# CPER MANIFEST

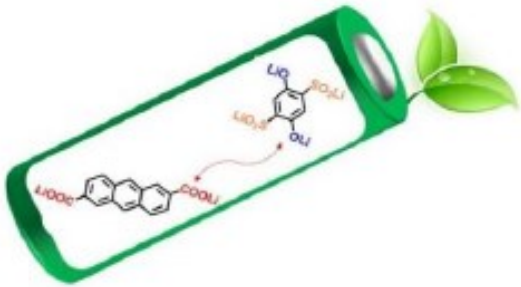
## Stockage de l'Energie

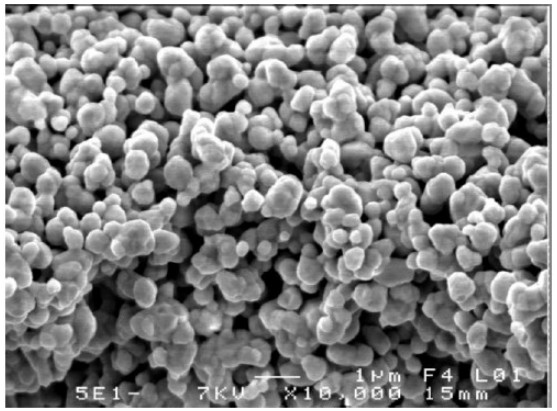
C. Masquelier, 7 Nov. 2023

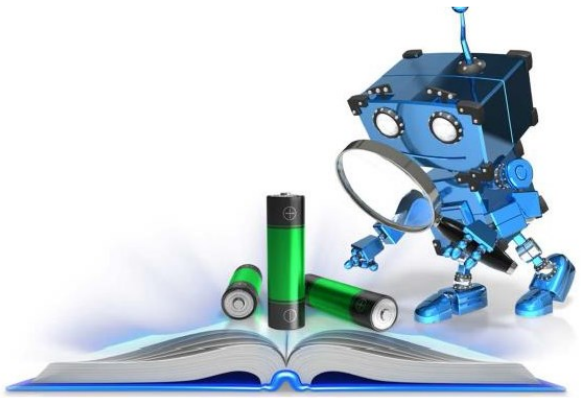
# Matériaux fonctionnels pour le Stockage de l'Energie

## LRCS, LG2A, LPMC, LAMFA, LPCA, UDSMM, LGCgE

Batteries Li-Ion et Na-Ion
Batteries Li-Air, Na-Air, Li-S
Modélisation multi-échelle des procédés et DFT
Batteries organiques, hybrides
Prototypage, réalisation de cellules « industrielles »
Batteries tout solide et électrolytes solides





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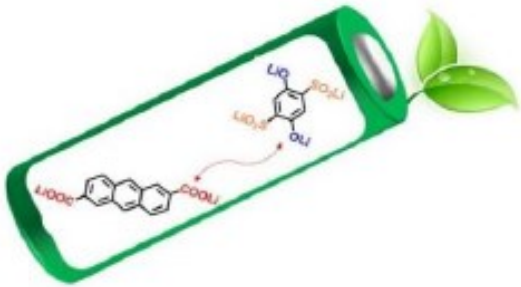
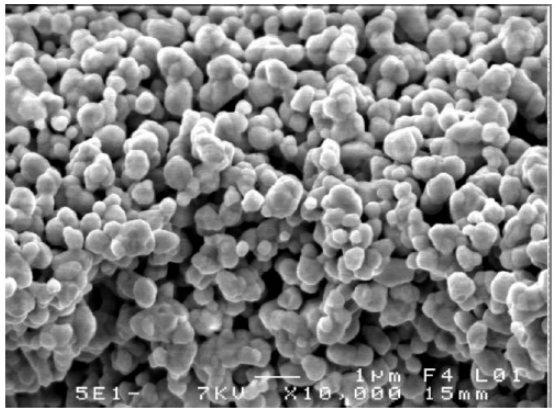
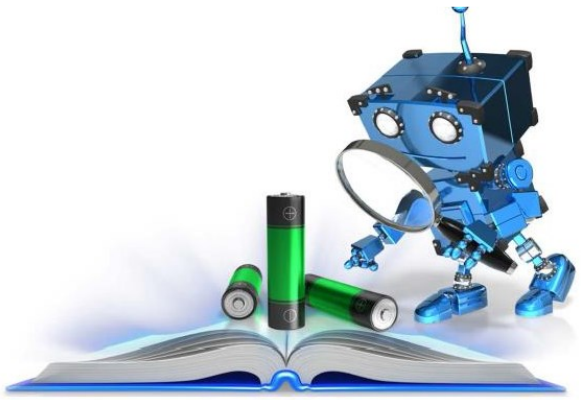
Batteries tout solide et électrolytes solides
Composites Piezo pour énergie bio-mécanique
Sécurité des batteries et réactivité des électrolytes
Matériaux à changement de phase pour le bâtiment
Stockage de l'Hydrogène
Systèmes Redox-Flow
Supercondensateurs,
Recyclage







# HdF : Public Labs skills in New Batteries

LSEE Laboratoire Systèmes Electrotechniques et Environnement — Electrical engineering (motors, EM circuits…)

lpca Laboratoire de Physico-Chimie de l'Atmosphère UR 4493 — Inorganic Materials, Glass-Ceramics

