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 Vehicles Consortium (CVC)

Report to Steering Committee

OUYANG Minggao (China Director, Tsinghua University)

Huei Peng (US Director, University of Michigan)

July 11, 2014

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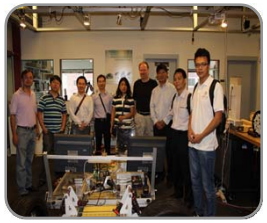
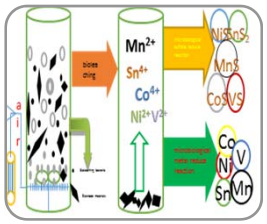
Outline

Consortium overview



Cooperation and exchange



Summary of outcomes

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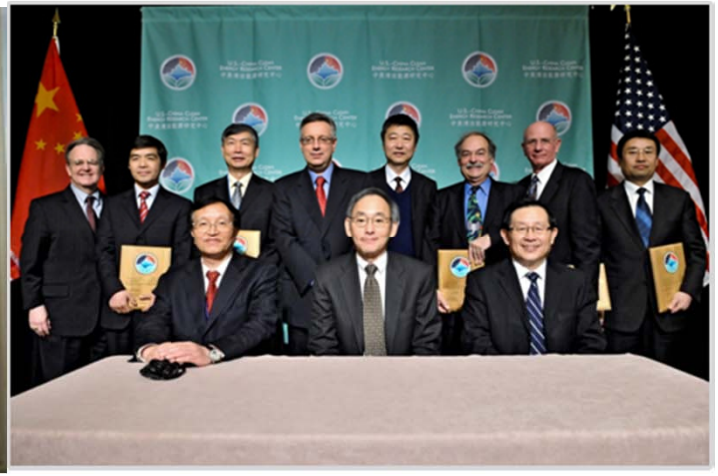
Background

Nov. 2009, joint China-U.S. statement and CERC Protocol are issued.



Jan. 2011, CVC Joint Work Plan was signed.

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CERC-CVC Funding Summary

DOE Funding: $2.5M/year for 5 years

- Approx. 25 research project tasks; more than 20 faculty and 20 graduate students at UM and partner schools and national labs

University + Industry Funding: >$2.5M/year for 5 years

- Additional research projects
- In-kind support for CERC-CVC test beds
- Support for center administration and collaboration
  - Full time manager
    - Full-time consortium manager & administrative support
    - Travel for consortium members to enhance collaboration with Chinese partners

US-China Clean Energy Research Collaboration on cutting-edge technology development of electric vehicle 2010.1-2013.12

Communication platform and basic technology research for U.S.-China EV 2011.1-2014.6

Energy and powertrain technologies of low carbon vehicle researching collaboration between THU and ANL 2011.10-2014.9

Key technology joint research on the next generation electric drive vehicle 2015---

2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017

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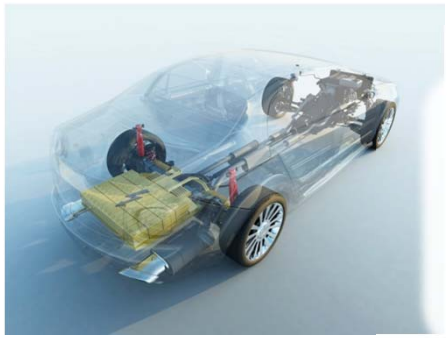
CERC-CVC Thrust Areas

1. Advanced Batteries System

4. Lightweight Structures

2. Advanced Biofuels, Clean Combustion and APU

5. Vehicle-Grid Integration



3. Vehicle Electrification

6. Energy Systems Analysis, Technology Roadmaps and Policies

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Consortium Overview

Academic & National Lab Partners

U.S.

University of Michigan
The Ohio State University
Massachusetts Institute of Technology
Sandia National Laboratories
Oak Ridge National Laboratory
Argonne National Laboratory
jbei Joint BioEnergy Institute

China

Tsinghua University
Tianjin University (Peiyang University)
Beijing Institute of Technology
Tongji University
Wuhan University of Technology
Chinese Academy of Sciences
Beihang University
Hunan University

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Industrial Partners

U.S.

Ford DELPHI DENSO EATON

TOYOTA HONDA pjm TE connectivity Aramco Services Company

China

SAIC GEELY JAC CAERI CATARC 上汽通用五菱 SGMW

LISHEN Potevio JJE ECTEK KeyPower 科易动力

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Organization

Director:
Huei Peng

Deputy Director:
Jun Ni

Director:
OUYANG Minggao

Deputy Director:
Wang Hewu

Deputy Director:
Qiu Xinping

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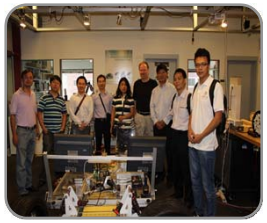

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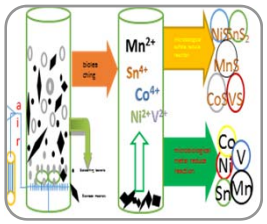

Summary of outcomes

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CERC-CVC Meetings

Kick-off meeting, Michigan, Jan 2011

1st annual meeting, Beijing, Oct 2011

2nd annual meeting, Michigan, Aug 2012

3rd annual meeting, Beijing, Aug 2013

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US-China Electric Vehicle and Battery Workshop

- 1st:September 2009 in Beijing, China
- 2nd:September 2010 in Chicago, USA
- 3rd:March 2011 in Beijing, China
- 4th:August 2011 in Chicago, USA
- 5th:April 2012 in Hangzhou, China
- 6th:August 2012 in Boston, USA
- 7th:April 2013 in Berkeley, USA
- 8th:September 2013 in Chengdu, China







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Upcoming Events

4th CVC annual meeting

Ann Arbor, Michigan **August 11 and 12, 2014**

9th battery meeting, Seattle, August 18-20, 2014

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Technical Conference Calls

59 meetings in 2013 (mostly by individual TA)

TA1 TA2 TA3 TA4 TA5 TA6 CVC

JANUARY 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1		1	2	3	4	5	6
2	7	8	9	10	11	12	13
3	14	15	16	17	18	19	20
4	21	22	23	24	25	26	27
5	28	29	30	31			

FEBRUARY 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
5					1	2	3
6	4	5	6	7	8	9	10
7	11	12	13	14	15	16	17
8	18	19	20	21	22	23	24
9	25	26	27	28			

MARCH 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
9					1	2	3
10	4	5	6	7	8	9	10
11	11	12	13	14	15	16	17
12	18	19	20	21	22	23	24
13	25	26	27	28	29	30	31

APRIL 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
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15	8	9	10	11	12	13	14
16	15	16	17	18	19	20	21
17	22	23	24	25	26	27	28
18	29	30					

MAY 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
18			1	2	3	4	5
19	6	7	8	9	10	11	12
20	13	14	15	16	17	18	19
21	20	21	22	23	24	25	26
22	27	28	29	30	31		

JUNE 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
22						1	2
23	3	4	5	6	7	8	9
24	10	11	12	13	14	15	16
25	17	18	19	20	21	22	23
26	24	25	26	27	28	29	30

JULY 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
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28	8	9	10	11	12	13	14
29	15	16	17	18	19	20	21
30	22	23	24	25	26	27	28
31	29	30	31				

AUGUST 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
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33	12	13	14	15	16	17	18
34	19	20	21	22	23	24	25
35	26	27	28	29	30	31	

SEPTEMBER 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
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36	2	3	4	5	6	7	8
37	9	10	11	12	13	14	15
38	16	17	18	19	20	21	22
39	23	24	25	26	27	28	29

OCTOBER 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
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42	14	15	16	17	18	19	20
43	21	22	23	24	25	26	27
44	28	29	30	31			

NOVEMBER 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
44					1	2	3
45	4	5	6	7	8	9	10
46	11	12	13	14	15	16	17
47	18	19	20	21	22	23	24
48	25	26	27	28	29	30	

DECEMBER 2013

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
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49	2	3	4	5	6	7	8
50	9	10	11	12	13	14	15
51	16	17	18	19	20	21	22
52	23	24	25	26	27	28	29

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Personnel Exchange

~ 100 short-term visits, 25 long-term (> 30 days) visits planned or executed

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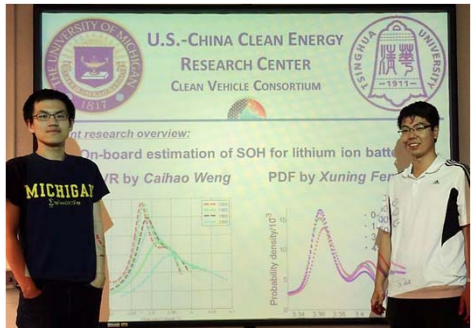
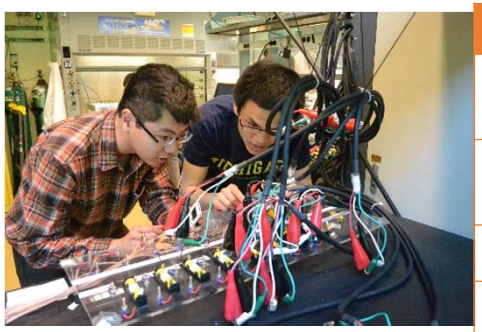
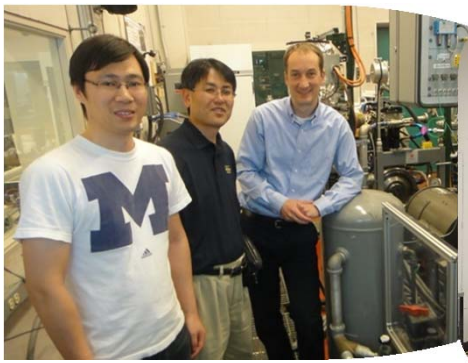
Personnel Exchange







	Name	Status	Research field	Date
1	Caihao Wang	Ph.D. student (UM)	BMS	05/11-06/11
2	Xiankun Huang	Ph.D. student (THU)	Battery chemistry	07/11-08/12
3	Hongmei Li	Professor (Hefei)	Diagnosis	05/12-11/12
4	Xiaowu Zhang	Ph.D. student (UM)	Hybrid powertrain	06/12-06/12
5	Xianli Su	Ph.D. student (WUT)	Thermal-electric	09/10-07/12
6	Lily Zhang	Asst. Prof. (WUT)	Thermal-electric	02/11-01/12
7	Xuerei Ma	Ph.D. student (SJTU)	Hybrid powertrain	12/12-12/13
8	Mingxuan Zhang	Ph.D. student (THU)	Powertrain control	01/13-02/13
9	Cong Hou	Ph.D. student (THU)	PHEV optimization	06/13-08/13
10	Yugong Luo	Assoc. Prof. (THU)	Vehicle-grid integration	08/13-08/14
11	Xuning Feng	Ph.D. student (THU)	Battery safety	12/13-12/14
12	Tze-You Song	Ph.D. student (THU)	Energy storage	12/13-12/14
13	Tanjin He	Ph.D. student (THU)	Biofuels	01/14-06/14
14	Lin-Jun Song	Asst. Professor (Beihang U.)	Wireless charging systems analysis	06/13-06/14

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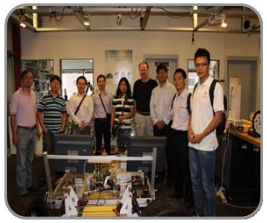

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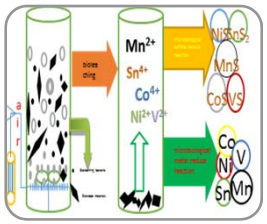

Summary of outcomes

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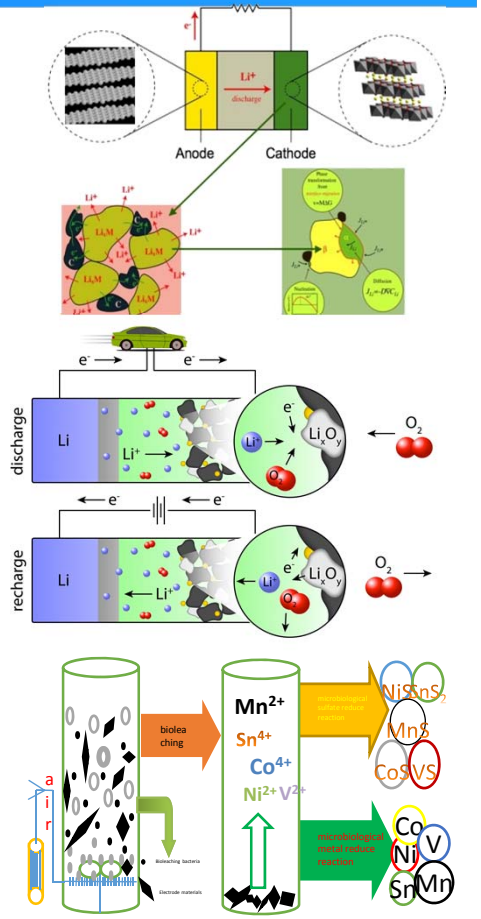
Thrust 1: Advanced Batteries System

- **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.
- **New Chemistries:** Advance Li-air and Li-sulfur chemistries towards commercial viability by revealing limiting phenomena and developing materials/architectures that overcome these obstacles.
- **Battery testing standards:** Review protocols for battery testing & safety.
- **Battery reuse & recycle:** Explore pathways for reuse & recycling of batteries.



