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Fast Rechargeable Zinc-Polymer Battery based on Ionic Liquids

Rendicontazione

Informazioni relative al progetto

POLYZION

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Sito web del progetto

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Final Report Summary - POLYZION (Fast rechargeable zinc-polymer battery based on ionic liquids)

Executive summary:

The POLYZION project received funding under the ENERGY and 'Nanosciences, Nanotechnologies, Materials and new Production Technologies (NMP)' Themes of the Seventh Framework Programme (FP7). Essential to this project are fundamental advances in several innovative areas of materials science. The POLYZION approach is to focus basic research towards the goal of a new type of energy storage device.

The concept of this project is to create a novel class of fast rechargeable zinc (Zn) battery for hybrid electric vehicle (HEV) and small electric vehicle (EV) applications. The project approach focuses fundamental advances being made in several innovative and rapidly developing materials disciplines towards the common goal of a new type of rechargeable Zn battery. The project combines a new low-cost, air and moisture insensitive and environmentally benign class of ionic liquids and nanostructured Zn deposits with conducting polymers and basic understanding in each area was advanced in reporting period one (18 months). Period two (24 months) built on the fundamentals developed in period one to scale up the technology and produce Zn polymer battery prototype cells.

Mass introduction of HEVs and EVs is widely expected within the next 8 - 15 years, driven by rising fuel pump prices and regulatory commitments towards lower CO2 emissions. However, the market leading commercial battery technology (nickel metal hydride (NiMH)) is unable to keep pace with the performance demands of HEVs and EVs for ever higher power and energy densities. The main competing technology under continuous development is the Li-ion battery which does perform better in terms of energy and power density, but brings new challenges such as reduced lifetime, high cost, low abuse tolerance and poor low temperature performance, as well as ongoing safety concerns.

The main science and technology (S&T) objective of this project is the development of a reversible and stable Zn/Zn2+ redox couple for secondary Zn cells. This will be achieved by using a new class of ionic liquids which will be optimised for this couple. In addition, charging regimes used to electrodeposit Zn are known to affect morphology of deposits, therefore if required ultra-fast pulse techniques will be developed

to deposit nanostructured Zn with good cyclability and low dendritic growth. The measureable targets for this objective are to optimise the charge-discharge efficiency and cyclability to be greater than 90 % and 1 000 cycles respectively, and to quantify how the charge efficiency and cyclability of the couple varies with current density.

Unlike their primary analogues, the development of Zn secondary (rechargeable) batteries has been beset with two major technical problems, namely dendrite growth and hydrogen gas evolution. Dendrites build up during charge-discharge cycling and inevitably lead to short circuits unless abated. Hydrogen evolution, on the other hand, takes place both as a competing reaction during recharge, and because of self-discharge. Overcoming these two problems is central to this project.

The work programme of POLYZION is wide-ranging and multidisciplinary in nature and scope, but with clear and focused objectives designed to give the best chance of successful completion within the 42 month project timescale. The consortium is formed by 9 partners from 7 countries including 2 European Union (EU) universities, 3 EU small and medium-sized enterprises (SMEs), 2 EU industrials, as well as one international cooperation partner country (ICPC) university and one research organisation from an Industrialized Country.

Project Context and Objectives:

Battery technologies for HEVs and small EVs have technological, cost or environmental limitations. Despite this, the global market for HEVs and EVs is growing rapidly. The objective of the POLYZION project was to create a new class of fast rechargeable Zn-polymer battery for hybrid and small EVs applications.

The research programme combined fundamental material and process advances in ionic liquids, rechargeable Zn electrodes and conducting polymers, as well as constructing prototypes battery units for industry standard testing. The resulting battery device aimed be low cost, have low environmental impact and have the energy and power density necessary to compete with alternative battery technologies in the HEV and EV markets.

POLYZION is a European-led consortium combining world-class research organisations in ionic liquids, conducting polymers, Zn deposition and batteries, as well as SME partners with expertise in technology development and specialised materials, and large industrial partners with industrial experience of battery manufacture and state-of-the-art testing facilities. The consortium also included 2 organisations with world-class research expertise from an Emerging Economy (Russia) and a High Income country (Canada) outside the EU.