UDSMM — UNIVERSITÉ D'ARTOIS — ulco Université Littoral Côte d'Opale

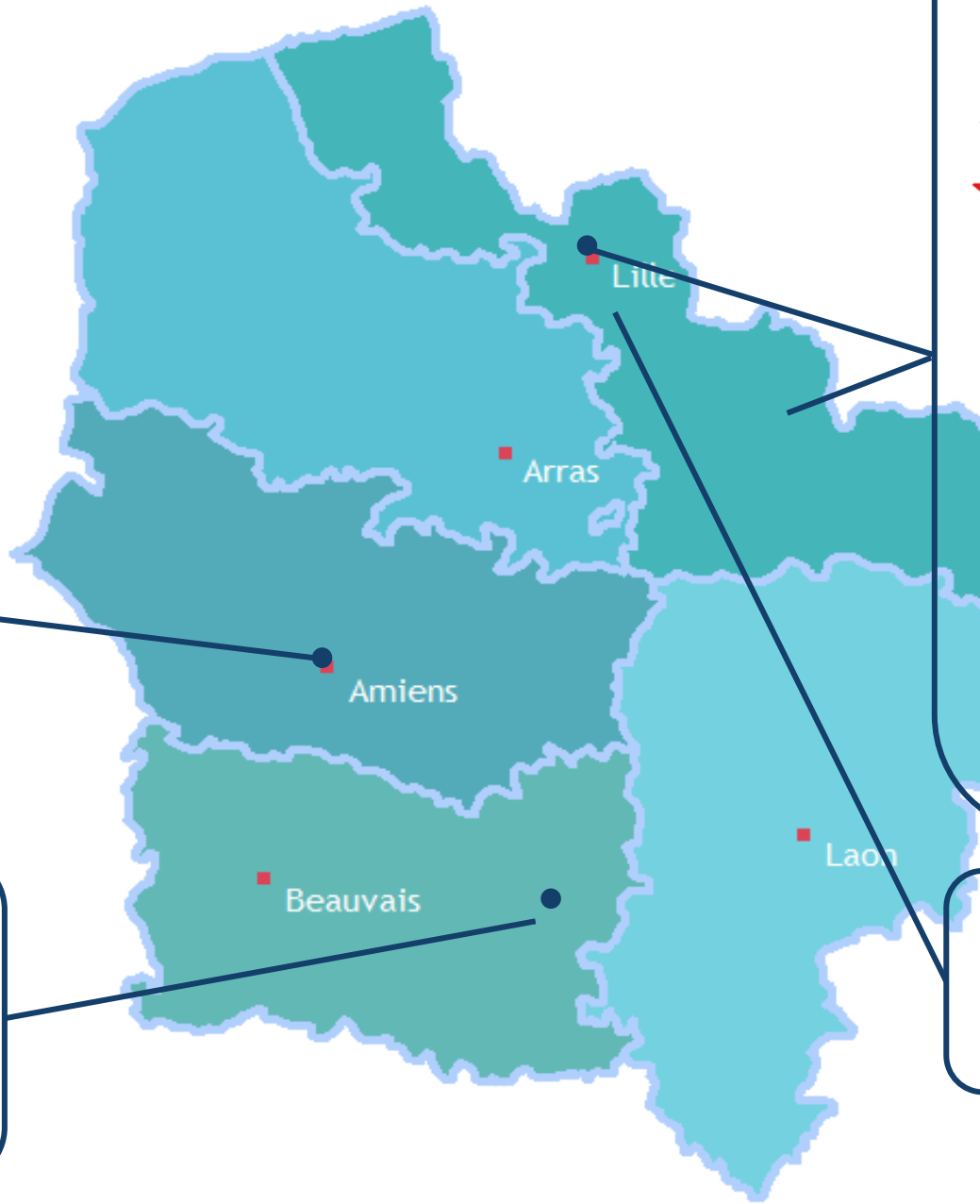
LRCS — All sorts….

LG2A Laboratoire de Glycochimie, des Antimicrobiens et des Agroressources — Organic batteries (bio-resourced)

UNIVERSITÉ de Picardie Jules Verne — cnrs

ALLIANCE SORBONNE UNIVERSITÉ — utc Recherche Roberval — BMS Li-ion / Na-ion
High power battery cyclers / Emulators

utc Université de Technologie Compiègne — cnrs




iemn — Thin film micro-batteries White rooms

UMET — Fire protection materials

LASIRE — Materials characterization (EPR)

UCCS — Materials characterization

LAMIH UMR CNRS 8201 — BMS, thermal management

CERAMATHS — Ceramics: energy storage, electronics…

cea tech — Université de Lille — UNIVERSITÉ D'ARTOIS

cnrs — centralelille — JUNIA — Université Polytechnique HAUTS-DE-FRANCE

IMT Nord Europe
École Mines-Télécom
IMT-Université de Lille

- Energy / Envt
- Digital systems
- Plasturgy / Composites

# Hauts de France: « valley » of battery pofessionnals

- Characterization & performance testing
- Endurance testing
- Abusive and environmental testing

