Electrochemical Energy Storage System for Fuel Cell Electric Vehicle

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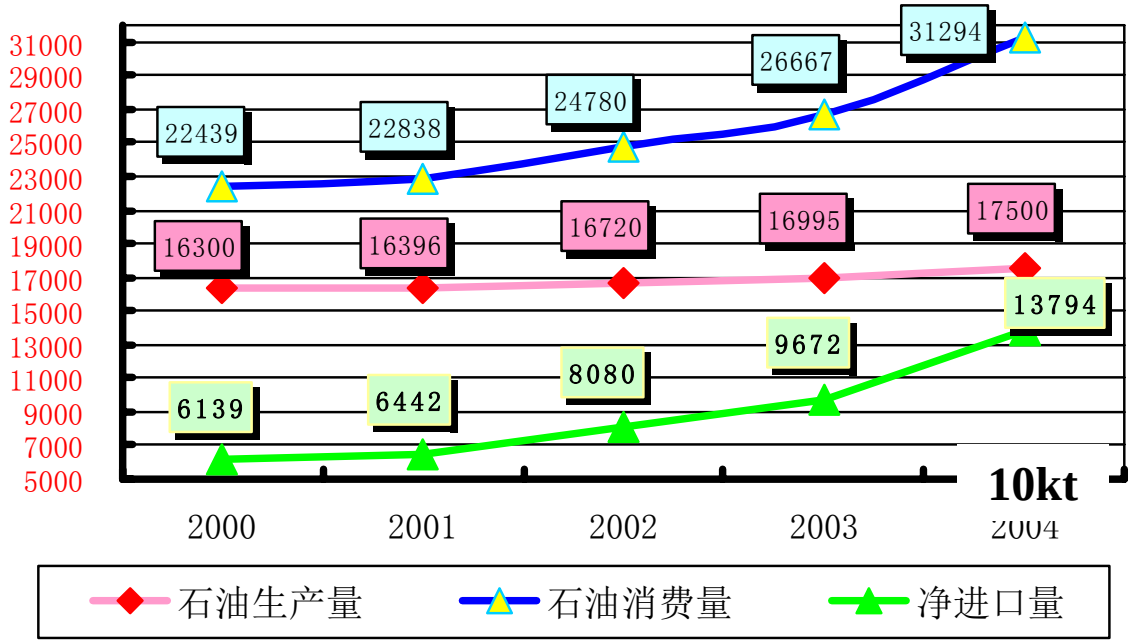
New Energy Automobiles

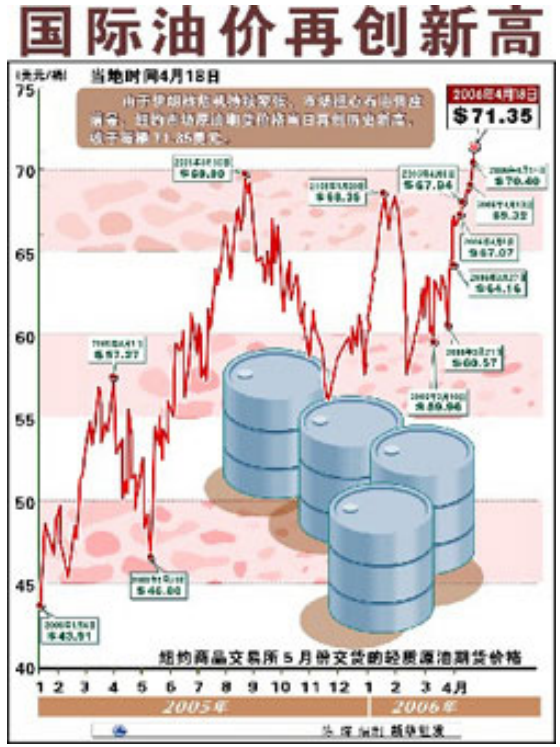
- China regulates development of new energy automobiles
- A new regulation regarding the qualifications of manufacturers for automobiles powered by new energies was promulgated on Nov. 1, 2007 by the country's top economic planner, the National Development and Reform Commission (NDRC).

- hybrid electric vehicles (HEV)
- battery electric vehicles (BEV)
- fuel cell electric vehicles (FCEV)
- vehicles powered by new types of fuel
- hydrogen-fueled vehicles

Why Electric Vehicle?

Oil price increases rapidly. It was 2.93 USD dollar per barrel in 1970's. Until now, oil price is over 100 USD per barrel.





China is putting more emphasis on economic measures to save energy and cut pollutants discharge. State Council Pressed *the measures for energy saving and cut pollutant discharge* on June 3, 2007

Electric Vehicle Types

- Battery Electric Vehicle (BEV): Battery or SC only
- Fuel Cell Electric Vehicle（FCEV）： Fuel Cell
- Hybrid Electric Vehicle (HEV）： B+Gas

  Plug-in

  B+FC

  FC+SC

  B+?

  FC+?

Type of Vehicle	Average daily fuel costs*		
	Gas	Electricity	Cents/mile
CV	$3.15	-	8.3
HEV	$2.21	-	5.8
PHEV20	$1.41	$0.48	5.0
PHEV40	$1.08	$0.72	4.7

*sources: NREL, Plug-in electric vehicle: current status, long-term prospects and key challenge

Electrochemical Energy Storage and Conversion System

- Rechargeable Secondary Battery
  - Lead Acid Battery
  - Ni-MH Battery
  - Lithium Ion Battery (LIB)
- Fuel Cell
- Electrochemical Supercapacitor

The keystone for electric vehicle

Chinese policies and Legislation

The guidelines on national medium- and long-term program for science and technology development (2006-2020) **was promulgated on February 9, 2006.**

Major fields and priority :

Transportation：New energy automobiles, Hydrogen storage and rechargeable battery for automobiles

Frontier technologies:

"New materials technologies"：Energy materials for hydrogen storage, secondary battery and supercapacitor