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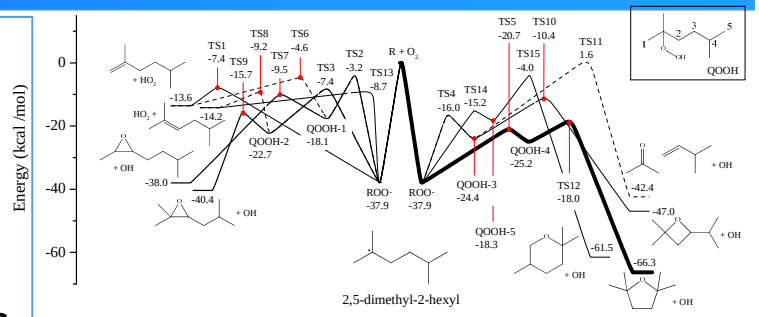
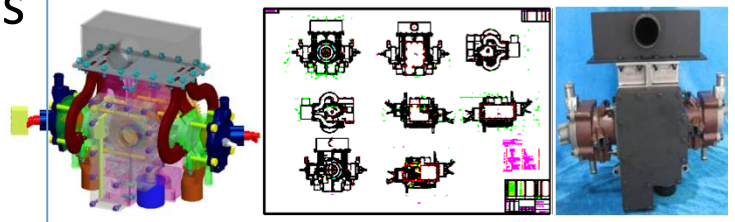
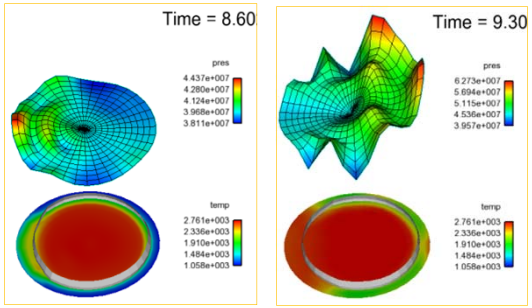
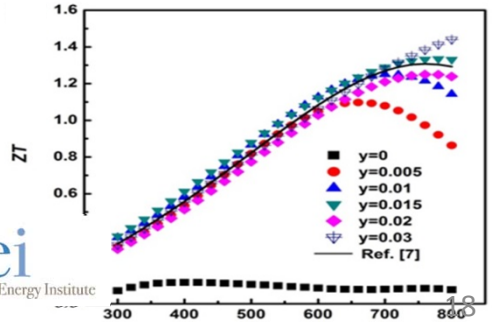
Thrust 2: Advanced Biofuels, Clean Combustion and APU

- **Biofuels:** Collaborative computational and experimental study of cellulosic biofuels produced using microbial synthesis.
- **APU Engines:** Challenges and opportunities of range-extender engines.
- **Integration of Powertrain and Aftertreatment:** Holistic consideration of fuel property, combustion modes, after-treatment systems, and hybrid powertrains.
- **Novel Thermoelectric Materials:** Develop highly efficient TE materials with high figure of merit, and the synthesis methods.









University of Michigan · Oak Ridge National Laboratory · Sandia National Laboratories · The Ohio State University · jbei Joint BioEnergy Institute

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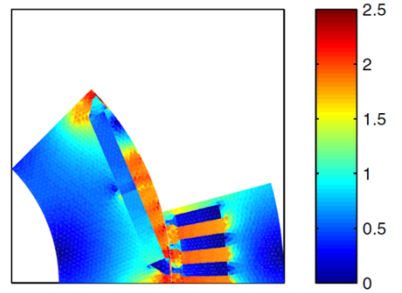
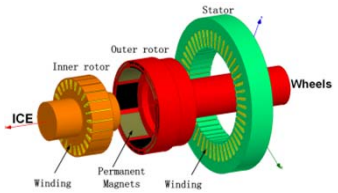
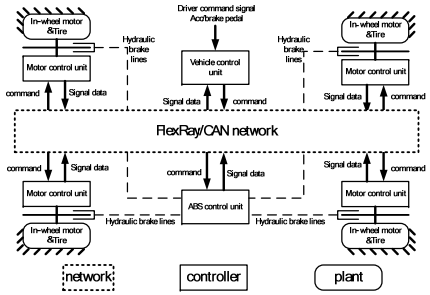
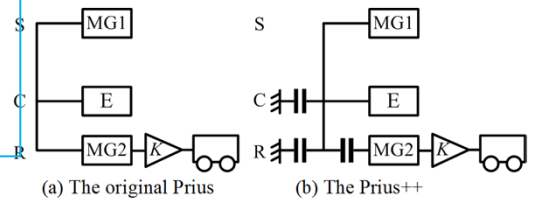
Thrust 3: Traction motor and control system

- **Components Design and Optimization:** Develop models for fast and accurate design and optimization of motors and power electronics.
- **Powertrain Control and Distributed Vehicle Control Networks:** To study critical communication and control issues of electrified vehicles.
- **System Integration Technologies:** Models, sizing and control for efficient hybrid vehicle powertrain development.
- **Data Drive Battery Modeling and Health Monitoring**: Model driven battery management systems.









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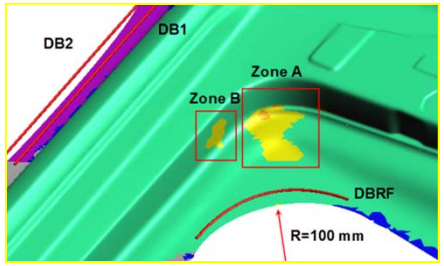
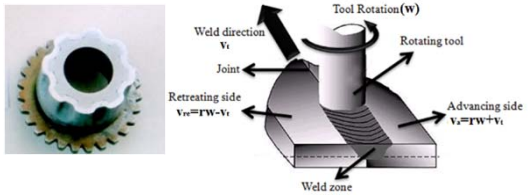
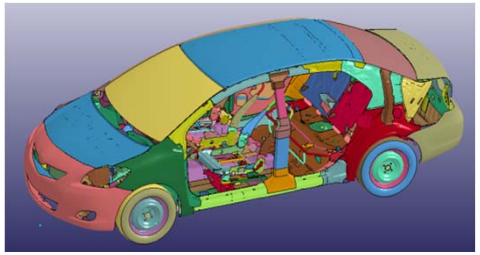
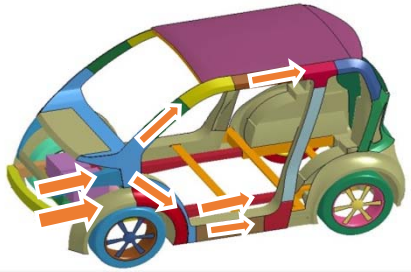
Thrust 4: Lightweight and crash safe of EV

- **Manufacturing processes of lightweight body**: Low-cost, energy efficient, and high quality processes for bulk forming lightweight materials and joining dissimilar lightweight materials.
- **Design of EV with lightweight structure**: Guidelines, tools, and methods for optimally integrating lightweight components into vehicle structures utilizing the developed forming and joining processes.
- **Crash safety of lightweight EV**: Experimental and computational methods for evaluating crashworthiness of components and assemblies made of lightweight materials.









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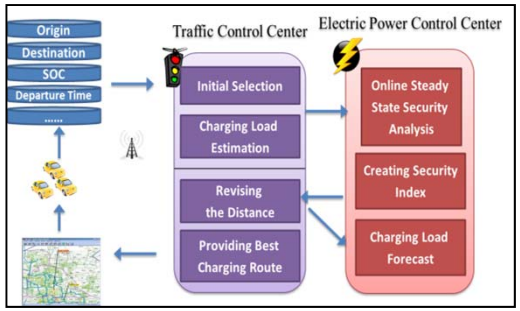
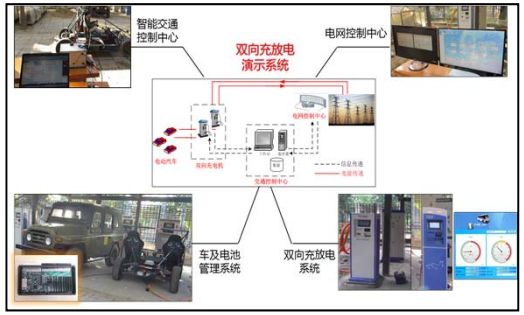
Thrust 5: Vehicle-Grid Integration

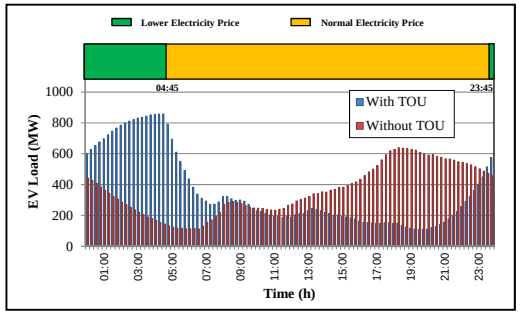
- **Vehicle-Grid Interaction:** Assess the impact of large-scale deployment of PEVs on the grid and develop technology and policy recommendations to accelerate EV deployment in the U.S. and China.
- **Vehicle-Grid Integration:** Develop control strategies and protocols for vehicle-grid interactions.
- **Information Grid:** Use of Intelligent Transportation Systems technology to optimize vehicle charging and energy use.



Smart Charging Guiding System (SCGS)



EV-RES Coordination



Charging load model based on transportation information

University of Michigan · Tsinghua University · The Ohio State University · Oak Ridge National Laboratory

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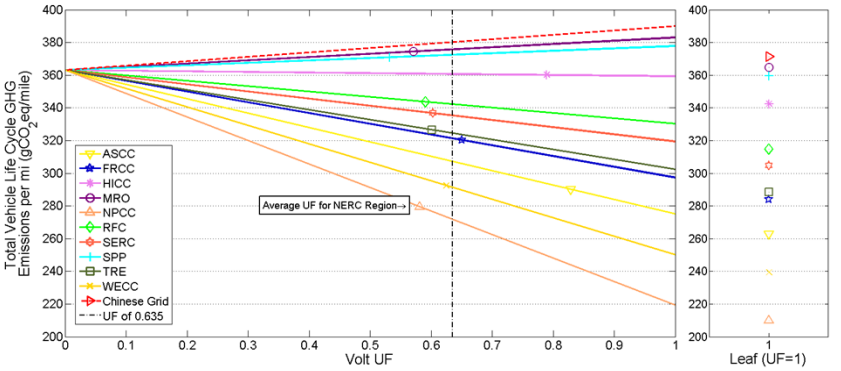
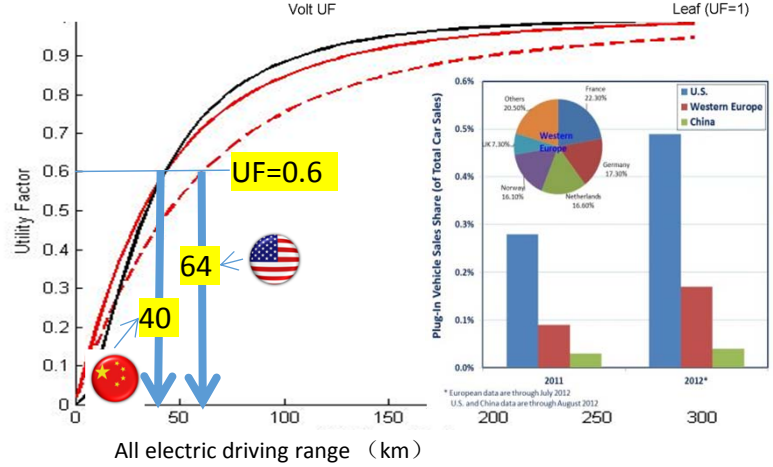
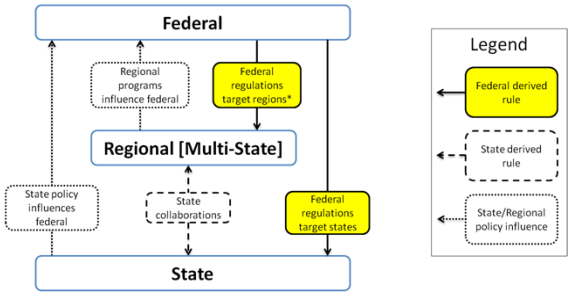
Thrust 5: Energy and system analysis of EV

- **Life Cycle Analysis:** Develop CV energy efficiency, carbon targets and evaluate life cycle performance of CV powertrain and lightweighting.
- **Mega Data sharing**: Driving pattern information in Mega cities and worldwide CV data book. Utility Factors for PEVs.
- **Roadmap and Strategy:** Identify optimal fuel mix strategies & constraints; recommendations for accelerating CV deployment.







