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HELIOS European project and EUCAR / VDA Research Roadmaps

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Abstract

The first part of this paper will focus on the presentation of the upcoming HELIOS European research project, federating eighteen partners and coordinated by Renault, who will start in autumn 2009. The second part presents a vision of the High Energy targets and Research Needs, the result of a working group uniting two different coordination platforms at European level, the association of European carmakers EUCAR, and the German VDA.

Keywords: Lithium-ion, Batteries, Roadmaps, HELIOS, EUCAR, VDA

1 Introduction

Quality control and reliability is now well established for HEV cells based on Nickel Metal Hydride technology – Toyota Prius proposes today eight years guarantee over the batteries) – and is under validation for HEV based on Lithium-ion technology. If we consider the High Energy (HE) applications, beside evident cost issue due to the larger dimensions of the battery itself, the state of the art on HE battery technology is behind that of High Power cells for HEV, in terms of safety, life and quality control.

This depends on the specificities of the HE cell large formats. Not only is the stored amount of energy larger than in hybrid electric vehicle, it is also much more difficult to find a crash protected location inside the vehicle to package such large battery systems. In addition, pure electric vehicles and plug-in hybrid vehicles will operate the battery systems at a higher state of charge than hybrid vehicles. At this higher state of charge, the abuse tolerance of "conventional" Li-Ion electrochemistries is reduced.

Large format HE cells also tend to age faster, possibly because of the larger internal gradients, but also because of the increased probability to generate defects in the manufacturing process. These are some of the reasons why no large series product using HE cells has been successfully commercialised until today.

The HELIOS project (High Energy Lithium-Ion Storage Solutions) is thus focused on improving the cells life and safety, though a thorough comprehension of the ageing mechanisms, and of the effects triggering hazardous events. It is a European Project federating eighteen partners who are all active in the advanced batteries domain. Johnson Control Saft will develop the samples, consisting in identical large format cells using four different electrochemistries.

In parallel, a "Battery Roadmap Workgroup" uniting members from EUCAR and VDA has been created both to update European targets for High Power end High Energy applications, and to propose a European automotive manufacturers vision of the strategic Research Needs.
We will present here the part of the work relating to the High Energy application.

2 HELIOS EU Project

2.1 General presentation

Cathode materials such as Lithium Iron Phosphate (LiFePO4), Lithium Manganese Spinelle (LiMn2O4), are currently considered promising "new generation" electrode materials. Together with reference Cobalt and Nickel based materials such as $Li(NiMnCo)O_2$ and $Li(NiCoAl)O_2$, these cathodes cover the main technological trends for the near future. It is however difficult to compare these technologies under different angles (see list below), because representative samples and prototypes usually come from different origins and many factors such as the cell size and design, the additives, the electrode engineering contribute the comparative evaluation results. The main issues to be addressed, studied and compared should include the following items.

- Safety:

LiFePO4 and LiMn2O4 cathode materials are considered intrinsically safer than conventional lamellar Li-ion chemistries that can present "thermal runaway" behaviour when the internal temperature increases over a given threshold. However, the trigger mechanisms should be assessed for larger cells than current "high power" commercial cells dedicated to power tools, for the results can be very different in the case of high capacity cells. Moreover, concerning the safety test procedures, it is fundamental to define a European standard for safety tests, taking into account the different realities of High Power and High Energy type Li-ion cells.

- Recycling:

The disposal of end-of-life batteries is a fundamental issue for all automotive application involving advances batteries. While the absence of Ni and Co based compounds should have a positive effect on the initial cost of the battery, it is still unclear if the recycling process for alternative chemistries is technically feasible and economically viable.

- Life:

Innovative cathode materials such as Lithium Phosphate and Lithium Manganese spinel are known to have an increased risk in terms of ageing due to the possible dissolution of the metals that trigger passivation reactions on the anode. Special attention should be given to calendar ageing, as the shelf life at high SOC and temperature conditions may sometimes be shorter than the cycle life.

- Cost:

The total cost of the cell should be evaluated, for an expensive process to enhance conductivity can compensate the apparent low cost of the cell's raw components (case of LiFePO4).

Of course, the general performances of the cell (in terms of energy and power capability) should stand up to the car makers requirements.