"Advanced energy technologies": Hydrogen and fuel cell

"Basic researches": Energy storage, energy saving, substitutional energy technology

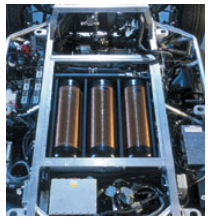
"Hybrid": Traditional *O-E hybrid* to *E-E hybridized*

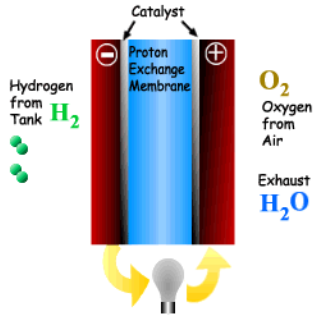
HEV → PHEV → Hybridized FCV

- GM "HydroGEN" : FC+NiMH
- Ford Focus sedan: FC+NiMH
- TOYOTA "Fine-T" CAR: FC+NiMH
- Honda "FCX" CAR: FC+SC
- AC Transit Fuel cell bus: FC+NiMH
- Tongji Univ; STAR Series fuel cell car: FC+LIB
- Tsinghua Univ; Fuel Cell Bus: FC+NiMH
- Shanghai Jiaotong Universiyt; Fuel cell Bus and Car: FC+SC, FC+LIB

Combined fuel cell and electrochemical energy storage system

Challenge to “fuel cell + energy storage devices” all electric hybrid power sources





H_2

Electricity storage

Hydrogen storage

Fuel cell system

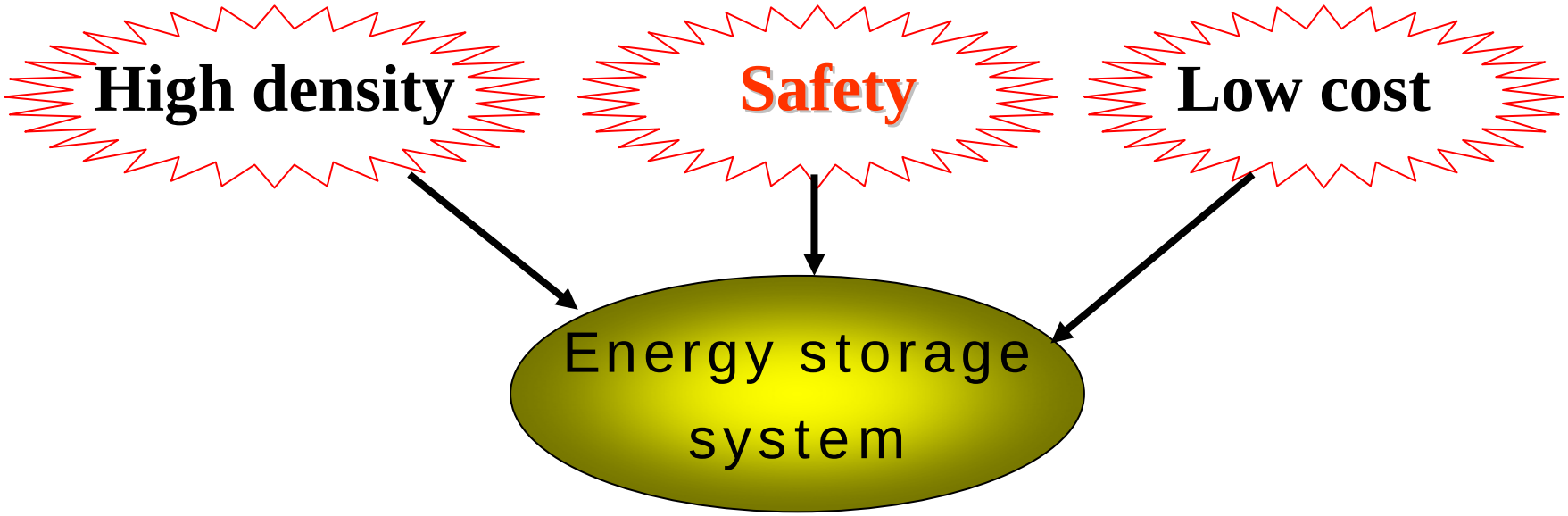
Materials → Energy storage ← Device

Barriers to FCEV power systems

- High performance
- Low cost
- Durability of fuel cell stacks
- Water transport within the stack
- Start-up and shut-down time
- Energy/Transient Operation.
- System Thermal and Water Management.
- Automotive-type compressors/expanders

