ACTIVITY REPORT

SMART ENERGY STORAGE

2015 / 2017

CIC energiGUNE

energy storage research centre

ACTIVITY REPORT

SMART ENERGY STORAGE

2015 / 2017

CIC energiGUNE

energy storage research centre

INDEX

0. WELCOME MESSAGE FROM THE GENERAL MANAGER

Nuria Gisbert
General Manager

Launched in 2011 with the aim of serving industry, CIC energiGUNE is the leading cooperative research centre in Europe in the field of energy storage. I joined the centre in 2015, taking over from the previous management team, who did an excellent job of creating and starting the project, without which energiGUNE would not be a leader in Europe today. Furthermore, since its inception as a strategic initiative of the Basque Country, the centre has received a great deal of support from the Department of Economic Development and Infrastructures of the Basque Government, the Provincial Council of Alava, as well as leading energy companies in the Basque Country and the main technology corporations.

In 2016, the year in which we celebrated our fifth anniversary, the project's start-up phase came to an end and, in order to enter the next consolidation phase, a new strategic approach was implemented covering the period from 2017 to 2020. This new approach coincided with the reorganisation of the Basque Science, Technology and Innovation Network (RVCTI) to which energiGUNE belongs.

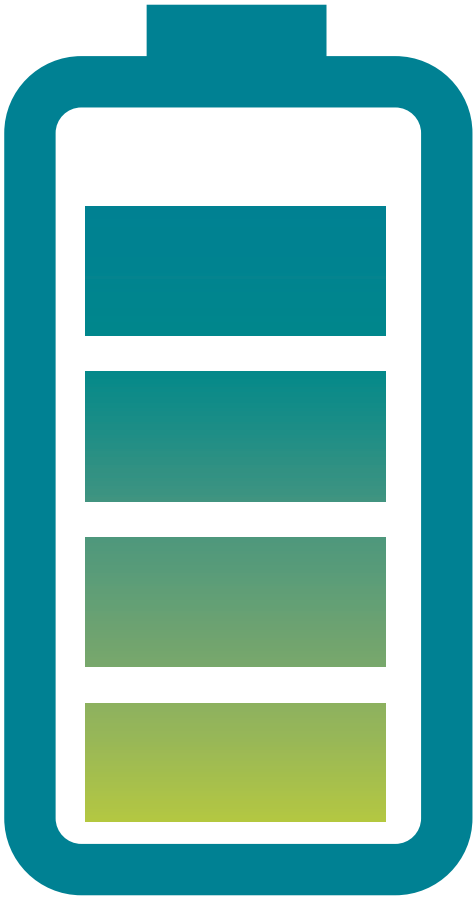
In line with the Euskadi RIS3 Smart Specialisation Strategy, in particular with the Energibasque 2.0 Strategy, and after a period of internal and external reflection, the conclusion reached with our partners was that CIC energiGUNE's 2020 vision would be to consolidate itself as one of the Top 5 research centres in Europe, in addition to being a leading partner of the leading Basque companies, in collaboration with RVCTI agents. To this end, the following strategic objectives covering the centre's 5 areas of activity (research, technology transfer, collaboration with other agents, communication and people) were proposed:

- Promote excellence in research with the potential to evaluate it.
- Maintain the level of excellence by achieving an appropriate balance in technology transfer.
- Work closer with companies.
- Enhance the value of abilities, progress and results.
- Make progress in our relationship with RVCTI agents.
- Increase our international presence.
- Improve the visibility of CIC energiGUNE.
- Have the best team and organisational model to carry out our activity.

In short, the future of the centre is tightly linked to working closer with industry and maintaining excellence in research, in order to consolidate our position as an international benchmark. We are experts in energy storage and, in that regard, we are highly energised, motivated and willing to face our greatest challenges. We will achieve them through our scientific expertise and the excellent team of people we have, whom I would like to thank for their dedication and effort.

1. ABOUT US

1.1 GENERAL OVERVIEW
Vision, Mission, Evolution



MISSION

To play a leading role on the international scientific scene, focusing on materials and systems related to energy-oriented storage applications.
To be a benchmark in technology transfer, with the collaboration of other scientific- technological agents and generating disruptive knowledge for Basque Industry.

EVOLUTION

2008
- Launch of the centre and identification of the strategic research lines

2011
- Opening of CIC energiGUNE and start of research activities

VISION

To consolidate us as one of the top 5 research centres in Europe and become a leading partner with Basque companies in the areas on which CIC energiGUNE focuses.

2013
- First national and international industrial collaborations

2014
- Significant increase in the number of patents

2015
- Launch of the ORC_ Plus and RESLAG EU H2020 projects, with RESLAG being the first European project coordinated by CIC energiGUNE
- ABAA8

2016
- Launch of MONBASA and Graphene Core 1 EU H2020 projects
- 5th Anniversary and Prototyping line - Dry room inauguration

2017
- Launch of a new Strategic Plan 2017 - 2020
- Launch of Laser4surf and IMAGE EU H2020 projects.
- 3rd Power Our Future Forum 2017

1.2 ORGANISATION

Governance and Scientific Advisory Board

SCIENTIFIC ADVISORY BOARD

TES

Dr. Eduardo Zarza
PSA

Dr. Gregory Glatzmaier
NREL

Prof. Manuel Tello
UPV/EHU

Dr. Michael Epstein
Weizmann Institute of Science

Dr. Rainer Tamme
DLR

EES

Dr. Claude Delmas
Bordeaux Institute of Condensed-Matter Chemistry ICMCB

Dr. Imre Gyuk
DOE

Dr. John Miller
JME, Inc.

Dr. John Owen
University of Southampton

Dr. Ander Laresgoiti
IK4 Ikerlan

Dr. Peter Novak
PSI

Dr. Steven Visco
Polyplus Battery Company

Dr. Michel Armand
CIC energiGUNE

Prof. John A Kilner
Imperial College

1.3 HIGHLIGHTS

Patents, European projects, Master's & PhD programmes

PATENTS

Improving thermochemical storage behavior by inserting additives (DE102012103427A1)

Authors: Christian Rosskopf, Inga Utz, Marc Linder, Abdessamad Faik

Hybrid electrolyte (EP12382290.0 // PCT/EP2013/051023)

Authors: Michel Armand, Irune Villaluenga, Teófilo Rojo

New high capacity materials based on transition metals of oxynitrides (EP13382227.0 // PCT/EP2014/062412)

Authors: Michel Armand, Montserrat Casas-Cabanas, Montserrat Galceran, Begoña Acebedo, Josh Kurzman, Nadir Recham

Process for the preparation of hierarchically meso and macroporous structured materials (PCT/EP2013/071705)

Authors: Mani Karthik, Abdessamad Faik, Stefania Doppiu, Josh Kurzman, Nadir Recham

A sodium ceramic electrolyte battery (EP14382393.8 // PCT/EP2015/073756)

Authors: Michel Armand, Teófilo Rojo, Gurpreet Singh, Laida Otaegui, Frederic Aguesse, Lucienne Buannic

EUROPEAN PROJECTS

Acronym: RESLAG

www.reslag.eu

Title: Turning waste from steel industry into a valuable low-cost feedstock for energy intensive industry

Partners: CIC energiGUNE, Arcelor Mittal Sestao, German Aerospace Center (DLR), IK4-Azterlan, Imperial College London, Friedrich-Alexander-Universität (FAU), Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA), Optimum Cement, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), Technical Research Centre of Finland (VTT), Fraunhofer IWKS, Life Cycle Engineering, Moroccan Agency of Sustainable Energy (MASEN), NOVARGI, Hasten, General Electric France, General Electric Switzerland, Renotech.