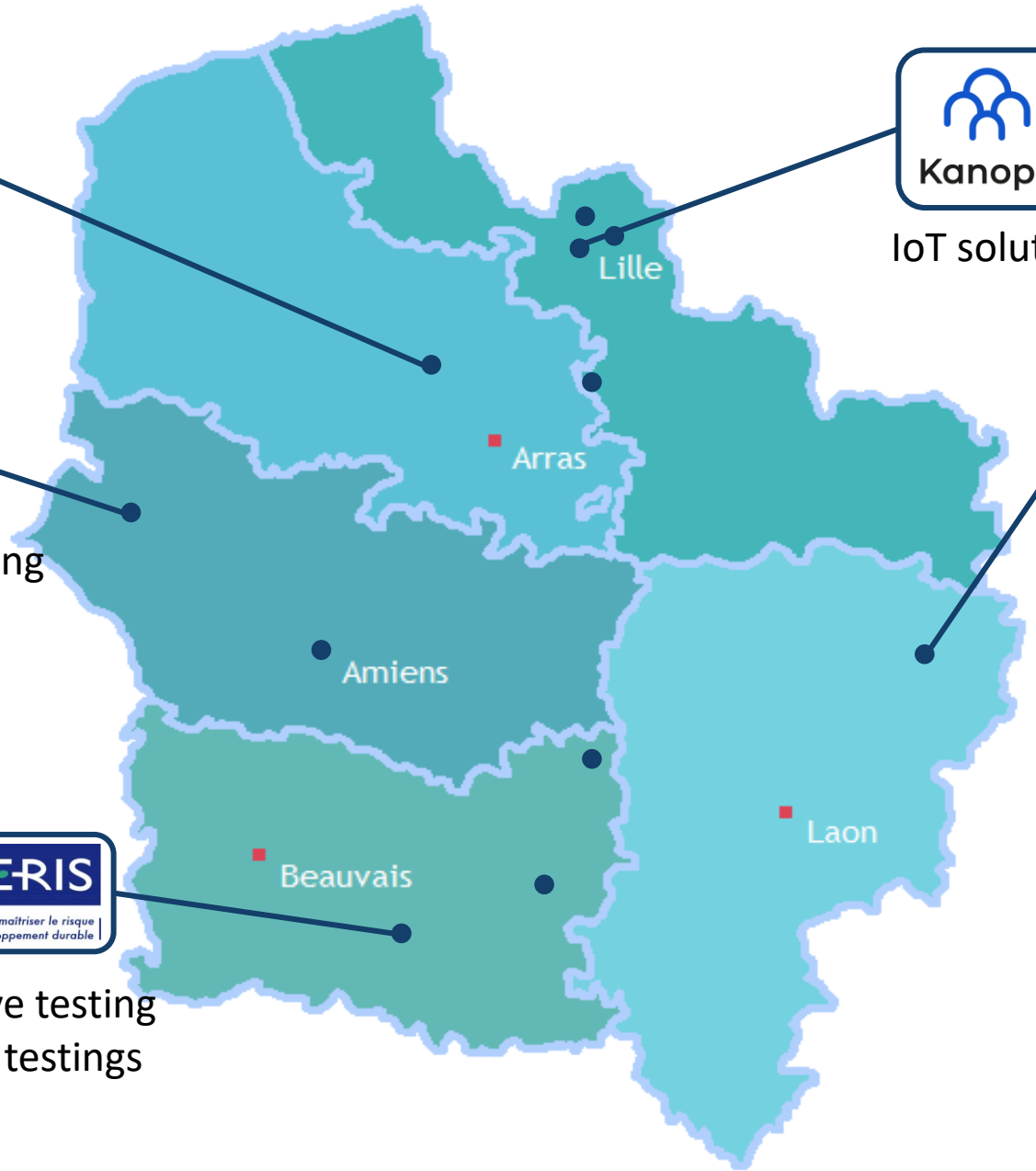
Kanope

IoT solutions

pressure die casting

A2MAC1

Industry-agnostic collaborative benchmarking data management platform,




- Abusive testing
- Safety testings

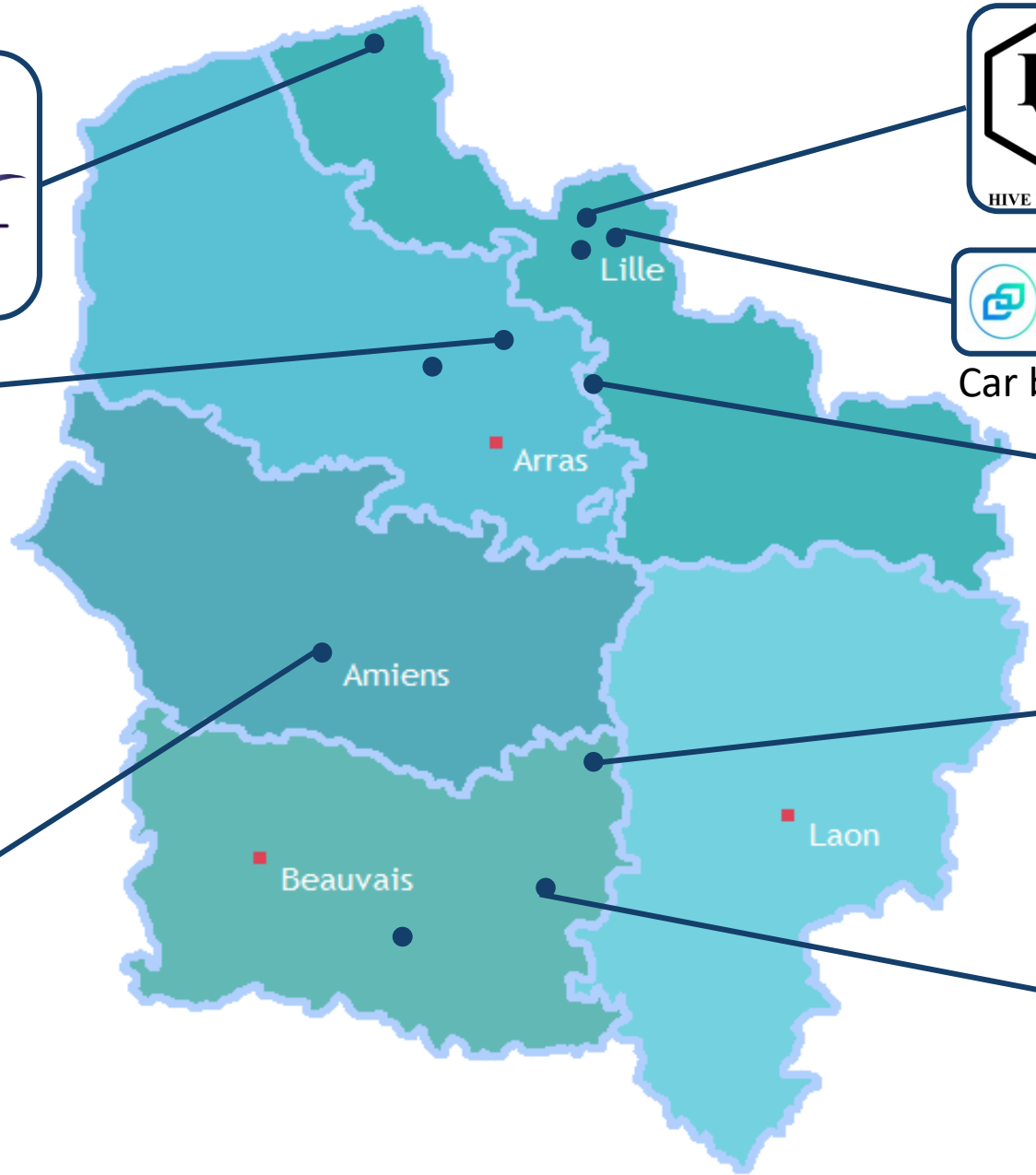
***Prochainement en HdF***

MECAWARE

MTB

alteo
SMART ALUMINA//

# Hauts de France: « valley » of battery pofessionnals




VERKOR, orano, ProLogium, XTC New Energy, eramet

STELLANTIS, ACC AUTOMOTIVE CELLS Co

DELVIATEK — Battery Heads Busbars

MOV'NTEC — Battery Pack Assembly

MERSEN — Battery assembly

TIAMAT

HIVE ELECTRIC

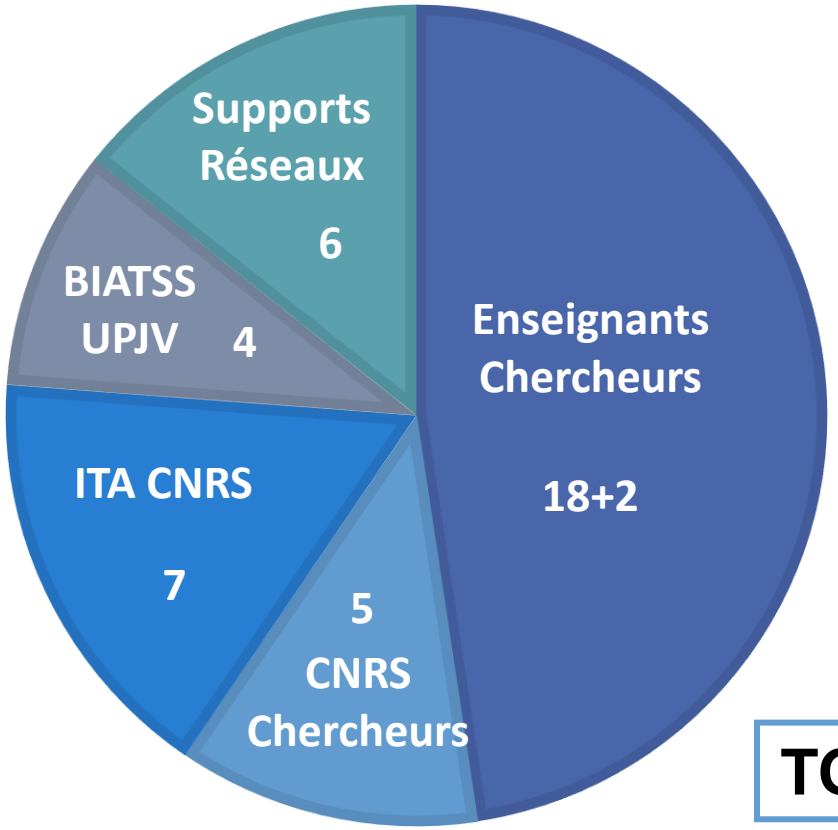
SWOOP ENERGY — Car batteries reuse