- Competition with Other Technologies
- Public Acceptance

R & D strategics



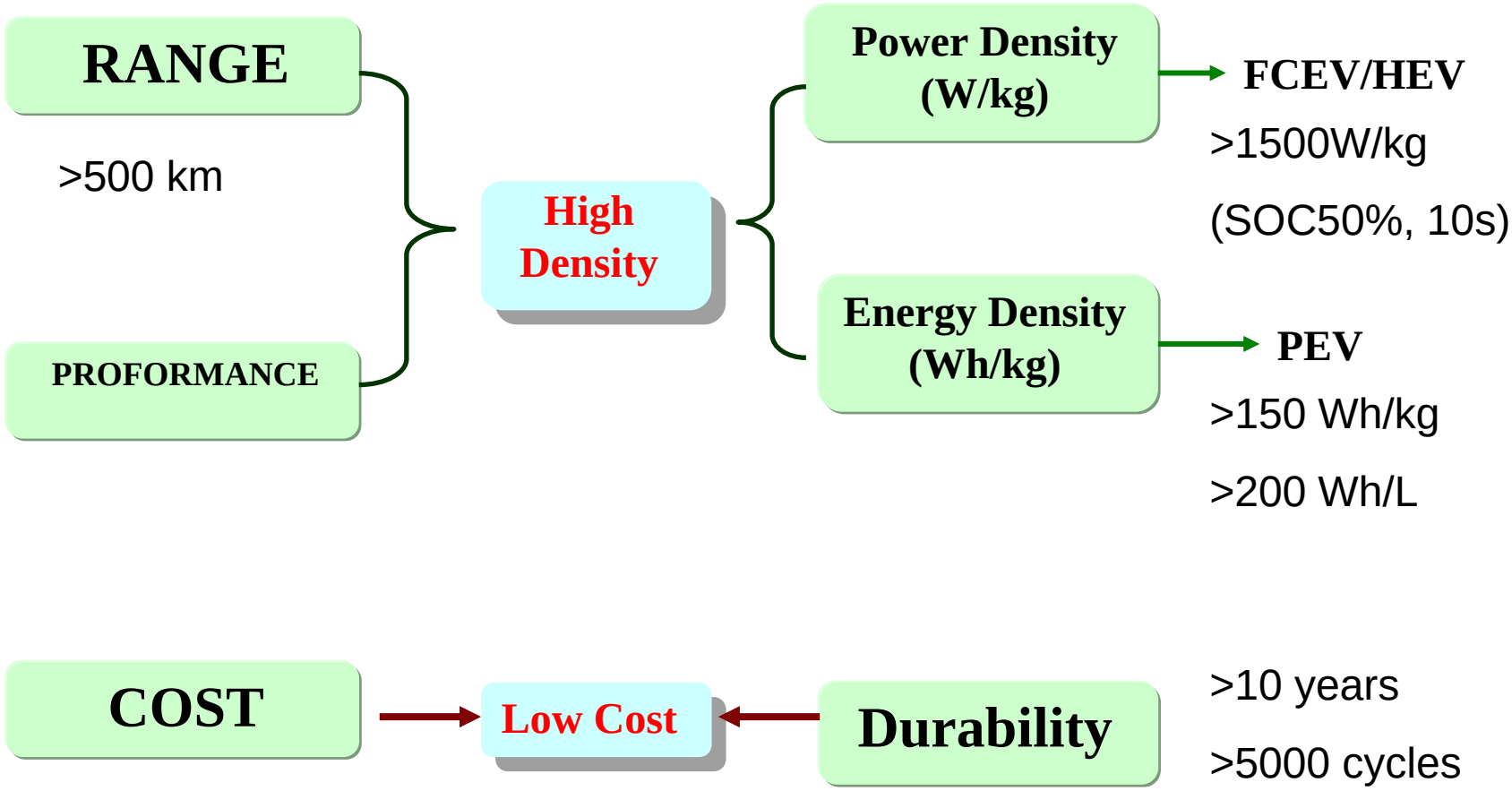
Material chemistry

Process engineering for material production

Energy material preparation

Manufacture of energy storage devices

Barrier to energy storage for EV



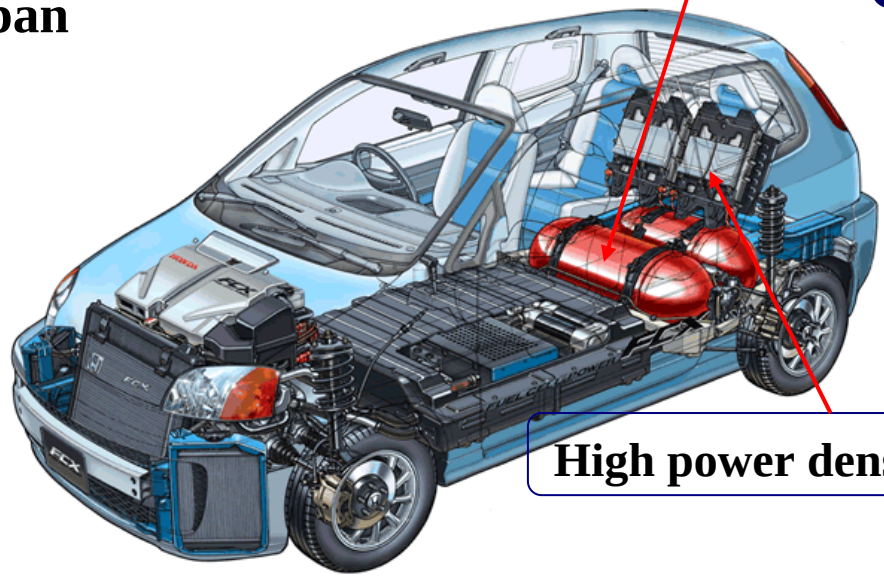
Barriers to FCEV power systems

BARRIERS

- Short range
- Poor transient response
- Short life-span
- High cost

SOLUTIONS

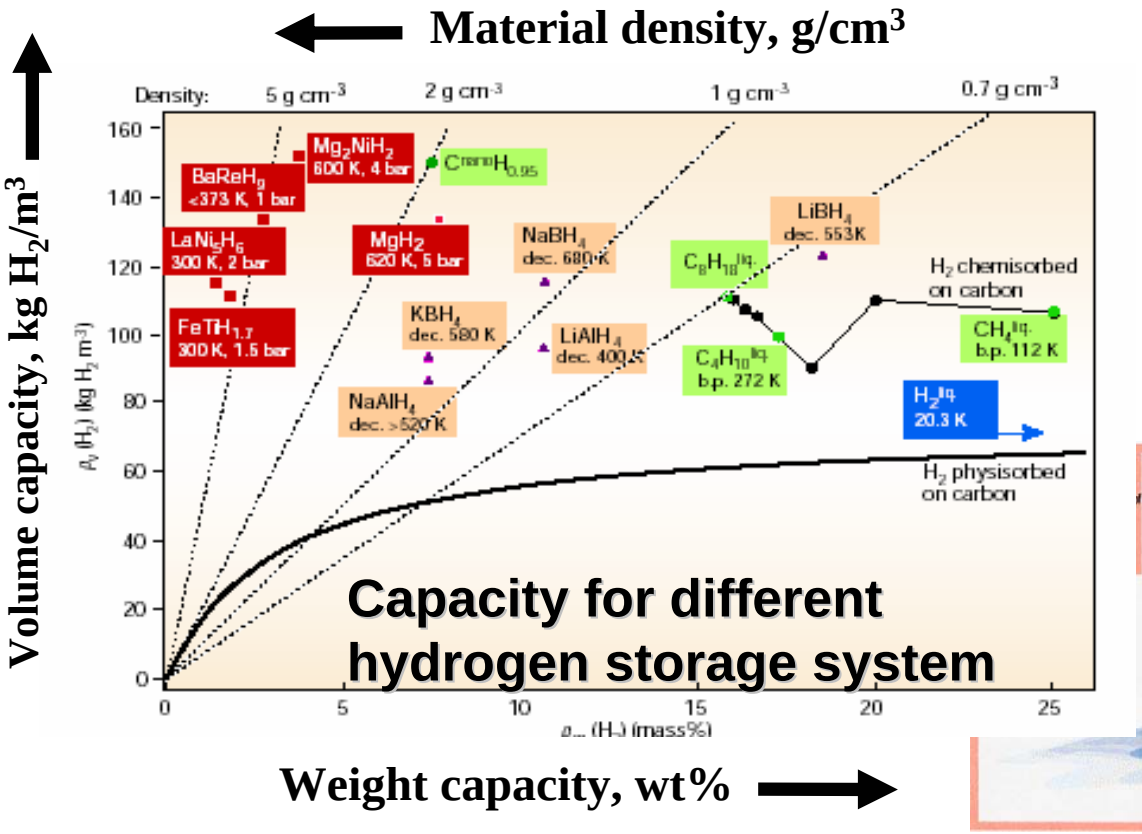
Hydrogen storage
- Volume capacity↑
- Weight capacity ↑



High power density
- Power density↑
- Cycling↑
- Cost↓

Power systems which combined fuel cell with rechargeable battery or supercapacitor are one of the options for new energy automobile

New “Energy Materials” design and preparation is the keystone to develop energy storage system



Louis Schlapbach & Andreas Züttel, ***Nature***, 2001，414（15）：353-358

National Basic Research Program of China

http://www.973.gov.cn/english/

National Basic Research Program of China

- The National Basic Research Program (973 Program) is China's on-going national keystone basic research program, which was approved by the Chinese government in June 1997 and is organized and implemented by the Ministry of Science and Technology (MOST).
