FINAL PUBLISHABLE REPORT

Contract n° TST4-CT2005-019351

POMEROL

Power Oriented low cost and safe MatErials fOr Li-ion batteries

STREP

SIXTH FRAMEWORK PROGRAMME
PRIORITY [6.1] Sustainable energy systems

date of the project: 1 December 2005 to 31 November 2008 **Duration**: 36 months

Project coordinator: Philippe BIENSAN – Cécile TESSIER

Project coordinator organisation name: SAFT

PARTNERS:
CEA (F)
Daimler (G)
Merck (G)
Saft (F)
Timcal (CH)
Umicore (B)
Volkswagen (G)

Project funded by the European Community
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Research Infrastructures

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1. Project overview

POMEROL project was dedicated at first to the new materials design and evaluation. The best grades of all materials have been scaled-up to kg quantities and delivered internally for processing. Several sets of cells and one module deliveries to the Partners have been achieved.

Project name: Power Oriented low cost and safe MatErials fOr Li-ion batteries

Project acronym: **POMEROL**

Contract number: **TST4-CT2005-019351**

Programme:

SP1 – Priority 6-1 – 6.1 Sustainable energy systems, 6.1.4.2.2.1. Fuel Cell and Hybrid Vehicle Development, *Activity Code : SUSTDEV-AERO-2004-Hydrogen-1.1*

Starting date 01/12/2005

Total costs (€) **4 863 845**

EC funding requested (€) **2 470 953**

1.1) Objectives and challenges

General objective(s) of the contract

POMEROL intended to develop high power, low-cost and intrinsically safe lithium-ion batteries by a breakthrough in materials. The materials and batteries are dedicated to fuel-cell hybrid and conventional hybrid drivetrain automotive applications.

Challenges

The challenging objective remained to develop new materials to strongly reduce cost of high power lithium-ion batteries to 25 EUR/kW, one of the very critical issues for a widespread development of this bottleneck technology for fuel-cell hybrids. There were also two other objectives: to provide a high power battery with a long life and an intrinsically safe electrochemistry. Technical and cost specifications were targeted for the battery, the cell and each new material developed in order to reach these goals.

WP n°	Technical or cost objective	Output- Fuel-cell & ICE hybrid At cell level
6	Specific power (18 seconds-R.T.)	3000 W/kg – mini 80 Wh/kg
6	Battery selling price	25 EUR/kW
6	Cell selling price	20 EUR/kW
6	Safety at cell level	Intrinsically safe in all abuse conditions
6	Cycle life	500 000 cycles @ 3-5 % DOD
6	Calendar life	>10 years 30°C
6	Operating temperature	-35°C / + 60 °C
6	Storage temperature range	-40°C / + 80 °C (short periods at 80 °C)

1.2) Consortium

We have proposed innovative solutions through the development of speciality materials ($LiFePO_4$, lithiated metal fluorinated oxides, non-flammable ionic liquids based electrolytes and high performance graphitised carbons) that respond to the very ambitious challenge of adequate low-cost, safety and life. POMEROL combined the complementary skills of 7 industrial partners and specialised subcontractors, having proven expertise in the research, development and production of materials and batteries. Having automotive end-users, material suppliers and a battery maker allowed a rapid validation of results, savings of time and resources.

SAFT

Saft is world leader in the design and manufacture of high-tech battery systems for industrial applications, providing businesses with energy solutions that are crucial and often invisible components of the systems they develop. SAFT has developed a large variety of high performance solutions to meet specific requirements in the three main sectors of its activity :

. Rechargeable batteries: SAFT is the leading European manufacturer of cells, battery packs, special power assemblies. Ni/Cd, NiMH and lithium based technologies are engineered to provide power to the full range of consumer and professional applications in the fields of portable and cordless communications, personal computing, power tools, emergency lighting, mobility…

. Industrial batteries: SAFT is the world leader in Ni/Cd batteries for industrial applications. In particular, SAFT has very strong or world leading positions in civilian and military aviation, railways or standby. SAFT is also the world leader for the commercialisation of Ni/Cd batteries for electric vehicles.

. Specialty batteries: SAFT has strong positions in batteries for Space and Defence applications, with the commercialisation of specific electrochemical systems (Li-ion, high-pressure Ni/H_2, AgO/Al, Ag/Zn), as well as in primary lithium cells.