Abstract: The RESLAG project proposal is aligned with the challenges outlined in the WASTE-1-2014 call: moving towards a circular economy through industrial symbiosis. In 2010, the European steel industry generated about 21.8 Mt of steel slag as waste. 76% of the slag was recycled for applications such as aggregates for construction or road materials, but these sectors were unable to absorb the total amount of slag produced. The remaining 24% was landfilled (2.9Mt) or self-stored (2.3 Mt). Landfilled slag represents a severe environmental problem. The main aim of RESLAG is to prove that there are industrial sectors able to make an effective use of the 2.9 Mt/y of landfilled slag, if properly supported by the right technologies. In proving this, the RESLAG project also demonstrates that there are other significant environmental benefits from an "active" use of slag in industrial processes, such as CO2 savings (up to 970 kt/y from CSP applications, at least 71 kg/ton of steel produced from heat recovery applications), and the elimination of negative impacts associated with mining (from the recovery of valuable metals and the production of ceramic materials). To achieve this ambitious goal, four large- scale demonstrations to recycle steel slag were considered: the extraction of high value-added non-ferrous metals; TES for heat recovery applications; TES to increase the dispatchability of CSP plants; and the production of innovative refractory ceramic compounds. Overall, the RESLAG project is aimed at creating an innovative organisational steel by-products management model that is able to reach high levels of resource and energy efficiency and includes a series of upgrading processes and a life cycle perspective. All these demonstrations are led by the industries involved in the RESLAG consortium. The RESLAG project is supported by the main organisations that represent the energy-intensive industries, the CSP sector, energy platforms, governments, etc.

Budget: €9,668,551.93

Acronym: ORC-Plus

www.orc-plus.eu

Title: Organic Rankine Cycle - Prototype Linkto Unit Storage

Partners: CIC energiGUNE, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo económico sostenibile (ENEA), Fraunhofer ISE, ENERRAY, Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN), Soltigua, Euronovia.

Abstract: In line with the H2020-LCE-03-2014 call, ORC-PLUS focuses on increasing the technological performance of renewable energy systems, reducing costs and improving dispatchability. The aim is to develop an optimised combination of innovative Thermal Energy Storage-TES units (specialised for CSP in the 1-5 MWe range) and engineering solutions to improve the number of production hours of an existing small CSP plant, located in a desert area and coupled with an ORC system. With an optimised TES solution, it is possible to extend the energy production periods of a CSP plant (also during non-solar radiation), eliminating or minimising the need to burn fossil or renewable fuels in hybrid or back-up systems. Nowadays, efforts are being devoted to R&D on TES for large-scale plants, although there is great potential for small/medium-scale CSP installations. ORC-PLUS is in the spectrum of "large scale prototype to pre-commercial scale demonstration". The technology proposed is based on a solar field, using thermal oil as a Heat Transfer Fluid and an ORC power unit coupled with an innovative TES unit. An experimental demonstration of two different industrial TES system prototypes was performed in relevant environment (TRL 6). For each prototype, a simulation model of the pilot processes was developed, with TES system prototypes. The models were optimised on the basis of the characteristics of the site and power load, to determine the conditions and relevant parameters of the real scenarios for each application and to select the TES technology that best fitted the needs of the targeted sector. The end result was an industrial pilot plant used to validate the technology in a real operational environment and demonstrate its feasibility (TLR7). Validation included an analysis of the techno-economic viability and environmental impact, and the replicability of the final design of the pilot plant. This proposal was backed up by three support letters from ESTELA, ANEST and Green Energy Park (Morocco).

Budget: €7,385,350

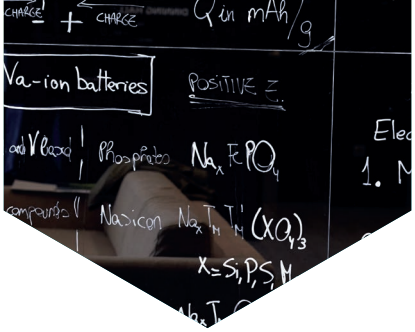
Acronym: MONBASA

www.monbasa.eu

Title: Monolithic Batteries for Space Applications

Partners: CIC energiGUNE, Tecnalia, Gencoa, Nanospace.

Abstract: MONBASA's overall aim is to develop an energy storage system for small satellites (nano-/microsatellites) that outperforms existing solutions and can be integrated with MEMS technology. To be both applicable and competitive, the innovative solution will have to respond to specific needs, namely: (1) high energy efficiency and density, (2) small size and low weight, (3) high reliability (4) compliance with existing standards and regulations, and (5) high cost-efficiency. Any energy storage system will have to first demonstrate its ability to store energy efficiently, within specific power, lifetime and safety specifications and eventually be available at a cost that is ultimately affordable by the nano/microsatellite sector, which is highly cost-sensitive. The worldwide nanosatellite sector is continuously growing and three main aspects are driving the development: miniaturisation, standardisation and cost. However, Europe has seriously fallen behind competitors from the US and Asia with regard to R&D in the field of energy storage, which is one of the crucial components for improving and widening the performance and applications of small satellites. With its approach, MONBASA is bridging the gap between R&D and the market, with the desired future impact being that the provision of tailored energy solutions becomes a



European discipline and business. By bringing together a cross-sector consortium that comprises actors from the areas of energy R&D, processing technologies and space applications, the exact needs of the space industry will be considered for innovative energy storage solutions at low TRL levels. This will not only significantly increase the future market uptake of an innovative solution that is currently in the basic research stage, but it will foster an urgently-needed intense knowledge exchange between non-space and space actors for jointly developing innovative solutions for a field where strong growth is expected.

Budget: €1,156,791.25

Acronym: Graphene Core 1

Title: Graphene-based disruptive technologies.

Partners: Coordinated by Chalmers Tekniska Högskola, the Graphene Core 1 project has a total of 155 partners. Within the "WP12 Energy Storage" were CIC energiGUNE participates, the involved partners are: Consiglio Nazionale delle Ricerche (CNR), the University of Manchester, Commissariat a l´Energie Atomique et aux Energies (CEA), Thales SA, Varta Micro Innovation GmbH, University of Cambridge, Fondazione Istituto Italiano di Tecnologia (IIT), REPSOL, Umeå Universitet, Fondazione Bruno Kessler, Technische Universitaet Dresden, Stichting Katholieke Universiteit and Nokia R&D (UK) Limited.

Abstract: This project is the second in a series of EC-financed Graphene Flagship projects. The Graphene Flagship is a ten-year research and innovation initiative with a total project cost of 1,000,000,000 euros, funded jointly by the European Commission, member states and associated countries. The first part of the Flagship was a 30-month Collaborative Project, Coordination and Support Action (CP-CSA) under the seventh framework programme (2013-2016), while this and the following parts are implemented as Core Projects under the Horizon 2020 framework. The Graphene Flagship's mission is to take graphene and related layered materials from a state of raw potential to a point where they can revolutionise multiple industries. This will bring a new dimension to future technology – a faster, thinner, stronger, flexible, broadband revolution. Our programme will put Europe firmly at the heart of the process, with a manyfold return on the EU investment, both in terms of technological innovation and economic growth. To realise this vision, we have brought together a large European consortium with about 150 partners in 23 countries. The partners represent academia, research institutes and industries, which work closely together in 15 technical work packages and five supporting work packages covering the entire value chain, from materials to components and systems. CIC energiGUNE is taking part in the Energy Storage work package, which is devoted to graphene-related materials and other two-dimensional crystals and scaffolds in strong synergy with the other work packages to develop batteries (Li- ion, Li-air, Li-S and Na-ion), supercapacitors and devices for hydrogen storage. Partners taking part in this work package are also looking at new approaches for energy storage and additional functionalities, such as conformability, that are made possible by the exploitation of two-dimensional crystals. As time progresses, the centre of gravity of the Flagship will move towards applications, which is reflected in the increasing importance of the higher - system - levels of the value chain. In this first core project the main focus is on components and initial system level tasks.

Budget: €89,000,000

Acronym: INSHIP

www.inship.eu

Title: Integrating National Research Agendas on Solar Heat for Industrial Processes.