The concept of this project is to create a novel class of fast rechargeable Zn battery for HEV and small EV applications. The project approach focuses fundamental advances being made in several innovative and rapidly developing materials disciplines towards the common goal of a new type of rechargeable Zn battery. The project combines a new low-cost, air and moisture insensitive and environmentally benign class of ionic liquids, nanostructured Zn deposits, novel ultra-fast pulse charge injection and conducting polymers, and aims to advance basic understanding in each area.

The following S&T objectives will be addressed:

(1) Ionic liquid electrolyte will eliminate hydrogen gas evolution due to the absence of aqueous electrolytes. An ionic liquid electrolyte has the additional advantage of permitting a larger cell voltage compared to aqueous systems. The new group of eutectic based ionic liquids can be prepared readily from renewable, non-toxic, naturally occurring chemicals, are very inexpensive and can be tailored to specific uses. These ionic liquids are stable to air and moisture, and environmentally benign with good biodegradability.

(2) At the same time, ultra-fast pulse charging techniques will be used to control the morphology of the Zn nanocrystallites which are deposited during the charging cycle, and thereby provide a means of avoiding dendritic growth. Factors affecting this surface morphology of the Zn nanocrystallites and optimisation of the pulse charging regime are covered by work package (WP)2.

(3) A further key objective is to investigate the behaviour of conducting polymers in the same ionic liquid. A conducting polymer electrode will bring benefits to the proposed battery system such as avoiding the need for a membrane to separate the two halves of the cell, and low weight. In addition, recent research suggests that the electrochemical performance of conducting polymers in ionic liquids is superior in terms of cyclability and fast reversible redox behaviour compared to aqueous and organic electrolytes, and this part of the project will in itself make an interesting study. Issues such as behaviour of conducting polymers in high ionic strength and solvent-free electrolytes; ingress and egress of counter-ions into and out of the polymer matrix; how the structure of the polymer matrix affects counter-ion mobility; rate of charge / discharge of the polymer; and double layer effects will all be addressed and the results used to develop new polymeric materials. The fundamental performance of these electrodes will be assessed; this work is the subject of WP3. Specific targets for the conducting polymer electrode is to have a charge-discharge efficiency and cyclability that will not limit that achieved for the Zn electrode, i.e. > 90 % and 1 000 cycles.

(4) To complete the central theme of a new fast rechargeable Zn battery, promising Zn and polymer electrodes will be combined into secondary cells. The fundamental performance of these cells will be assessed; this work is the subject of WP4. The measurable targets for the whole battery cell are to achieve at least a specific power density of 1 000 W kg-1, excellent cyclability (> 1 000) and a large open circuit potential (approximately 1.9 V).

Battery prototype cells and concept modules will then be constructed by the SME and industrial partners (WP5) and tested against the performance criteria of the battery industry (WP6). In order to be able to compete with the other commercial storage systems, we give the following targets for the POLYZION cells: power density in the region of 1 000 W / kg, energy density of 100 Wh / kg, with life cycle greater than 1 000 cycles and a cell cost of less than 500 EUR / kWh.

(5) One final objective is to assess the market competiveness of the POLYZION technology in terms of its cost, environmental impact and energy efficiency. To achieve this objective a lifecycle assessment (LCA) (including end-of-life), a techno-economic assessment and a study of the implications of the REACH Regulations (if required) will all be performed as part of a developing a strong exploitation platform for the new device and its component materials. WP7 deliverables due at the end of the project (month 42) will

detail these studies.

A summary of the S&T aims is given below, together with a description of performance indicators:

