HIGH ENERGY DENSITY LI-ION CELLS FOR TRACTION

EUROLIION

"EuroLiion Publishable Summary"

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1. Publishable summary

Summary description of project context and objectives

Development of EVs for the transport sector is high on the list of EU priorities for economic recovery within the framework of the Green Car Initiative. Most work to date has focused on technical development and market analyses. Important challenges will also be faced in terms of durability, safety, cost and the required charging infrastructure.

Although conventional Li-ion cells have become widespread, some have too low energy density for transport applications. Others are either too expensive or do not meet environmental or safety standards. The EU-funded project 'High energy density Li-ion cells for traction' (http://www.euroliion.eu/ (EUROLIION)) focused on developing novel Li-ion batteries that combine high energy density, low cost and enhanced safety. Benefits were obtained through a change in materials. The new cell has an innovative silicon (Si) anode (negative electrode), novel low-cost salts, and a modified iron or manganese/nickel-based cathode (positive electrode). These electrode materials are cheaper and can store higher charge densities than the conventional electrodes. In addition, they require a higher operating voltage to increase cell energy density.

Scientists defined new formulations for synthesising nano-Si materials for the negative electrode, and different binders and additives. The produced Li-ion cells with a positive electrode that includes a combination of lithium, nickel and manganese demonstrated stable cycling. With a novel well-purified salt as an electrolyte, the nano-Si electrodes showed satisfactory capacity retention. More lithium salts were also synthesised, tested and even further purified since some were found to degrade the positive electrode.

Scientists produced and tested 20 cylindrical cells with commercial lithium iron phosphate (LFP) and graphite electrodes, and 20 cells with LFP and nano-Si electrodes. These tests served for cell modelling. A safety assessment according to the test procedure was carried out. Finally, a full vehicle simulation was performed.

EUROLIION has paved the way for widespread use of EVs by developing higher-efficiency, cheaper and safer rechargeable batteries. The new technology should enhance the competitiveness of the EU while supporting its dedication to a low-carbon–output and sustainable economy.

Initial Goals

The research described in this project aims to develop a new Li-ion cell for traction purposes with the following characteristics:

• high energy density of at least 200 Wh/kg;
• low costs i.e., a maximum of 150 Euro/kWh;
• improved safety.

Other important goals that are being targeted on are:

• a specific power of at least 1000 W/kg during normal operation;
• durability, reflected by a life time of 10 years and a cycle life of 2500 cycles;
• operating temperature from -40 ^{o}C to 50 ^{o}C;
• using environmentally friendly and sustainable materials;
• protecting European technology.

Description of work performed and main results

The work of EuroLiion is constructed along 8 WPs. The work concerned introductions of new materials, in which various steps required an iterative process so as to come to the final cells. The work performed since the beginning of the project is described by WP.

Coordination, management and dissemination (WP1, WP2)
WP1 The project started with a kick-off (KO) meeting where the structure of the project was explained in all its aspects, followed by every six month a project meeting.
WP2 concerned coordination of the R&D part. Here important decisions were taken such as the type of electrodes to be used, i.e. LNMO and Si as purchased by CEA with commercial electrolytes. Besides, the consortium decided to adjust the cell size to 18650 and pouch cells since these sizes were more appropriate according to the available coating sizes at CEA and EU safety reasons..

Materials synthesis (WP3, WP4, WP5)
WP3: two new formulations for electrode fabrication were defined for nano-Si electrodes, including different binders and additives as analysed with a synchrotron, AFM, NMR and XPS. Initial Li-ion cells with optimised LNMO positive electrode were performed. Using well-purified LiTDI salts, the nano-Si electrodes show a good capacity retention in the defined electrolyte.
WP4: novel electrolyte salts were synthesized and tested. The nano-Si electrolyte interface showed partial decomposition of the novel salt. Exposure to LNMO also led to decomposition. Most of the degradation seem to be caused by the high voltage of the cell.
WP5: work was focussed on the optimisation of the LNMO electrode, achieving an adequate electrode formulation, a decent cycleability, and stable adequate capacity. It was decided to use LNMO as cathode material in the 3rd series of test cells. For this reason, about 4 kg was purchased form EuroSupport according to the recipe developed within EuroLiion.

Electrode and cell manufacturing (WP6)
WP6 concerns the fabrication of the electrodes, made with the formulations achieved in WP3-WP5 with the formulations decided in WP2. Twenty 18650 cylindrical cells have been produced with commercial LFP/Graphite electrodes and tewenty 18650 cylindrical cells with LFP/nano-Si for testing in WP7. The 3rd series of test cells contained 20 pouch cells with LNMO/nano-Si.