Partners: Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V., Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas Ciemat, Arbeitsgemeinschaft Erneuerbare Energien - Institut für Nachhaltige Technologien.
AEE INTEC, Fondazione Bruno Kessler Applied Research on Energy Systems, Universidade de Évora, The Cyprus Institute Limited, Center for Renewable Energy Sources, Eidgenössische Technische Hochschule Zürich (ETHZ), Commisariat a l'energia atomique et aux energies alternative (CEA), Middle East Technical University, EERA ASBL.
Additional Research Partners: Centre national de la recherche scientifique (CNRS), Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Agenzia nationale per le nuove tecnologie, l'energia e lo sviluppo economico sostenible (ENEA), Consiglo nazionale delle ricerche (CNR), Università degli Studi di Palermo (UNIPA), Università degli studi di Napoli (UNINA), Università degli studi di Firenze (UNIFI), Laboratório Nacional de Energia e Geologia (LNEG), Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (IST-ID), National Renewable Energy Centre (CENER), IMDEA Institutes (IMDEA), Centro Tecnológico Avanzado de Energías Renovables (CTAER), Tecnalia Corporación Tecnológica (TECNALIA), IK4-TEKNIKER Research Alliance (IK4-TEKNIKER), Universidad de Sevilla (USEVILLA), CIC-energiGUNE Energy Coop. Research Center (energiGUNE), Cranfield University (CRANFIELD).

Abstract: Despite process heat being recognised as the application with the highest potential among solar heating and cooling applications, Solar Heat for Industrial Processes (SHIP) still presents a modest share of about 0.3% of total installed solar thermal capacity. At the current stage of technological development (economic competitiveness restricted to low temperature applications; technology implementation requiring interference with existing heat production systems, heat distribution networks or even heat consuming processes), solar thermal potential is mainly identified for new industrial capacity in countries outside America and Europe. In this context, INSHIP aims to define ECRIA by bringing together major European research institutes, with recognised SHIP-related activities, into an integrated structure to successfully coordinate the objectives of: more effective and intense cooperation between EU research institutes; aligning different SHIP-related national research and funding programmes, avoiding overlaps and duplications and identifying gaps; accelerating knowledge transfer to European industry, to be the benchmark organisation promoting and coordinating international cooperation on SHIP research to and from Europe, while developing coordinated TRL 2 to 5-related R&D activities with the objective of progressing SHIP beyond state-of-the-art through: easier integration of low and medium temperature technologies that suit the operation; durability and reliability requirements of industrial end users; expanding the range of SHIP applications to the EI sector through the development of suitable process-embedded solar concentrating technologies, overcoming the present barrier of applications that only exist for low and medium temperature ranges; increasing the synergies within industrial parks, through centralised heat distribution networks and exploiting the potential synergies of these networks with district heating and with the electricity grid.

Budget: €2,858,798.75

Acronym: IMAGE

www.inship.eu

Title: Innovative Manufacturing Routes for Next-Generation Batteries in Europe.

Partners: CIC energiGUNE, Avl List Gmbh, Vrije Universiteit Brussel, Bayerische Motoren Werke Aktiengesellschaft, Varta Microbattery Gmbh, Umicore, Arkema France, Hydro-Quebec, Cidetec, Rheinisch-Westfaelische Technische Hochschule Aachen, Technische Universitaet Graz, Varta Storage Gmbh, Manz Italy Srl.

Abstract: At the present time, Europe is not very competitive in terms of Lithium battery cell development, and manufacturing in particular. This lack of competence and competitiveness could quickly spiral into a complete loss of this key technology for electrification in the EU. To combat this, IMAGE will significantly contribute to sustainably developing a European Li-battery cell manufacturing competence and capability by creating a competitive, production-oriented research & development framework within Europe. A realistic, well-documented roadmap for manufacturing cost-effective, competitive battery cells in Europe will emerge. This will be implemented by establishing a distributed battery cell production base that will, after carefully upscaling production, be able to supply the now burgeoning electric vehicle industry. In this regard, the main goal of IMAGE is to push the European Li-battery industry and academia to take a leading role in the development and manufacturing of next generation Li-Ion cells. IMAGE's main objectives are as follows:

1) To develop generic production techniques for next generation battery cells based on high specific energy Li-metal battery cells. This will include a modular development approach that will be easy to up-scale, while remaining flexible and safer to replace in the event of any contingencies and market/manufacturer configuration changes.
2) To identify energy- and resource-efficient cell manufacturing technologies and assets tailored to the existing European industrial infrastructure. This will include the identification of bottleneck factors and challenges that could be addressed in the present European industrial context.
3) To develop a progressive, multiple-tier technological and production framework that is able to cope with the inherent technological changes and advancements that are characteristic in this dynamic field. Thus, several technologies will be covered by IMAGE, each with a different level of technological maturity.

Budget: €4,948,026.25

Acronym: LASER4SURF

www.laser4surf.eu/

Title: Laser for mass production of functionalized metallic Surfaces.

Partners: CEIT-IK4, CIC energiGUNE, Laser Engineering Applications, Multitel, Iris Advanced Engineering, Fagor Automation, Rescoll, European Science Communication Institute (ESCI).

Abstract: The main goal of the LASER4SURF project is to develop a laser-based solution for the functionalisation of metal surfaces with textures ~1µm or less on mass production. This solution will be based on surface functionalisation with ultrashort pulses via Laser Induced Periodic Surface Structures (LIPSS). The LASER4SURF project will develop a Laser Texturing Prototype to overcome the current barriers for the LIPSS technique to reach mass production, achieving a production rate of 0.1 min/cm^2:

- High process time for large 3D pieces.
- Need for inline inspection methods.
- Need for modelling tools for parameter selection.
- The development will be focused on the three main steps of the Laser texturing value chain:
  - Laser technology/equipment. To generate LIPSS of different pattern sizes with multiple orientations, LASER4SURF will develop an easy to integrate and control, compact and low cost optical module.
  - In-line inspection tool. A whole optical measurement system based on diffractometry technology will be integrated with the laser equipment, including hardware and software, in order to be able to monitor all of the different nano properties on the functionalised surfaces.
  - Simulation tool that will automatically show the process parameters required to obtain the desired functionality for a specific material. The simulation tool will automatically transfer the optimum laser parameters to the LIPSS equipment in order to configure it for the desired pattern.

The project will combine the developments in an all-in-one solution, which will be validated by three different use case products that represent a broad range of the main industries, metal alloys used and required functionalities.

The LASER4SURF project will be developed by a well-balanced consortium that brings together 8 partners: 3 technology developers (CEIT, MULTITELL and VISUM), a solutions integrator (LASEA), three industrial partners (FAGOR, RESCOLL and CIC) and a dissemination partner (ESCI).