(1) To develop a reversible and stable Zn/Zn2+ redox couple for secondary Zn cells. The measureable targets for this objective are to optimise the charge-discharge efficiency and cycleability to be great than 90 % and 1 000 cycles respectively, and to quantify how the charge efficiency and cycleability of the couple varies with current density.
(2) Optimise an ionic liquid electrolyte which will eliminate hydrogen gas evolution due to the absence of aqueous electrolytes, and permit a larger cell voltage compared to aqueous systems (approxiamately 1.9 V).
(3) Develop an ultra-fast pulse charging methodology to control the morphology of the Zn nanocrystallites which are deposited during the charging cycle, thereby avoiding dendritic growth.
(4) Optimise the behaviour of conducting polymers in the same ionic liquid. Fast pulse charge algorithms for the polymer electrode will also be developed. Specific targets for the conducting polymer electrode is to have a charge-discharge efficiency and cycleability that will not limit that achieved for the Zn electrode, i.e. > 90 % and 1 000 cycles.
(5) Optimise a new fast rechargeable Zn battery. Specific power density of 1 000 W kg-1, excellent cyclability (>1000 cycles) and a large open circuit potential (approximately 1.9V).
(6) Combine cells into a secondary battery packs, scale up and test the performance of secondary POLYZION battery prototypes.
(7) Assess the market competitiveness of the POLYZION technology in terms of its cost, environmental impact and energy efficiency.

Project results:

The work programme was divided into eight logical WPs (WPs), covering research and technological development (RTD), dissemination and exploitation and management activities.

Management activities were addressed in WP1. The dissemination and exploitation activities are carried out under WP8. Both of these WPs are led by the project coordinator, C-Tech Innovation.

The RTD activities made up the remaining work effort (WP2 to WP7). These WPs covered the necessary research, development and evaluation of the project�s innovative ideas. One final RTD WP (WP7) was focused on assessing the life cycle and techno-economic impact of the POLYZION technology and implications of REACH on any new materials which are developed.

The work programme was designed to enable the consortium to carry out their individual or collaborative tasks such that specific objectives and deliverables were achieved in a timely and systematic manner.

WP overview:

Management activities are addressed in WP1. This WP included all management aspects, both internal and external, and ensured the partnership has the best prospect of achieving the projects� aims and objectives. The consortium was managed using a proven hierarchical structure and a protocol for regularly reviewing progress and results was established and rigorously followed throughout the duration of the project.

WP8 (dissemination and exploitation) was concerned will all issues relating to dissemination, exploitation and protection of IP. Regarding dissemination, this WP aimed to:
(a) establish strong interaction with SMEs and other stakeholders in relevant sectors;
(b) disseminate results, primarily through national and international associations;
(c) set up and implement a web-based dissemination process (including private area website for project management);
(d) initiated seminars, workshops, publications and newsletters.

The WP also developed and implemented an active policy on intellectual and property right (IPR) protection and an exploitation strategy. The objective was to ensure IPR protection and confidentiality but to maximise the exploitation of the technological advances throughout.

The RTD activities made up the remaining work effort (WP2 to WP7). These WPs covered the necessary research, development and evaluation of the project?s innovative ideas and their market potential (WP7). In brief:

WP2, WP3 and WP4 consisted of the fundamental research effort of the project. WP2 was concerned with the research and development of the Zn half-cell and ionic liquid formulation, while WP3 was focused on the polymer half-cell. Progress made during these two WPs was vital to the successful development of the POLYZION battery technology, as well as being of interest for many other energy technologies. These two self-contained WPs continuously fed into WP4, where the battery technology was developed at the laboratory scale. WP4 involved both fundamental researchers and technology developers to ensure effective technology transfer to the prototype stages, and included establishing test protocols, and the construction and testing of small scale cells. A further key task in WP4 was the scale-up of the component materials for WP5.

WP5 and WP6 focused on the prototype battery system. The key tasks here included:
(a) construction of prototype cells and concept modules for testing in a realistic battery environment;
(b) development of test protocols; and comparison of the POLYZION technology with market leading alternatives such as Li ion and NiMH batteries.

WP7 included tasks designed to answer further questions relevant to market potential and barriers to exploitation. Tasks included an LCA (including end-of-life) and a techno-economic study, and in each case comparisons were made with competing technologies. In addition, REACH Regulations with respect to the materials developed in the project were considered and a strategy developed and implemented where appropriate.

Summary of activity within each WP:

WP1: Management

The objectives of this WP are:

(a) to make sure that the activities in each of the different WPs (tasks, deliverables and milestones) are carried out in line with the agreed budget and timing;
(b) to coordinate the communication between the project partners;
(c) to manage the communication with the European Commission (EC) and the requirements in respect to reporting and financial management as detailed in the contract between the EU and the POLYZION consortium.