Saft was co-ordinator of the project and responsible for evaluation in prototype cells of the new materials and electrolytes. It was also in charge of manufacturing scale-one cells and module.

CEA

CEA effort in this project was ensured by two teams, first one being in charge of $LiFePO_4$ synthesis and second one being in charge of electrode process. The material team, with senior experts in the domain, had already 4-year experience in the $LiFePO_4$ synthesis at the beginning of the project, with a part of this experience obtained through 5th PCRD projects such as PEARL and Nanobat. The process team worked jointly with SAFT in order to increase its knowledge in the domain. CEA is equipped with a Li-Ion prototype assembly line and a material processing plate-form including the following equipments: (i) mixing, coating, calandering and winding machines, (ii) mills and ovens of different batch size. During the project, additional equipment needed or modification of existing machines were defined and ordered by CEA. The team that was constituted by CEA to fulfil POMEROL objectives can be considered as the most advanced team in Europe on the topic of $LiFePO_4$ synthesis and processing, proved by several patents and many communications on that topic. CEA is the only research institute that offers this complementarity on material synthesis and scale-one prototype assembly with an evident increase of efficiency in resources.

CEA was involved in WP1 of this project dedicated to new positive materials and WP4 dedicated to scale up of materials and processes.

DAIMLER [1]

Daimler is unique in the automotive industry: their product portfolio ranges from small cars to sports cars and luxury sedans; and from versatile vans to heavy duty trucks or comfortable coaches. Daimler' passenger car brands include Maybach, Mercedes-Benz, Chrysler, Jeep®, Dodge and smart. Commercial vehicle brands include Mercedes-Benz, Freightliner, Sterling, Western Star and Setra. It offers financial and other automotive services through Daimler Services.

Daimler's strategy rests on four pillars: global presence, strong brands, broad product range, and technology leadership.

The Daimler employees participating in this program have many years of experience in alternative drive train components like fuel cells and batteries. Working fields during this time have been stability test of active electrochemical materials, performance tests of cells, modules and batteries, safety tests of cells, modules and batteries, construction of batteries and modules, safety investigations of vehicles and battery systems.

Daimler was in charge of assessment of safety of delivered cells and modules in WP5 and WP6.

MERCK KGaA

Merck headquartered in Darmstadt, Germany, is the lead organisation of the international Merck Group of chemical and pharmaceutical companies. Worldwide, the Merck Group has approximately 34 000 employees; roughly 8 000 employees working in Darmstadt. The Merck Group has a long and successful history in the development and manufacture of chemicals and pharmaceuticals. Its product range contains more than 15 000 items, including pharmaceuticals, laboratory reagents, pigments, fine chemicals and speciality materials, such as liquid crystals, for use in state-of-the-art industrial and electronic applications. With ten percent of its employees engaged in active research, the Merck Group has consistently demonstrated a strong commitment to Research and Development. It has also always given its support to academic research and institutions.

[1] During the project phase, 'Chrysler' has been separated from 'Daimler' in Oct. 2007. Therefore the partner 'DaimlerChrysler' has become 'Daimler', but there was no influence on the project.

For this research and training project, the New Business Chemicals (NBC) has taken responsibility for managing the Marie Curie Fellow. NBC has research facilities located in Darmstadt as well as in Southampton in England. NBC nurtures research into young, developing areas of science and technology, providing them with the time and resources to grow. As a centralised unit within Merck's business sector Chemicals, NBC acts as a source for new business opportunities on a global base. Research within NBC complements existing businesses and enhances current core competencies. NBC has an international network that covers both research organisations and companies where interdisciplinary specialists and experts translate technical product ideas into chemistry. The IOLI group within NBC, which carries out research and development of ionic liquids, consists of about fifteen NBC employees working in every aspect of the chemical industry, including research and development, marketing, sales and customer development and support.
The IOLI group has access to several modern and well-equipped laboratories which offer the best opportunities for inorganic, organic and material science. "State of the art" equipment and work is carried out in six modern, well-equipped purpose built laboratories located in Darmstadt. Processing equipment can handle small batches; production scale batches are handled in pilot plant. Many analytical methods are available in-house, including grain characterisation, surface tension measurement, thermal analysis, SEM, XRD, RFA, SIMS, AAS, ESMA (electron beam microanalysis), IR- and Raman-spectroscopy, NMR, Mößbauer-analysis, optical emission spectroscopy, optical microscopy, and UV/VIS spectroscopy.
Merck was involved in WP3 of this project dedicated to ionic liquid based electrolytes and WP4 dedicated to scale up of materials and processes.