2.1.1 Partners

Partners of the Project include entities coming from both public areas – laboratories – and private background – industrial partners.

- ***6 Automotive manufacturers***: Renault (coordinator), Opel, Volvo, PSA Peugeot Citroen, Ford Aachen, CRF/Fiat.
- ***3 Laboratories***: LRCS (F), Uppsala University (SW), RWTH-ISEA (D) + RWTH-IME (D), ENEA (I);
- ***5 Test Institutes***: ZSW (D), EDF (F), CEA (F), INERIS (F), Arsenal (AU);
- ***1 Recycler***: Umicore (B);
- ***1 Battery Maker***: Johnson Control Saft, through both its entities Saft and JCI Hannover.

All partners are recognized experts in the advanced battery evaluation and understanding.

2.1.2 Programme & funding Scheme

The European Commission funds the project in the framework of the FP7 programme. The project has been submitted in May 2008 to answer to the SUSTAINABLE SURFACE TRANSPORT (SST)-2008-RTD-1 call published in November 2007: it will start in autumn 2009.
The total budget is around 4M€, of which 2,9M€ will be funded by the European Commission.
Renault is coordinator of the project, with the support of Opel.

2.2 Object of the study & target applications

The main goal of the project is to study the effect of the chemistry and the electrode material characteristics on life and safety, using one large identical prototype cylindrical format, corresponding to a capacity of 35Ah to 45Ah cells – depending on the chemistry.

The tested chemistries include "standard" Nickel based NCA and NMC, Iron Phosphate, and blended Mn-spinel material, all four coupled with a graphite anode.

Type of chemistry (cathode/anode)	Type of batteries	Vehicle applications
$Li(NiCoAl)O_2$ / C	High Energy Cells (30 to 50 Ah)	- High e-range (40miles) Plug-in Hybrid - EV - HEV heavy-duty trucks
$Li(NiMnCo)O_2$ / C		
$LiMn_2O_4$ + NCA / C		
$LiFePO_4$ / C		

Figure1: Type of cell chemistries, cell formats and possible applications studied in the HELIOS Project

These samples will be evaluated life-wise and safety-wise through a large test campaign involving the laboratories and test-institutes. The end-of-life samples will be teared apart by Saft and then analysed by the academic partners, in order to identify the different failure mechanisms, and relate them to the testing conditions and the cell composition.

The secondary goal of the project is to study the impact of the different choices in chemistries on the system level (battery pack), considering the following:

- Consequence of the cell safety tests results on the battery pack concept: impact on safety devices (valves, balancing, safety devices, fuse…);
- Feasibility of fast charge at battery pack level;
- Estimation of extra recycling needs when treating modules or large battery packs: comparison between manual dismantling and one-step thermal treatment.

This should enable the estimation of global battery pack cost for each defined application.

2.3 Main deliverables & impacts

The updated review of the aging mechanisms for the new electrochemistries and the post mortem analysis of the cells cycled and stored at different conditions will help to understand what is causing the aging of high-energy cells. After the project is completed, the industry will have learned how the batteries have to be operated, and which electrochemistries needs to be chosen in order to optimize the corresponding operating and calendar life times.

Furthermore, the project will give valuable information on the abuse behaviour of the various electrochemical couples for Li-Ion batteries for high-energy applications. Abuse tolerance of high-energy cells is of supreme importance for vehicle applications with a large amount of electric energy stored like pure electric vehicles or plug-in electric vehicles.

Common European test procedures for the assessment of novel battery technologies for electric and plug-in hybrid applications will be established. These procedures will be then published, in order to help the standardisation on battery technology evaluation.

3 EUCAR Research Roadmaps

3.1 Introduction

3.1.1 Motivation

The European automotive industry's leading experts are currently working upon the definition of common Roadmaps for advanced battery research. The motivation for this work is dual. On one side, we wish to provide guidelines for battery manufacturers that take into account the European specificities. On the other side, there is also the purpose to express some Research Needs, or Resarch Roadmaps, enabling to fill the gap between the Targets and the State of the Art.

3.1.2 Participants

Partners of the Project include most members of the EUCAR (European Carmakers Association) consortium, as well as some members of the VDA.