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Performance Metrics

- Joint conferences, workshops and symposia organized
  - 4 CERC-CVC-wide meetings, 8 EVI workshops
  - >100 Technical meetings (mostly by individual TA)
- Journal and conference papers published
  - >292 papers published or accepted
- IP disclosures filed; US, China, and international patents issued
  - 30 in China, 28 in US (17 from Chinese side)
- Number, frequency, duration of personnel exchanged/collocated among organizations
  - ~ 100 short-term visits, 25 long-term (> 30 days) visits planned or executed

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U.S.-China Clean Energy Research Center Clean Vehicles Consortium (CVC) Report to Steering Committee

OUYANG Minggao (China Director, Tsinghua University)

Huei Peng (US Director, University of Michigan)

July 11, 2014

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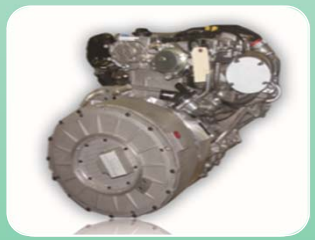
Outline

Summary of Key Outcomes

Research on EV Traction battery safety technologies



US-China Cooperation and industrialization of electric driving system

Focus of the next 18 months

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Summary of Key Outcomes

1. Advanced Batteries system

（1）Material development for safety improvement

（2）Thermal runaway mechanism of traction battery.

3. Vehicle Electrification

EV battery management system

4. Lightweight Structures and crash safety

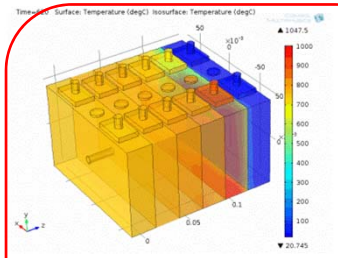
Battery safety issue during vehicle crash

5. Vehicle-Grid Integration

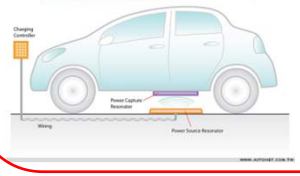
Advanced charging technologies: wireless charging

6. Energy Systems Analysis, Technology Roadmaps and Policies

Battery testing standards



Address safety issues associated with traction batteries

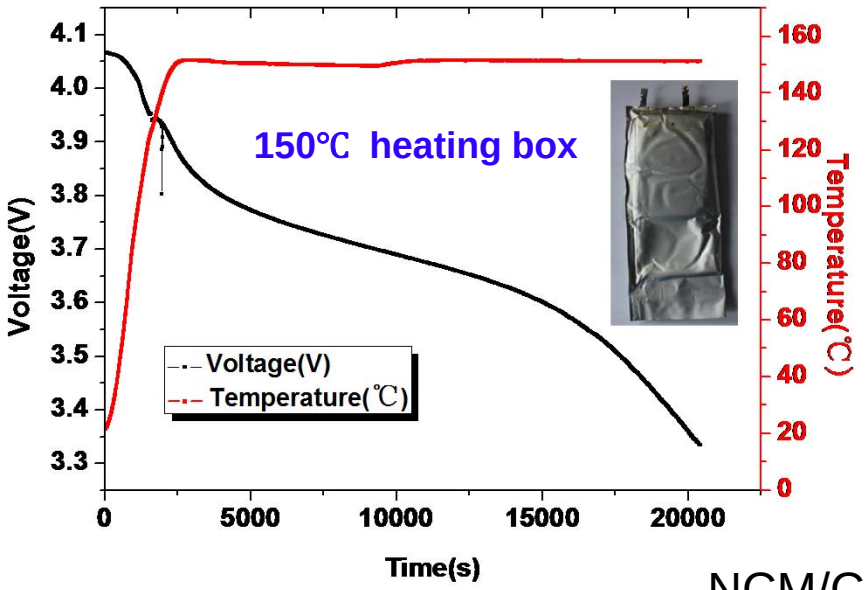


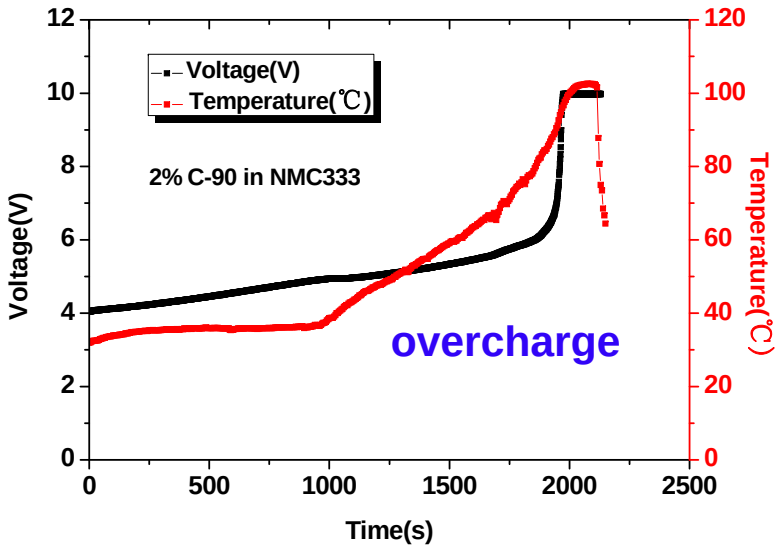
Thrust 1（1）Advanced material development targeting safety

Polymer additive of safety： stabilizing electrolyte

1. Design of polymer structure for safety additive, optimized synthesis, scale-up of preparation
2. Patented technology
3. Stabilizing interface, improving safety and life of cell

Scale up





NCM/C cell safety tests

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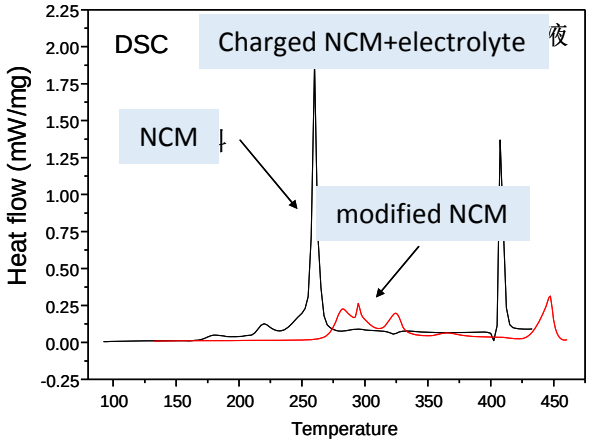
Thrust 1（1）Advanced material development targeting safety

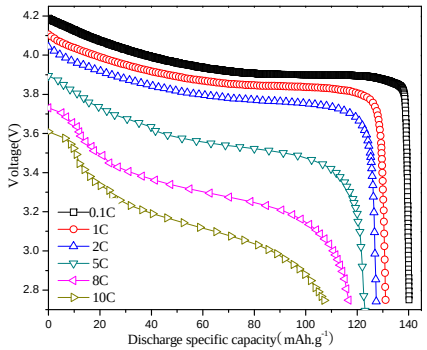
Modified NCM：highly stable against thermal runaway

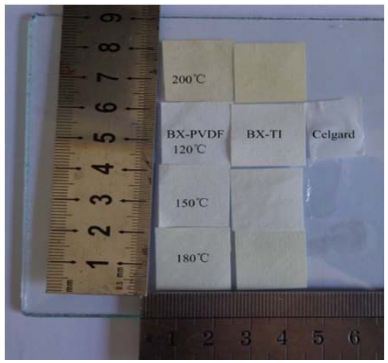


1. Low heat generation
2. High onset temperature

Massachusetts Institute of Technology

Low shrinkage separator at high temperature





1. High electrochemical performance
2. No shrinkage up to 150℃

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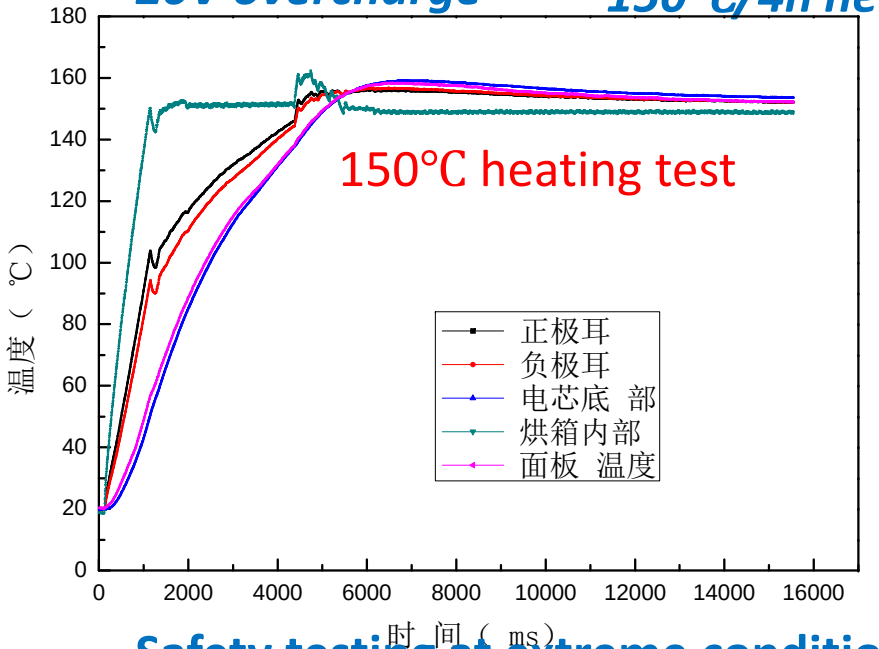
Thrust 1（1）Advanced material development targeting safety

System specific energy density： 156Wh/kg

specific energy density of cell made of new material:180-200Wh/kg

20V overcharge ***150℃/4h heating*** ***Short circuit***



Testing conditions： 100%SOC, 150℃
Constant temperature （>4hr）

No fire, no leakage and no explosion under abuse tests

Safety testing at extreme conditions

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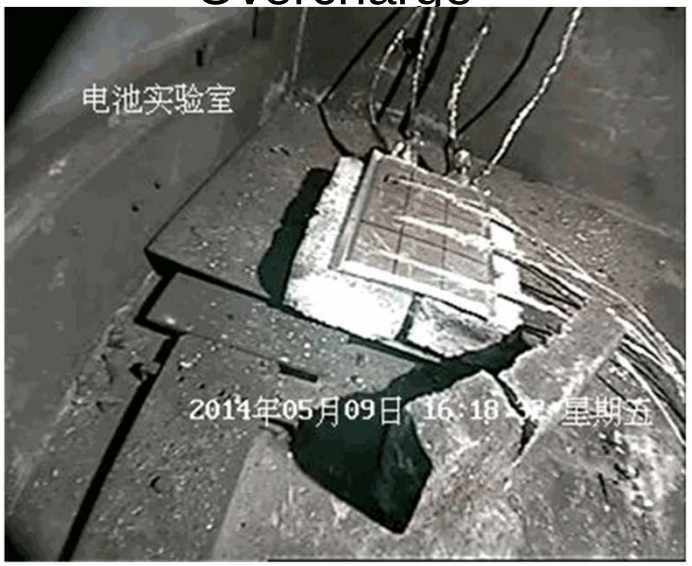
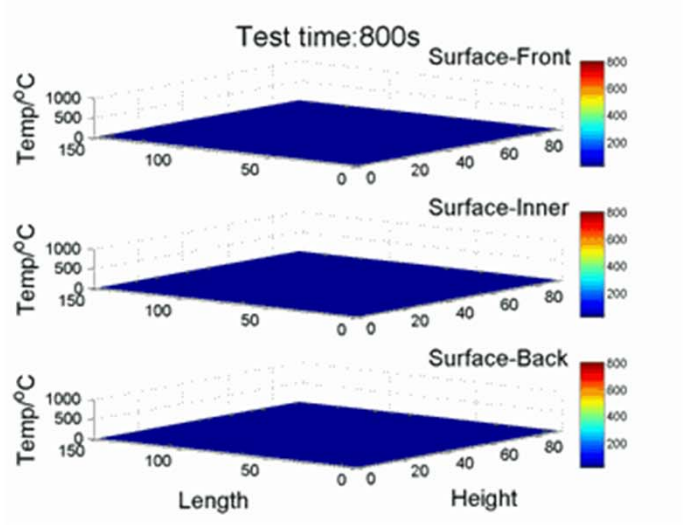
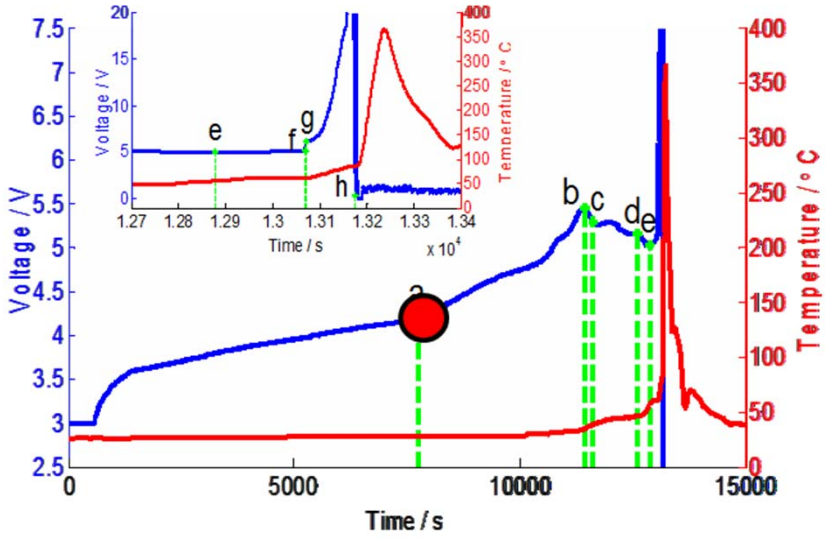
Thrust1 (2) Thermal runaway mechanism of battery