TIMCAL S.A.
Timcal located in Bodio, Switzerland is the head quarter of TIMCAL Group which is the business unit for all carbon activities of the French Group IMERYS, being a world leader in adding value to minerals. Nowadays TIMCAL Group unifies the synthetic graphite company TIMCAL SA located in Bodio, Switzerland (ex LONZA G+T), the natural graphite mining and processing company TIMCAL Canada (ex-Stratmin Graphite Co., Inc.) as well as the carbon black producing company TIMCAL Belgium located in Willebroek, Belgium (ex-MMM Carbon). TIMCAL Group is globally active in releasing customer-related challenging solutions in graphite and carbon black applications. Its competencies are focusing on the areas of research and development, manufacturing, processing, and marketing of synthetic and natural graphitic carbon materials as well as conductive carbon blacks. TIMCAL Group offers a broad range of high quality graphite grades for many fields of application throughout a worldwide presence consisting in plants, commercial offices as well as a network of distributors and agents. The products manufactured and sold are natural and synthetic graphite powders, cokes, graphite dispersions, lubricants, descaling agents, carbon black, and silicon carbide. These products are used in following application fields**:**

- Mobile Energy such as alkaline, lithium and lithium-ion batteries, fuel cells, capacitors.
- Engineering Materials such as friction pads, clutch facings, carbon brushes, iron powder metallurgy, sintered ceramics, lubricants, pencil leads, conductive coatings, lubricating coatings, plastics, elastomers, catalyst supports, industrial diamonds
- Hot Metal Forming such as mandrel bar lubricants and descaling systems, spray mill lubricant systems
- Conductive polymer applications
- Refractories and Foils such as bricks, crucibles, foils, flame retardants.

The TIMCAL Group has about 300 employees worldwide, 20 of them active in the centralised R&D department at Bodio. The Group turnover is about 75 Mio. Euro. TIMCAL S.A. in Switzerland has about 180 employees and a turnover of about 50 Mio. Euro. At Bodio, the R&D department, the production site for synthetic graphite and graphites processing, as well as the European sales department, is located.
Timcal was involved in WP2 of this project dedicated to new advanced graphite materials and WP4 dedicated to scale up of materials and processes.

UMICORE

Umicore is an international metals and materials group. Its activities are centred on five business areas: Precious Metals Services, Precious Metals Products and Catalysts, Advanced Materials, Zinc and Copper. Each business area is divided into market-focused business units.
Umicore focuses on application areas where it knows its expertise in materials science, chemistry and metallurgy can make a real difference, be it in products that are essential to everyday life or those at the cutting edge of exciting, new technological developments. Umicore's overriding goal of sustainable value creation is based on this ambition to develop, produce and recycle metals in a way that fulfils its mission: "materials for a better life".
Speciality Oxides and Chemicals, one of its business lines, is a world leader in active materials for as well primary as secondary batteries, with production units in Belgium, Canada, South Africa, China and Japan. Production brand includes cobalt oxide and lithium cobalt dioxide for Li-ion batteries, Nickel hydroxide, cadmium oxide, and cobalt additives for NiCd and NiMH batteries and zinc powders for alkaline batteries.
Important R&D efforts will be devoted to the improvement of existing products and the development of new materials.
Umicore was involved in WP1 of this project dedicated to new positive materials and WP4 dedicated to scale up of materials and processes.

