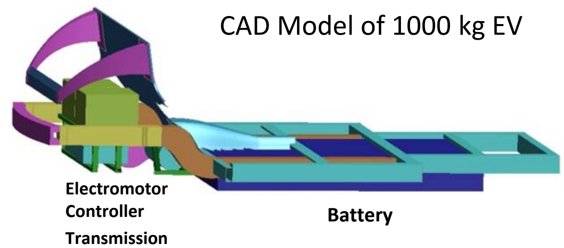
Achievements

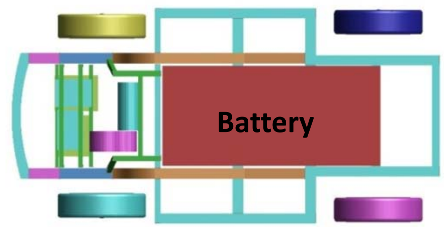


CAD Model of 1000 kg EV



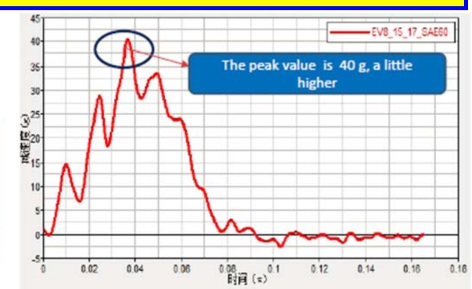
Finite Element Model





Influence of mass distribution of the battery and passengers on crash performance
Influence of using lightweight material on mass reduction and vehicle safety

Load path of crash force



The parameters that influence the crash pulse
- The height of the center of mass
- The thickness and structure of the front rail
- The thickness of the A pillar
- The thickness of the front wheel cover board
- The mass distribution of the battery

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TA#4 LIGHTWEIGHT STRUCTURES MANUFACTURING AND ASSEMBLY PROCESSES OF LIGHTWEIGHT CAR BODY

LAI Xinmin (SJTU), Li Yongbin (SJTU), YU Zhongqi (SJTU)

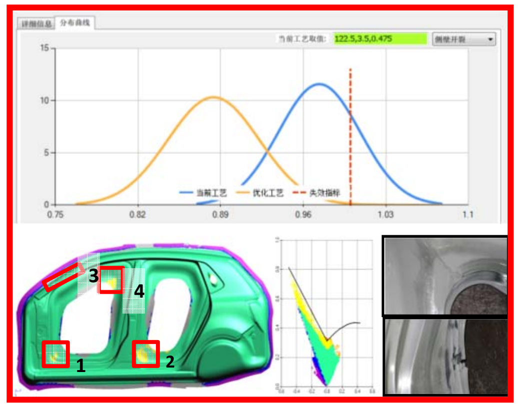
Research Objectives

•Study of advanced forming and joining processes of lightweight materials
•Assembly variation prediction and control of car body

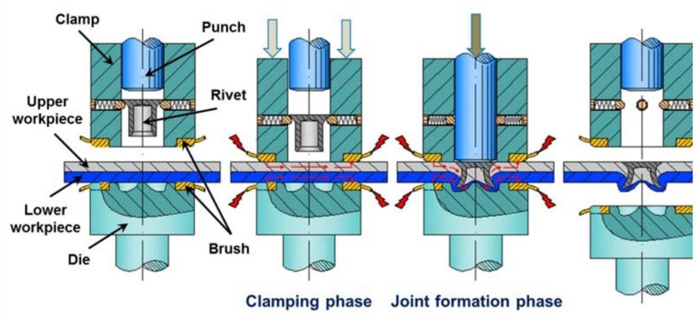
Technical Approach

•Study on stamping of AHSS & UHSS
– Statistical analysis and prediction model of HSS properties
– Robust optimization of forming process
•Electro-Plastic Self-Piercing Riveting
– Construction of EP-SPR Prototype system
– Study of EP-SPR mechanism
– Application of EP-SPR method to AHSS and Magnesium
•Modeling and Prediction of Assembly Variation for Lightweight Vehicle Bodies
– Multi-materials auto body assembly variation prediction method
– Lightweight auto body assembly fixture robust design under low cost manufacturing mode

