

11/03/2016

Project Overview:

Interfaces of Fluid Electrodes: New Conceptual Explorations

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Outline

- General information
- Motivation
- Project objectives and scientific approach
- WP structure and relation between WPs
- Main challenges, Go-No Go criteria
- Expected impact



General information

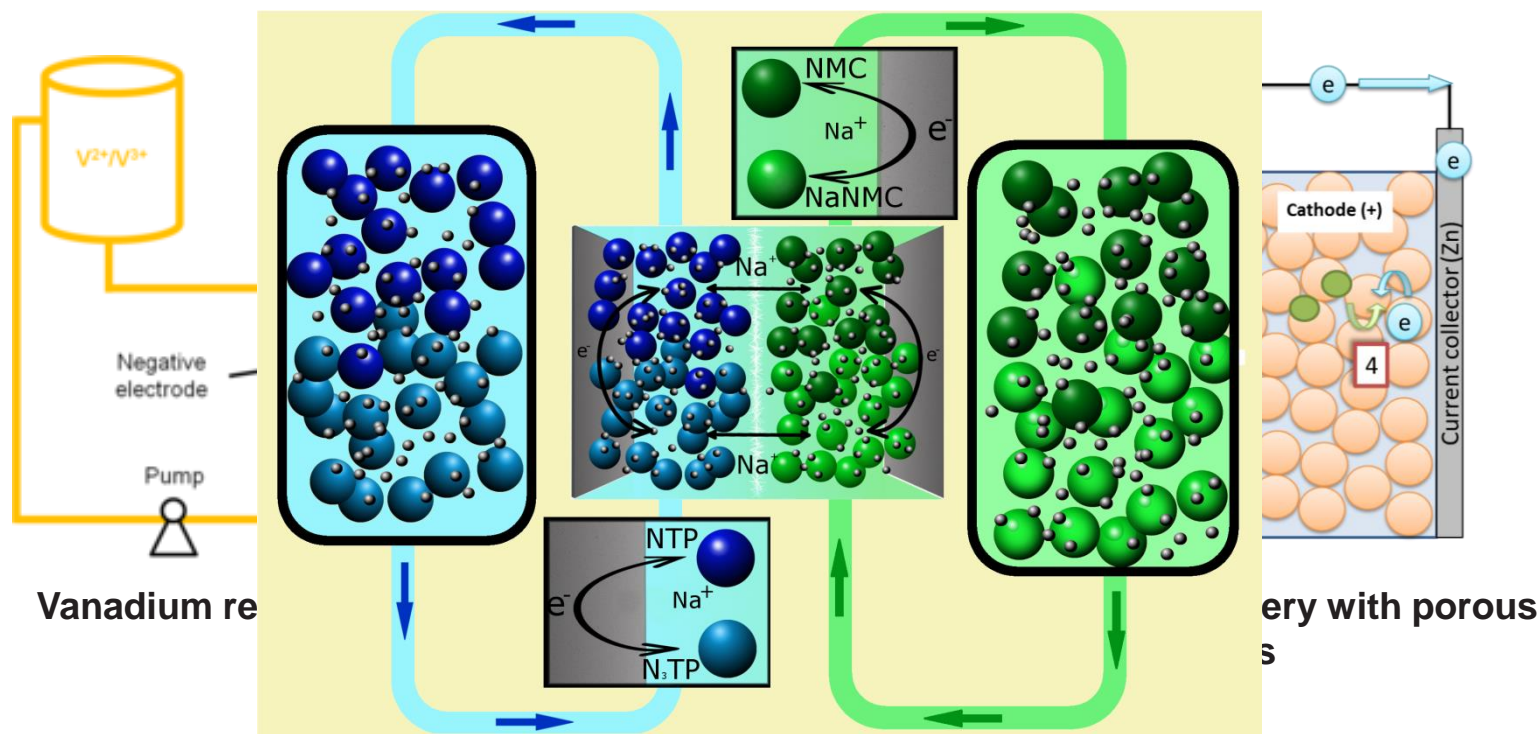
- » The FP7-project **InFluENCE** started on September 1, 2013
- » The contract has a duration of **36 months**
- » Grant agreement no.: 608621
- » Total budget: ca. 3.3 M€; EC funding: ca. €2.6 M€

- » Programme: FP7-Cooperation (collaborative project)
- » Theme: ENERGY
- » Subprogramme: ENERGY.2013.7.3.3 – Understanding interfaces in rechargeable batteries and super-capacitors through *in situ* methods.