Envision AESC

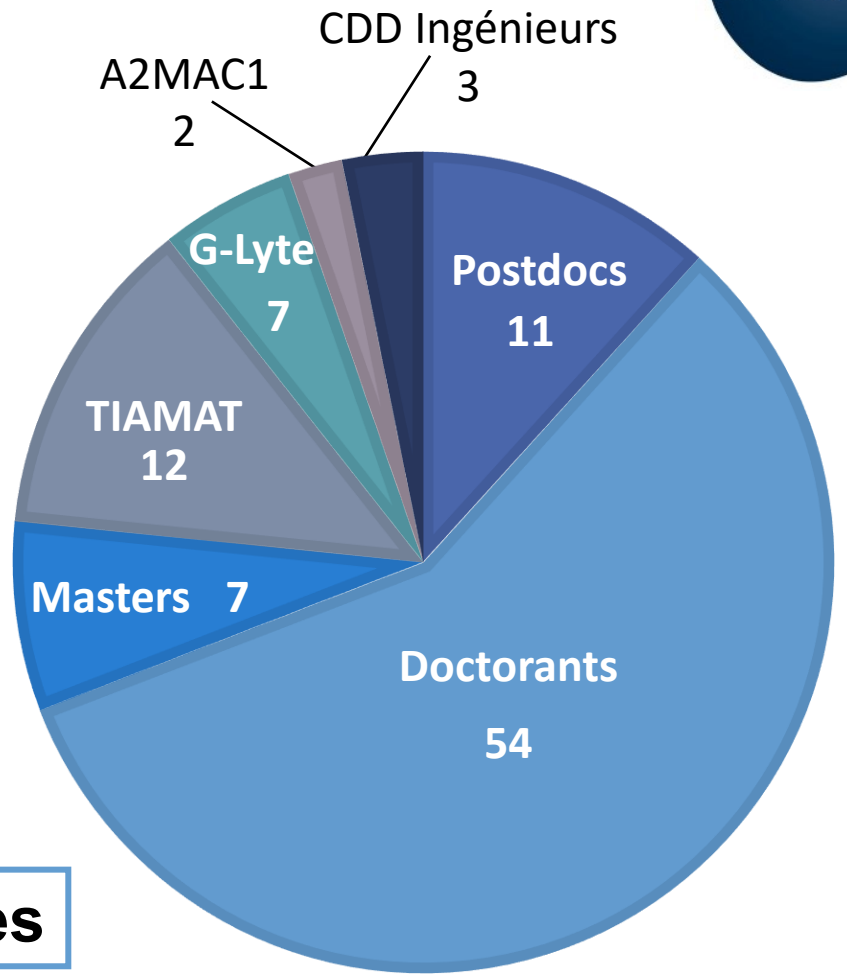
DANA — Battery thermal management

PLASTIC OMNIUM — Electric battery module manufacturing

# Personnels du LRCS en 2023




LRCS
Laboratoire de Réactivité et Chimie des Solides
UMR 7314 - UPJV/CNRS




**TOTAL = 136 Personnes**

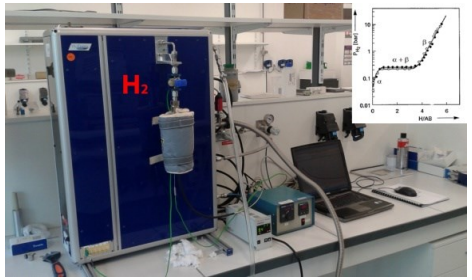
**2023**
42 Personnes

**2023**
75 non-permanents + 19 entreprises

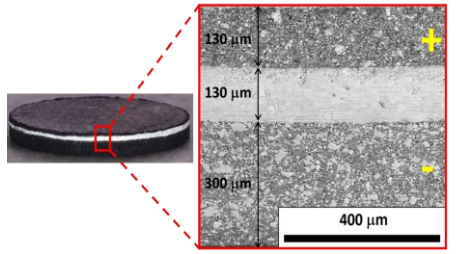
# Technologies étudiées au LRCS

## Batteries Lithium-ion


## Stockage de l'hydrogène

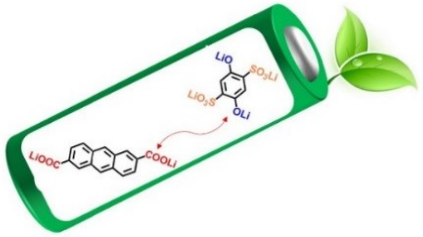



## Batteries tout solide

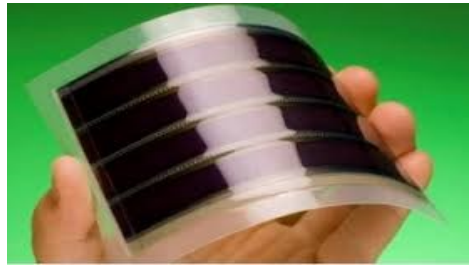