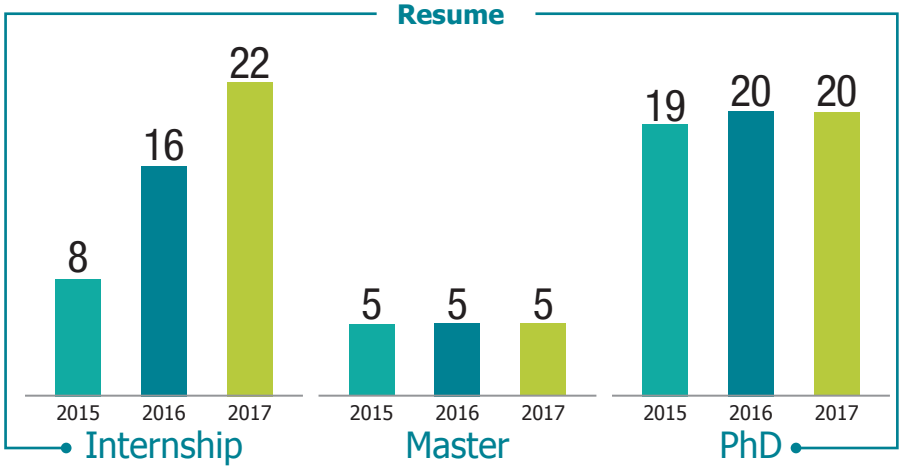
Budget: €4,077,750.00

MASTER'S & PHD PROGRAMMES

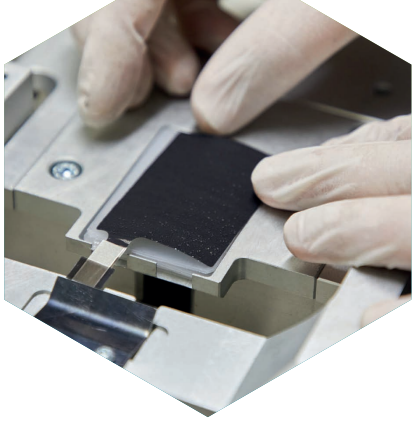
Programmes

- PhD in Physics and Materials Technology (UPV/EHU)
- PhD in Materials Science and Technology (UPV/EHU)
- PhD in Mechanical Engineering and Electric Power (MU and UPV/EHU)
- PhD in Physics of Nanostructures and Advanced Materials (UPV/EHU)
- PhD in Chemical Engineering (UPV/EHU)
- Master´s Degree in New Materials (UPV/EHU)
- Master´s Degree in Chemical Processes Engineering and Sustainable Development (UPV/EHU)
- Master´s Degree in Energy and Power Electronics (MU)
- Master´s Degree in Physics of Nanostructures and Advanced Materials (UPV/EHU)
- Master´s Degree in Chemical Engineering (University of Caen, France)
- Master´s Degree in Materials for Energy Storage and Conversion (University of Picardie Jules Verne, France)

Resume



1.4 COLLABORATIONS ACADEMIA



1.5 COLLABORATIONS INDUSTRY

AEG POWER SOLUTIONS
Ingeteam
BOSCH
masermic MECHATRONICS
MAPSA
ZIV
SWM
CAF

IBERDROLA
Jema
REBATTERY ECOLOGICENERGY
cecasa
BTI Battery Technologies Inc.
ArcelorMittal

SENER
ZIGOR
ORMAZABAL velatia
ennera energy for a new era
MYRUNS Technology
RENAULT

Aitor Patxi Oregi

Director of Energy, Mines and Industrial Management. Economic Development and Infrastructures Department. Basque Government. President of CIC energiGUNE

The activity carried out by CIC energiGUNE represents a differential value, both in the research environment and in the business ecosystem of the Basque Country. In record time, the Basque Government's early commitment to research into energy storage is bearing fruit. In just 6 years we have a reference centre, a leader in basic research in Europe, with a young, international and highly committed team. This research excellence is also perfectly attuned to today's changing industrial reality and is reflected in the different collaboration projects with Basque and European companies.

The future of CIC energiGUNE, excellently managed, in cooperation with other scientific and technological agents, looks promising for a centre whose area of specialisation lies at the heart of society's most urgent needs, the decarbonisation of the energy sector.

José Ignacio Hormaeche

General Manager
Basque Energy Cluster

Since the launch of the Energy Storage Working Group of the Basque Energy Cluster at the end of 2014, CIC energiGUNE has been one of its key agents in the promotion and development of the Group.

Over the last three years, from 2015 to 2017, CIC energiGUNE has been particularly active in the activities developed by the Working Group and has maintained permanent contact and dialogue with both companies and other Technology Centres. I think it is worth highlighting its involvement as a reference centre in the field of energy storage in initiatives such as the drawing up of a map of collaborations between companies and centres in the value chain, cataloguing infrastructures for testing and validating materials, cells and modules and defining the "Energy Storage Basque Country" brand.

I would especially like to thank the CIC for the technological leadership it has shown over the years in defining and implementing two ambitious R&D projects in collaboration with companies and technology centres. I am referring firstly to CALOR initiative, which aims to develop technologies and solutions for using waste heat in industrial processes. The second project is mGRIDSTORAGE, which aims to design, develop and implement an advanced microgrid model based on disruptive storage technologies, including the design and development of network management algorithms. The mGRIDSTORAGE project was approved in the HAZITEK Strategic 2017 call for proposals and 11 companies and 8 RVCTI agents are taking part in it.

I therefore believe that it is only fair to acknowledge and congratulate CIC energiGUNE for having responded in the 2015-2017 period to the mission that led to its creation and to the demanding expectations of the energy sector, helping Basque companies to position themselves competitively in the markets related to the application and use of energy storage, based on the development of innovative products and services.

Juan Ignacio Burgaleta

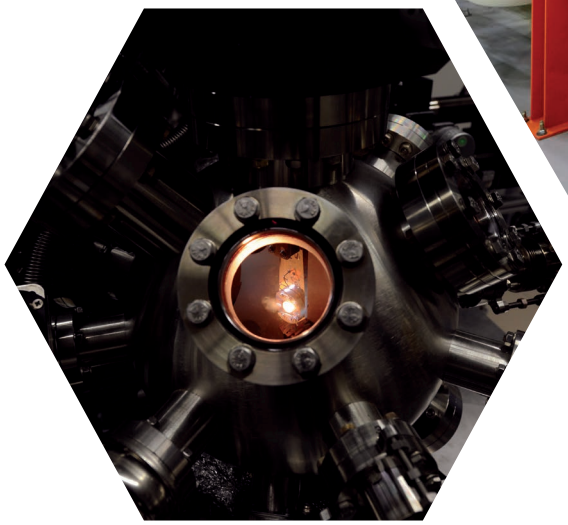
Former Director of Technology
SENER

As a member of the Board of CIC energiGUNE since its foundation in 2007, I have been able to follow its remarkable evolution, starting with the design and construction of its facilities, and the training of its team of researchers, which have led to it **currently being an international reference in the field of energy storage. It is worth mentioning the development of its research related to thermal energy storage and its application in solar thermal power plants. It is the only renewable energy source with the capacity to adapt the electricity supply to the grid demand,** thanks to its storage system and being able to generate electricity even in the absence of sunlight. In relation to these activities, the excellent collaboration between CIC energiGUNE's team of researchers and SENER is noteworthy.

Igor Cantero

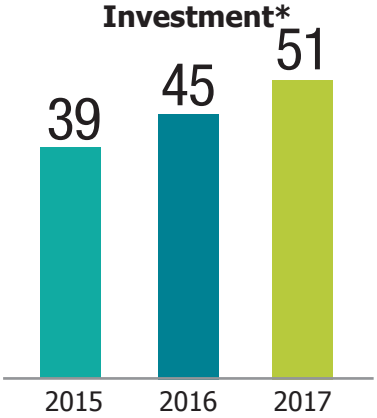
Chief Technical Officer
Cegasa

I believe that all companies need to carry out basic research, including SMEs. The most efficient way to attain a first-rate team is to collaborate with a research centre like CIC energiGUNE. **For CEGASA, working side by side with CIC energiGUNE is like having a window open to the future, knowing first-hand what is on our technological horizon and being ready for it when it becomes an industrial reality.**