- » Call : FP7-ENERGY-2013-1

Semi Solid Flow Batteries (SSFB)

Energy conversion and storage system, “hybrid” between an aqueous redox flow battery and a solid state Li-ion or Na-ion battery



- ❑ SSFB vs aq RFB: energy densities ca.10 times higher
- ❑ SSFB vs Li-ion: decoupling power and energy



Why SSFBs?

Large scale applications:

- Storage of excess energy from the grid → key contribution to low-carbon economy
- Continuous power supplies, balancing the grid.
- power and energy are decoupled → safety and reliability

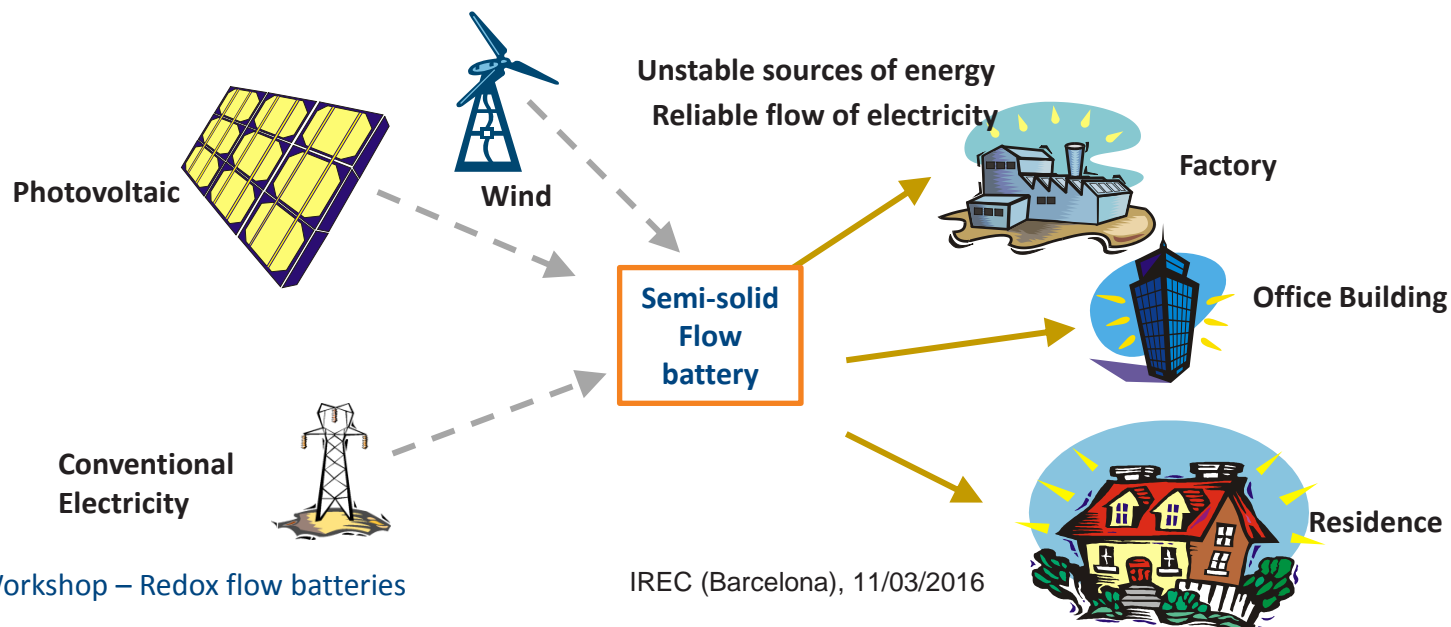
Highly relevant in the framework of EU energy policy and SET plan:

- Increasing share of energy from RES
- Multiple power sources, wind, solar, hydro...
- Next-generation storage systems: adaptation to offer/demand (on-peak & off-peak kWh cost)

Why SSFBs?