## Batteries Sodium-ion


## Batteries organiques

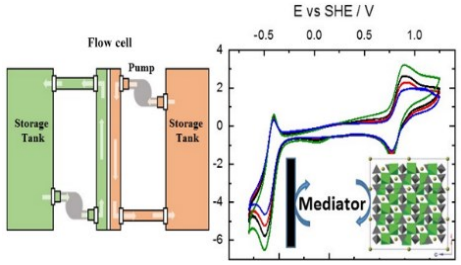



## Dispositifs photovoltaïques

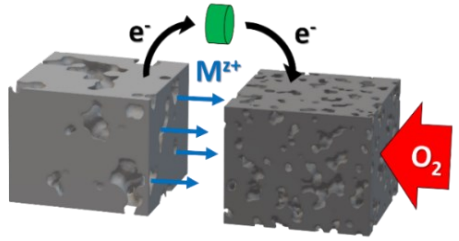


## Batteries Lithium-Soufre

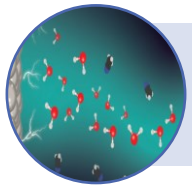
## Batteries à flux redox




## Batteries Métal-Air



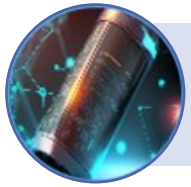
# Les PEPR « Batteries » où le LRCS est actif….



**BATMAN** data mining, IA, jumeau numérique

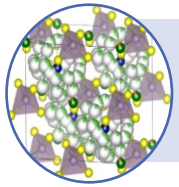
**HIPOHYBAT** forte puissance Na-ion & hybride

**FRISBI** tout solide à ions fluorure



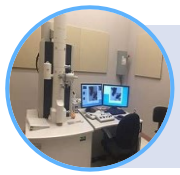
**SONIC** batterie organique anionique tout solide