1.6 CIC ENERGIGUNE AT A GLANCE

Investment*



Total Staff

77 2015

84 2016

91 2017

Publications

96 2017

85 2016

65 2015

Researchers

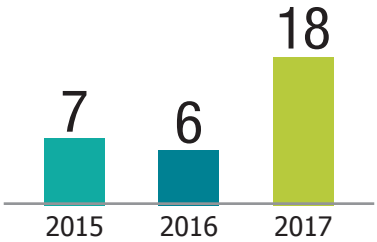
66 2015

70 2016

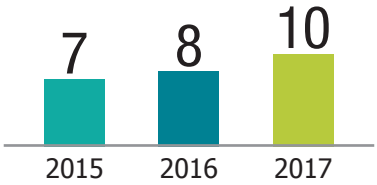
78 2017

(*) Accumulated data

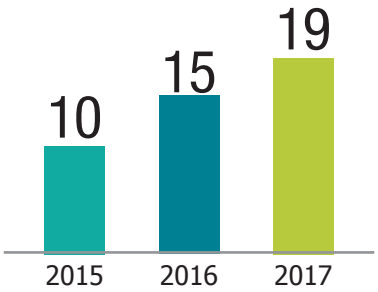
Industrial collaborations



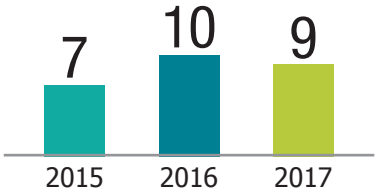
European projects



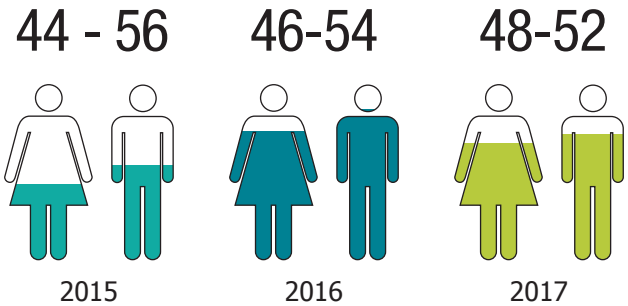
Competitive research projects*



Patents*



Women – Men (%)



Participation at conferences

Events organised

(*) Accumulated data

2. POWER STORAGE; BATTERIES AND SUPERCAPS AREA

EES

Prof. Teófilo Rojo. Scientific Director
Dr. Lide M. Rodríguez. Technology Coordinator

2015 - 2017 RESEARCHERS

Acebedo / Acebo / Aguesse / Ajuria / Aldalur / Anne / Arcelus / Arnáiz / Ayape / Baloch / Baraldi / Bekaert / Benyoucef / Berlanga / Bhattacharjya / Bondarchuk / Bonilla / Botas / Buannic / Carrasco / Carriazo / Casas / Castillo / Castro / Coya / Devaraj / Díez / Drewett / Eguia / Enterría / Etxebarria / Fernández / Galcerán / García / García de Cortázar / Gebresilassie / Giner / Goikolea / Gómez / Gómez C. / Gómez U. / Gonzalo / Gracia / Gucciardi / Gutiérrez / Han / Herrán / Iturrondobeitia / Jauregui / Júdez / Lago / Lakuntza / Li / Liendo / Llordés / López del Amo / López-Aranguren / Madinabeitia / Manalastas / Martín / Martínez / Martínez de Ilarduya / Muñoz / Mysyk / Navarro Suárez / Orayech / Ortiz / Otaegui / Oteo / Panja / Piernas / Piszcz / Quintela / Redondo / Reynaud / Rikarte / Rojo / Roldán / Samarasingha / Sánchez E. / Sánchez P. / Saurel / Serrano / Silván / Singh / Villaverde / Wizner / Zagorski / Zhang H. / Zhang W. / Zhang Y.

2.1 RESEARCH LINES

METAL AIR

The goal of the "Metal air" research line is to develop new battery chemistries to enable breakthroughs in stationary and mobile applications, particularly in terms of battery performance, lifetime and safety. This will be achieved by developing descriptors based on key parameters/properties, developing high-performing electrodes and understanding mechanisms during battery operation.

NA-BASED

The aim of the "Na-based" research line is to develop and demonstrate the competitiveness of Na-ion secondary battery technology, reaching the performance of present Li-ion technology but with lower costs. Thanks to knowledge gained previously, we will continue to explore new materials for Na-ion batteries: new approaches and new classes of materials are needed to push the limits of this technology. The project aims to approach several aspects of the research, focusing first on all of the material-related aspects, with the objective of developing a pouch cell for industry.

ADVANCED CATHODES

The aim of the "Advanced cathodes" research line is the rational design of (novel) electrode materials by understanding the chemistry and physics of intercalation materials and component interactions. Through a combination of exploratory and applied research coupling synthesis routes, advanced characterisation and modelling, our goal is to enhance the performance of LIBs at a lower cost and prepare for next-generation solid state batteries.

POLYMER-RICH ELECTROLYTES

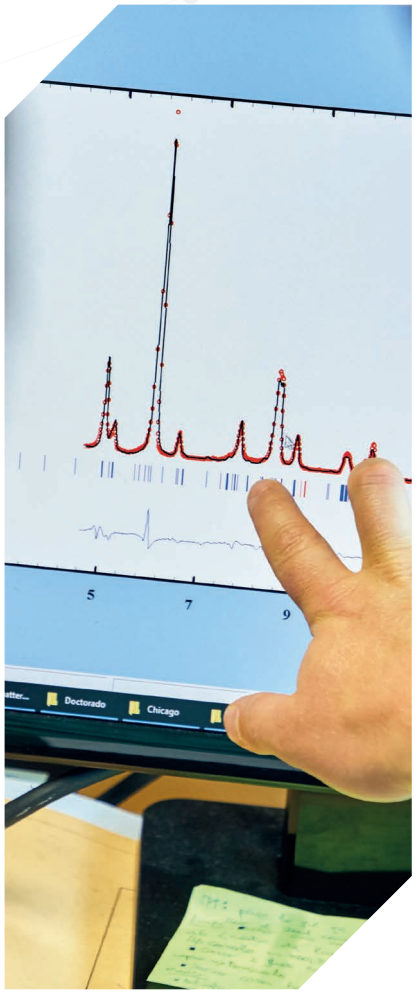
The aims of the "Polymer-rich electrolytes" research line are targeted at providing safe solid electrolyte solutions and key components for rechargeable solid batteries used for xEVs. In addition, it encompasses research on redox flow batteries used for stationary application, to improve their performance.

SUPERCAPACITORS

The "Supercapacitors" research line aims to improve the performance of EDLC and hybrid supercapacitors. The goal is to increase the energy density of supercapacitors while maintaining a large power density, wide operational temperatures and a long life cycle.

METAL ANODES

The aim of the "Metal anodes" research line is to enable next generation battery technologies, such as all solid state, metal-air or metal-sulphur, by developing new processing methods and coatings that result in stable metal anodes. In particular, lithium anodes are our priority, but we are also interested in metallic sodium and other metal anodes such as magnesium and aluminium.



CERAMIC-RICH ELECTROLYTES

The "Ceramic-rich electrolytes" research line aims to tackle current scientific challenges that are limiting the practical application of solid-state battery technology. By focusing on the development of ceramic-rich electrolyte materials and on cell integration and cell design, we aim to generate key fundamental knowledge needed to progress towards a functional Solid State Battery device.

LI-S

The aim of the "Lithium Sulphur" research line is to obtain high energy density, and safe, low cost solid state Li-S battery concepts.

2.2 SCIENTIFIC HIGHLIGHTS

IN VIVO INTEGRITY OF POLYMER-COATED GOLD NANOPARTICLES

Wolfgang G. Kreyling[1], Abuelmagd M. Abdelmonem[2], Zulqurnain Ali[2], Frauke Alves[3,4], Marianne Geiser[5], Nadine Haberl[1], Raimo Hartmann[2], Stephanie Hirn[1], Dorleta Jimenez de Aberasturi[2,6,7], Karsten Kantner[2], Gülnaz Khadem-Saba[1], Jose-Maria Montenegro[2], Joanna Rejman[2], Teofilo Rojo[6,8], Idoia Ruiz de Larramendi[6], Roser Ufartes[3], Alexander Wenk[1] and Wolfgang J. Parak[2,7]

1) Institute of Lung Biology and Disease and Institute of Epidemiology 2, Helmholtz Zentrum München – German Research for Center for Environmental Health, Neuherberg/Munich 85764, Germany.
2) Department of Physics, Philipps Universität Marburg, Marburg 35032, Germany.
3) Department of Molecular Biology of Neuronal Signals, Max Planck Institute of Experimental Medicine, Göttingen 37075, Germany.
4) Department of Hematology and Medical Oncology, University Medical Center Göttingen, Göttingen 37075, Germany.
5) Institute of Anatomy, University of Bern, Bern 3012, Switzerland.
6) Department of Inorganic Chemistry, UPV/EHU, Bilbao 48080, Spain.
7) CIC Biomagune, San Sebastian 20009, Spain.
8) CIC energiGUNE, Miñano 01510, Spain.