- 973 Program involves multi-disciplinary, comprehensive research on important scientific issues in such fields of ***agriculture***, ***energy, information, resources and environmental, population and health, materials, synthesis and frontier science***, providing theoretical basis and scientific foundations for solving problems.

Four projects are relevant to hydrogen energy, fuel cell, battery and electric vehicle

1 Basic study for mass production of hydrogen, hydrogen storage and fuel cell application (2000-2005)

Chief Scientist: Prof. Zongqiang Mao (Tsinghua University)

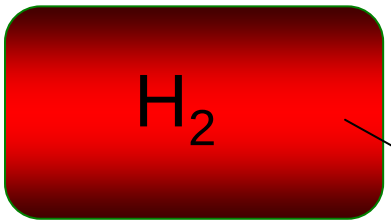
2 Fundamental Research of Novel and Green Systems of Secondary Batteries (2002-2007)

Chief Scientist : Prof. Feng Wu (Beijing Institute of Technology)

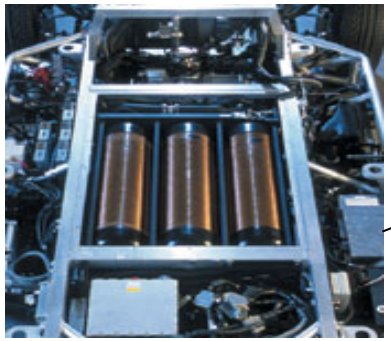
3 Basic study of hydrogen production by renewable energy (2003-2008)

Chief Scientist : Prof. Lie-Jin Guo (Xi'an Jiaotong University)

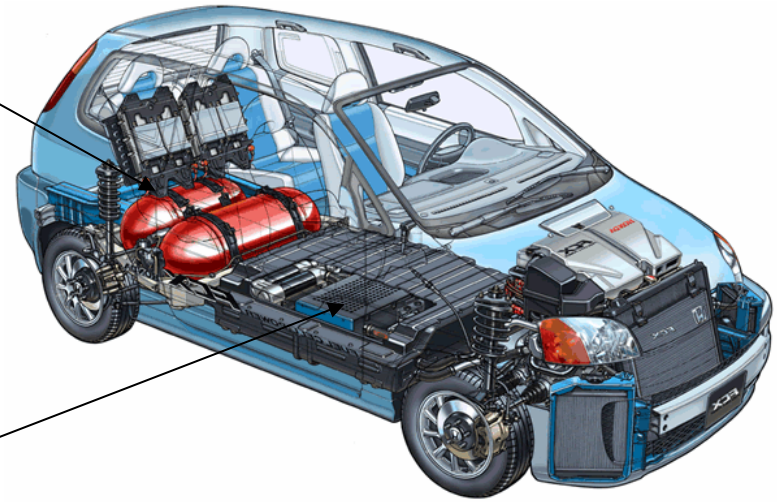
National Basic Research Program of China