Results: The management of the RTD objectives was carried out by the Project Coordinator (C-TECH) and the respective WP Leaders. Administrative support for financial management and reporting was carried out by C-TECH.

WP2: Fundamental studies on the Zn half-cell

The overall aims of this WP were:

(a) to develop and extend the underpinning knowledge of the electrochemical deposition and dissolution of Zn in room temperature ionic liquids and deep eutectic solvents;
(b) to optimise the electrochemical protocols and substrate materials for high energy density and high efficiency Zn deposition / dissolution;
(c) to focus on the morphology of Zn deposit with respect of the deposition protocol and time scales e.g. pulse charging;
(d) to produce an optimised Zn half-cell reaction / system for the prototype battery construction and testing (WP4, WP5 and WP6).

Results:

(a) Two candidate Ionic liquid Zn electrolyte formulations developed and optimised for deposition and dissolution of Zn metal as well as for the anode polymer material. To a large extent the choice was governed by the response of the polymer electrode to the electrolyte.
(b) Substrate material optimised for Zn half-cell. A number of candidate materials had to be excluded either due to the morphology of the Zn deposit or due to migrate of Zn into the substrate.
(c) Detailed understanding of the electrochemical parameters and kinetics influencing the deposition and dissolution of Zn metal together with the morphology of the deposit was achieved using a variety of fundamental techniques.
(d) Optimised deposition / charging protocol was obtained for the Zn half-cell. Overall, two possible optima for charging protocol and Zn coating; one at high performance high cost, the other at lower performance, but much lower cost.

WP3: Fundamental studies on the conducting polymer half-cell

The overall aims of this WP were:

(a) to advance the basic scientific knowledge of the electrochemical deposition and doping behaviour of electronically conducting polymers, polymer blends and composites in room temperature ionic liquids and deep eutectic solvents;
(b) to optimise the electrochemical protocols, electrolyte, polymer and substrate materials for a high energy density, high efficiency polymer doping/de doping (charge-discharge) process;
(c) to discover an optimum polymer morphology and internal microstructure which maximises charge storage through investigation of polymer type, chemical functionality and physical formulation (e.g. blend, layered or composite);
(d) to produce an optimised conducting polymer half-cell reaction / system for the prototype battery construction and testing (WP4, WP5 and WP6).

Results:

(a) Two candidate Ionic liquid electrolyte formulations developed and optimised for polymer deposition as well as for the charge / discharge reaction of the anode polymer material.

(b) The polymer composition and physical formulation was optimised for (i) electrochemical thermodynamics (maximised anodic redox potential); and ii) kinetic transfer of charge carrier species during the doping / de-doping charge-discharge cycle. Commercially available polymers and polymers produced from monomers synthesised specifically for the POLYZION project were trialed. The candidate polymer electrode material was selected on the basis of the consistency of films cast from it and good performance on charge storage and cyclability in IL electrolytes.

(c) Detailed understanding of the electrochemical parameters and kinetics influencing the doping / de-doping (charging / discharging) of the conducting polymer half-cell together with the morphology of the deposit.
(d) Factors which influence the mechanical stability and cycleability of the polymer half-cell have been investigate and are now better understood and an optimised polymer system has been developed. The challenge of this task was not to find the best material in each case, but find the best compatibility between ionic liquid, polymer electrode, current collector and additives.

WP4: Fundamental studies on the Zn polymer battery

The overall aim of this WP was to construct and test laboratory-scale cells based of the results from the half cells in WP2 and WP3. To achieve this:

(a) Battery cells were constructed from the most promising Zn and conducting polymer half cells obtained in WP2 and WP3, as well as using half cells based on commercial polymers.
(b) The performance of the cells was fully characterised, including charge-discharge cycling and cycle life.
(c) Pulse charging regimes were optimised for most promising complete cell(s) prior to WP5 and WP6.

Results:

(a) Test and characterisation protocols for the complete Zn polymer battery cell(s) have been determined.

(b) The testing and characterisation of the complete Zn polymer battery cell(s) at the lab-scale cell has been completed for the best candidate materials. Coin cell testing showed the best performing system achieved an energy density of 123 Wh / kg, power density of of 1034 W/kg, cell voltage of 1.2V and cycleability of greater than 2 000.