ABSTRACT Inorganic nanoparticles are frequently engineered with an organic surface coating to improve their physicochemical properties, and it is well known that their colloidal properties[1] may change upon internalisation by cells[2,3]. While the stability of such nanoparticles is typically assayed in simple in vitro tests, their stability in a mammalian organism remains unknown. Here, we show that polymer shells firmly grafted around gold nanoparticles may degrade when injected into rats. We synthesised monodisperse radioactively labelled gold nanoparticles (^{198}Au)[4] and engineered an ^{111}In-labelled polymer shell around them[5]. Upon intravenous injection into rats, quantitative biodistribution analyses performed independently for ^{198}Au and ^{111}In showed partial removal of the polymer shell in vivo. While ^{198}Au accumulated mostly in the liver, part of the ^{111}In showed a non-particulate biodistribution similar to an intravenous injection of chelated ^{111}In. Further in vitro studies suggested that degradation of the polymer shell was caused by proteolytic enzymes in the liver. Our results show that even nanoparticles with high colloidal stability can change their physicochemical properties in vivo.

Letter | Published: 15 June 2015
Nature Nanotechnology volume10, pages 619–623 (2015)
DOI: 10.1038/nnano.2015.111

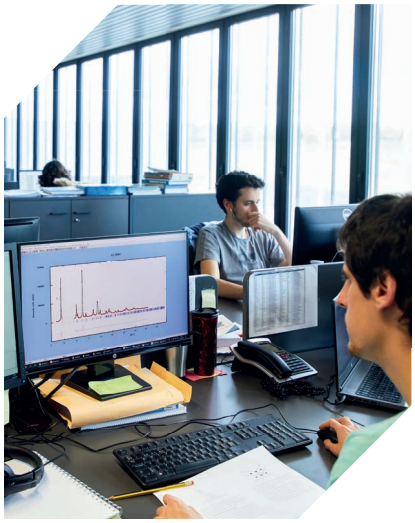
HIGH PERFORMANCE MANGANESE-BASED LAYERED OXIDE CATHODES: OVERCOMING THE CHALLENGES OF SODIUM ION BATTERIES

Nagore Ortiz-Vitoriano[1,2], Nicholas E. Drewett[1], Elena Gonzalo[1] and Teófilo Rojo[1,3]

1) CIC energiGUNE, 01510 Miñano, Spain
2) IKERBASQUE, Basque Foundation for Science, 48013 Bilbao, Spain
3) Departamento de Química Inorgánica, Facultad de Ciencia y Tecnología, Universidad del País Vasco (UPV/EHU) 48940 Leioa, Spain

ABSTRACT Currently, there is increasing interest in developing 'beyond lithium' battery technologies to augment or, in certain situations, replace lithium ion batteries (LIBs). Room temperature sodium ion batteries (NIBs) offer an attractive combination of low costs and plentiful constituents and a wide range of phases, structures and stoichiometries available for optimisation. Sodium-layered oxides are considered to be promising candidates as cathode materials, due to their flexibility and versatility, as well as their intrinsically fast structural diffusion of Na ions, which leads to enhanced rate capability. In particular, sodium manganese-based layered oxides (generally $Na_xMn_{1-y-z}M_yT_{Mz}O_2$, where TM represents one or more transition metals, and M consists of one or more non-transition metals) are a key family of materials, in part due to the relatively low cost and environmentally friendly nature of the manganese, and consequently are worthy of a detailed investigation. Examination of these systems, particularly in terms of stoichiometry and phase, has shown that significant advances have been made recently, both in terms of understanding the mechanisms behind electrochemical performance, and in terms of refining these to produce improved materials. The goal of this review is to present the current developments in sodium manganese-based layered oxides (particularly with respect to their electrochemical performance, physical properties and manganese content), to discuss the current state of this field of research and to draw conclusions regarding where future investigations may be most fruitfully directed.

Review Article
DOI: 10.1039/C7EE00566K
Citation: Energy Environ. Sci., 2017,10, 1051-1074



ORIGINS OF BISTABILITY AND NA ION MOBILITY DIFFERENCE IN P2- AND O3-$NA_{2/3}FE_{2/3}MN_{1/3}O_2$ CATHODE POLYMORPHS

Nebil A. Katcho, Javier Carrasco, Damien Saurel, Elena Gonzalo, Man Han, Frederic Aguesse, Teofilo Rojo

CIC energiGUNE. 01510 Miñano, Spain

ABSTRACT Layered transition metal oxides are promising cathode materials for sodium-ion batteries. Phase transitions involving different stacking sequences of the oxide layers often plague the electrochemistry of these materials during cycling, which strongly impacts on their electrochemical performance. However, the underlying mechanisms of these processes remain elusive. Interestingly, P2- and O3-$Na_{2/3}Fe2_{/3}Mn_{1/3}O_2$ phases are the first layered transition metal oxide polymorphs that have been synthesised with exactly the same composition. This offers unprecedented access to the study of bistability in these systems, and also isolates the effect of the local structure on Na ion mobility. Here, first-principles calculations and experiments are combined to unveil the physical origin of such bistability and identify important differences in Na ion diffusion between these two phases. It has been found that electrostatic interactions between oxide layers control the bistable nature of P2 and O3 phases. It is also suggested that the interlayer distance between oxide layers may be a useful descriptor to rationalise the relative stability of other P and O phases in general. Furthermore, this study tracks down to the molecular level the differences regarding Na ion mobility in P2- and O3-$Na_{2/3}Fe_{2/3}Mn_{1/3}O_2$ by computing activation energies and estimating diffusion coefficients.

First published: 05 September 2016
https://doi.org/10.1002/aenm.201601477

LITHIUM AZIDE AS AN ELECTROLYTE ADDITIVE FOR ALL-SOLID-STATE LITHIUM-SULFUR BATTERIES

Dr. Gebrekidan Gebresilassie Eshetu, Xabier Judez, Dr. Chunmei Li, Dr. Oleksandr Bondarchuk, Dr. Lide M. Rodriguez-Martinez, Dr. Heng Zhang, Prof. Michel Armand

CIC energiGUNE, 01510 Miñano, Spain.

ABSTRACT Of the various beyond-lithium-ion battery technologies, lithium–sulfur (Li–S) batteries have an appealing theoretical energy density and are being intensely investigated as next-generation rechargeable lithium-metal batteries. However, the stability of the lithium-metal (Li°) anode is among the most urgent challenges that need to be addressed to ensure the long-term stability of Li–S batteries. Herein, we report lithium azide (LiN3) as a novel electrolyte additive for all-solid-state Li–S batteries (ASSLSBs). It results in the formation of a thin, compact and highly conductive passivation layer on the Li° anode, thereby avoiding dendrite formation, and polysulfide shuttling. It greatly enhances the cycling performance, Coulombic and energy efficiencies of ASSLSBs, outperforming the state-of-the-art additive lithium nitrate ($LiNO_3$).