VOLKSWAGEN

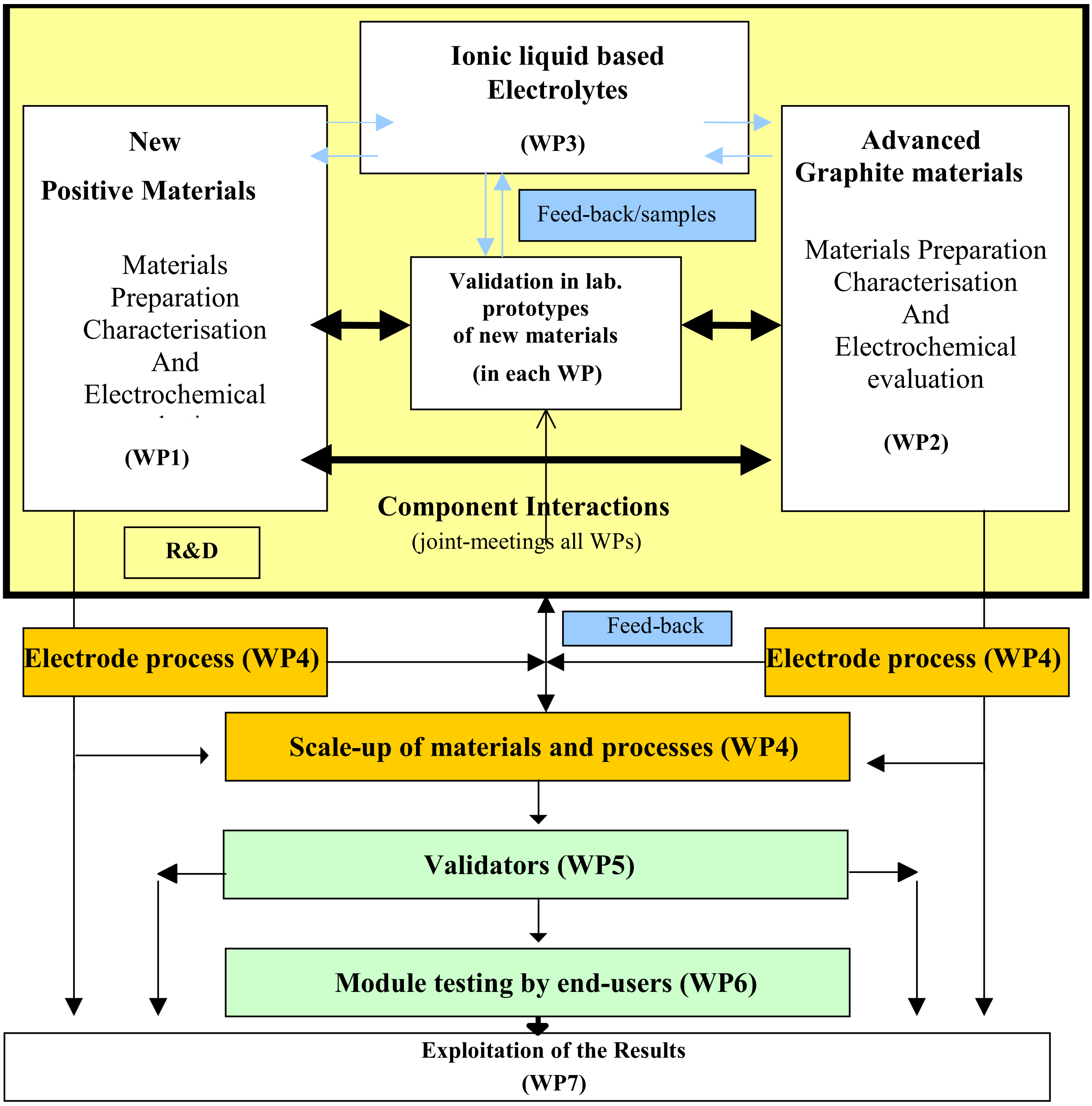
With production facilities in 15 countries and a broad product range stretching from the ultra-economical "3-litre" passenger car to luxury and sports cars, light trucks and commercial vehicles, the Volkswagen Group has grown up to one of the largest globally active automotive manufacturers with world-wide sales of roughly 5 million units in 2003 (market share 12.1 %). The company consists of nine independent brands from six European countries. Since many years VW is market leader in Western Europe.
Volkswagen's aim is to produce vehicles with ever increasing quality, safety and technology standards and at the same time reduce fuel consumption and emission levels. VW is interested in the application of new developments in all automotive areas not only to meet all relevant technical and legal requirements but also to satisfy customer demands on a consistently high level.
Volkswagen's Group Research is working on every field of automotive application and is responsible for identifying, evaluating and transferring innovative technologies to advanced engineering or series development departments of all brands of the Volkswagen Group i.e. AUDI, SKODA (Czech Republic), SEAT (Spain) etc.
Volkswagen`s extensive investigations in battery systems started already in the early seventies, today there is a long time of experience in this field. In collaboration with the battery industry, investigations were carried out in the past to optimise battery systems with regard to the requirements of electric vehicle, hybrid electric vehicle and fuel cell vehicle in order to increase

vehicle efficiency, to lower fuel consumption and to reduce exhaust emissions. Efforts have been focused on the five key issues of advanced battery systems energy, power, life, safety, and cost.