(c) A protocol for pulse-charging of the full Zn-polymer cell(s) was not required. Low efficiency of polymer charging limits the pulse charge capability. However, very good cyclability has been achieved with the development of Zn degreasing and charge / discharge activation protocols. These type of batteries have shown more than 2 000 cycles retaining more than 80 % of the charge storage capacity, at 100 % depth of discharge.
(d) The required materials for WP5 have been scaled up and the materials and knowhow transferred to WP5.

WP5: prototype construction %l%l objectives: %l%l (a) the best candidate zn polymer Battery Cell system(s) obtained in WP4 to be designed and constructed into prototype units, and will include prototypes made with commercially available conducting polymers, for benchmarking purposes.
(b) Prototype design and construction to be in 2 phases, allowing easy monitoring of progress, these are defined as small- and medium sized prototype units.
(c) To provide small and medium-sized prototype units for testing and characterisation in WP6.
(d) Optimised scaled-up preparation of the component materials required for prototype construction.

Results:

(a) Cell design of up to 1Ah capacity defined: Laminated pouch format with a total cathode active area of at least 735 cm2 ((anode / separator / cathode / separator) x9). Zn coated foil anode, polymer electrode coated on both sides of a substrate foil and separator sheets soaked with the electrolyte.

(b) Anode, separator and electrolyte were prepared for the prototype cells. The polymer-based electrode required different optimisation steps in order to scale it up and adapt the slurry composition to obtain a homogeneous cathode coated on both sides for prototype cell assembly. The study led to an optimised polymer electrode ink formulation and drying conditions suitable for coating in pilot line. Roll of homogeneous electrode coated on both sides with relatively low polymer loading was realised.

(c) POLYZION prototype pouch cells have been assembled manually in a reproducible manner from up-scaled polymer electrodes from task 5.2. After process optimisation, cells based on two different electrolyte formulations were fabricated and delivered for testing and evaluation of the technology in WP6.

(d) A module prototype development to reach representative results (with efficient mechanical, thermal and electrical design to avoid performance losses) requires also a prior full characterisation and high reliability of cells, which cannot be ensured for early stage development prototype cells such as the ones achieved for this new technology. Moreover, for new battery chemistries such as POLYZION, the construction of a module would need further development beyond the scope of the project and would add limited value towards technology evaluation.

WP6: Prototype construction

The objectives of this WP are:

(a) to test the battery prototypes supplied from WP4 and WP5 (Individual cells and concept module(s));
(b) to evaluate the results in comparison to other state-of-the-art technologies for HEV and EV applications.

Results:

(a) For the synthetic tests, a set of parameters that needs to be monitored and/or controlled during charge / discharge cycles is identified to determine the prototype performance. For the application derived testing, an application specific dynamic loading profile is developed which aims to capture the loading of a battery in an EV application.
In anticipation of POLYZION cells, the profile was tested on Li-ion cells to validate the protocols.

(b) During 2012 a number of samples were made available for testing in the �standard performance tests of the prototype' task. The first set of 6 samples received in spring 2012 consisted of a single anode/cathode couple. Each was life cycle tested at room temperature at different rates. The second set received end of 2012 consisted of multiple anode/cathode electrodes.

(c) The prototype test results provide insight into the performance of the POLYZION prototypes at the end of the project. The POLYZION aims to develop a battery chemistry for EV application. To determine whether the POLYZION technology is suitable, it is compared to the state of the art in commercially available EV battery performance.

For the state of the art, a set of factsheets on currently commercially available EV and PHEV is developed. The information made available by operational equipment manufacturers (OEMs) worldwide is gathered. The details of 24 different models are recorded in a set of factsheets. Most full electric and plug-in hybrid vehicles make use of Li-ion technology currently.

It was identified that due to the modest results in the pouch prototypes, it would be relevant to compare the performance with lead acid. Lead acid is very mature, but still widely applied, battery chemistry for use in traction and stationary applications.

Outcome: The evaluation of the POLYZION samples and a comparison with Li-ion and lead acid was made. While the prototypes are comparable with lead-acid in some regards, Li-ion still is the clear winner in all performance parameters.