- EUCAR (Renault, Opel, Ford Aachen, Volkswagen, Volvo, PSA Peugeot Citroen, BMW, Daimler)

- VDA (German carmakers above + Audi, VDA chair).

The kick-off of this working group took place in September 2008, and the final version is expected by April/May 2009.

3.2 High Energy Targets

Within such working group, the first step was to translate the European tendencies into battery system targets for each automotive application.
Two different target tables exist for two groups of applications. The first covers the High Power targets from Mild- HEV to low e-range PHEV. A second target table is dedicated to the High Energy applications ranging from high e-range PHEV to large EV. The Auxiliary Power Unit application for large trucks is included into this second section.
We will here focus on the second table, presenting the draft-updated version for High Energy battery systems.

High Energy UPDATED DRAFT EUCAR TARGETS		EUCAR 2010 targets (BOL)	EUCAR 2015 BOL targets	EUCAR 2020 BOL targets
Energy Density	Wh/kg	90…100	130...150	180...200
Specific Energy	Wh/L	130...150	200...250	300...400
Power density (discharge)	W/kg	400…750	500…950	600…1250
Specific Power (discharge)	W/L	550…1000	850…1200	1200…2000
Peak duration	s	@ 20s	@ 20s	@ 20s
Power to Energy ratio		3.7 to 7.5	3,3 to 6,3	3 to 6,25
Low Temp (-0°C) Discharge Power Capability	% RT Pow	50...60	55…70	60…85
Low Temp (-20°C) Discharge Power Capability	% RT Pow	10…20	25...30	40...50
Regen power density	W/kg	300...500	350...650	450...800
Peak duration	s	@ 10s	@ 10s	@ 10s
Fast charge (continuous)	W/kg	120...180	180...250	250...400
Low Temp (-10°C) Charge Power Capability	% RT Chg Pow	10…20	25...30	40...50
Battery Life	y	8...10	10	15
Cycle Life (Charge depleting mode)	Cycles	3000…4000	4000	5500
Cost	$/kWh	400…500	300	150
Corresponding Volumes	MWh/y	500	7 000	15 000

Figure 2: EUCAR Target grid for High Energy (EV/PHEV) applications. The figures correspond to the DRAFT version updated April 15th 2009. White boxes show the critical targets, grey boxes show the items offering a competitive edge, and the black boxes are not targets but boundary conditions not to trespass.

The targets refer to the complete battery systems including the cells, cables, connections, rack, battery disconnect unit and fuse box, BMS, thermal management, tray and cover.

Compared to the existing and USABC targets [1] for EV application and to the METI (Japanese Ministry of Economy, Trade and Industry) targets [2], EUCAR projects a more moderate specific energy for the long term (2015 and 2020), but remain challenging. The specific power goals are much lower than those of METI, as they are to be considered not as a target, but as a boundary condition to respect in order to assure a correct behaviour of the vehicle. The strategic targets for the High Energy applications are highlighted in white.

3.3 Research Needs

Having defined the targets and their evolution for 2015 and 2020, the second step has been to assess the priority Research Needs, divided into six main technological axes: energy, power, life, cost, safety for the battery cells and their components, plus a specific technological axe on battery system improvement.

3.3.1 Energy

The main trend to improve the energy density of HE cells consists in developing high capacity anodes and high voltage cathodes.

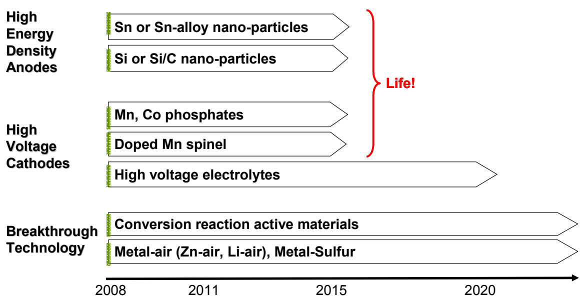

Figure 3: Energy Technical Roadmap.

We emphasize that high voltage systems require new research on new electrolytes that can tolerate an enlarged voltage window.
In addition, when dealing with components enhancing energy density, particular attention must be given to conserving an acceptable cycle and calendar life.

3.3.2 Power

Power increase strategy aims either an internal resistance decrease, or a general lightening of the cells and/or components.