Volkswagen has experience in co-ordination of and participation in EC funded projects involving European car manufacturers, suppliers and universities (e.g. FP5: ASTOR, FUERO, SUVA, DIGAFA, CLEAN, GET-DRIVE, KnowNOx, DIDTREAT, STORECAT, PREMTECH, TECABS, LIRECAR, MgChassis, DIAMOND, ENIGMATIC, Supercar. FP6: RENEW, NICE, HyTRAN, InMar, PReVENT, APROSYS, APSN etc.).
Daimler was in charge of assessment of performances of delivered cells and modules in WP5 and WP6.

1.3) Technical objectives

The different work-packages of the project and their interactions are represented in the following diagram.



WP1: new positive materials

Main goals of this WP were:

(i) To develop low cost and high performance lithium iron phosphate and lithium transition metal fluorinated oxide positive electrode material based on Ni and Mn .

(ii) To design adapted materials particle size, composition and morphology.

(iii) To carry out physico-chemical and structural characterisations

(iv) To evaluate the electrochemical and safety behaviour
(v) To select the best material for further up scaling

WP2: advanced graphite materials

Main goals of this WP were:
(i) To develop a new low cost graphite material according to project specifications.
(ii) To develop a graphite with a controlled surface to reduce capacity consumption during cell formation.
(iii) To identify key graphite material parameters which influence the cell performance in the high current drain.
(iv) To prepare and characterise different carbon additives and to study and optimize their effect on the cell performance at high charge and discharge currents.

WP3: ionic liquid-based electrolytes

Main goals of this WP were:
(i) To develop innovative ionic liquids compatible with Li-ion electrochemistry
(ii) To select additives to passivate the negative electrode
(iii) To identify and eliminate critical impurities of the ionic liquids and electrolytes with cost effective processes
(iv) To formulate electrolytes containing the ionic liquids and evaluate all their electrochemical properties
(v) To validate performances at laboratory scale of cells including the ionic liquid based electrolytes.

WP4: scale-up of materials and processes

Main goals of this WP were:
(i) To achieve and demonstrate the scale-up of the selected positive electrode material, negative electrode material and show the feasibility of an industrial manufacturing process
(ii) To achieve and demonstrate the scale-up of the selected ionic liquid based electrolyte
(iii) To achieve and demonstrate the scale-up of the electrode processes to obtain high power and low-cost electrodes
(iv) To provide electrodes for prototype and scale-one cells assembly
(v) To evaluate their electrochemical performances
(vi) Economic assessment of the retained materials

WP5: Validators

Main goals of this WP were:
(i) To assess the performance in complete cells, specific to the selected applications.
(ii) To characterise the life and performance parameters of the Li-Ion battery for FCEV and ICE-HEV applications based on the new materials
(iii) Based on the results of these battery tests, the different partners will adapt the parameters of their own components to reach the general Li-Ion target: required performance, cost and safety.

WP6: Demonstration activities

Main goals of this WP were:
(i) To build the final scale-one cells.
(ii) To build the final modules.

(iii) To evaluate the electrical performance of the final modules
(iv) To validate the improvements in terms of safety under abuse tests on the final modules

2. Main technical achievements

2.1) New positive materials

WP	Technical or cost objective	By the MTA	Final Goal
	New positive electrode materials		
1	Power, C rate at material level in adequate electrode technology	20 C pulses (18 sec)	> 30 C pulses (18 sec)
1	Cost (1000 tons/y)	<15 EUR/kg	<12 EUR/kg
1	Specific reversible capacity	> 120 Ah/kg at 10C rate	> 140 Ah/kg at 10C rate
1	Thermal stability at charged state	> 300 °C, <500J/g	> 300 °C, <300J/g
4	Particle size (Average/Max)	5 / 25 µm	5 / 25 µm