Hydrogen Storage



Electricity Storage

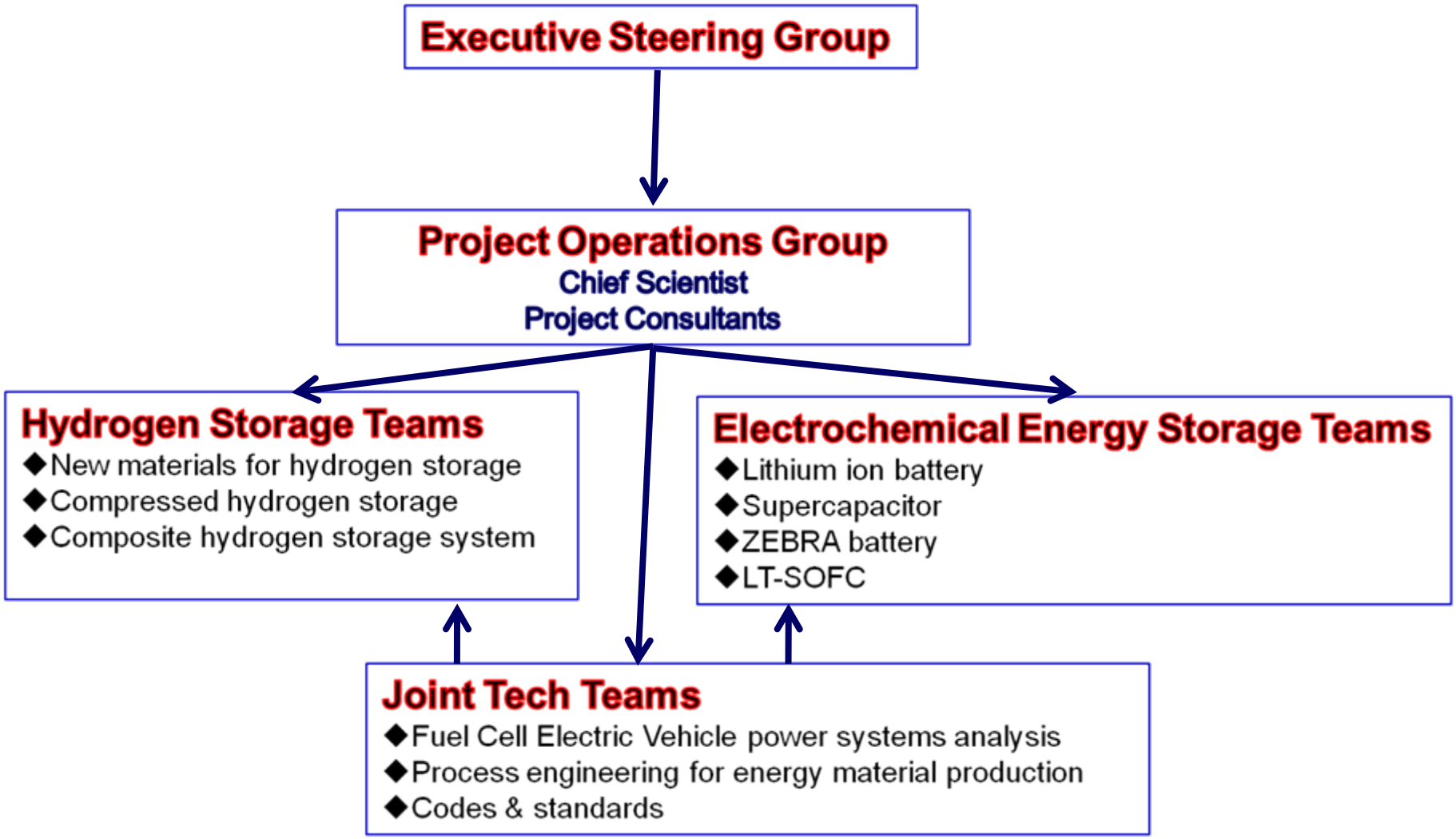


Energy supply and management

Basic study to energy storage system (H_2 & electricity storage) with low cost and high power density for electric vehicle (2007-2011)

Chief Scientist: Prof. Zi-Feng Ma (Shanghai Jiaotong University)

973 Project Organization



Sub-projects of the 973 projects

1. Molecular design and synthesis of hydrogen storage materials with high capacities (SJTU, ZJU)
2. Study on low cost electrode materials and their mechanism for lithium ion battery (Xiamen U, Fudan U)
3. Fundamental studies of low cost electrochemical supercapacitors (NUAA, Fudan U)
4. Basic study of solid-state electrolytes and related materials for LT-SOFC-ZEBRA battery system (NUT, SIC-CAS)
5. Chemical process engineering of energy storage materials production with low cost (SJTU, Tsinghua U)
6. Development of novel on-board hydrogen storage system with high density and of safety evaluation method for FCEV (ZJU, Tsinghua)
7. Fundamental study of system management and environmental compatibility of on-board energy storage systems for FCEV (SJTU)

973 Project for Energy Storage System

Technology-specific Research Goals

◆The solution to Electric-Electric hybrid FCEV commercialization depend on the reliable technique of energy storage systems with low cost and high density, as well as hydrogen storage systems with security and reliability.

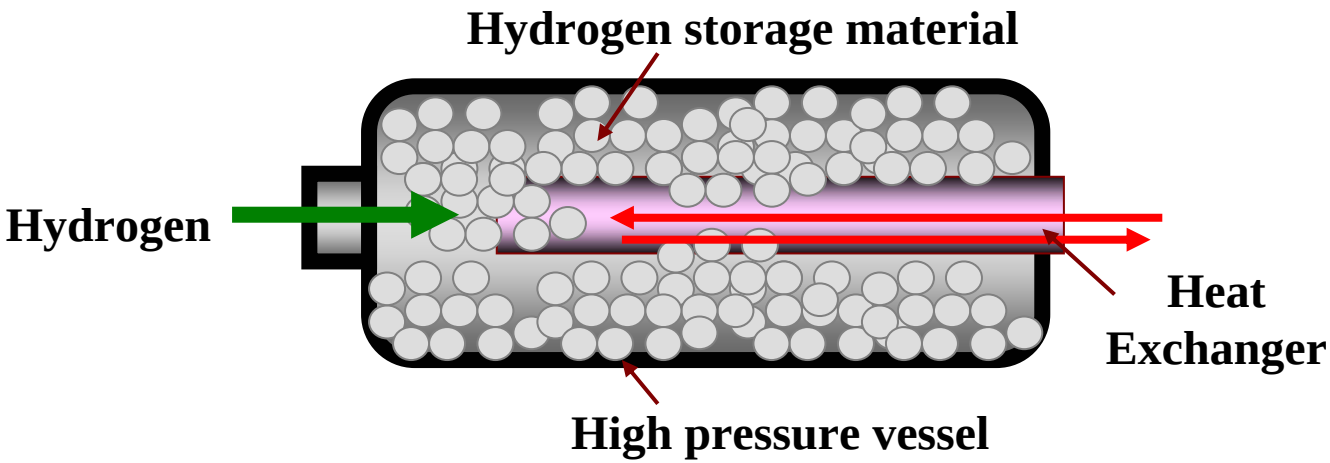
◆1-2 novel materials for composite hydrogen storage will be developed; Capacity of hydrogen storage will achieve more than 32 kg/m^3.