First published: 10 October 2017
https://doi.org/10.1002/ange.201709305

3. THERMAL ENERGY STORAGE AREA

TES

Prof. Elena Palomo del Barrio. Scientific Director
Eng. Daniel Bielsa. Technology Coordinator

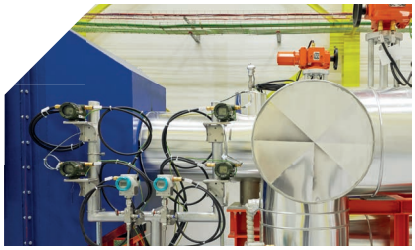
2015 - 2017 RESEARCHERS

Blanco / D'Aguanno / Dauvergne / Doppiu / Faik / Floris / González / Grosu / Hernández / Intxaurrondo / Luengo / Mani / Ortega / Pérez / Polat / Risueño / Rodríguez / Soguero / Udayashankar / Uriz / Varela / Wang / Zaki

3.1 RESEARCH LINES

POWER GENERATION

This research line is aimed at developing thermal energy storage (TES) technologies suitable for power generation applications, such as concentrated solar power, fuel-driven thermal power or CHP. The R&D activity covers the design and development of new materials to systems prototyping on a significant scale. Current research activities include sensible heat storage based on either low-cost ceramic materials or improved molten salts, latent heat storage based on new metal alloys and thermochemical storage through solid-liquid and solid-gas chemical reactions in peritectic compounds and mixed metal oxides respectively.



INDUSTRIAL HEAT PROCESSES

The objective of this line of research is to develop TES technologies suitable for connecting intermittent heat sources or waste heat production sites to industrial heat processes. Special attention is paid to steam processes where TES is required at temperatures ranging from 100 ºC to 250 ºC. The R&D activity covers the development of materials to systems prototyping on a significant scale. Ongoing research covers sensible heat storage by using near-critical fluids, latent heat storage-based renewable solid-solid and solid-liquid phase change materials and the study of peritectic compounds with outstanding energy density.

HEAT DISSIPATION, TEMPERATURE CONTROL & HYBRID CONCEPTS

This line of research is aimed at developing TES solutions for improving the performances and lifetime of batteries and electronic devices. The application fields include power microelectronics and the automotive industry, mostly electrical vehicles. This research line is also concerned with developing hybrid storage systems that are capable of simultaneously storing energy under different forms. Innovative solutions for heat absorption and dissipation based on the use of near-critical fluids or magnetic phase change materials are being researched. Molecular spring systems that are capable of simultaneously storing mechanical, thermal and electrical energy are also under development.

INTRUSION AND EXTRUSION OF WATER IN HYDROPHOBIC NANOPORES

Antonio Tinti[1], Alberto Giacomello[1], Yaroslav Grosu[2], and Carlo Massimo Casciola[1]

1) Dipartimento di Ingegneria Meccanica e Aerospaziale, Sapienza Universita di Roma, 00184 Rome, Italy
2) CIC energiGUNE, Minano 01510, Spain

ABSTRACT Depending on their characteristics, heterogeneous systems composed of hydrophobic nanoporous materials and water are capable of efficiently dissipating (dampers) or storing ("molecular springs") energy. However, it is difficult to predict their properties based on macroscopic theories (classical capillarity for intrusion and classical nucleation theory (CNT) for extrusion) because of the peculiar behaviour of water in extreme confinement. Here we use advanced molecular dynamics techniques to shed light on these non-classical effects, which are often difficult to investigate directly via experiments, owing to the small dimensions of the pores. The string method in collective variables is used to simulate, without artifacts, the microscopic mechanism of water intrusion and extrusion in the pores, which are thermally activated, rare events. Simulations reveal three significant non-classical effects: the nucleation free-energy barriers are reduced eightfold compared with CNT, the intrusion pressure is increased due to nanoscale confinement, and the intrusion/extrusion hysteresis is practically suppressed for pores with diameters below 1.2 nm. The frequency and size dependence of hysteresis exposed by the present simulations explains several experimental results on nanoporous materials. Understanding physical phenomena peculiar to nanoconfined water paves the way for a better design of nanoporous materials for energy applications; for instance, by decreasing the size of the nanopores alone, it is possible to change their behaviour from dampers to molecular springs.

PNAS November 28, 2017. 114 (48) E10266-E10273; published ahead of print November 14, 2017. https://doi.org/10.1073/pnas.1714796114

MECHANICAL, THERMAL AND ELECTRICAL ENERGY STORAGE IN A SINGLE WORKING BODY: ELECTRIFICATION AND THERMAL EFFECTS UPON PRESSURE-INDUCED WATER INTRUSION–EXTRUSION IN NANOPOROUS SOLIDS

Yaroslav Grosu[5,1,2,3], Michał Mierzwa[4,5], Valentine A. Eroshenko[3], Sebastian Pawlus[4,5], Mirosław Chorażewski[6], Jean-Marie Nedelec[1,2], and Jean-Pierre E. Grolier[5,1,2]

1) Université Clermont Auvergne, CNRS, SIGMA Clermont, ICCF, F-63000, Clermont-Ferrand, France
2) CIC energiGUNE, Albert Einstein 48, Miñano (Álava) 01510, Spain
3) Laboratory of Thermomolecular Energetics, National Technical University of Ukraine "Kyiv Polytechnic Institute", Pr. Peremogy 37, 03056 Kyiv, Ukraine
4) Silesian Center for Education and Interdisciplinary Research, University of Silesia, 75 Pulku Piechoty 1A, 41-500 Chorzow, Poland
5) Institute of Physics, University of Silesia, Uniwersytecka 4, 40-007 Katowice, Poland
6) Institute of Chemistry, University of Silesia, Szkolna 9, 40-006 Katowice, Poland

ABSTRACT This paper presents the first experimental evidence of pronounced electrification effects upon a reversible cycle of forced water intrusion–extrusion in nanoporous hydrophobic materials. Recorded generation of electricity combined with high- pressure calorimetric measurements improves the energy balance of {nanoporous solid + non-wetting liquid} systems by compensating mechanical and thermal energy hysteresis in the cycle. Revealed phenomena provide a novel way of "mechanical to electrical" and/or "thermal to electrical" energy transformation with unprecedented efficiency and additionally open a perspective to increase the efficiency of numerous energy applications based on such systems taking advantage of electricity generation during operational cycle.

ACS Appl. Mater. Interfaces, 2017, 9 (8), pp 7044–7049
DOI: 10.1021/acsami.6b14422

A SIMPLE APPROACH FOR FABRICATION OF INTERCONNECTED GRAPHITIZED MACROPOROUS CARBON FOAM WITH UNIFORM MESOPORE WALLS BY USING HYDROTHERMAL METHOD

M. Karthik, A. Faik, S. Doppiu, V. Roddatis, B. D'Aguanno

CIC energiGUNE, 01510 Miñano, Spain

ABSTRACT Three-dimensional (3D) highly interconnected graphitized macroporous carbon foam with uniform mesopore walls has been successfully fabricated by a simple and efficient hydrothermal approach using resorcinol and formaldehyde as carbon precursors. The commercially available cheap polyurethane (PU) foam and Pluronic F127 were used as a sacrificial polymer and mesoporous structure-directing templates, respectively. The graphitic structure of carbon foam was obtained by catalytic graphitization method using iron as catalyst. Three different carbon foams such as graphitized macro-mesoporous carbon (GMMC) foam, amorphous macro-mesoporous carbon (AMMC) foam and graphitized microporous carbon (GMC) foam were fabricated and their physicochemical and mechanical properties were systematically measured and compared. It was found that GMMC possess well interconnected macroporous structure with uniform mesopores located in the microporous skeletal walls of continuous framework. Besides, GMMC foam possesses a well-defined graphitic framework with high surface area (445 m^2/g), high pore volume (0.35 cm^3/g), uniform mesopores (3.87 nm), high open porosity (90%), low density (0.30 g/cm^3) with good mechanical strength (1.25 MPa) and high electrical conductivity (11 S/cm) which makes it a promising material for many potential applications.

http://dx.doi.org/10.1016/j.carbon.2015.02.060

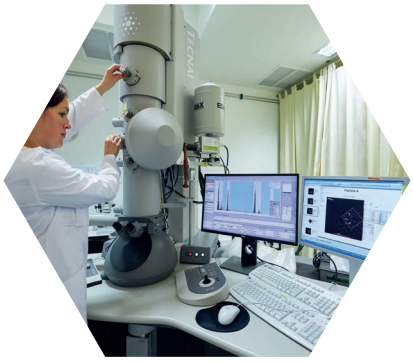
4. FACILITIES

4. FACILITIES

DRY ROOM

The Dry Room provides the environment required for processing materials and assembling the prototyping cells, giving the opportunity to perform cutting edge research not only at a material but also at a device level. It provides the opportunity to tackle and understand the problems involved in further tuning the performance of materials.