CEA, Saft and Umicore were involved in this WP.
F-NMC and $LiFePO_4$ have been considered as new positive active materials. F-NMC material work was stopped by decision at the MTA meeting and the project was subsequently focussed only on $LiFePO_4$. Five different Fluorine-doped Ni-Co-Mn based materials were synthesised with different routes and many samples of $LiFePO_4$ materials were synthesised from different routes (CEA and UMICORE) with different particles sizes, morphologies and compositions. Low-cost samples have also been delivered during year 3.
All $LiFePO_4$ materials were investigated and compared one to the others by Umicore, CEA and Saft. Best $LiFePO_4$ material from Umicore showing good power properties was stabilized at lab scale and further transferred to pilot scale (WP4). More properties have been improved such as moisture content. This work will continue after the end of POMEROL project.
The delivered material which was scaled-up at UMICORE displayed the best performance in coin cells, which was confirmed in Laboratory cells (WP4) in terms of power towards objectives.
All materials synthesised or delivered between the Partners were characterised with different tools by Umicore, CEA and Saft including:

- Chemical analyses: mainly derived from ICP-AES, X-ray fluorescence, Mossbauer (sub-contracted)
- Physical analyses: X-ray analyses, particle size distribution, density, BET measurements, magnetic susceptibility

Purity of the materials has increased throughout the contract period to reach high quality.
Saft ran some thermal stability studies and Umicore, Saft and CEA have performed electrochemical tests in coin cells as planned. Thermal stability (safety related) looked very good for the different materials. For F-NMC, it was demonstrated that thermal stability increases but the capacity decreases as the fluorine content increases. The intrinsic thermal stability of $LiFePO_4$ was demonstrated.
Calendar life of $LiFePO_4$ at elevated temperatures appeared to be the most critical issue that was pointed at during the first year. Work at SAFT was thus focused also on this issue, trying to understand the mechanism and to improve the life. A first critical parameter was identified: the

water content of $LiFePO_4$. Umicore has worked on that topic and has delivered low-moisture content materials during the last year for all scale one cells.
The best material was chosen for scale up after discussion between partners for implementation in scale 1 cells. The level of moisture in delivered samples was decreased all along the project and low water material was delivered for manufacturing of Validators and final module.

Results obtained in scale 1 cells show that the product performances are in line with program expectations with high reversible capacity and excellent power performances (continuous and pulse).

Economic assessment of the $LiFePO_4$ process has been done and gives price range slightly above project objectives at the material level (regime price for a production of large volumes). Nevertheless, the high level of performances allows reaching the price targets at cell level.

2.2) Advanced graphite materials

WP	Technical or cost objective	By the MTA	Final Goal
Advanced graphite materials			
2	Power at material level	20 C pulses (18 sec)	> 30 C pulses (18 sec)
2	Cost (1000 tons/y)	5 EUR/kg	3 EUR/kg
2	First charge efficiency	> 85 %	> 90 %
2	Specific reversible capacity	> 320 Ah/kg at 10 C Rate	> 340 Ah/kg at 10 C Rate
4	Particle size (Average/Max)	5 / 30µm	5 / 30µm

Timcal and Saft were involved in WP2.

The objectives of the POMEROL project focus on the development of a new low cost graphite material with high power capability which can be used in auxiliary batteries of fuel cell systems and in hybrid electric vehicle batteries. The newly developed graphite material should demonstrate an optimized surface to reduce the capacity loss during the cell formation and the necessary safety, and lifetime. Based on these objectives, the influence of graphite bulk and surface properties has been studied in order to identify the key parameter influencing the high power capability of graphite materials. New graphite negative electrode materials have been synthesized, characterized and electrochemically tested in lab cells by TIMCAL and SAFT as well as in industrial batteries by SAFT. The development activities have focused on the following research directions:

- The particle size and shape of graphite materials based on synthetic and natural graphite have been improved in order to optimize the electrode packing and electrode porosity for an optimal high power capability of the cell.
- The graphite particle size distribution of the graphite electrode materials have been optimized to minimize the surface area and thus to allow sufficient storage at elevated temperatures, safety, and battery life.
- To evaluate the influence of the graphite crystallinity on the high current rate performance, new graphite materials with various degree of crystallinity were prepared from different carbon precursors and with different graphitization procedures.

- The influence of the graphite surface have been investigated by preparing graphite materials with specially designed surface morphologies

Three promising graphite materials have passed the challenging high current pulse power and storage tests requirements and were selected for further investigations in pilot batteries. The up-scaling of these graphite materials has been evaluated and cost calculations for industrial quantities have been performed.