Advantages of SSFBs versus conventional batteries:

- ❑ Possible to **adjust the chemistry of the system during its operative life** by adding the necessary chemical into the electrode flow.
- ❑ Potential for **prolonging the operative life of the battery system**.
- ❑ **Simple (in-situ) measurements** of conductivity, viscosity and density might supply crucial information to **monitor the state of health of the system**.



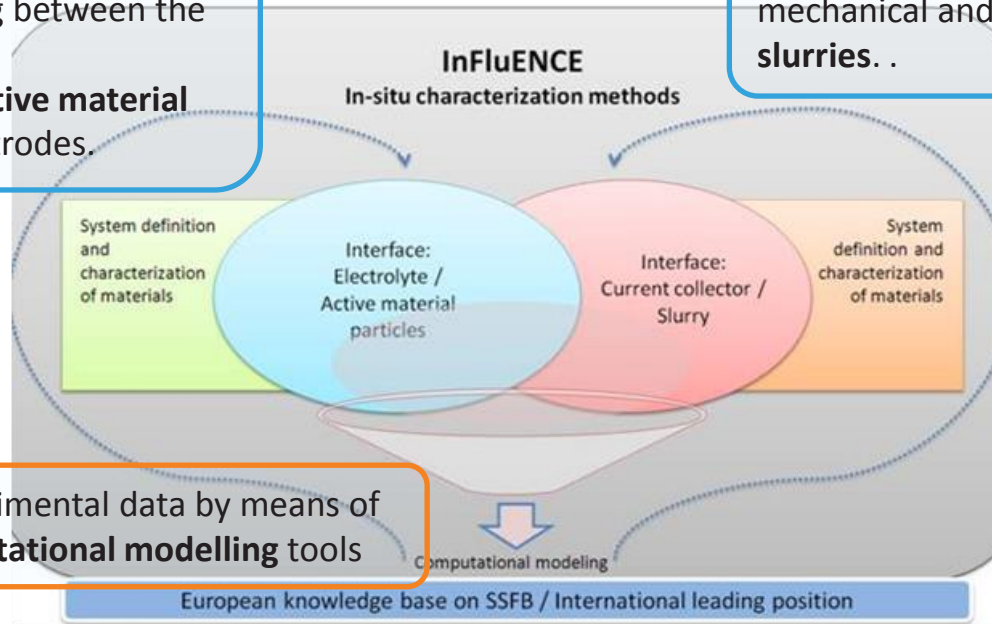
Project objectives

GOAL: Improve fundamental understanding and control of interfaces in **semi- solid flow batteries** (SSFB) based on Li-ion and Na-ion active materials

→ methods and techniques developed could also be implemented for conventional Li- and Na-ion systems

to investigate and optimize of **interfaces** developing between the **electrolyte** and the **electrochemically active material** particles in fluid electrodes.