The main characteristics of the platform are: Dew point: - 60 ºC, Temperature: 21 ºC + 1 ºC. 7 class ISO clean room, Area: 55 m^2 Overpressure: 30 Pa, Conductive floor.



EM
ELECTRONIC MICROSCOPY

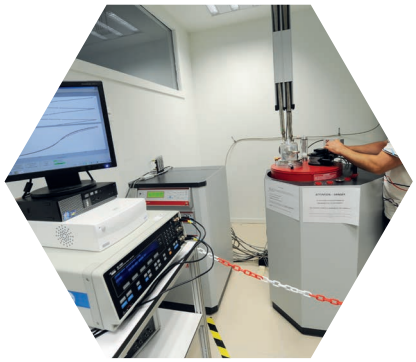
EM offers an internal and external service for sample characterisation (morphology, composition and microstructure) using electron microscopy techniques. The platform includes a scanning electron microscope (SEM) with high vacuum, low vacuum and environmental modes and the possibility to measure samples that are sensitive to the atmosphere. The platform also has a transmission electron microscope (TEM) to characterise materials on the nano-metric scale.

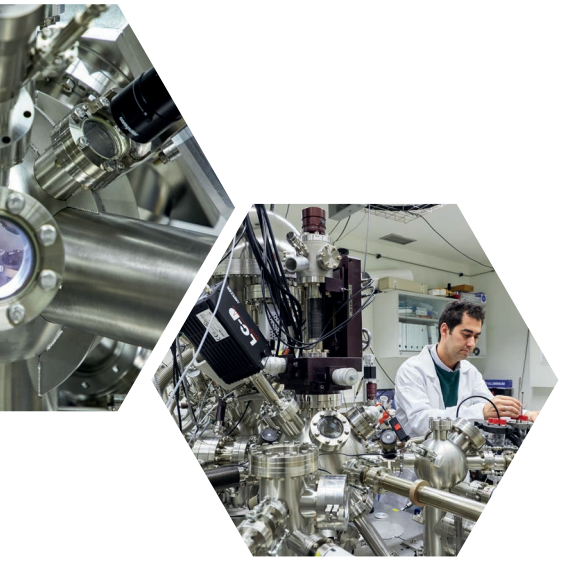
NMR
NUCLEAR MAGNETIC RESONANCE

Nuclear magnetic resonance is an analytical technique that makes the most of the magnetic properties of atomic nuclei to obtain structural, kinetic and thermodynamic information from a wide variety of materials: micro-crystalline to amorphous, semi-liquid, liquid, or even metal.

PPMS
PHYSICAL PROPERTY MEASUREMENT SYSTEM

A Physical Properties Measurement System made by Quantum Design is used to measure a wide variety of physical and chemical-physical properties of bulk, powder and thin film samples, such as heat capacity, magnetisation measurements, electrical resistivity and thermal conductivity from cryogenic temperatures up to 126 ºC under magnetic fields of up to 9 Tesla.





SAU SURFACE ANALYSIS PLATFORM

The surface analysis platform offers a wide range of experimental techniques to characterise surfaces and interfaces that include state-of-the-art instrumentation in photoemission spectroscopy (XPS and UPS), low energy electron diffraction (LEED), Auger microscopy (SAM), scanning probe microscopies (STM and AFM), profilometry and optical spectroscopy (Raman and FTIR). In terms of surface and coatings processing, the platform is equipped with effusion cells, e-beam evaporators and a magnetron sputtering system with 5 heads and an integrated quartz microbalance that allows the deposition of conductive films, as well as insulating thin films.

TESTING LAB

Once the electrochemical cells have been assembled, their performance is tested by means of measuring the cyclic voltammetry and galvanometry and impedance spectroscopy in different operating conditions. To do this, we have six potenciostats, several climatic chambers and two battery testers, one of them equipped with high current moduls (up to 15A) for pouch cells or bigger devices, connected to a safety chamber.

THERMAL ANALYSIS PLATFORM

This laboratory has the equipment necessary to synthesise new materials focused on storing thermal energy. It has different types of reactors and chamber ovens and ovens with tubular heating elements to synthesise materials at temperatures of up to 1600 ºC with coupled thermo-gravimetry under a controlled atmospheric flow. The laboratory is equipped with a glove box for preparing samples and a synthesis of materials under controlled atmosphere as well as smoke hoods for working safely.

X RAY

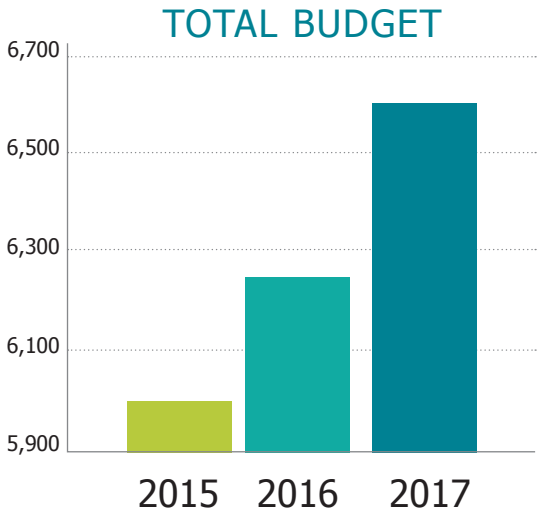
This platform includes a Bruker D8 X-Ray Diffractometer and Bruker Nanostar U (a grazing incidence small angle X-ray scattering (GI-SAXS)) instrument for particle size analysis and surface to volume ratio determination. A home-made in-situ cell that allows us to collect XRD data as the battery goes through cycles.

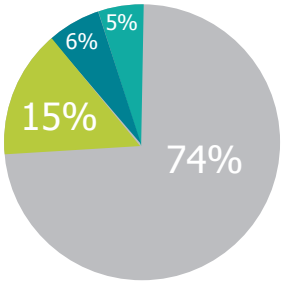
TES PROTOTYPING LAB

The thermal storage prototyping lab has a large space for experimental testing on a laboratory scale and pre-demonstration of thermal energy storage systems. It stands alongside a thermal oil installation that can study different thermal storage systems and configurations at temperatures of up to 400 ºC. In addition, a closed cycle air facility is available, extending the temperature range up to 1000 ºC.

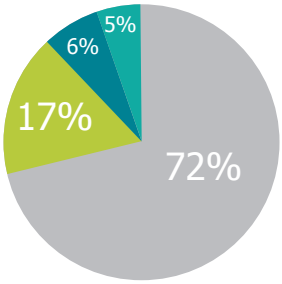
5. FINANCIAL REPORT

5. FINANCIAL REPORT

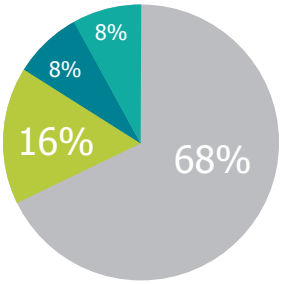




2015
TOTAL BUDGET 100%



2016
TOTAL BUDGET 100%



2017
TOTAL BUDGET 100%

● Funds from Basque Government - Economic Development and Competitiveness ● Funds from European Union
● Other Public Funding ● Private Funding


Synthesis

CIC energiGUNE
energy storage research centre

Parque Tecnológico de Álava
Albert Einstein 48 -
01510 Vitoria-Gasteiz.
Basque Country