**OPENSTORM** caractérisations operando



**LIMASSE** tout solide Li-métal/NMC Li-métal/C-S

**DISCOVERY** batteries à circulation aqueuse redox organique, boosters

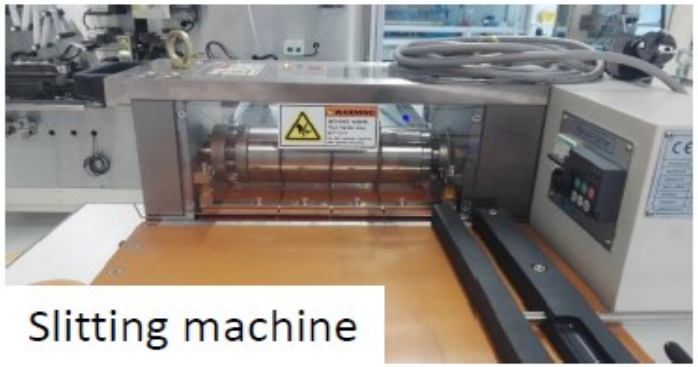


**EQUIPBAT-CNRS** : Equipements PEPR

# Prototypage

Coating machine

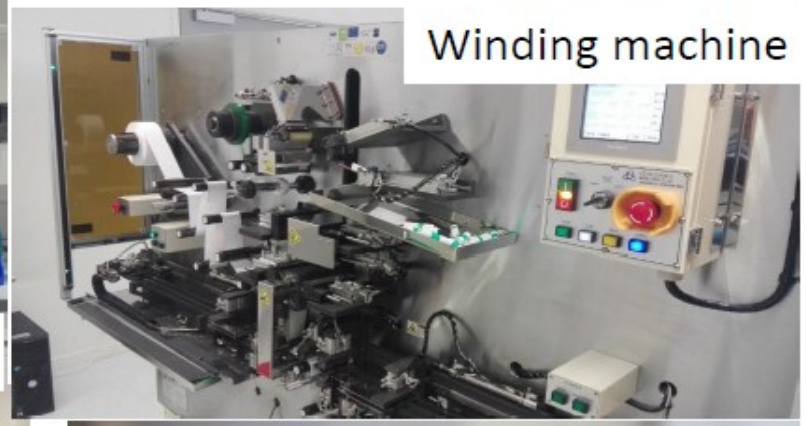
Calandering machine



Slitting machine

A dry Room

Winding machine

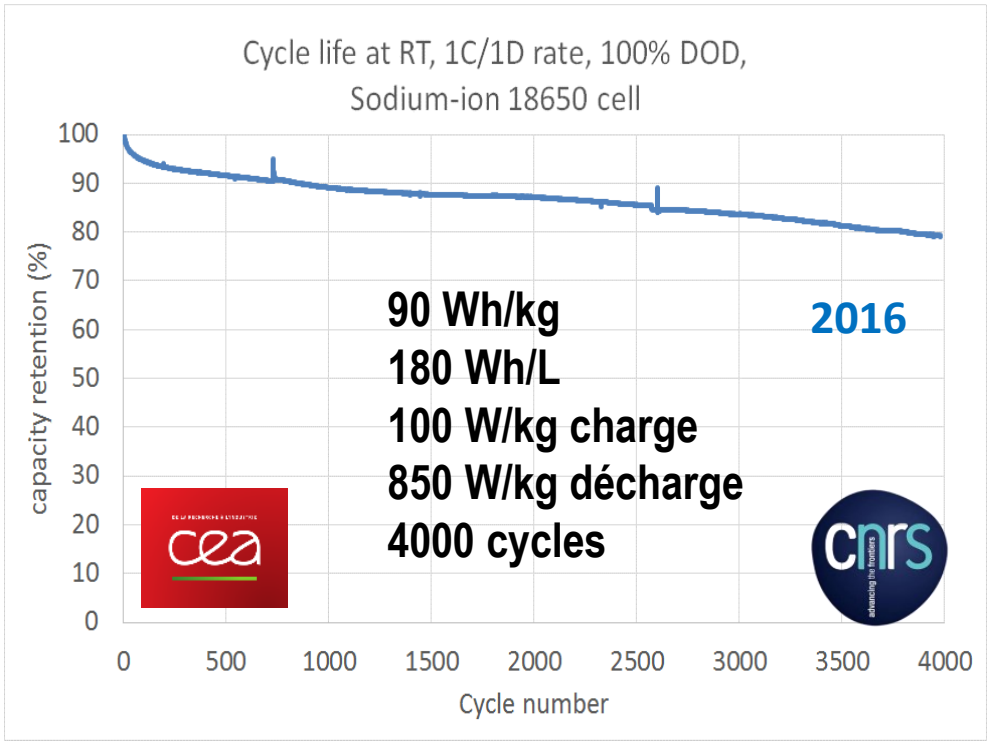


Mixing machine

Electrochemical Testing

# Valorisation des travaux du LRCS sur les Batteries Na-ion

TIAMAT

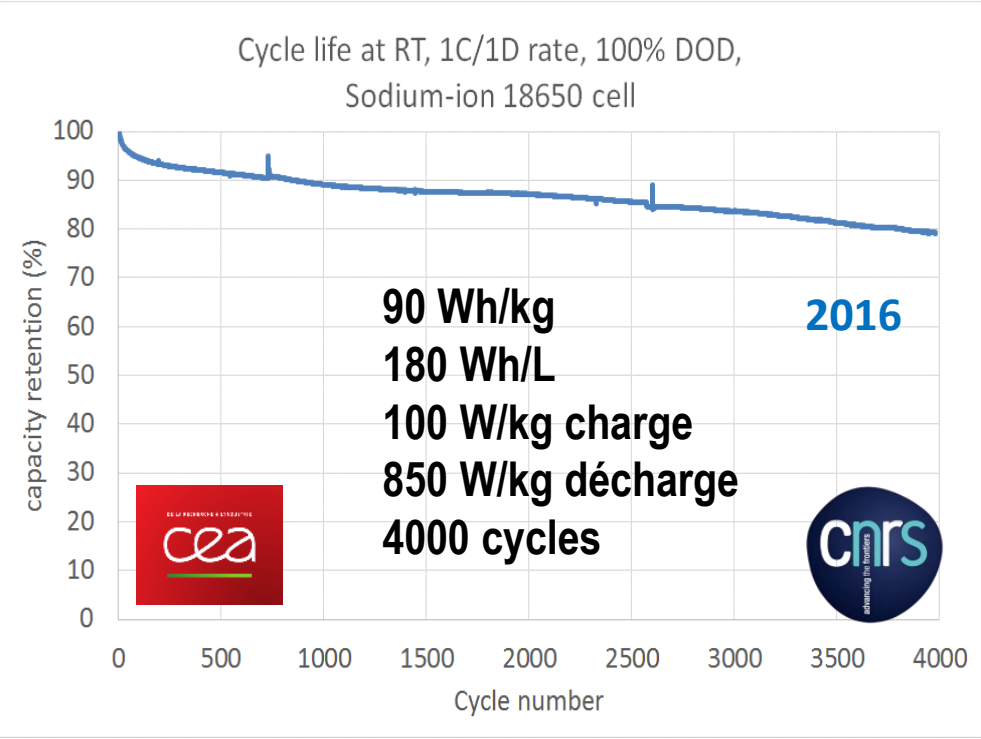


# Valorisation des travaux du LRCS sur les Batteries Na-ion

TIAMAT

DGA – Ministère de la Défense

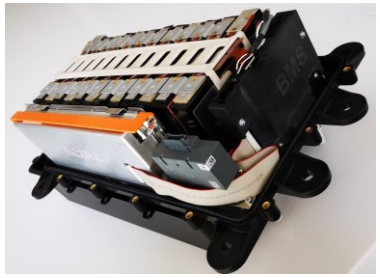
Agence Nationale de la Recherche – ANR

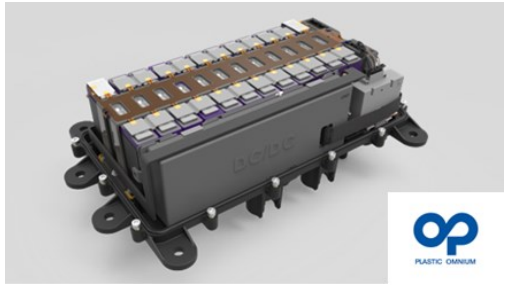



# Valorisation des travaux du LRCS sur les Batteries Na-ion


1st Na-ion 18650 cell in 2015

Formula 4, 2023

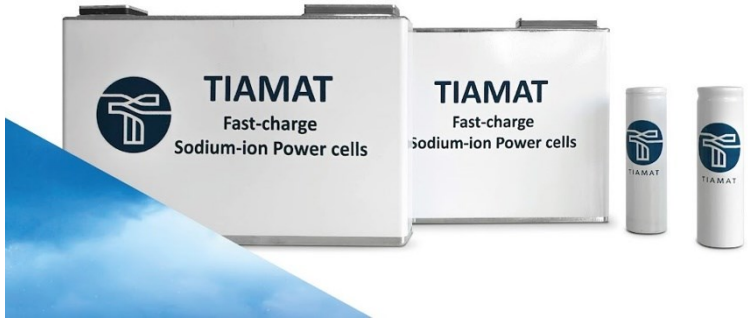





30 kW

STARTEC developpement

TIAMAT




To be on the market in 2023


25 kW

TIAMAT

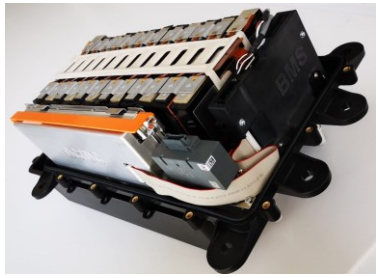
# Valorisation des travaux du LRCS sur les Batteries Na-ion