2.3) Ionic liquid based electrolytes

WP	Technical or cost objective	By the MTA	Final Goal
Ionic liquid based electrolytes			
3	Conductivity	6 mS/cm (25°C)	> 8 mS/cm (25°C)
3	Electrolyte cost (1000 tons/y)	50 EUR/kg	< 30 EUR/kg
3	Stability	Non-flammable	Non-flammable
3	Low temperature operation	-25°C	-35°C
3	Conductivity	6 mS/cm (25°C)	> 8 mS/cm (25°C)

Merck and Saft were involved in WP3.

One of the technical hurdles to non-flammable, safe lithium ion is the need to use an organic solvent as a component in the electrolyte. Organic solvents bring with them a number of problems - the relatively high vapour pressures of organic solvents, mainly organic carbonates, mean that the smallest holes in the construction of the battery can lead to solvent loss through evaporation, and therefore failure of the battery. Their high vapour pressures make many organic solvents flammable that may lead to safety concerns.

Organic solvents are inherently non-conductive, and are often characterised by poor solubility of the necessary supporting electrolyte and lithium salts. The liquidous range of organics solvents (from the freezing point / glass transition temperature to the boiling point / decomposition temperature) are also characteristically small, limiting the temperature range over which they can function.

Within POMEROL, Merck KGaA investigated and promoted the use of ionic liquids as a replacement for organic solvents to circumvent these problems.

Because they are salts, ionic liquids have extremely low vapour pressures (in comparison to organic solvents), making them non-flammable and effectively eliminating solvent loss due to evaporation. Ionic liquids are inherently conductive, eliminating the need for addition of a supporting electrolyte (thus simplifying composition), and show high solubility to a large range of lithium salts. Liquid ranges for ionic liquids over 300 °C have been discovered.

During the project, Merck KGaA synthesised, purified to electrochemical grade, characterised and optimized a huge variety of electrochemical stable ionic liquids. The techniques used for characterisation include conductivity and viscosity measurement of single ionic liquid and complex electrolyte formulation, determination of the electrochemical stability using cyclic voltammetry at different electrode materials and the measurement of the flashpoint of selected electrolyte solutions.

26 ionic-liquid and ionic liquid-based electrolytes were synthesised in amounts of several hundreds of grams and delivered to Saft.

The electrochemical performance of mixtures containing different ionic liquids were evaluated by Saft first in coin cells and then in laboratory prototype cells. One patent was filed beginning of year 2.

Saft assessed the thermal behaviour of ionic liquid based electrolytes into laboratory prototype cells and compared to similar cells with standard electrolytes.

Best electrolyte compositions were chosen for further tests in scale 1 cells.

2.4) Scale up of materials and processes

Since mid-term of the project, materials selected during the first half of the project were scaled-up by the different partners. For $LiFePO_4$, process was stabilized at >50kg/mth scale by Umicore. Scale-up of graphite materials to pilot of three selected graphite materials was performed by TIMCAL. High purity (battery grade) ionic liquid was selected and was scaled-up to 1kg scale (MERCK). Several deliveries to kg scale occurred from MERCK to SAFT, electrolyte was formulated and full cells were assembled to evaluate the impact on safety and performances of chosen electrolytes.

CEA (positive electrode) and SAFT (positive electrodes for Validators and Final module and negative electrodes) adapted and optimised processes to scale-up electrode fabrication from these new materials. From these electrodes, first Validators cells were assembled successfully. The cells were delivered to the Partners and evaluated by Partners. Two following batches of cells with improved materials have been delivered to DAIMLER and VW to compare two different cell designs (with vs without ionic-liquid-based electrolyte). Design without ionic-liquid-based electrolyte has been chosen as Final cells design.

2.5) Demonstration activities in cells and module

For the bench testing activities of the POMEROL Validator cells, it was agreed among the partners SAFT, Daimler and VW, to use the 'VDA Test Specifications for Li-Ion Battery Systems for HEVs, Release 1.0 (2007-03-05)' as basic test specification. This was used for assessment of performance, calendar & cycle life as well as for abuse testing activities.