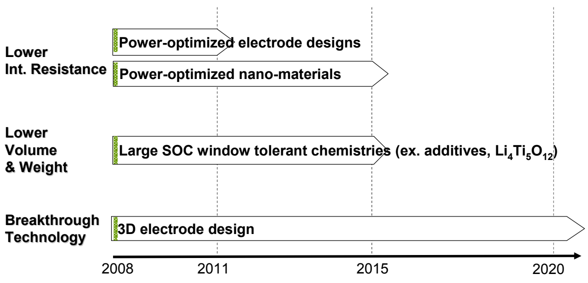

Figure 4: Power Technical Roadmap.

An interesting advanced technology would be the development of a 3D electrode design.

3.3.3 Life and Cost

These two axes are closely related, in fact an increase in the lifetime of the battery has a direct positive consequence on the cost of usage.

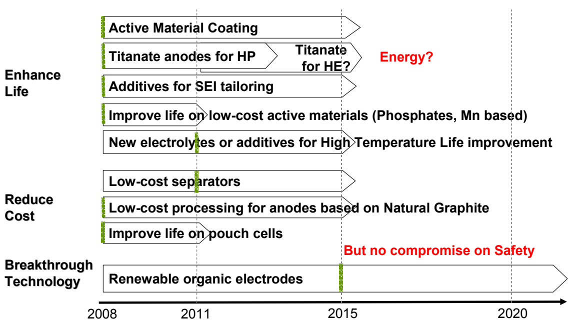

Figure 5: Life and Cost Technical Roadmap.

Main strategies to increase the lifespan of existing active materials consist in mastering an external protective layer either by coating or by SEI controlled growth. Lithium Titanate appears to be a very interesting anode material but its low voltage difference with most cathode materials makes it unsuitable for high-energy applications on the short term.

A strategic issue is to resist to high temperature ageing.

Finally, cost reduction strategies should not have negative effect on the safety.

3.3.4 Safety

The main issue when increasing the intrinsic safety of the battery components is the risk of added cost. Promising technology such as High Temperature melt down separators or non-fluorine based salts should be available at the same or lower price than current separator and lithium salt.

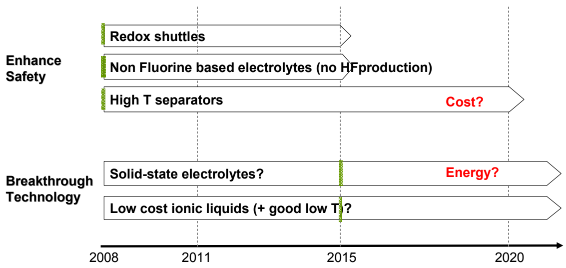

Figure 5: Safety Technical Roadmap.

Redox shuttles are an interesting approach to dissipate heat during balancing or accidental overcharge. However, this technology applied to large format cells should be combined with an effective device to dissipate the extracted heat into the environment.

3.3.5 System

Some research needs concern directly the complete battery system.

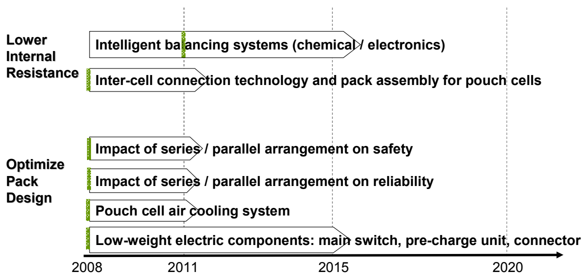

Figure 6: Battery System Technical Roadmap.

An interesting approach besides the connectors and cell balancing is the study of the impact of the electric architecture (series, parallel) and its effect upon safety and reliability. A typical question would be if it were more safe and reliable to work with one 50Ah cell, or with two 25Ah cells connected in parallel.

Also strategic is the development of an effective and low cost air-cooling system for the PHEV application, adapted to pouch cell design.

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Authors

Dr. Anna Teyssot, material scientist, obtained her PhD in Electrochemistry at the Ecole Polytechnique (FR), jointly with EDF (French national electric company), on Lithium Metal Polymer Batteries for EV applications. Since 4 years, she works on advanced electrical energy storage systems at Renault's Research Department. Her fields of expertise include battery ageing modelling, battery evaluation and new technologies.