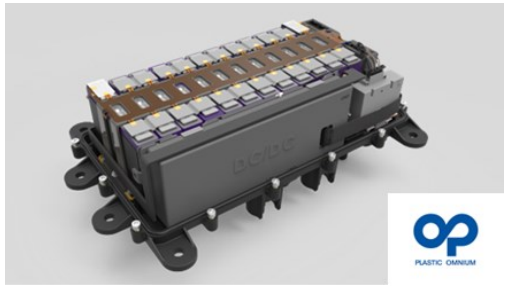

1st Na-ion 18650 cell in 2015

Formula 4, 2023

TIAMAT

LEROY MERLIN

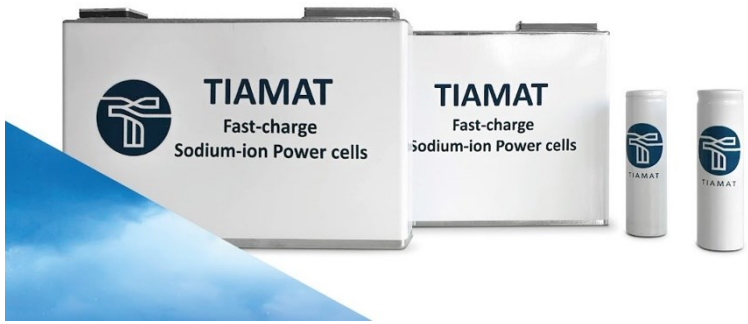




30 kW

STARTEC developpement

TIAMAT




To be on the market in 2023


25 kW


JUST RELEASED (October 2023)

# Gigafactory Na-Ion ?

Région Hauts-de-France

TIAMAT

## Targeting a 5 GWh factory starting production by year-end 2025E

### Tiamat's project is to build the first fully dedicated Sodium-ion battery cells plant in Europe

**Tiamat factory plan**

**Tiamat current production plan**

Starting production by year-end 2025E...

... to reach a 5 GWh capacity by the end of 2031E(1)

Source: Company

Note: (1) Production plan built on the basis of current customer needs identified. Ability to accelerate the ramp-up timeline and/or increase the targeted production depending on the evolution of ongoing lead discussions

5 A 5 GWh factory by 2025E

Gen1

LOCATED IN FRANCE

1ST SODIUM-ION CELLS PLANT IN EUROPE

MANUFACTURING PROCESS SIMILAR TO LITHIUM-ION PLANTS

THE PLAN DESIGN WILL OFFER HEADROOM FOR ADDITIONAL PRODUCTION CAPACITY

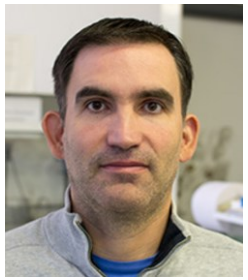
# Permanent people @ LRCS dealing with ASSBs