WP7: LCA, techno-economic study and REACH

The objectives of this WP are:

(a) to develop a streamlined LCA methodology for POLYZION and to perform this assessment;
(b) to perform a techno-economic assessment for POLYZION;
(c) to consider the implications of the REACH Regulations on materials being developed within POLYZION, to advise the materials developers accordingly and, if appropriate, to develop a course of action.

Results:

(a) All partners provided input in order to develop lifecycle inventory and perform a streamlined assessment. The lifecycle of a battery starts with the collection of the raw materials and ends with the deposit of the battery components that cannot be used anymore. The production of primary and auxiliary materials, the manufacturing, the use and the recycling of the battery are the intermediate stages in the battery?s life. Each one of these stages bears a certain environmental burden.

These burdens are highly changeable since several factors may, positively or negatively, affect their magnitude. Performing an LCA implies the collection, evaluation and, finally, use of information concerning all these stages which are derived from project partners, manufacturers and the literature.

The three possible FUs for the battery EVs resulted in similar conclusions. Pb-acid and NiMH have a comparable and larger environmental impact than Li-ion. When the FU was changed and large assumptions made for the POLYZION battery the results showed lifecycle energy inputs comparable with Zn-air and lead-acid batteries. When looking at efficiencies and temperature dependency, the POLYZION prototypes have a performance similar to Pb-acid. With regards to energy density and cycle life the POLYZION prototypes still require development. Li-ion batteries are still considered to be state of the art for EV applications.

(b) The prototype test results provide insight into the performance of the POLYZION prototypes at the end of the project. The POLYZION aims to develop battery chemistry for EV applications. To determine whether the POLYZION technology is suitable, it is compared to the state of the art in commercially available EV battery performance. Similarly to the LCA, it was identified that due to the modest results in the pouch prototypes, it would be relevant to compare the performance with lead acid. Furthermore it was recommended that in order to make the POLYZION battery more competitive it would have to adhere to the outlined cost estimates derived in the Techno-economic assessment.

(c) The REACH assessment exercise drew the following conclusions: There is a lower limit of 1 tonne per manufacturer per year for registration of substances to apply. This limit provides an exclusion for the activity within the research program of POLYZION as the total amount of any substance produced or imported during the project was less than 1 tonne.

However, this does not mean that REACH does not need to be considered by individual partners and the consortium as a whole as exploitation of the project results would require scaling up beyond the 1 tonne per year limit. Another important consideration is that while polymers are excluded from REACH any residual monomer and additives contained within them may need to be registered.

The other constituent part of the POLYZION battery that has to be considered under REACH is the electrolyte. Two types of electrolyte have been considered as potential electrolytes for scale up. End-user CEGASA would be an importer of both electrolyte and polymers in order to manufacture POLYZION cells and have existing protocols in place for working with suppliers to ensure compliance.

WP8: Dissemination and exploitation

The objectives of this WP are:

(a) to ensure that the project outputs are disseminated for the maximum benefit of workers in the EU battery and energy industries, the consortium members, and to the wider research communities;
(b) to ensure that the project�s outputs are disseminated to the relevant industries and research communities out of the EU;
(c) to establish strong interactions with SMEs, industrials and other stake holders in the HEV and EV battery, ionic liquid and conducting polymers sectors;
(d) to set-up and implement a dissemination process based on a public access website, with a private link for internal project management purposes;
(e) to set-up and implement an exploitation strategy based on market demands and project�s outputs;
(f) to set up and implement a clear Policy for the protection of the IPR for the consortium members.

Results:

(a) A web site http://www.polyzion.eu was established with a public and private area during the project, with the private partners only area being used for confidential document storage and exchange. Project logo and branding implications have been addressed and registered. An extensive and wide ranging list of dissemination activities and details have been uploaded via the participant portal.

(b) The fundamentals for control of IP protection and exploitation activity were set out in Collaboration Agreement. An Exploitation committee comprising of representatives from C-Tech (Chair), ULEIC, KEMA and CEGASA was set up with a view to controlling IP and patent activity. This committee met in conjunction with the biannual review meetings and had responsibility for approving the content of disseminated material, particularly around presentation of papers at conferences and for publications in scientific journals.