Short circuit/Penetration

Overcharge

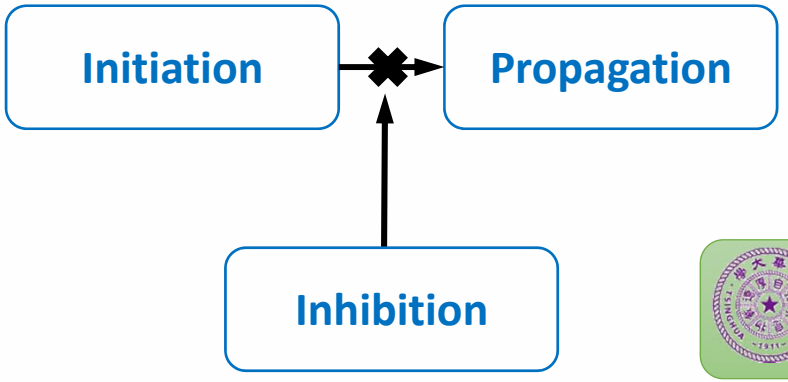


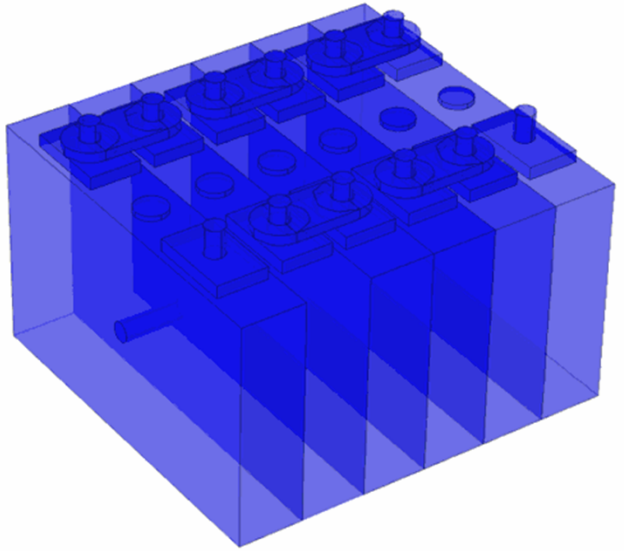


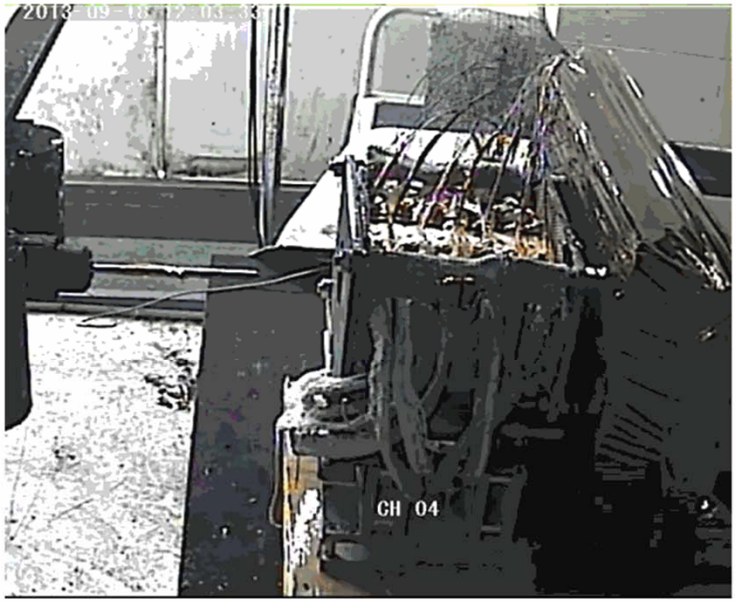


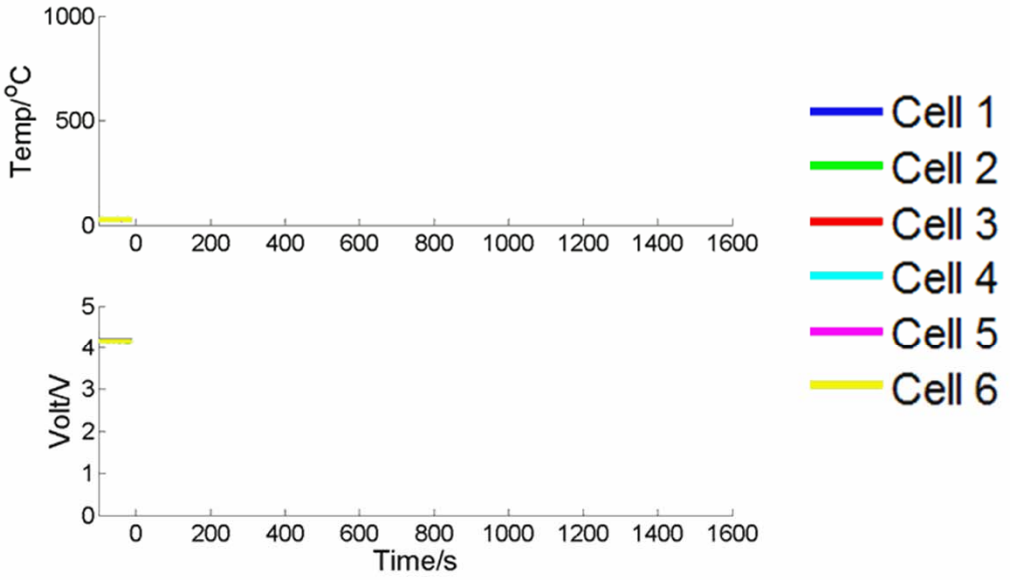
Thrust1 (2) Thermal runaway mechanism of battery

Thermal runaway propagation









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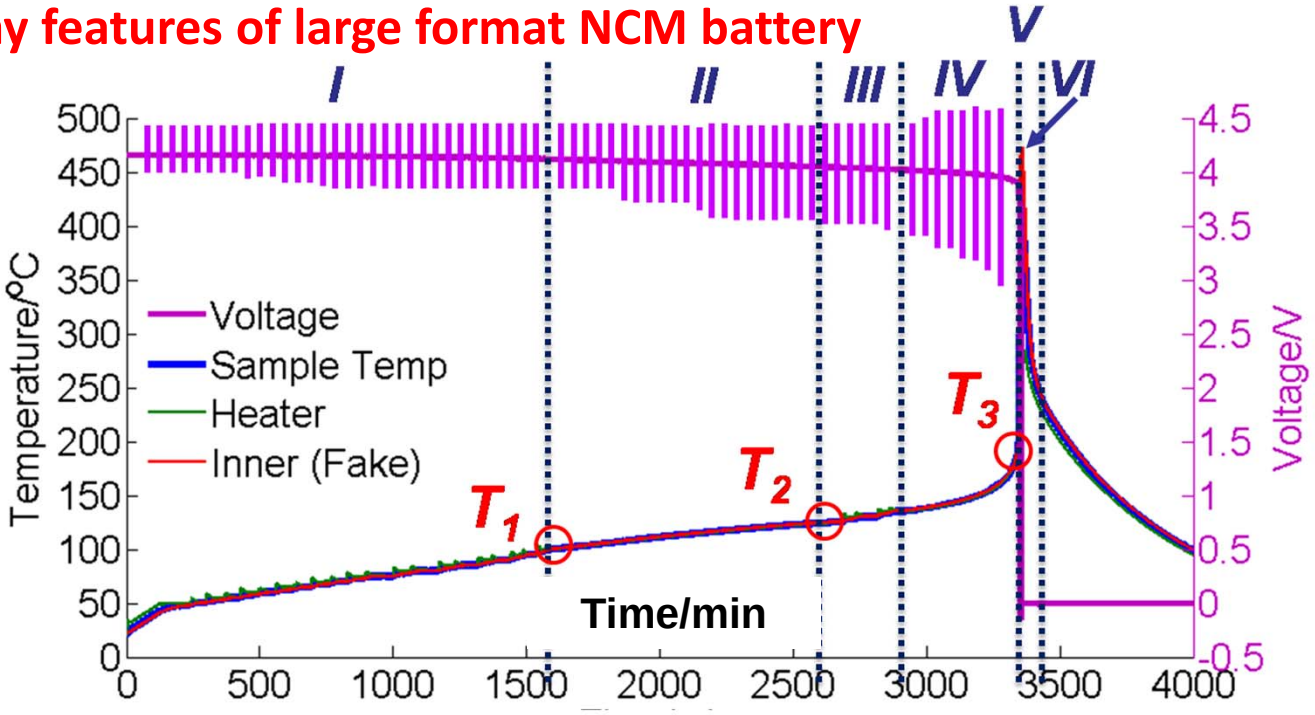
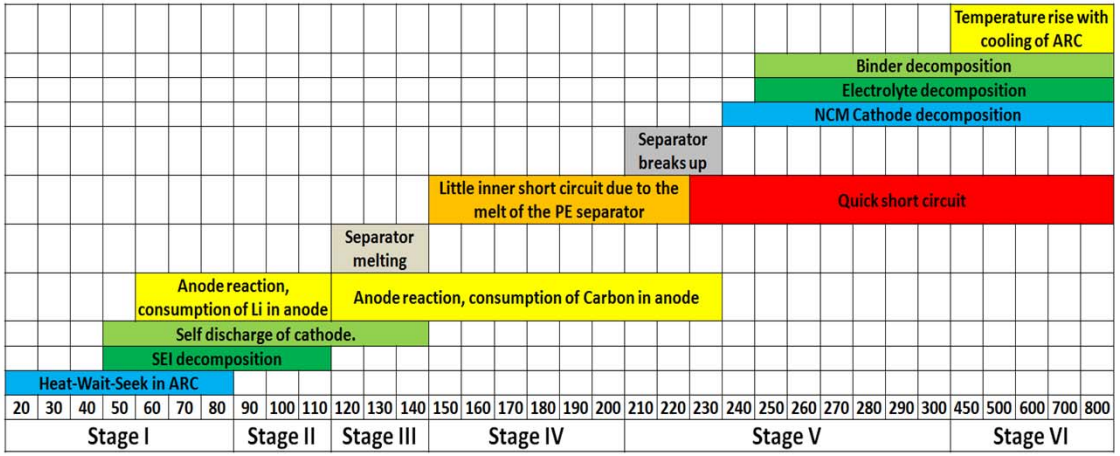
Thrust1 (2) Thermal runaway mechanism of battery

Thermal runaway features of large format NCM battery





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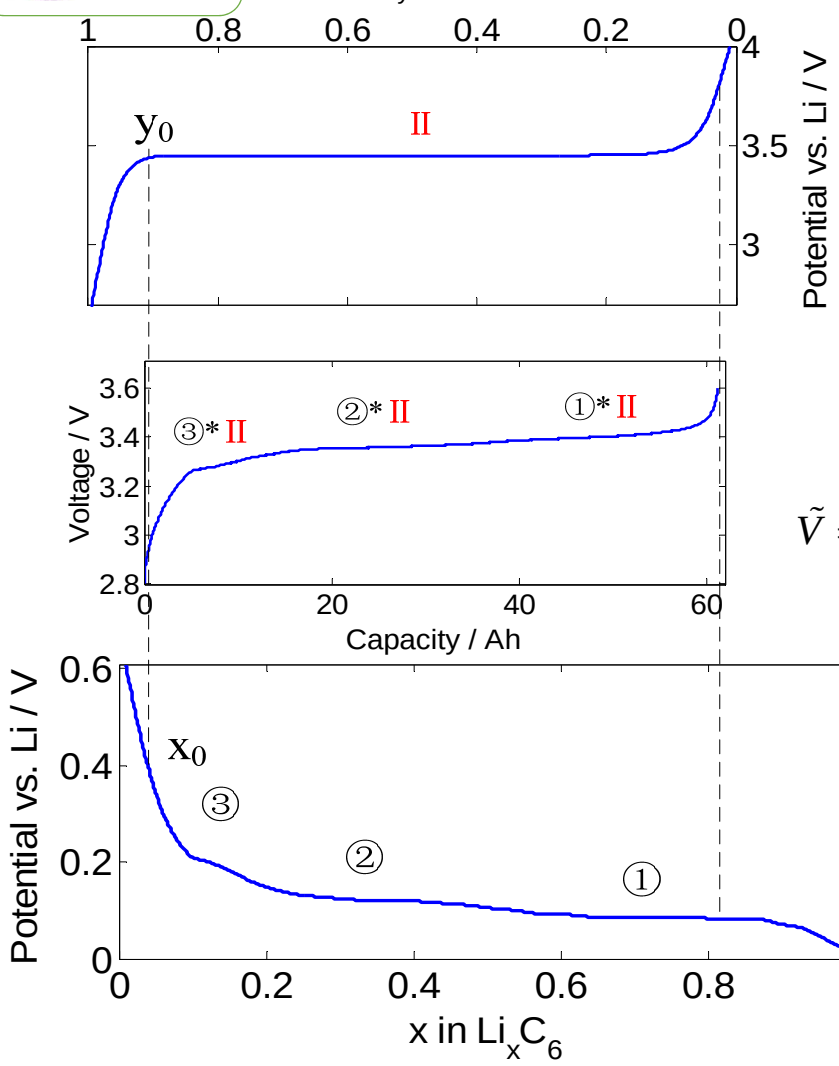
Thrust 3： battery system design-BMS(battery management system)