Testing and benchmarking of the cells (WP7)
WP7: cycle life testing of the prototype cells has been performed at ±0, +23 and +45ºC, following the procedure developed here. Tests were used to extract necessary parameters for cell modelling, which was further necessary for the development of the battery management, i.e. the algorithm for estimation the SOC. A safety assessment according to the test procedure was carried out. Finally, a full vehicle simulation was performed. For the 3rd series of test cells, it can be stated that the response of cell ranges from good to acceptable. The results might be positively compromised by the high internal resistance and the high ratio of surface to volume.

Eco-design and costs assessment (WP8)
In WP8 an evaluation was carried out on the new cell design and components regarding its LCA, recyclability and cost. The differences are minor when the materials are considered, while the production shows bigger differences. The new LNMO/Si cell design shows slight improvements compared to state of the art LFP/G. It shows an important aspect of an environmentally friendly battery design such as energy input for production, metal scarcity, etc. The suggested scarcity of Li seems no longer relevant due to huge Li sources, therefore recycling of Li was no longer studied.
Three recycling processes are identified, a pyrometallurgical, a hydrometallurgical, and a physical route. The 1st method gives basically a slag containing a Li product that is incorporated in e.g. construction materials, the 2nd one uses a separation technique from where components are recovered via dissolution/precipitation reactions. The 3rd route includes almost full dismantling of the cell so as to recover as much materials as possible.
Cost wise the EuroLiion goals of 150€/kWh could not be reached, mostly because of the high price of nano-Si. There is also no cost advantage compared to state-of-the-art NMC/G or LFP/G. However, if the price of nano-Si drops and the cell design is optimized, the LNMO/Si cell has great potential to be significantly lower priced than those cells and also to undershoot the ambitious EuroLiion target.
Another important conclusion is that recycling cannot be seen separated from battery costs LCA.
Hence, the LNMO/Si cell has the potential to reduce cost and environmental impact, but needs further development and engineering towards a mature technology.

Expected final results and potential impacts

Electrification of transport is a priority in the Community Research Programme. It also figures prominently in the European Economic Recovery Plan presented in November 2008, within the framework of the Green Car Initiative. Besides that the policy related to battery-powered vehicles is mainly focused on technological optimisation and market development, future challenges in this field include reliability and durability of batteries and super-capacitors, reducing battery weight and volume, safety, cost reduction, improved hybrid electric power-trains, charging infrastructure and plug-in solutions.
A successful introduction of electric cars in the market requires the development of cheap, safe, reliable, light, small, highly efficient, and high power electrochemical storage devices – batteries. The introduction of electric cars will have an enormous impact on the production volume of rechargeable batteries, as this has never been achieved before. Clearly this put a strain on the availability of some raw materials, and therefore, attention has been paid toward selection of materials that are abundantly available.

Outcome
The outcome will be a newly developed cell, manufactured and tested by end-users. The new cell consists of:
• a newly formulated Si-negative electrode;
• newly designed low cost salts;
• modified positive electrodes.

Assumption and external factors that may determine whether the impacts will be achieved
With regard to the battery producer CEA, with this collaboration, it could lead to establishing the basis for a world level European automotive battery industry. Besides, with these significant contributions it may also lead to large market shares in the area of electric cars on a global level. Also, it opens up the possibility to manufacture custom-made electric vehicles within the area of for instance in-house transportation. This is particularly of interest for Spijkstaal, a Dutch SME. Hence, by fostering the partners, this interdisciplinary consortium will bring about a battery with technical specifications of 200 kW/kg and a power density of 1000 W/kg, which is at the same time cost-effective, and has materials with a low environmental impact. Besides, all the end users are involved in the life cycle analysis so as to review the recyclability and life-cycle sustainability, and take actions based on the outcome.

The strategic impact can be broken down by hardware and “software”:

- the battery producer CEA could well benefit from the outcome of the project so as to produce a battery that fulfils the requirement for electric vehicles;
- the knowledge gained from the project can be used for batteries for other applications as well;
- once the batteries are accepted the automotive industry can implement them into the cars;
- the ALISTORE-ERI will receive additional resources to sustain and therefore attains durability;
- the various academic research groups will gain knowledge that are been published in international journals.

Further benefits – contribution to environmental EU policies.
Besides the above listed benefits, there are many environmental benefits to recall from already identified by the EC (http://europa.eu/pol/env/index_en.htm) – to recall the main environmental EC policies concern:

- climate change;
- emissions trading;
- biodiversity;
- environmental health;
- sustainable development.

Project public website address:
http://www.euroliion.eu/