◆The cost of the electrochemical supercapacitor is low than ¥80 RMB/Wh (12USD/Wh)

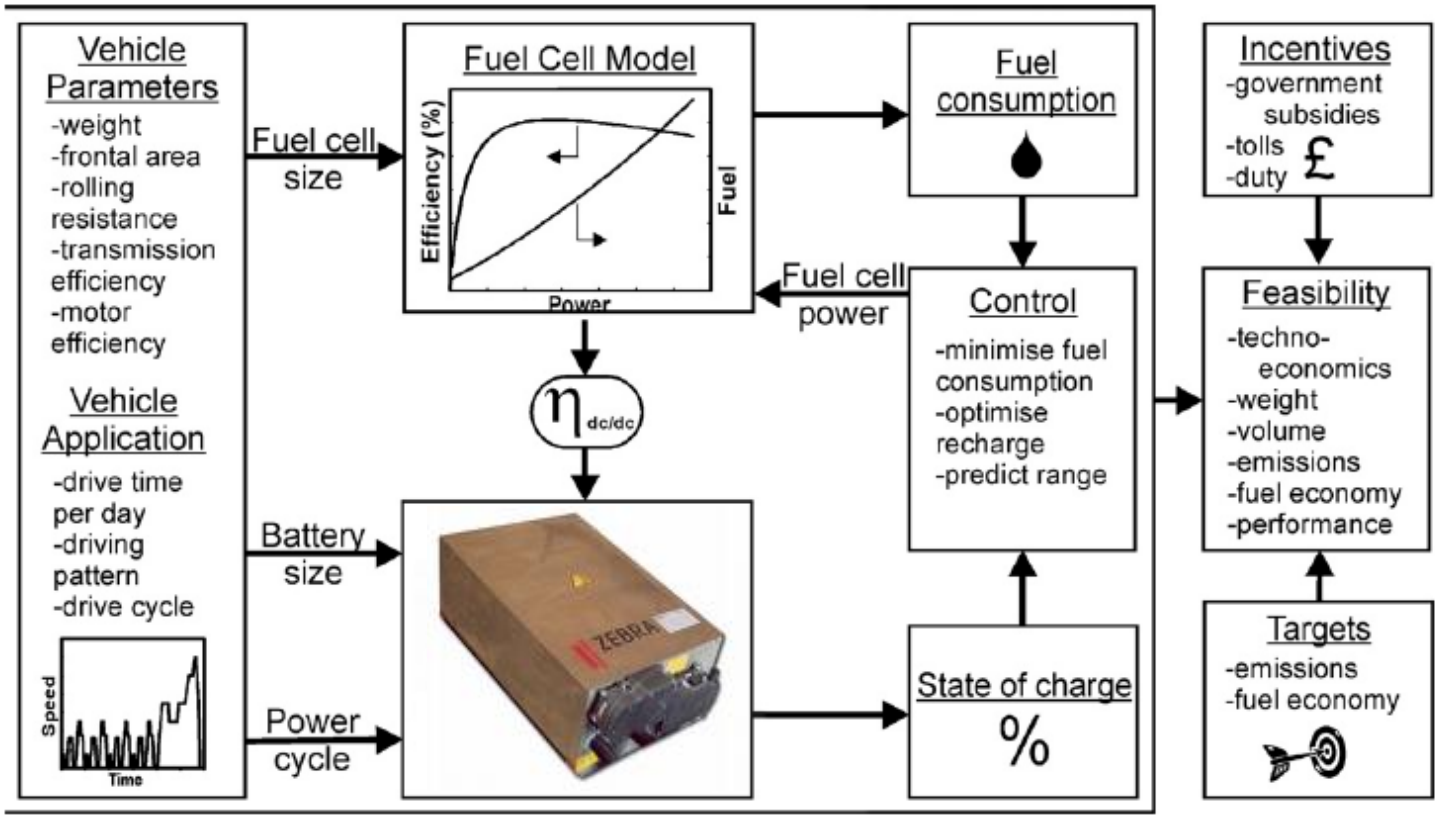
◆The cost of the rechargeable battery is low than ¥ 2-3 RMB/ Wh

973 Project for Energy Storage System

- Developing on-board composite hydrogen storage system; Novel light hydrogen storage materials design, preparation and characterization.
- Multi-energy supply and management system integration and optimization for FCEV.



973 Project for Energy Storage System



Combined a sodium-nickel chloride (ZEBRA) battery and an intermediate temperature solid oxide fuel cell (IT-SOFC) to form an all-electric hybrid package that surpasses the efficiency and performance of a purely fuel cell electric vehicle.

China Manufacturer

In China, we can find all of dealers to supply the fuel cell stack, lithium ion battery, Ni-MH battery, supercapacitor, motor and vehicles for demonstration. But the qualities still need to be improved.

Lithium ion battery

BYD Company Ltd

星恒电源 Phylion Battery

Suzhou Phylion Battery

DLG [次世代]

DLG Batteries Co. Ltd.