Identifying (using Genetic algorithm)

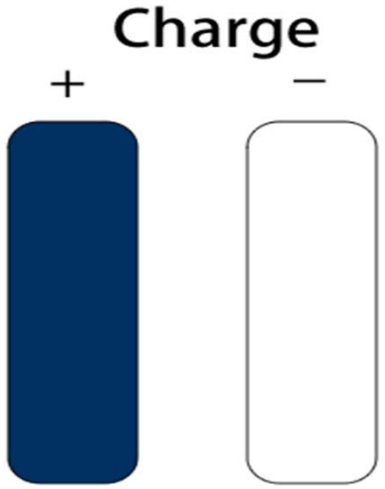


positive equilibrium potential

$$y = y_0 - \frac{Q}{C_p}$$

1/3C charging voltage curve

$$\tilde{V} = U_p(y) - U_n(x) + IR$$



negative equilibrium potential

$$x = x_0 + \frac{Q}{C_n}$$

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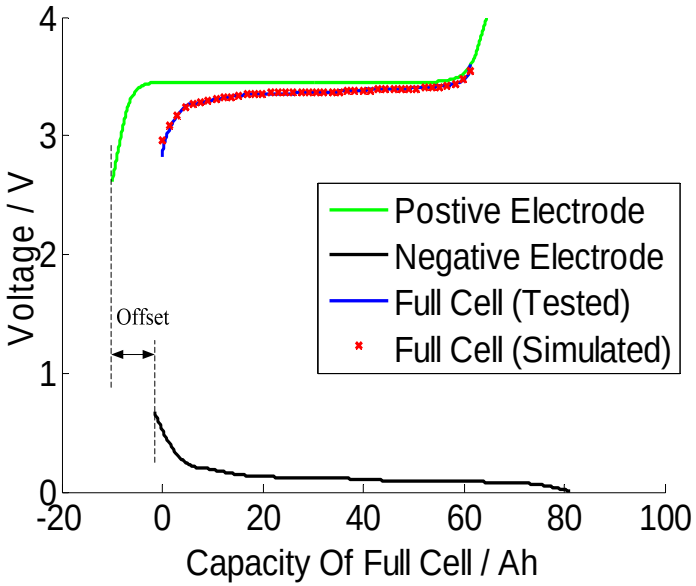
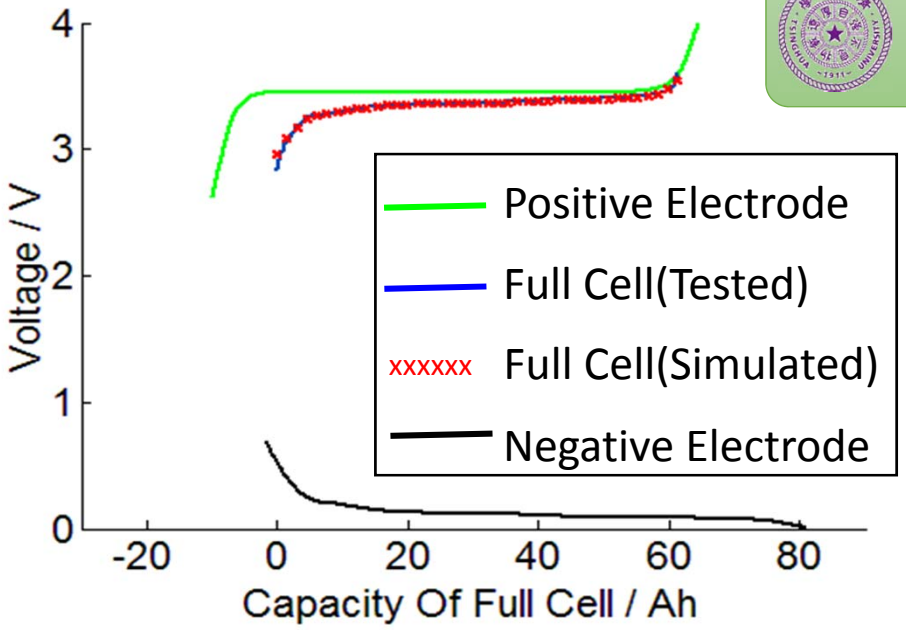
Thrust 3： battery system design-BMS(battery management system)

internal observer of the battery fade

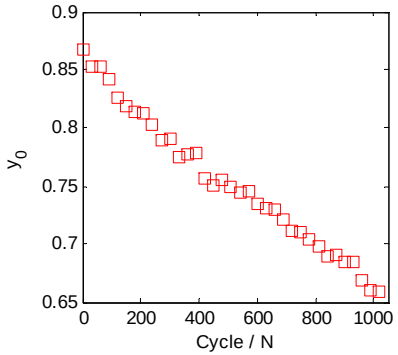




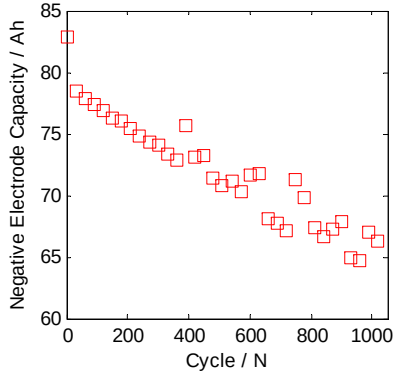
Offset indicate the loss of Li+

$$Offset = (1 - y_0)C_p - x_0 C_n$$

$$RMSE = \frac{1}{n}\sum_{t=t_0}^{t_n}\left(V(t) - \tilde{V}(t)\right)^2$$



the usable lithium ions loses



the capacity of the negative electrodes fades

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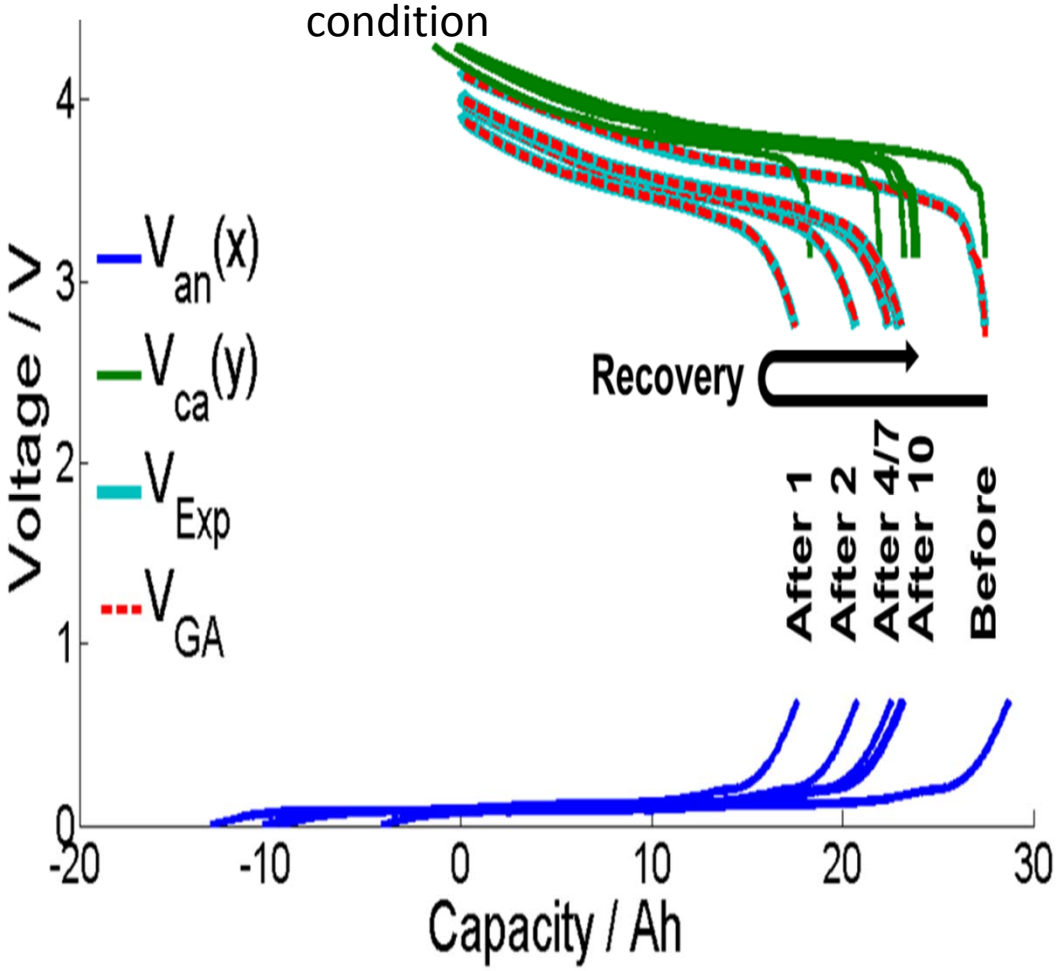
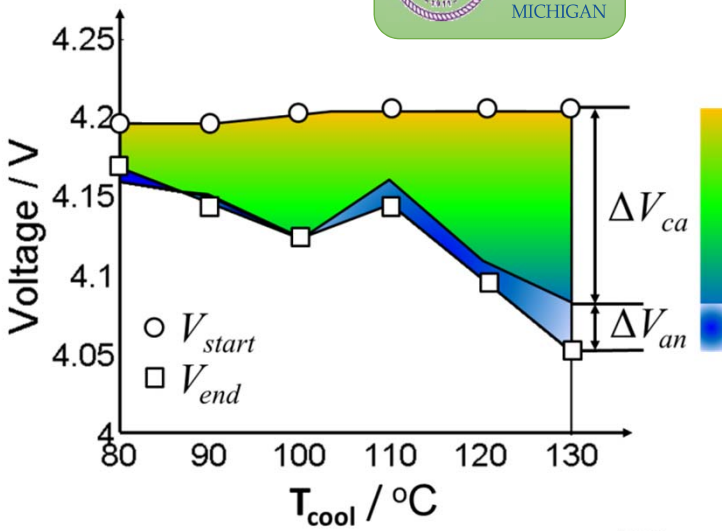
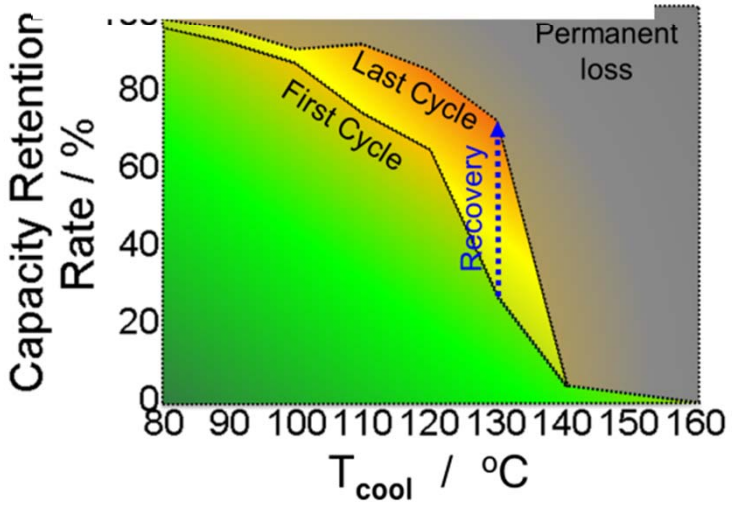
Thrust 3： battery system design-BMS(battery management system)