(c) A plan for the use and dissemination of foreground was produced in draft form at month 24 and reviewed in two subsequent sessions, the second of which was at the month 42 meeting in order to agree on the content for the final document. Details of the exploitable results were uploaded via SESAM as part of the final reporting procedures, but only two of these results are considered non-confidential. Further details are provided in the subsequent section of this report.

Summary of S&T results

The following S&T objectives have been addressed during the project:

(a) Ionic liquid electrolyte will eliminate hydrogen gas evolution due to the absence of aqueous electrolytes. An ionic liquid electrolyte has the additional advantage of permitting a larger cell voltage compared to aqueous systems. The new group of eutectic based ionic liquids can be prepared readily from renewable, non-toxic, naturally occurring chemicals, are very inexpensive and can be tailored to specific uses. These ionic liquids are stable to air and moisture, and environmentally benign with good biodegradability.

The project has established two candidate none aqueous electrolyte formulations and optimised them for the new battery chemistry. These formulations have been use in scale up activity in subsequent tasks.

(b) At the same time, ultra-fast pulse charging techniques will be used to control the morphology of the Zn nanocrystallites which are deposited during the charging cycle, and thereby provide a means of avoiding dendritic growth. Factors affecting this surface morphology of the Zn nanocrystallites and optimisation of the pulse charging regime are covered by WP2.

Low efficiency of polymer charging limits the pulse charge capability. However, very good cyclability has been achieved with the development of Zn degreasing and charge/discharge activation protocols.

(c) A further key objective is to investigate the behaviour of conducting polymers in the same ionic liquid. A conducting polymer electrode will bring benefits to the proposed battery system such as avoiding the need for a membrane to separate the two halves of the cell, and low weight. In addition, recent research suggests that the electrochemical performance of conducting polymers in ionic liquids is superior in terms of cyclability and fast reversible redox behaviour compared to aqueous and organic electrolytes, and this part of the project will in itself make an interesting study. Issues such as behaviour of conducting polymers in high ionic strength and solvent-free electrolytes; ingress and egress of counter-ions into and out of the polymer matrix; how the structure of the polymer matrix affects counter-ion mobility; rate of charge/discharge of the polymer; and double layer effects will all be addressed and the results used to develop new polymeric materials. Specific targets for the conducting polymer electrode is to have a charge-discharge efficiency and cyclability that will not limit that achieved for the Zn electrode, i.e. > 90 % and 1 000 cycles.

The project has produced 19 different monomer, binders and surfactants and electrochemical polymerisation has been used to study the potential of these materials as polymer electrodes. 20 formulations of polymers containing a range of additives have been evaluated and polymer electrodes produced for both coin cell testing and for scaled up prototype cells. In addition the IL has been optimized for the polymer half cell.

(d) To complete the central theme of a new fast rechargeable Zn battery, promising Zn and polymer electrodes will be combined into secondary cells. The fundamental performance of these cells will be assessed and the chemistry achieving the highest performance scaled up to 1Ah pouch cells. The measureable targets are to achieve at least a specific power density of 1000 W kg-1, excellent cyclability (>1 000) and a large open circuit potential (approximately 1.9 V).

Coin cell testing demonstrated the best performing system was able to meet the power density specification, achieved 2 000 cycles at above 80% of original capacity, but that the cell voltage achieved was below target at 1.2V. This chemistry was successfully scaled up to cells of nominal 1Ah capacity, but replication of the encouraging lab scale performance from these cells has not been achievable within the timeframe of the project.

(e) One final objective is to assess the market competitiveness of the POLYZION technology in terms of its cost, environmental impact and energy efficiency. To achieve this objective an LCA (including end-of-life), a techno-economic assessment and a study of the implications of the REACH Regulations (if required) will all be performed as part of a developing a strong exploitation platform for the new device and its component materials. Detailed LCA, Techno-economic assessment and exploitation reports have been produced during the second reporting period and the impact of REACH regulation on beneficiary exploitation plans has been assessed.