Fuel cell stack

神力科技 SHEN-LI HIGH TECH

Shanghai Shen-Li

Dalian sunrise power

Supercapacitor

奥威科技 AOWEI TECHNOLOGY

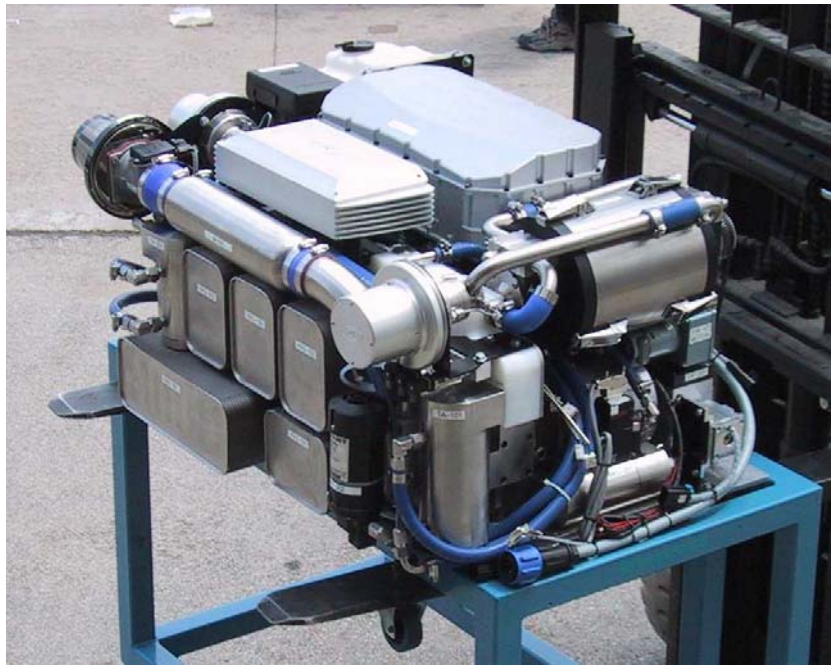
哈尔滨巨容新能源有限公司 HARBIN JURONG NEWPOWER CO.,LTD

上海交通大學
Shanghai Jiao Tong University

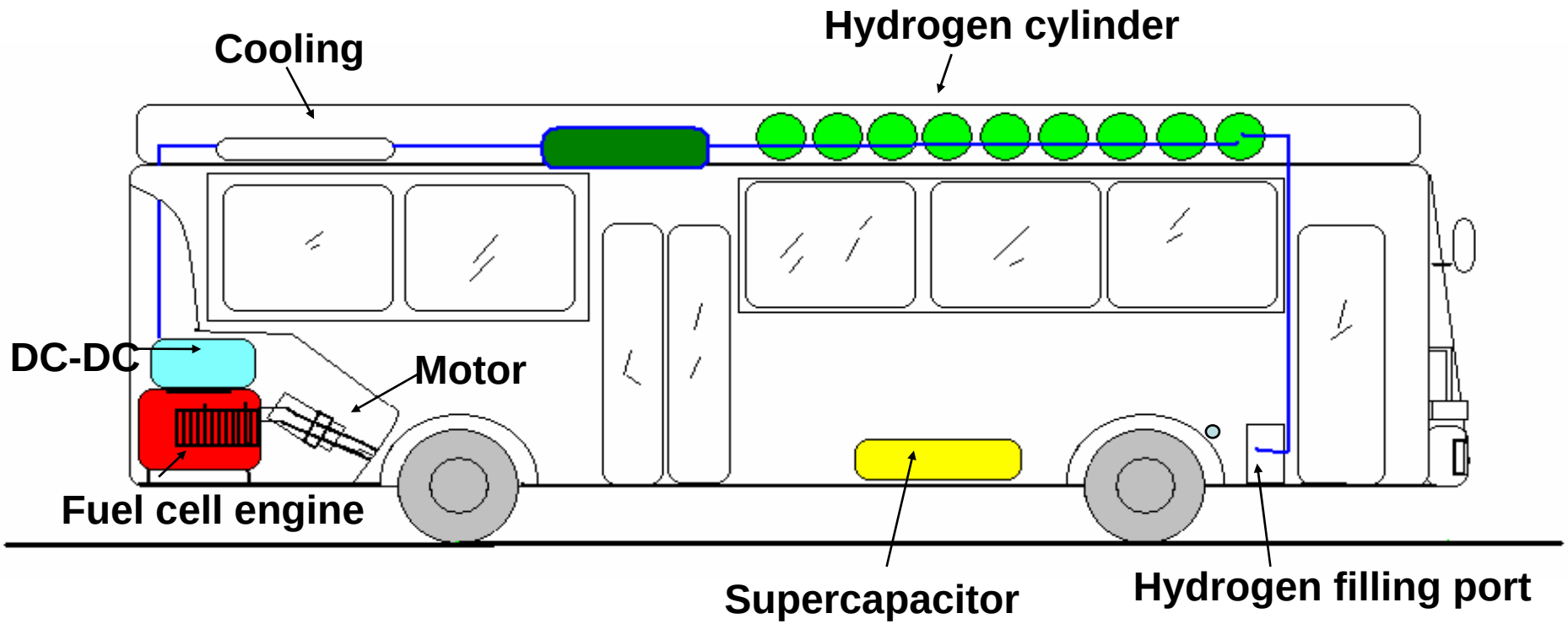
FCEV demonstration activity at Shanghai Jiao Tong University

Fuel cell powered mini van was designed by SJTU and Pan Asia Automobile Technology in Oct. 2001

- 35kW PEMFC stack
- 72L Compressed H2, 350bar
- Max Speed: 113 km/h
- 85kW、 AC Inductive motor
- PIM power convert controller
- Rechargeable Battery



FCEV demonstration activity at Shanghai Jiao Tong University



Shanghai Shen-Li, SJTU, Suzhou Chuangyuan Group, Suzhou Golden dragon Bus Co Ltd developed INNOVATION Ⅰ fuel cell city bus together.