Capacity and voltage estimation at high temperature base on observer

Voltage and capacity under thermal runaway condition







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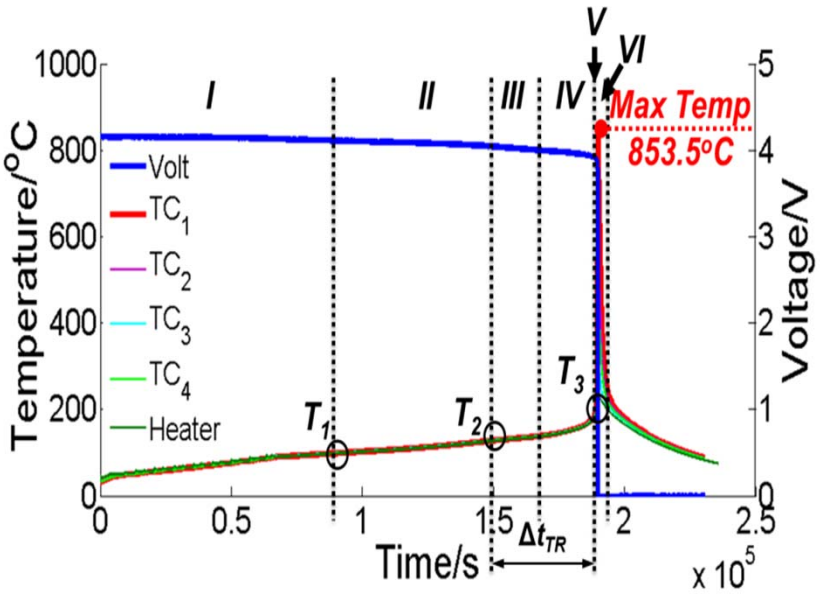
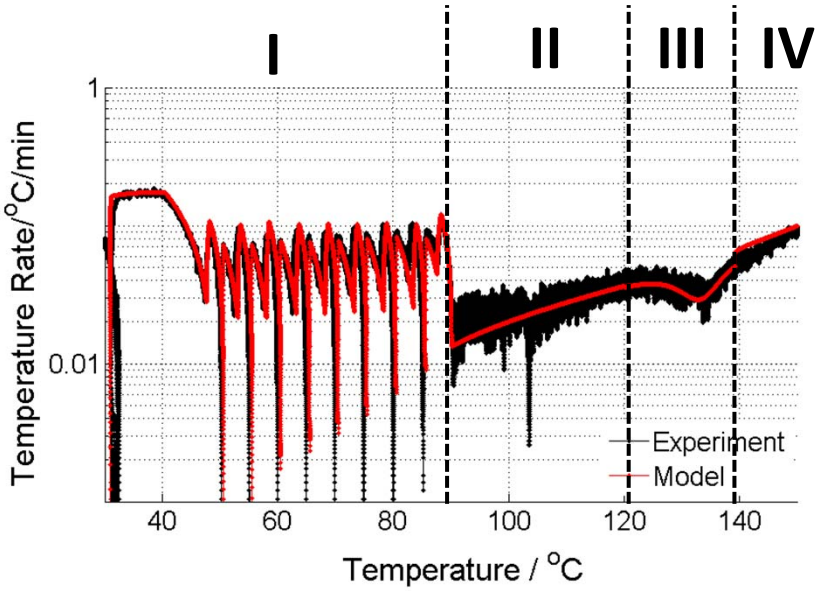
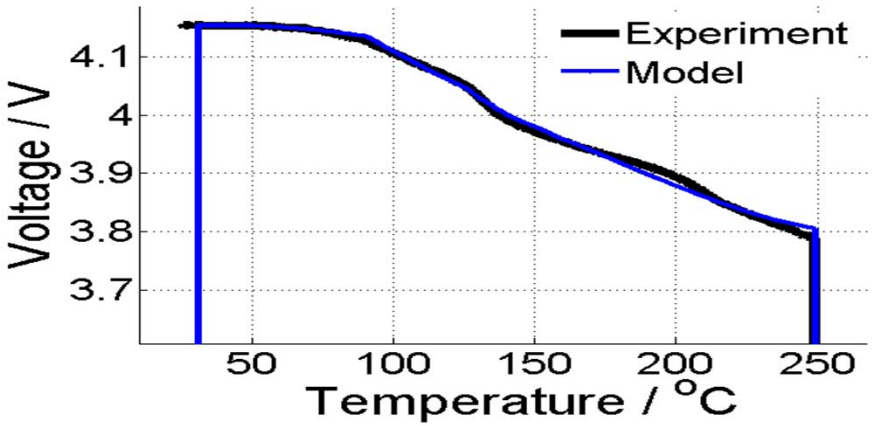
Thrust 3： battery system design-BMS(battery management system)

Estimation of SOS with Electro-chemical-thermal coupled TR model

- Based on capacity and voltage estimation
- Multi-physics coupled Equations
- A model to predict V&T simultaneously







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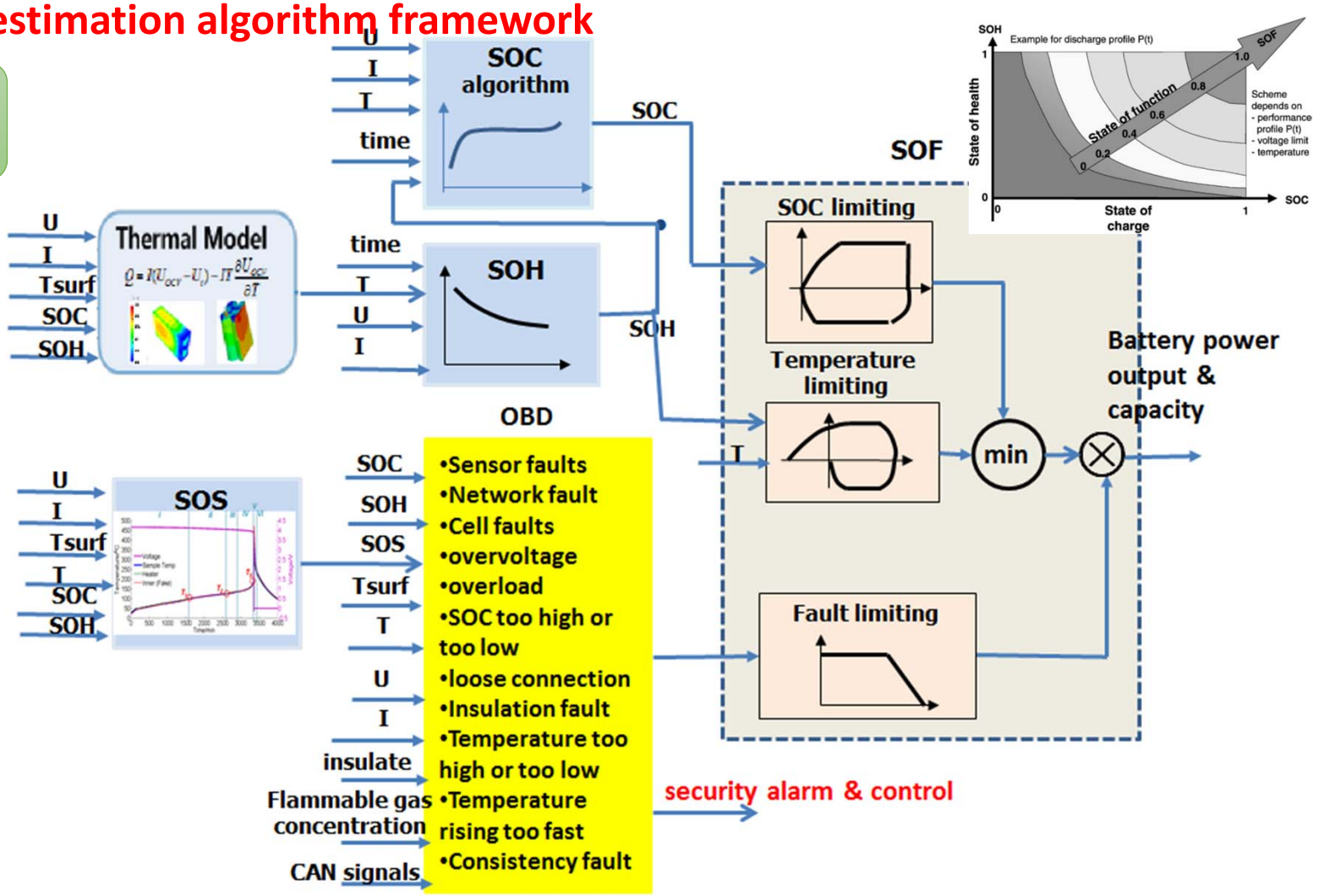
Thrust 3： battery system design-BMS(battery management system)

BMS state estimation algorithm framework



A review on the key issues for lithium-ion battery management in electric vehicles , Journal of Power Sources 226 (2013) 272-288 ESI 论文 一年内 他引48次，刊物热门论文 排行第8名

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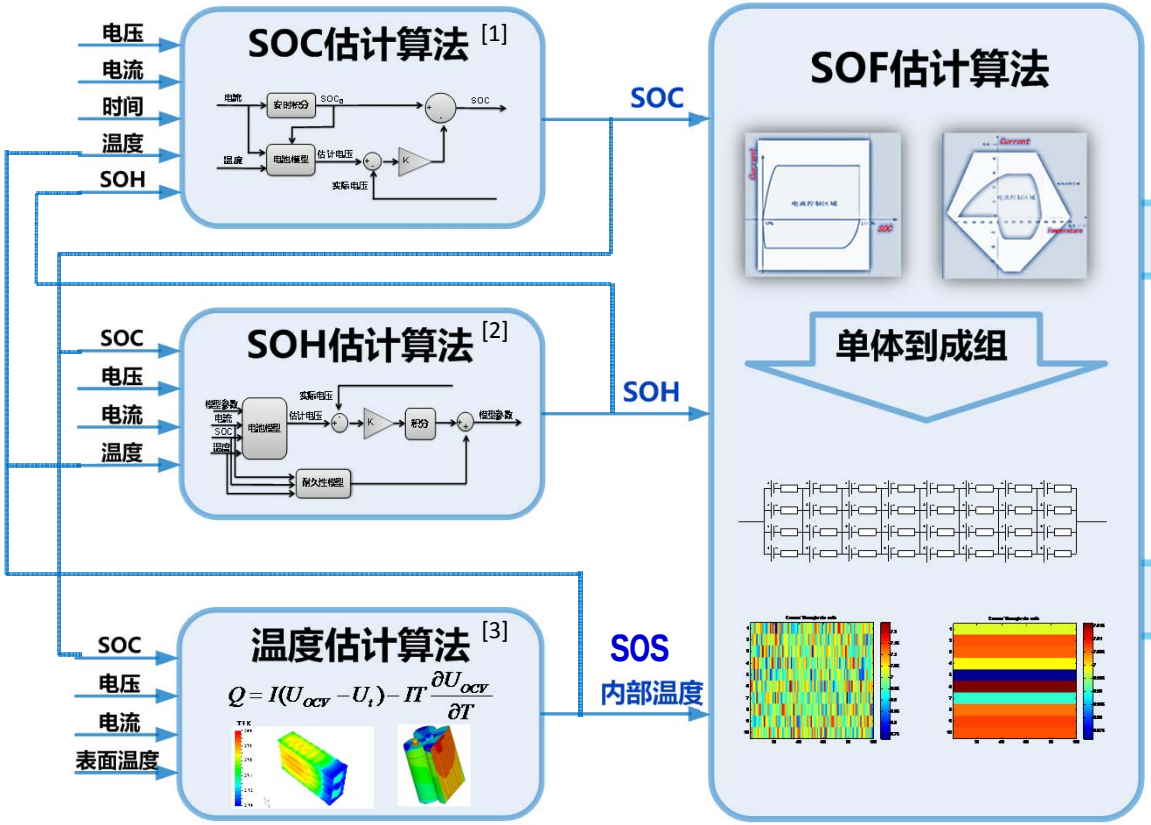
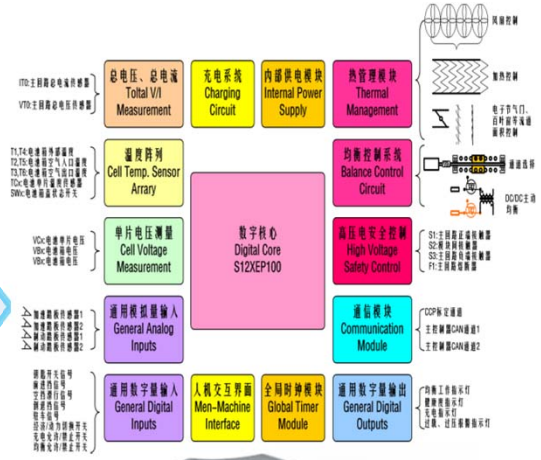
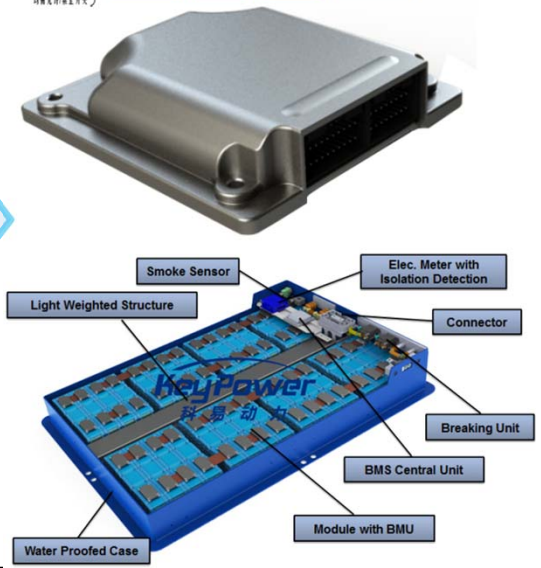
Thrust 3： battery system design-BMS(battery management system)

Battery management system







[1] Lu L,Li jianqiu Ouyang minggao. A review on the key issues for lithium-ion battery management in electric vehicles [J] . Journal of Power Sources, 2013,226(1) :272-288.

[2] Remmlinger J, et al. State-of-health monitoring of lithium-ion batteries in electric vehicles by on-board internal resistance estimation [J]. Journal of Power Sources, 2011, 196 (15): 5357–5363.

[3] Chen S C, et al. Thermal analysis of lithium-ion batteries [J]. J Power Sources, 2005, 140(1): 111-124.