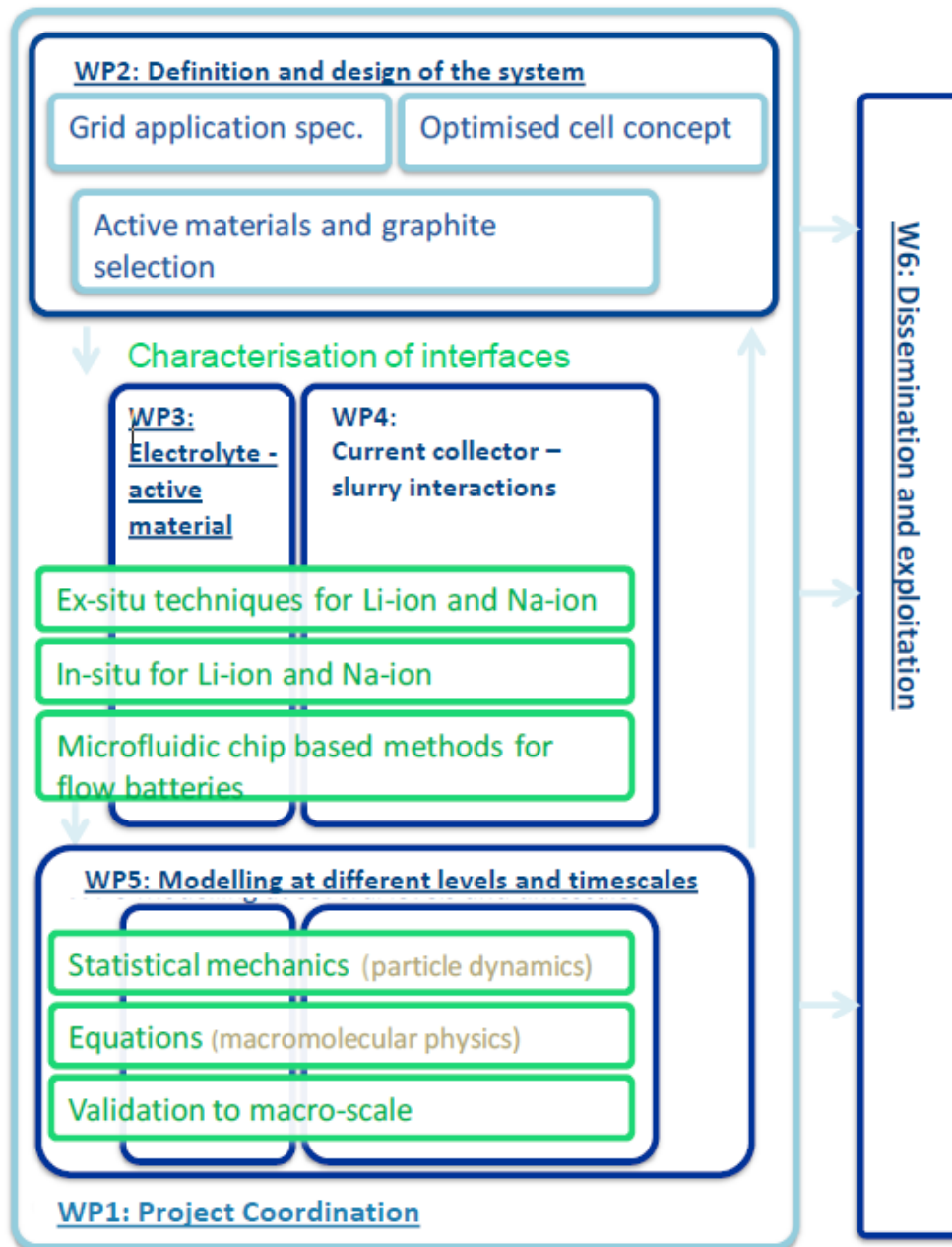
to improve **understanding** and **control** the mechanical and conductive **behaviours** of the slurries. .



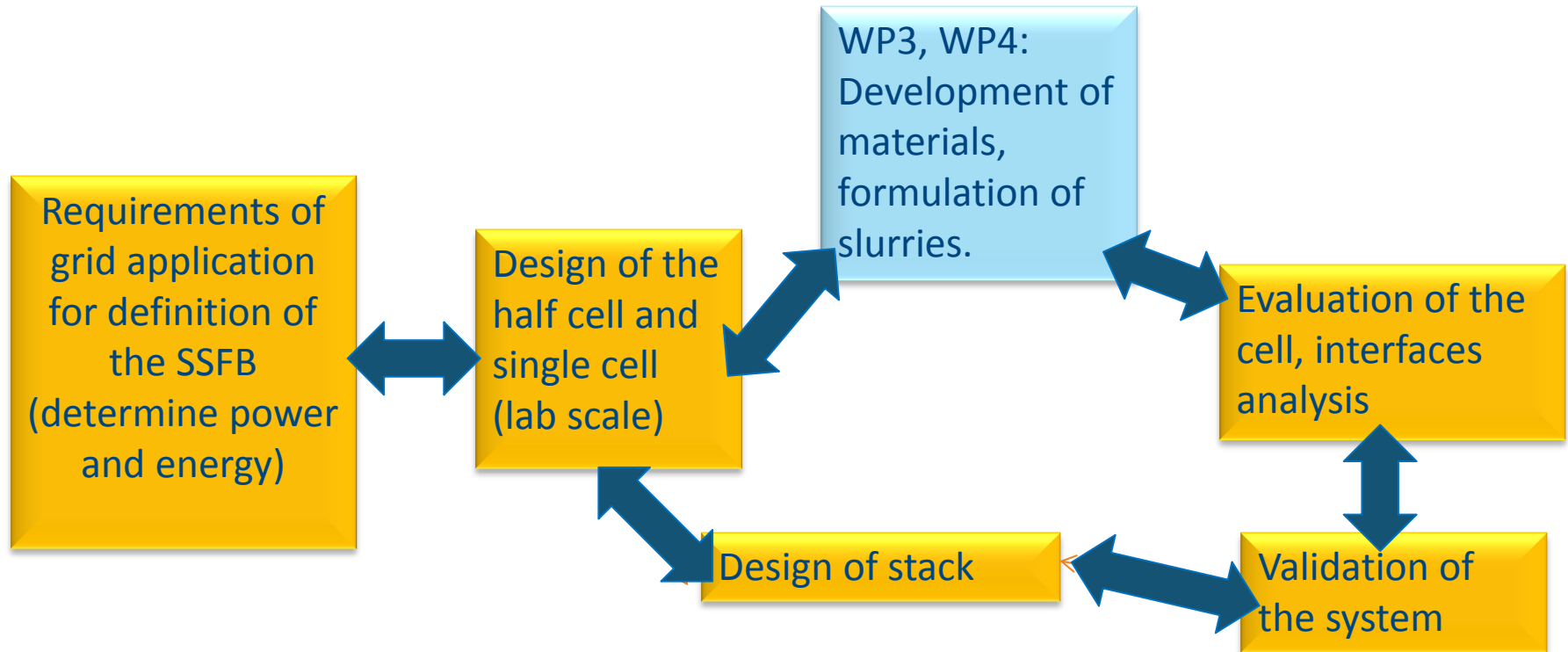
to complement experimental data by means of implementing **computational modelling** tools