INNOVATION ｌ Fuel cell city bus was running in Shanghai Jiao Tong University campus during her 110 anniversary (April,2006)

Performance of FC Bus

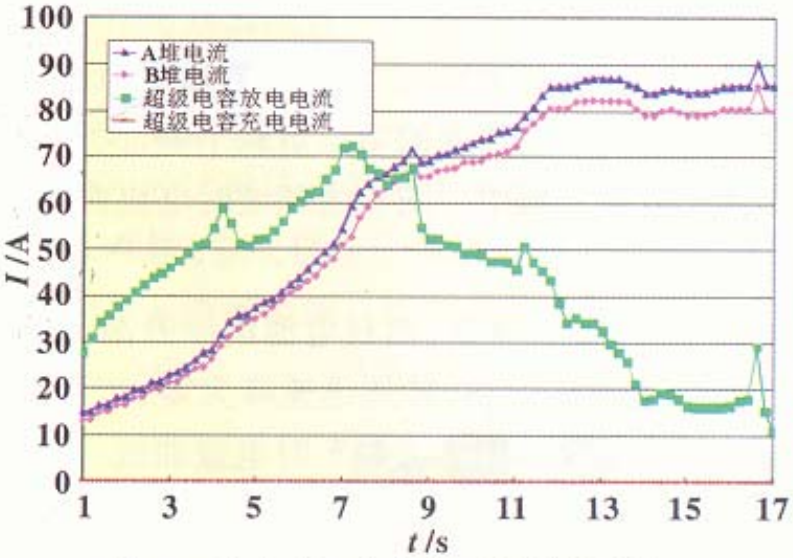


图 3　启动时混合动力系统性能输出

Fig.3　Output performance of the hybrid power system in start–up state

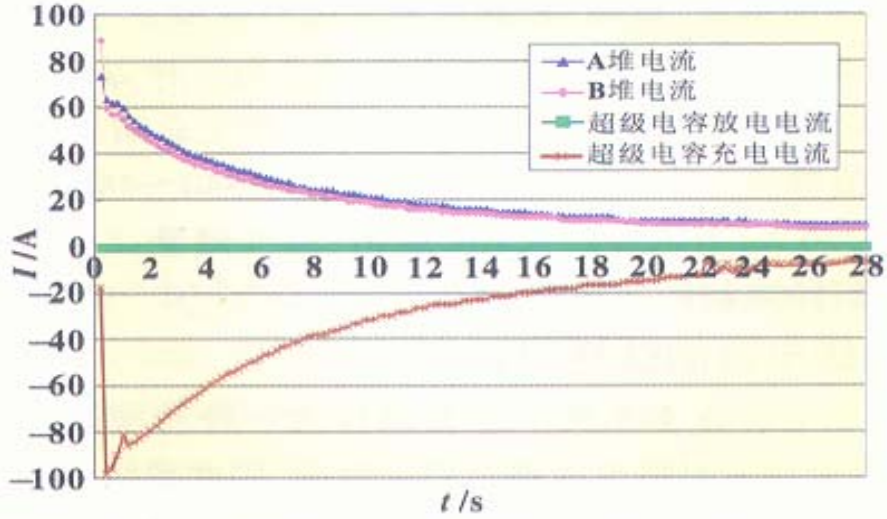


图 7　刹车状态下混合动力系统性能输出

Fig.7　Output performance of the hybrid power system in braking state

Fuel cell stack

DC-DC system

Performance of FC Bus

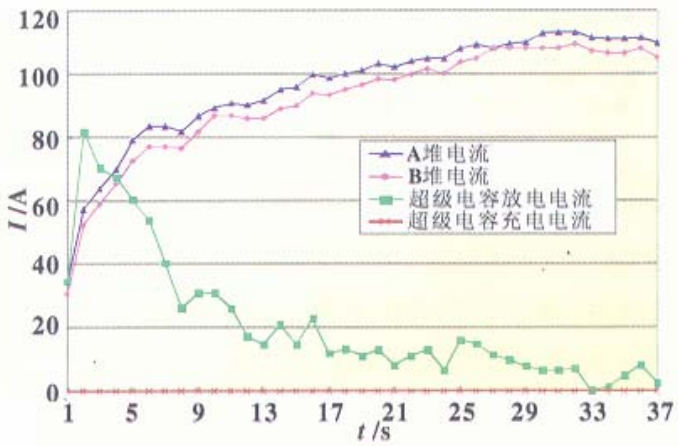


图 5　加速状态下混合动力系统性能输出

Fig.5　Output performance of the hybrid power system in speed–up state

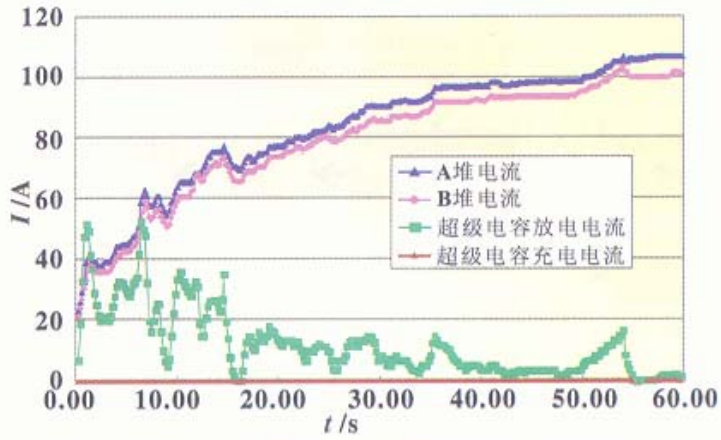


图 6　爬坡状态下混合动力系统性能输出

Fig.6　Output performance of the hybrid power system in climbing state

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