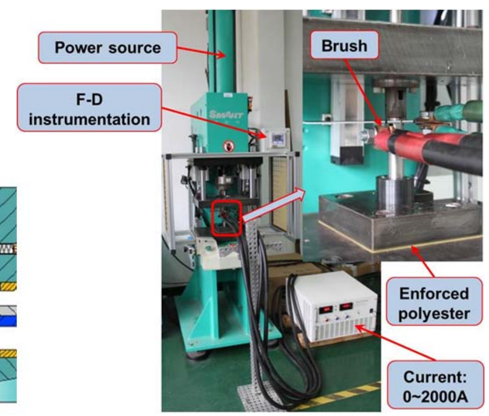
Achievements

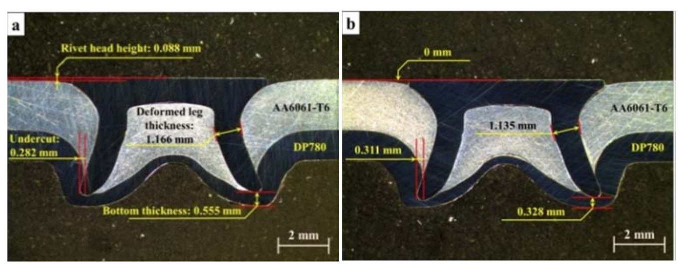


▪Develop agent model of sheet forming process in robust design
▪Develop an application software "Robust Design of Stamping Process"
▪Using the robust design software to solve engineering problem

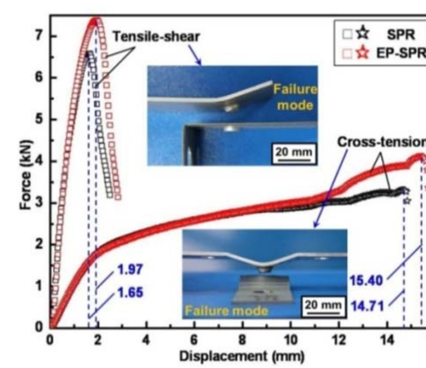


Schematic diagram of EP-SPR system





Traditional SRP EP-SRP



U.S.–China Clean Energy Research Center
中美清洁能源研究中心
Clean Vehicles Consortium

TA#4 LIGHTWEIGHT STRUCTURES
HIGH VACUUM DIE CASTING AND SQUEEZE CASTING

Collaborators: LIU Baicheng (THU), XIONG Shoumei (THU), HAN Zhiqiang (THU)

Research Objectives

•To develop high vacuum die casting and squeeze casting technologies and develop simulation technologies to support the manufacturing of aluminum and/or magnesium components for electric vehicles

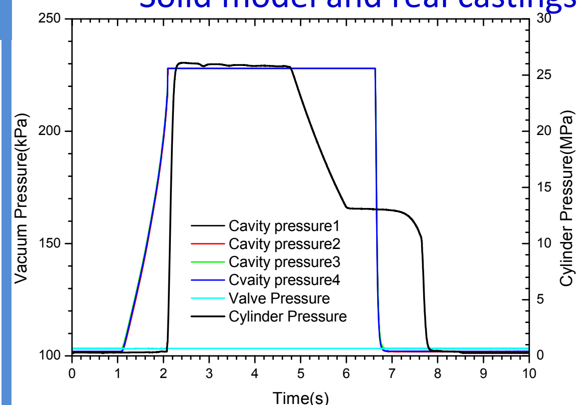
Technical Approach

•Develop a high vacuum die casting system, where the pressure in the mold can achieve less than 10 kPa within 1.5 s.
•Establish an experimental platform for squeeze casting of aluminum and/or magnesium alloys.
•Investigate the process-structure-property of high vacuum die casting and squeeze casting of aluminum and/or magnesium alloys.
•Develop numerical simulation technologies for high vacuum die casting and squeeze casting.

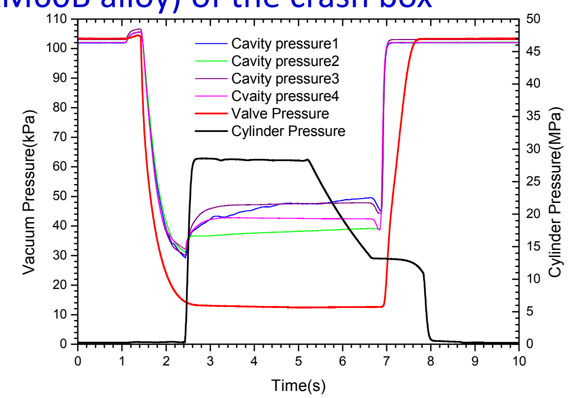
Achievements

A Crash Box test casting was designed and developed under vacuum die casting condition

Solid model and real castings (AM60B alloy) of the crash box

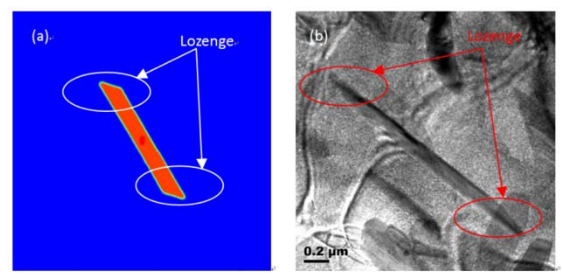


Back pressure in the cavity under convention die casting condition



Vacuum pressure in the cavity under vacuum die casting condition

Development of experiment station



Development of microstructure model for heat treatment of squeeze casting