to establish and maintain active exchange of information with research groups from third countries

Approach



WP2: definition and design of the system



WP3: Interface Electrolyte / Active Particles

Task 3.1:
Identify influence of
particle morphology
and electrolyte

Task 3.1
Identify reactions
at interface

Task 3.1:
Identify suitable In-
situ techniques

Task 3.1:
Ex-situ
characterization of
solid/liquid
interphase

Task 3.2
Design of optimized
interphase
(active material &
electrolyte)

Task 3.2
Investigation of the
electrochemical
performance

**Development of long-
term stable
active material
electrolyte interfaces
in fluid electrodes**

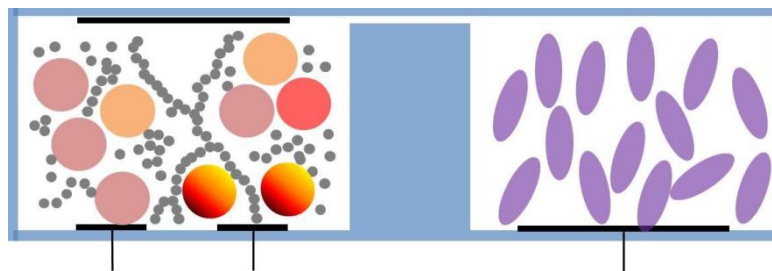
**Task 3.3: In-situ
characterization of
the solid/liquid
interphase**

Task 3.3:
Development of
suitable techniques
for in-situ
monitoring

Task 3.4:
Investigate
safety of the
system

WP4: Interface current collector/slurry

- **high density** of Electro-Active Particles, **but still 'flowable'** electrodes
- additional **conductive network of nanoparticles**
- **cell walls** influence charge-transfer and suspension-flow
- **changes in morphology, surface chemistry** due to electrochemical cycling



Pre-investigate formulations

- Investigate particle interactions → key parameters for **stable slurries**

Ex-situ

- Study electric percolation in microfluidic chips
- Study flow behaviour

In-situ (electrochemistry in chip)

- Determine influence of electrochemical cycling
- Investigate diffusion effects



WP5: Modelling the processes

molecular level

- Interface using MPCD and LB methods
- Rheology and colloidal stability of suspensions using MPCD
- Transport in membrane and electrolyte by EC techniques
- Electron transfer by electrochemical (EC) techniques

cell scale








- cell in static conditions with COMSOL
- cell in dynamic conditions: coupling of kinetics and hydrodynamics
- tentative optimisation by electrochemical engineering methodology

overall process scale

- Battery design
- Simulation of battery performance (capacity, current, power, voltage, time of discharge, lifetime, etc.) in “real conditions”
- Influence of thermal behaviour
- Energetic performance of the overall system