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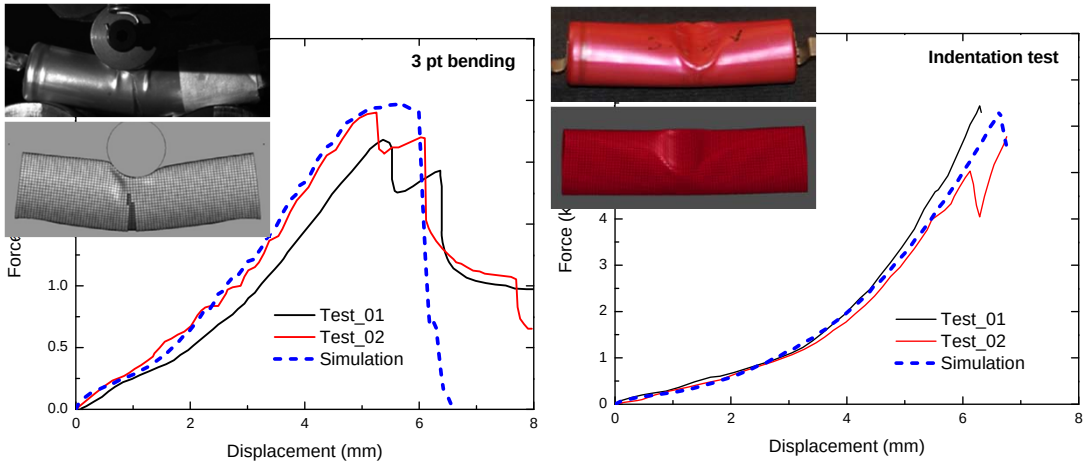
Thrust 4 (1) Battery safety during crash

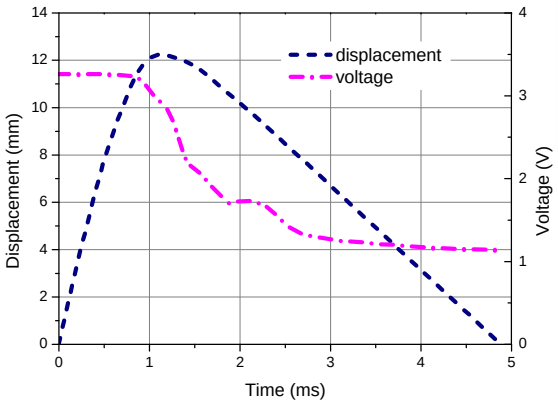
Traction battery crash test

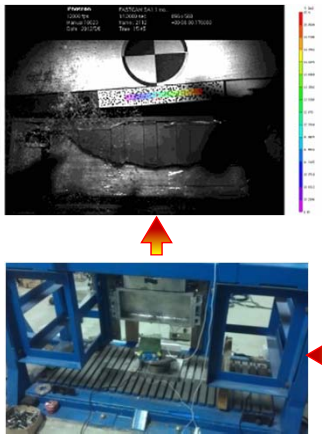
- Quasi-static tests of battery cells by monitoring real-time change of load, voltage and temperature
- Reveal correlation between mechanical failure and battery short circuit
- Homogenized model, currently capable of predicting battery short circuit under some quasi-static loading cases



Key: Equivalent characterization of jellyroll in battery cell, including failure criterion

- Drop-tower impact tests of battery
- Large deformation and damage – voltage drop
- Provide info for developing crash model and tolerance of batteries





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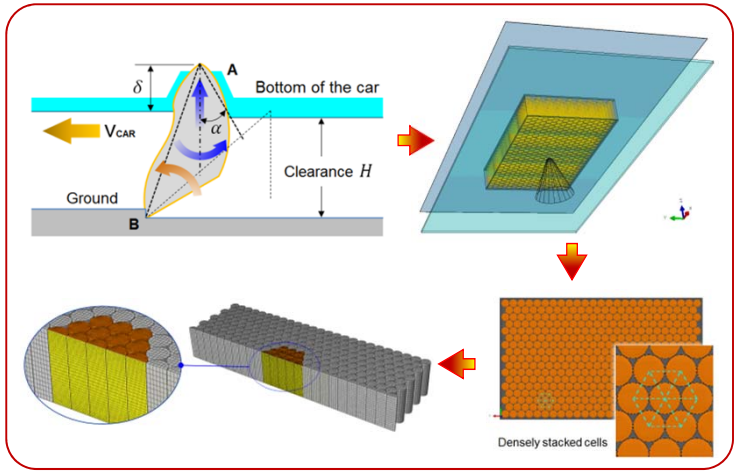
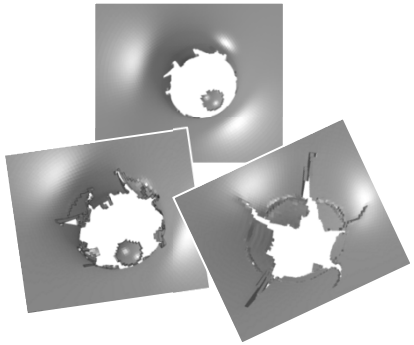
Thrust 4 (1) Battery safety during crash

Model of ground impact of battery packs in EVs

- Background: fire of Tesla Model S caused by debris impact on highway
- Definition of model for ground impact of plate-like battery pack, and parametric study
- Analysis of metal shield perforation and crack propagation pattern

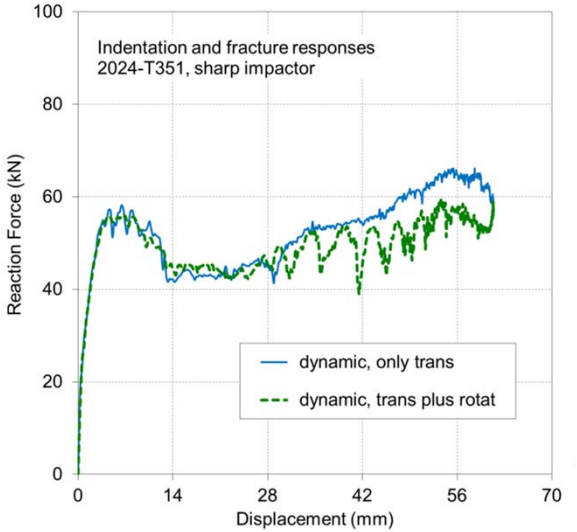


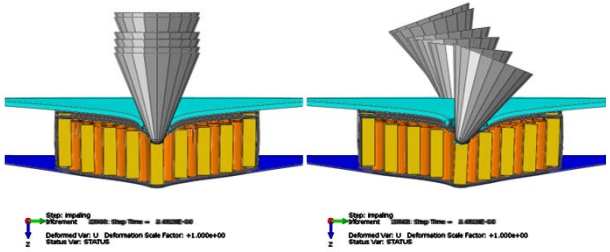


Crack propagation patterns of shields made of different materials

Massachusetts Institute of Technology

TSINGHUA UNIVERSITY 1911





Translational vs. rotational impact

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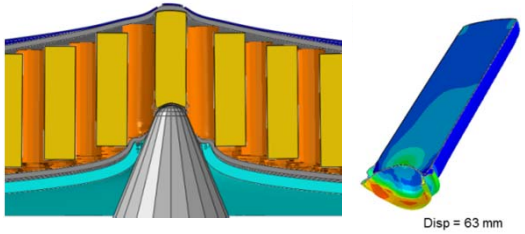
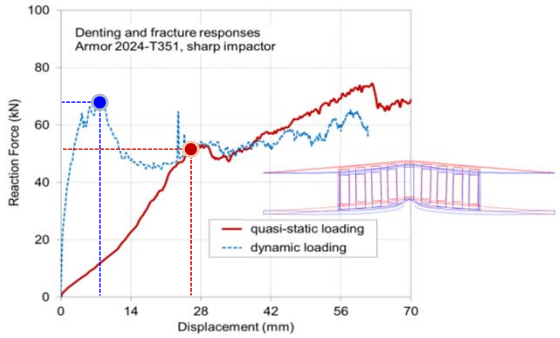
Thrust 4 (1) Battery safety during crash

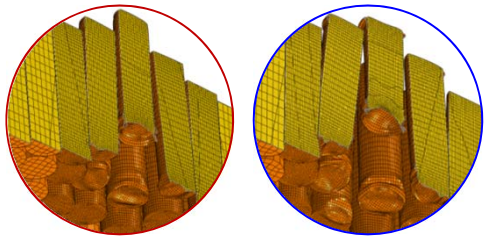
Model of ground impact of battery packs in EVs

- Analysis with multi-scale models
  - Bottom structure deformation and perforation → localized deformation of individual battery cells → detailed analysis of battery cells

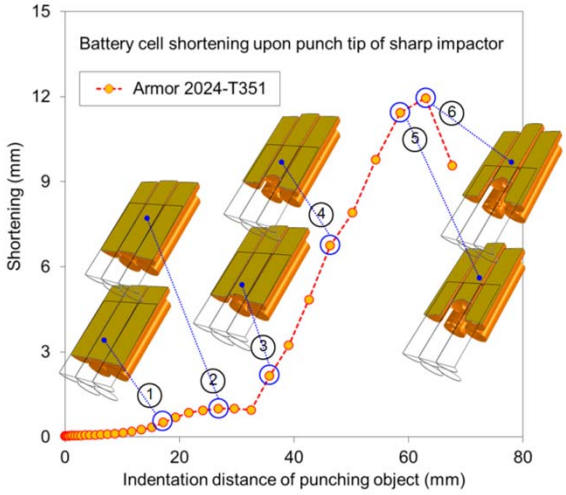


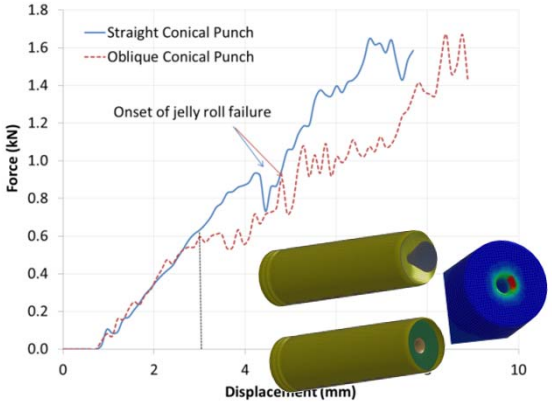


Difference of indentation response between quasi-static and dynamic cases

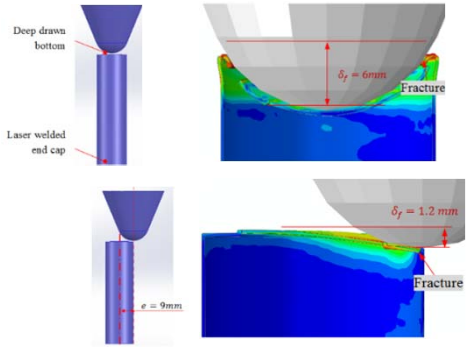


Localized deformation of battery cells beneath different floor panel structures





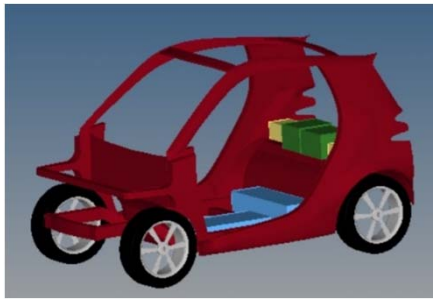
Deformation and failure of jellyroll in battery cells under different indentation modes



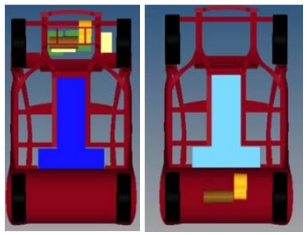
Deformation and failure of shell casing of battery cells under different indentation models

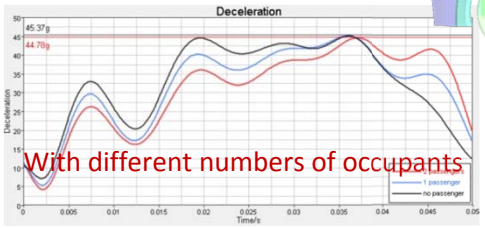
Thrust 4 (2) Lightweight EV crash simulations

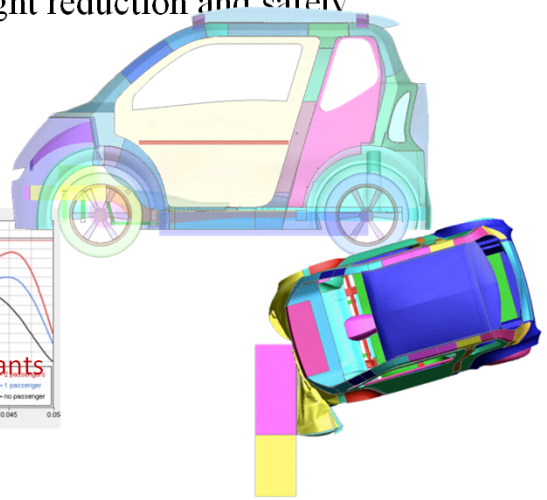
Design of lightweight Micro-EV bodies, full vehicle crash simulations