The following performance testing activities were agreed for POMEROL scale one cells:

- Cell formation and final control (SAFT)
- Initial characterisation : IEC capacities, cell energy, discharge Peak Power test, charge Peak Power tests (Saft, VW)
- Accelerated calendar life testing at 40°C and 80% SOC (VW)
- Parameter Testing (Energy, Capacity and Power Test) (VW)
- Cycle Life Testing (VW)

The first set of Validator cells for the above mentioned performance & life testing activities were delivered at beginning of September 2007 from SAFT to VW. Second set of scale one cells were sent to Volkswagen and Daimler in March 2008 for design without ionic liquid and in April 2008 for design with ionic-liquid based electrolyte. Performances were evaluated by Saft and Volkswagen. Post mortem analyses of Validators and final cells were performed at Saft. Very promising results have been obtained with power of 2900W/kg, very close to 3000W/kg target. Using ionic liquid-based electrolyte significantly decreases power to 1800W/kg.

Safety tests were performed by Saft and Daimler and showed that intrinsic safety is already insured for the design without ionic liquid. Surprisingly, no significant improvement in terms of safety was observed with Validators containing ionic liquids and it was decided to keep standard electrolyte in final cells. Intrinsic safety was proven on Final cells with neither fire nor flames in all tests as summarized in the following Table.

Test Type	Hazard Level (EUCAR)	Test Results
Overcharge 50A/12V/200% SOC	**Hazard level 3** ☺	**Leakage, Δmass < 50%** Cell opened in result of the overcharge as expected Clear interruption of current Highest temperature was 110°C
Short Circuit	**Hazard level 3** ☺	**Leakage, Δmass < 50%** Cell opened in result of the short circuit Highest temperature was 90°C
Controlled Crush Vertical, 50% dimension, 8 tons	**Hazard level 4** ☺	**Venting, Δmass ≥ 50%** Short circuit of the cell, temperature rise, leakage of electrolyte, smoke generation Highest temperature was 105°C
Thermal Stability Heating to 150°C keeping for 10 minutes	**Hazard level 2** ☺	**Defect / Damage** No visual change of the cell, kept closed

Cost assessment has been performed for final cells. It is very close to target at cell level with 20,6€/kW vs 20€/kW.

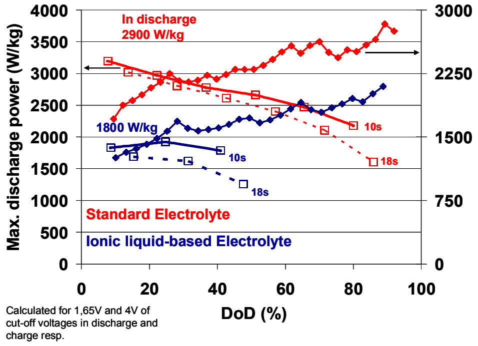
Delivery of the final module allowed addressing safety issue also in module on the most critical test. Short circuit test was passed with high level of safety (level 3) without fire, only leakage on one of the cell.

Electrochemical performances

Initial power at 30°C

Pulse power tests

- Discharge C/5 – Pulse 30C 18s
- Charge C/5 – Pulse 9C 10s

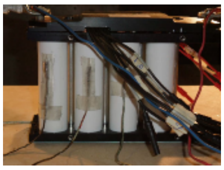


Target: 3000 W/kg

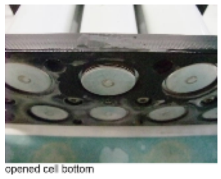
Almost achieved with 2900 W/kg

Abuse tests at module level

Kind of test	Hazard Level	Test Result
Short Circuit	Hazard level 3	One cell opened in result of the short circuit at the rated break point Current achieved in maximum 1719A Gaseous and liquid electrolyte was emitted but no solid material Highest temperature was 90°C in maximum



Short circuit test



Module before test

Module after test

No fire or flame

Intrinsic safety achieved

3. Exploitation and follow-up actions

Those results that are of great commercial interest will be exploited by the consortium Partners themselves. This policy is implicit in the Consortium Agreement that was made between the Partners.

The most significant deliverables at the end of the project are cells with good power and low cost. Furthermore, safety was demonstrated at the level of cells and module (short circuit test).

The results obtained in this project led to a large number of publications in scientific journals and participation in several international meetings. Moreover, two patents were filed from the results of this project.

Co-operation between partners has been reinforced thanks to this project.

EC funded project Helios involving three of the partners from Pomerol was started nov 2009 in order to investigate various electrochemistries, in particular the one studied in POMEROL project, for batteries for EV, PHEV and heavy duty hybrid trucks applications.