Consortium

| Participant no. | Participant legal Name | Country | Organisation type* | |
|--------------------|---|-----------------|--------------------|---|
| 1 (Coordinator) | Flemish Institute for Technological Research (VITO) | Belgium | RTD |  |
| 2 | Karlsruhe Institute of Technology | Germany | RTD |  |
| 3 | Universiteit Twente | The Netherlands | RTD | UNIVERSITEIT TWENTE. |
| 4 | IREC | Spain | RTD |  |
| 5 | Eckart | Germany | LE |  |
| 6 | Solvionic | France | SME |  |
| 7 | 6T-MIC | France | SME |  |
| 8 | Imperial College London | United Kingdom | RTD |  |



Consortium: partner roles

- » **VITO:** Coordinator. Expertise in batteries, battery testing and system integration for smart grids. Experience in electrochemical modelling and in characterisation of cell components.
- » **KIT (prev. WWUM):** Expertise in synthesis and characterization of Na-ion and Li-ion materials. Expertise in the investigation and optimization of the interfaces and interfaces between active materials and electrolytes, and full cells (batteries). WPL for WP3. TL in WP2. Partner in tasks for WP2, WP4 and WP6.
- » **U Twente:** Expertise in colloids, rheology and microfluidics. Equipment and experience in microscopy (AFM and CSLM), rheometry, contact angle goniometry, microchip fabrication
- » **IREC:** Expertise and skills in electrochemical characterization of battery components. Experience in redox flow batteries..



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*This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under **grant agreement No 608621**.*



Consortium: partner roles

- » **ECKART:** Expertise in metal particles and interface analysis of non-spherical particles.
- » **Solvionic:** Expertise in ionic liquids .
- » **6TMIC:** Expertise in computational modelling and electrochemical engineering.
- » **Imperial College:** Expertise in molecular modelling.



Scientific output

| Title, d.o.i. | Author(s) | Title of the journal | Vol./Issue | Date of publication | Pages | Open access ? |
|--|--|--|------------|---------------------|-----------------|---------------|
| Water sensitivity of layered P2/P3-Na; 10.1039/C4TA02627F | Daniel Buchholz , Luciana Gomes Chagas , Christoph Vaalma , Liming Wu , Stefano Passerini | Journal of Materials Chemistry A | 2/33 | 06/2014 | 13415-13421 | |
| Unfolding the Mechanism of Sodium Insertion in Anatase TiO ₂ ; 10.1002/aenm.201401142 | Liming Wu , Dominic Bresser , Daniel Buchholz , Guinevere Giffin , Claudia Ramirez Castro , Anders Ochel , Stefano Passerini | Advanced Energy Materials | 5 | 08/2014 | 1401142-1401153 | |
| P-type Na x Ni 0.22 Co 0.11 Mn 0.66 O 2 materials: linking synthesis with structure and electrochemical performance; 10.1039/C4TA03946G | L. G. Chagas , D. Buchholz , C. Vaalma , L. Wu , S. Passerini | Journal of Materials Chemistry A | 2/147 | 10/2014 | 20263-20270 | Yes |
| Non-aqueous semi-solid flow battery based on Na-ion chemistry. P2-type Na; 10.1039/C4CC09597A | Edgar Ventosa , Daniel Buchholz , Stefan Klink , Cristina Flox , Luciana Gomes Chagas , Christoph Vaalma , Wolfgang Schuhmann , Stefano Passerini , Joan Ramon Morante | Chemical Communications | 51 | 12/2014 | 7298-7301 | Yes |
| Nanocrystalline TiO ₂ (B) as Anode Material for Sodium-Ion Batteries; 10.1149/2.0091502jes | L. Wu , D. Bresser , D. Buchholz , S. Passerini | Journal of the Electrochemical Society | 162/2 | 01/2015 | A3052-A3058 | Yes |