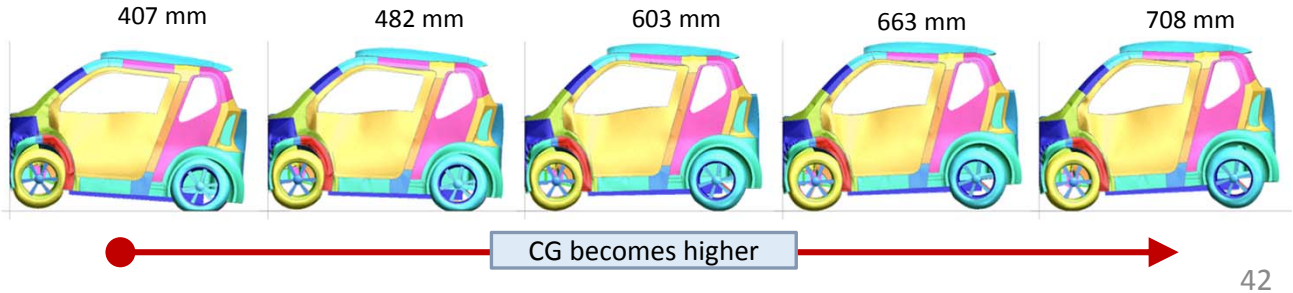
- Create 1000kg / 600kg Micro E-car models, for analysis related to
  - Influence of mass distribution of batteries and occupants on crash performance
  - Influence of lightweight materials on weight reduction and safety







- Battery location → CG of full car
  - → Pitching motion
  - → Energy absorption in crash



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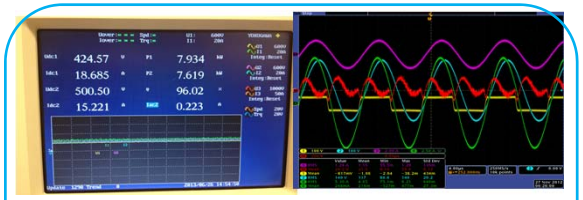
Thrust 5-Wireless Charging

Electromagnetic Resonance type

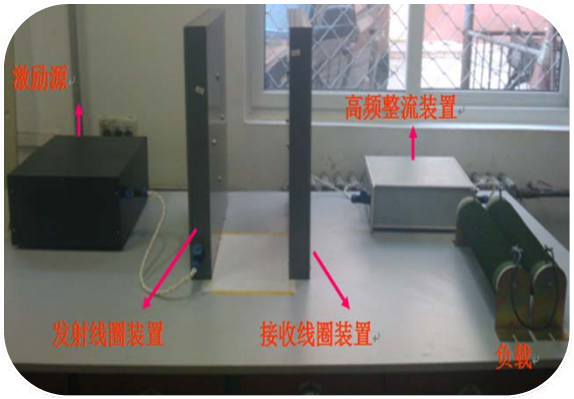
1st gen

1kW，3.3kW wireless charging testing bed were setup

DENSO OAK RIDGE National Laboratory UNIVERSITY OF MICHIGAN



Simulation platform



2nd gen

3rd gen

Power:3.3kW
Transmission distance:20cm
System Efficiency:90%

in-vehicle Testing

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方向6：电动汽车能源与系统分析-动力电池测试标准

A Comparison of US and Chinese EV Battery Testing Protocols

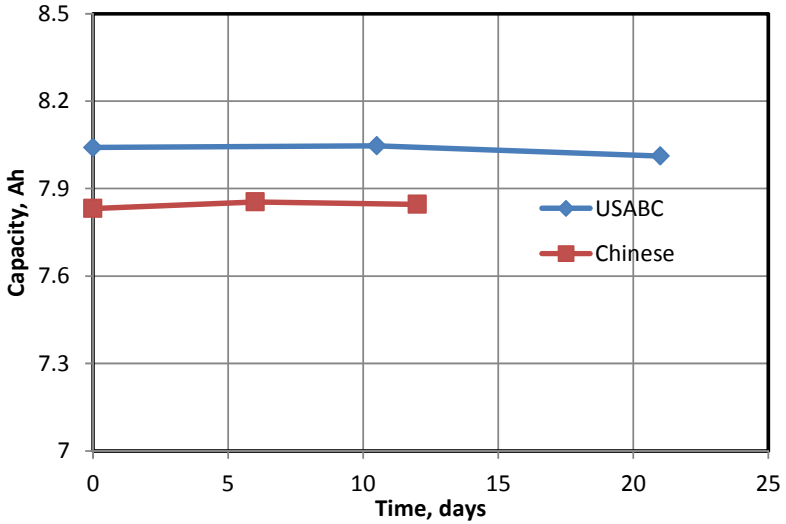
- **similarities between China and US battery testing protocol：**

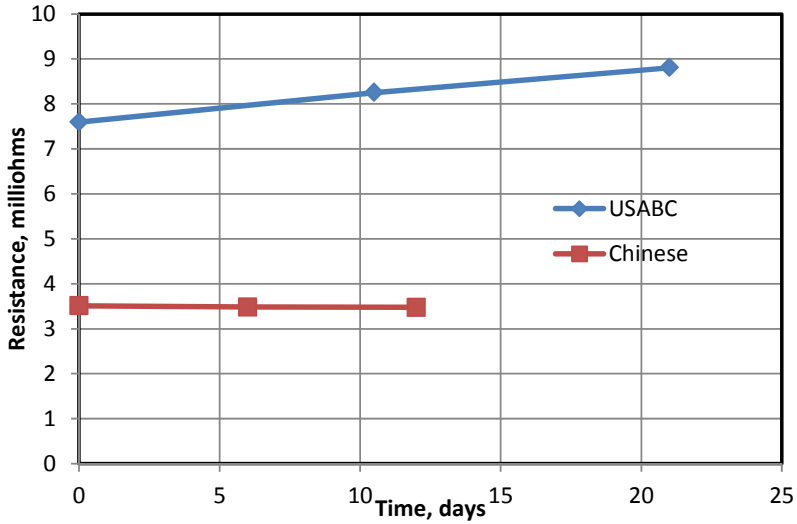
Voltage window, temperature and 80% capacity value is set as the end limit of cycle life.

- **Differences between China and US battery testing protocol：**

battery performance testing method of constant current cycle, power density testing method, testing frequency of reference performance.

Testing result comparison





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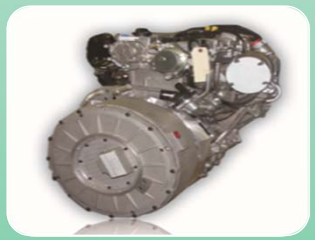
Outline

Summary of Key Outcomes

Research on EV Traction battery safety technologies



US-China Cooperation and industrialization of electric driving system

Focus of the next 18 months

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CVC Company Member's Collaboration in Development and Commercialization

JJE driving the next

精进电动

- Jing-Jin Electric (JJE) is one of CVC's Chinese Company Member. JJE's collaboration principle is to "Combine the Best of China and US； Foster Cross Innovations"
- JJE has collaborated with many US companies, including **Fisker Automotive, Chrysler, Mission Motors, EDI, Transpower,** to co-develop advanced electric motors to support the innovations of its US colleagues
- Over 10,000 high performance electric motors for passenger vehicles and commercial vehicles have been exported to the US. The volume will continue to grow over the next few years


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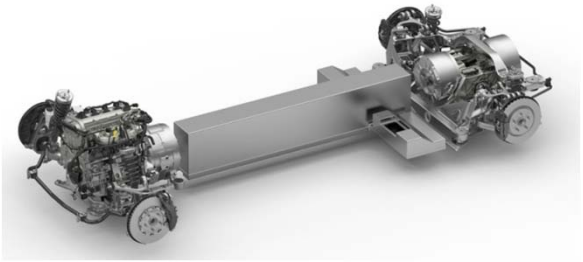
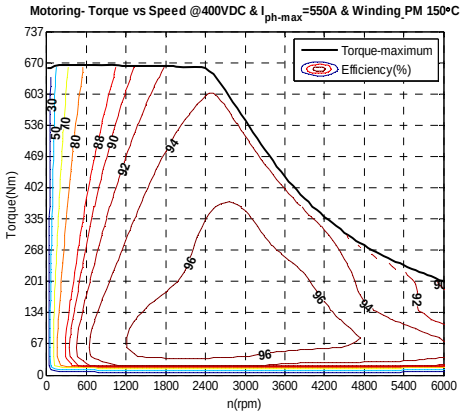
Developed High Performance Traction Motors for Fisker Karma

- JJE Developed and Commercialized High Performance Electric Motors for Fisker Karma
  - 150kW/665Nm high power, high torque permanent magnet synchronous electric motors
  - 175kW permanent magnet synchronous generators, optimized for the engine for high generation efficiency
  - Achieved 3.2kW/kg power density (power/effective motor materials) and became industry's highest power density motors under volume production
  - Received strong review by top automotive journalists, from performance to NVH (noise vibration harshness) profile

Fisker Karma Extended Range EV





Power Density, Effecitive Material, kW/kg	3.2
Torque Density, Effecitive Material, Nm/kg	13.2
Peak Power / Continuous Power (kW)	150/110
Peak Torque / Continous Torque (Nm)	665/450
Maximum Speed, rpm	7000
Peak Efficiency	97%
High Efficiency Area (>80%)	90%
Protective Class	IP6K9K

JJE Electric Motor for Fisker Karma

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JJE's Collaboration with US Colleagues on the Fisker Karma Motor Program

- Collaborated with US Colleagues to develop highly integrated electric drive assemblies
  - Developed thin, light high torque motors, reducing mass while make provision for crash space, critical to crashworthiness
  - Collaborating with Ricardo North America and Tremec Transmission Company, Developed highly integrated dual motor reduction –differential assembly
  - With Ricardo North America, Co-developed Range Extender Assembly with optimized efficiency match between motor and engine. Developed damper system to reduce vibration and eliminate resonance
- Collaborated with US manufacturing equipment supplier to develop production process technologies
  - Developed balance machine with Hoffman America, which can balance high weight, magnetized motor rotors
  - Developed industry's first magnet wire ultrasonic welding process and equipment with Ultrasonic Solutions
- Developed oil-cooled, high speed motors for Fisker's 2nd Generation Atlantic, achieving 5.0kW/kg power density and leading the high performance, light weight powertrain trend

Fisker Karma Generator Assembly

Fisker Karma Traction Motor – Reduction Differential Assembly

Magnetized Rotor Balance Machine

Magnet Wire Ultrasonic Welding

High Speed Oil-cooled Motor for Fisker Atlancic

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JJE's Innovation in Electric Motors Becomes Key Part of Vehicle Electrifications in the US

- **Passenger vehicles** – oil cooled PM motors for a Chrysler key vehicle model in 2016, estimated annual volume 100,000
- **Commercial vehicles** – co-developed electric motors with Cummins for hybridizing Cummins' diesel engine for lower emission and better efficiency
- **Buses** – supported EDI in applying JJE's dual motor traction system to buses, developing hybrid and plug-in hybrid buses for both US and Chinese market
- **Trucks** collaborated with Transpower (Truck Powertrain) and EPC Power (Inverter) and developed electric drive system for Class-8 heavy duty drayage trucks, meeting challenging requirements and helping ports reduce truck emissions
- **Motorcycles** – developed high speed, light weight motor for Mission Motors "Mission R" electric motorcycles

JJE-Cummins Hybrid Motor for Diesel Engine

JJE Dual Motor System for Cars

JJE Dual Motor System for Buses

JJE High Speed Light Weight Motor, 90kW, 18kg (Stator & Rotor)

Mission R Electric Motorcycle

Class-8 Drayage Truck wit JJE Traction Motors

JJE driving the next

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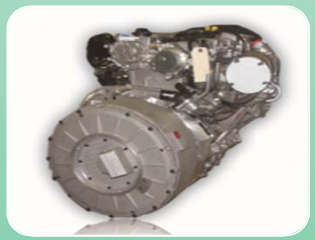

US-China Cooperation and industrialization of electric driving system

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Focus of the next 18 months

Industrial Collaboration Through "Implementation Projects"

- **DELPHI** — Diagnosis of electrified powertrain
- **Ford** — F-150 power split hybrid design
- **EATON** — Drivetrain lightweight structure simulation
- **DENSO** — Wireless charging prototype

- **万向集团 WANXIANG GROUP** — Battery management and safety protection system
- **JJE driving the future** — Electric powertrain with dual motor design
- **GM 上汽通用五菱 BAOJUN** — Micro EV light weight structure design
- **Potevio 中国普天** — Demonstration and evaluation of electric vehicle charging and infrastructure technologies

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2016 and beyond

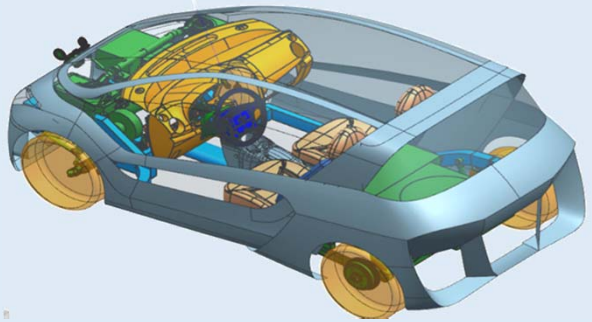
- Fundamentals for improved battery safety(Design, manufacturing, management)
- Electrification technologies SUV&LT
- Lightweight and crash safety
- Key technologies of small EV (BEV/PHEV/REEV)
- Connected and automated vehicles
- Evaluation of the key technologies of BEV/PHEV for industrialization(policy, standards, charging and business models)

2016 and beyond

SGMW

New Li-ion battery & BMS

Powertrain optimization & VCU



Lightweight structure & battery crash safety

Intelligent charging & V2G

Energy flow optimization & Driving management

Thank you for your attentions !