Potential impact:

The project aim was to create a highly innovative class of rechargeable Zn battery for HEV and EV applications. This was achieved through technological progress in several new paths of materials science. The partners considered the approach to be high risk, but achievable, within the 42 month timescale. The impact from this project is relevant in both the short and long term, in that S&T advances made during the research performed have formed the foundation for ongoing research into this new class of battery and also initiated follow-on investigations in several complimentary energy technologies. For example, design variations to this new Zn battery are potentially applicable to portable and standby power needs, and this would make for interesting follow-on research. Beyond battery research, advances made in each of the separate materials disciplines could benefit other energy technologies, many of which are emerging as innovative technologies and are worthy of much attention in themselves. For example, the behaviour of conducting polymers in ionic liquids is of great interest in disciplines such as photo-electrochemical solar cells, flexible electronics and electrochromic materials. Similarly the application of well-defined and fast electrical pulsing could benefit many battery and capacitor types, as well as being an interesting field of study for the electrodeposition of materials with controlled morphology.

Ionic liquids, particularly of the easily manageable, low cost and environmentally benign types further developed here, could greatly benefit mass produced energy technologies which require an electrolyte that has a large electrochemical potential window, high conductivity and good environmental credentials, as well as being of interest in many of the applications and processes where volatile organic solvents are presently used. European research organisations, SMEs and industries, not least the partners in this project, are well placed to take these technologies forward provided there is sufficient fundamental understanding of the materials. Therefore, although not the central focus of this project, the consortium is also enthusiastic about the potential impacts of the project?s outputs in these technology areas, and considers the project as being a springboard to future collaborative research projects and intellectual property in allied energy technologies. The consortium also believes that the broad applicability of the materials advances made during this project mitigated the high risk nature of the project and increases the likelihood of significant long term impact.

In terms of environmental considerations, this project has two main expected impacts. Firstly, similar to any technology that promotes the introduction of HEVs and EVs, the POLYZION battery will help to reduce CO2 emissions by decreasing the reliance on fossil fuel powered vehicles. The mass introduction of HEVs and EVs will also decrease ground level pollution such as ozone, NOx and particulate emissions.

Secondly, this project is also consistent with European directives on end-of-life disposal and recycling of battery materials, in particular lead. There is currently no technology that can displace Pb acid batteries from their market dominant position as the traditional auto start battery. At the same time, the established HEV battery, NiMH and the most promising alternative, Li-ion batteries, suffer from inherent high material costs and the limited abundance of nickel, lithium and cobalt which can only stimulate further price rises. There are also safety concerns for Li-ion batteries which mean that these are not mass replacement technologies for the tried and tested Pb acid battery. In contrast to NiMH and Li-ion, the rechargeable Zn battery developed within the project could, with further development, be a low cost and environmentally benign technology suitable for displacing the Pb acid battery.

Main dissemination activities:

A web site www.POLYZION.eu was established with a public and private area during the project, with the private partners� only area being used for confidential document storage and exchange. The project logo and branding implications have been addressed and registered. An extensive and wide ranging list of 32 separate dissemination activities events and details have been uploaded via the participant portal. These included websites / applications, workshops, conferences, posters, publications, including articles in the popular press, Press releases and an interview with Cars21.

Exploitation of Results:

The fundamentals for control of IP protection and exploitation activity were set out in Collaboration Agreement. An Exploitation committee comprising of representatives from C-Tech (Chair), ULEIC, KEMA and CEGASA was set up with a view to controlling IP and patent activity. This committee met in conjunction with the biannual review meetings and had responsibility for approving the content of disseminated material, particularly around presentation of papers at conferences and for publications in scientific journals. One patent was prepared by IrICH, but search reports indicated prior disclosures would limit claims and the patent has not to date been filed. At present there are no plans to patent the results of the POLYZION project, but the IP is being retained as knowhow for further development or being protected in other ways.

A plan for the use and dissemination of foreground was produced in draft form at month 24 and reviewed in two subsequent sessions, the second of which was at the month 42 meeting in order to agree on the content for the final document. Details of the exploitable results were uploaded via SESAM as part of the final reporting procedures, but only two of these results are considered non-confidential. The confidential exploitable results relate to the POLYZION battery chemistry and knowhow relating to procedures and process for scaling up production of component of the battery. List of websites: http://www.polyzion.eu

Documenti correlati

Final Report - POLYZION (Fast rechargeable zinc-polymer battery based on ionic liquids)

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Permalink: https://cordis.europa.eu/project/id/226655/reporting/it