Scientific output

| Title, d.o.i. | Author(s) | Title of the journal | Vol./Issue | Date of publication | Pages | Open access ? |
|--|--|--|------------------|---------------------|-------------|---------------|
| Electron Bottleneck in the Charge/Discharge Mechanism of Lithium Titanates for Batteries; 10.1002/cssc.201500349 | Edgar Ventosa , Marcel Skoumal , Francisco Javier Vazquez , Cristina Flox , Jordi Arbiol , Joan Ramon Morante | ChemSusChem | 8/10 | 04/2015 | 1737–1744 | Yes |
| Charge inversion and colloidal stability of carbon black in battery electrolyte solutions; | Yan Zhang , Aditya Narayanan , Frieder Mugele , Martien A. Cohen Stuart , Michel H.G. Duits | Colloids and Surfaces A: Physicochemical and Engineering Aspects | 489 | 08/2015 | 461–468 | No |
| Solid electrolyte interphase in semi-solid flow batteries: a wolf in sheep's clothing; 10.1039/C5CC04767F | E. Ventosa , G. Zampardi , C. Flox , F. La Mantia , W. Schuhmann , J. R. Morante | Chemical Communications | Vol. 51/Issue 81 | 10/2015 | 14973-14976 | Yes |
| Extraordinary Performance of Carbon-Coated Anatase TiO ₂ as Sodium-Ion Anode; 10.1002/aenm.201501489 | Muhammad Nawaz Tahir , Bernd Oschmann , Daniel Buchholz , Xinwei Dou , Ingo Lieberwirth , Martin Panthöfer , Wolfgang Tremel , Rudolf Zentel , Stefano Passerini | Advanced Energy Materials | n/a-n/a | 12/2015 | n/a-n/a | Yes |
| Layered Na-Ion Cathodes with Outstanding Performance Resulting from the Synergetic Effect of Mixed P- and O-Type Phases; 10.1002/aenm.201501555 | Marlou Keller , Daniel Buchholz , Stefano Passerini | Advanced Energy Materials | n/a-n/a | 11/2015 | n/a-n/a | Yes |



Scientific output – open access

The screenshot displays the OpenAIRE website interface. On the left, there are search filters for various metadata fields:

- TITLE:** Interfaces of Fluid Electrodes: New Conceptual
- FUNDER:** FP7
- FUNDING STREAM:** SP1
- SCIENTIFIC AREA:** ENERGY
- CALL:** FP7-ENERGY-2013-1
- CONTRACT (GA) NUMBER:** 608621
- START DATE:** 2013/09/01
- END DATE:** 2016/08/31
- SPECIAL CLAUSE 39:** yes
- ORGANIZATIONS:** IREC, Imperial, VITO, 6TMIC, SOLVIONIC SA, UNI KIT, WWU
- MORE INFORMATION:** [Detailed project information \(CORDIS\)](#)

At the bottom of the filter section, there are tabs for "Publications", "Data", and "Statistics".

The main content area on the right shows a list of publications:

- P-type $\text{Na}_x\text{Ni}_0.22\text{Co}_0.11\text{Mn}_0.66\text{O}_2$ materials: linking synthesis with structure and electrochemical performance** (Open Access icon)

Chagas, Luciana G.; Buchholz, Daniel; Vaalma, Christoph; Wu, Liming; Passerini, Stefano (2014)
Projects: INFLUENCE (608621)

P-type layered oxides are promising cathode materials for sodium-ion batteries and a wide variety of compounds have been investigated so far. Nevertheless, detailed studies on how to link synthesis temperature, structure and electrochemistry are still rare. Herein, we present a study on P-type $\text{Na}_x\text{Ni}_0.22\text{Co}_0.11\text{Mn}_0.66\text{O}_2$ materials, investigating the influence of synthesis temperature on their structure and electrochemical performance. The change of annealing temperature leads to various materials...
- Non-aqueous semi-solid flow battery based on Na-ion chemistry. P2-type $\text{Na}_x\text{Ni}_0.22\text{Co}_0.11\text{Mn}_0.66\text{O}_2\text{-NaTi}_2(\text{PO}_4)_3$** (Open Access icon)

Ventosa, Edgar; Buchholz, Daniel; Klink, Stefan; Flox, Cristina; Chagas, Luciana G.; Vaalma, Christoph; Schuhmann, Wolfgang; Passerini, Stefano; Morante, Joan Ramon (2014)
Projects: INFLUENCE (608621)

We report the first proof of concept for a non-aqueous semi-solid flow battery (SSFB) based on Na-ion chemistry using P2-type $\text{Na}_x\text{Ni}_0.22\text{Co}_0.11\text{Mn}_0.66\text{O}_2$ and $\text{NaTi}_2(\text{PO}_4)_3$ as positive and negative electrodes, respectively. This concept opens the door for developing a new low-cost type of non-aqueous semi-solid flow batteries based on the rich chemistry of Na-ion intercalating compounds.
- Nanocrystalline $\text{TiO}_2(\text{B})$ as Anode Material for Sodium-Ion Batteries** (Open Access icon)

Wu, Liming; Bresser, Dominic; Buchholz, Daniel; Passerini, Stefano (2014)
Projects: INFLUENCE (608621)

High surface area, nanostructured, and phase-pure $\text{TiO}_2(\text{B})$ noodles-like secondary particles were successfully synthesized by a facile one-pot synthesis, based on the hydrolysis of TiCl_3 using a mixture of ethylene glycol and water at moderate temperature. The primary nanoparticles have a uniform size and are about 15 nm in diameter as determined by TEM analysis and exhibit an increased exposure of the (010) facet as indicated by XRD analysis. Unlike the electrochemical reaction with l...



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This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under **grant agreement No 608621**.



Project website: www.fp7-influence.eu

The screenshot shows the InFluENCE project website. At the top left is the InFluENCE logo. The main heading reads "Interfaces of Fluid Electrodes: New Conceptual Explorations". Below this is a "View" button and an "Edit" button. The "Welcome" section contains text about the FP7 project's goals and the use of semi-solid flow batteries (SSFB). A "NEWS !" section highlights two workshops: one in Barcelona (February 2016) and one in Orlando (May 2016). On the right side of the screenshot, there is a smaller version of the European Commission logo and a text box stating: "This project has received European Union's Seventh research, technological demonstration under gra".

Home

- Project scope
- Consortium
- Downloads
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View **Edit**

Welcome

The FP7 project **InFluENCE** aims at improving the fundamental understanding and control of interfaces of a battery type based on Li-ion and Na-ion active materials: **semi solid flow batteries (SSFB)**. The fact that the case study will be a SSFB set-up instead of classic lithium ion batteries is an asset, given that the methods and techniques developed are generic and could as well be implemented for conventional Li- and Na-ion systems for the techniques that are not concentrated on flow aspects.

A main objective is the investigation and optimization of the **interfaces** developing between the electrolyte and the electrochemically active material particles in **fluid electrodes**. The acquired knowledge would allow the chemical and morphological optimization of active materials as well as the design of **optimized** interfacial layers (also called artificial Solid Electrolyte Interfaces, **art-SEI**) capable of warrant stable interfaces.

NEWS !

26 February 2016: workshop '**Flow batteries**' at IREC in Barcelona (Spain) --> [More information and registration](#)

New publications (open access):

- <http://pubs.rsc.org/en/content/articlehtml/2015/cc/c5cc04767f>
- <http://onlinelibrary.wiley.com/doi/10.1002/cssc.201500349/full>
- <http://pubs.rsc.org/en/content/articlepdf/2015/cc/c4cc09597a>

27 May 2016: SIRBATT workshop '**Controlling Lithium Battery Interfaces**' in Orlando (Florida, USA) --> More information and registration: www.sirbatt.eu or [here](#)

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Project website: www.fp7-influence.eu

View Edit COMMI

Downloads

- [FP7 Influence - project overview](#)
- [FP7 Influence - Midterm report summary](#)

Publications

- [Ventosa et al. Solid electrolyte interphase in semi-solid flow batteries; ChemComm 2015.](#)
- [Ventosa et al. ChemSusChem 2015.](#)
- [Ventosa et al. Non-aqueous semi-solid flow battery based on Na-ion chemistry; ChemComm 2015](#)
- [Wu et al. JES 2015](#)
- [Chagas et al. 2014](#)

Upcoming events:

- [Topical workshop on rheology and system design for SSFB. - Barcelona, beginning 2016. Programme and registration](#)

Past events:

- [Influence Short Course Electrochemical Engineering and Modeling - Programme and registration](#)
- [Influence workshop KIT Ulm: Presentations](#) [Influence Workshop Ulm; programme](#) [Influence Workshop Ulm](#)

11/03/2016

Thank you!