Vincent Seznec

Virginie Viallet

Mathieu Morcrette

Christian Masquelier



Raphael Janot

Loïc Dupont

Arnaud Demortière

Matthieu Becuwe

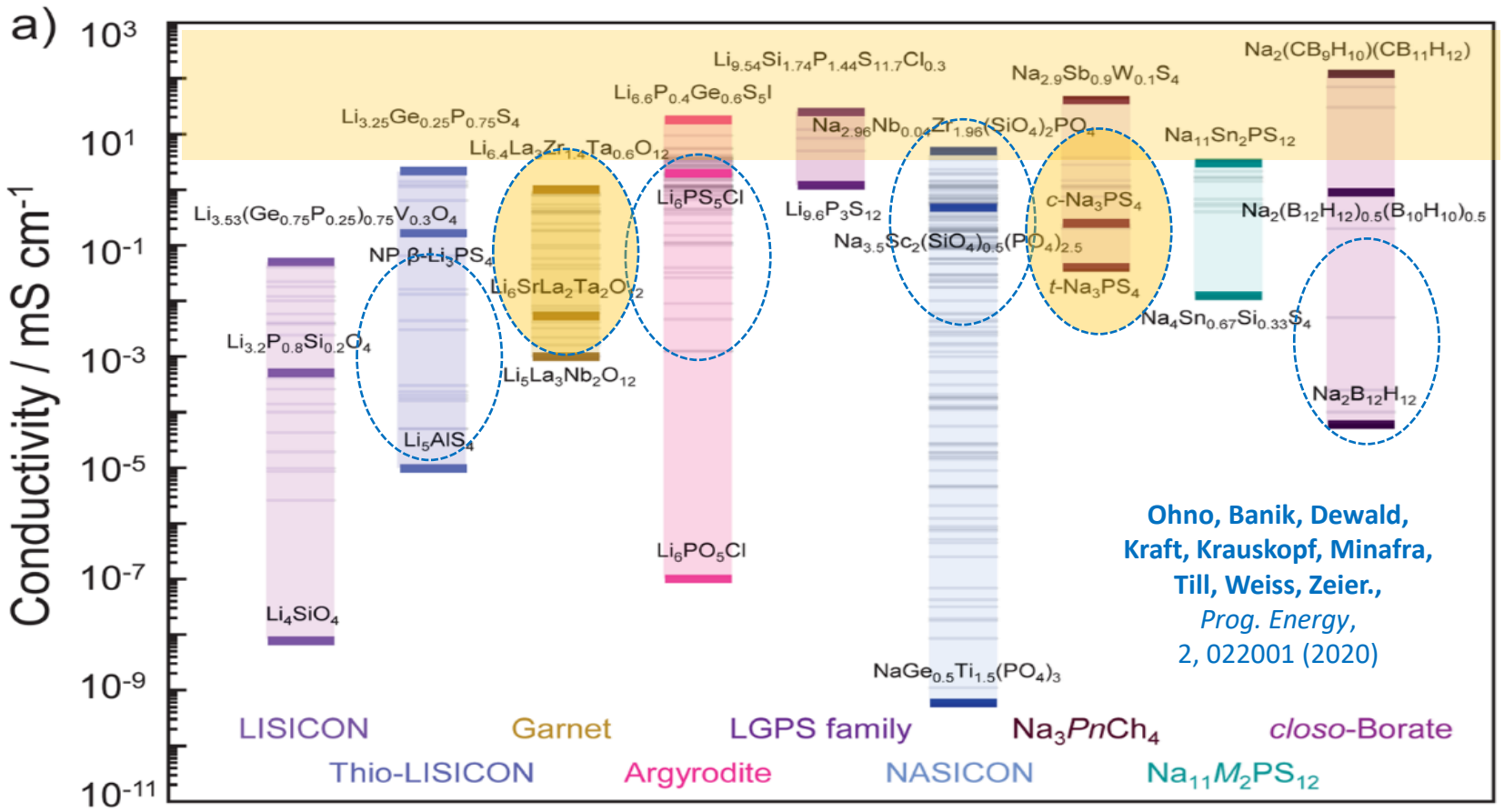
Jean-Noël Chotard

Carine Davoisne

François Rabuel

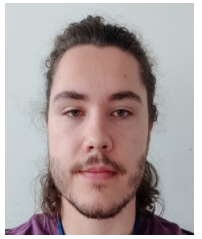
Pierre Gibot

# Current PhD works @LRCS on ASSBs




**Ohno, Banik, Dewald, Kraft, Krauskopf, Minafra, Till, Weiss, Zeier.,** *Prog. Energy*, 2, 022001 (2020)


**Kuma**


**Dufrene**


**Yadav**


**Shanbhag**


**Mahayoni**


**Mercadier**

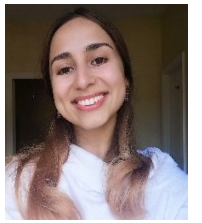

**Pham**


**Urrutia**


**Porcq**


**Al Abdali**


**Brasini**

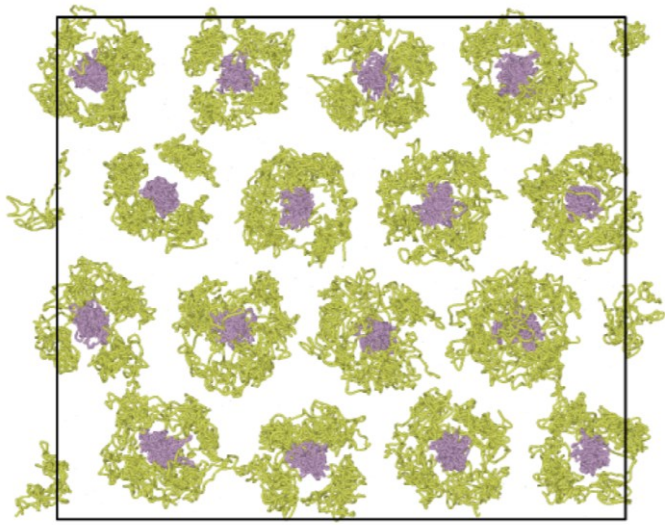

**Guluzade**

# EXAMPLE 1 : SULPHIDE SOLID ELECTROLYTES FOR Na SOLID STATE BATTERIES

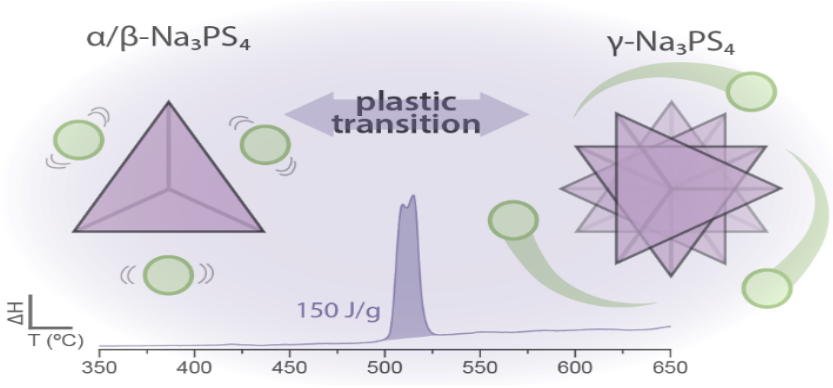
Romain Dufrene

Pierre Gibot

- **TOPIC: Sodium ionic conductors derived from the sodium tetrathiophosphate $Na_3PS_4$**
- **FUNDING:** Region Hauts-de-France / UPJV (50/50)
- **PROJECT TYPE:** PhD (since October 2023)



**$Na_3PS_4$**: one of the most investigated solid electrolytes for Na SSB
High ionic conductivity ($10^{-3}$ S/cm) => required criterion
Na more abundant than Li

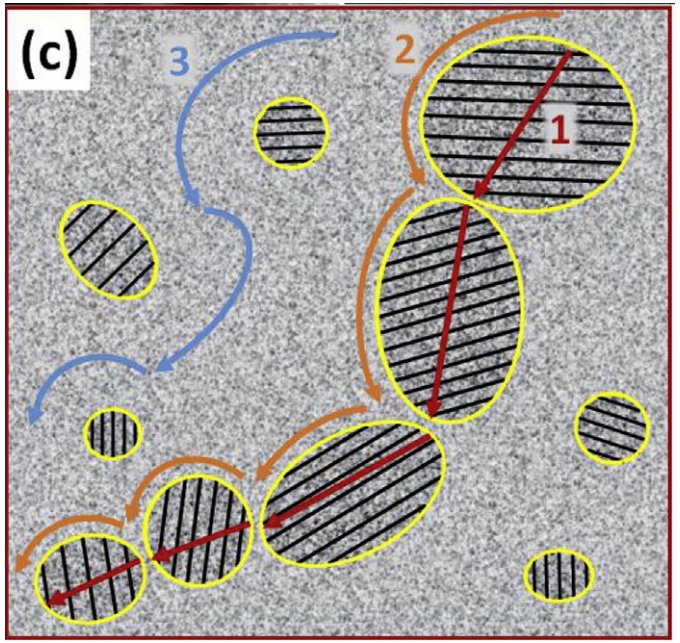



- ✓ **Synthesis of $Na_3PS_4$** by means of a **liquid approach**.
- ✓ "**Doped-$Na_3PS_4$**": oxygen to enhance the chemical stability (air/moisture), metal (Sn, W) to improve ionic conductvity.


Famprikis et al.,
*Nature Materials, 18(12),* 1278 (2019)
*ACS Materials Letters,* 1, 641-646 (2019)
*J. Amer. Chem. Soc.* 142(43), 18422 (2020)
*Chem. Mater., 33(14) 5652* (2021)

# EXAMPLE 2 : SULPHIDE SOLID ELECTROLYTES FOR SOLID STATE BATTERIES

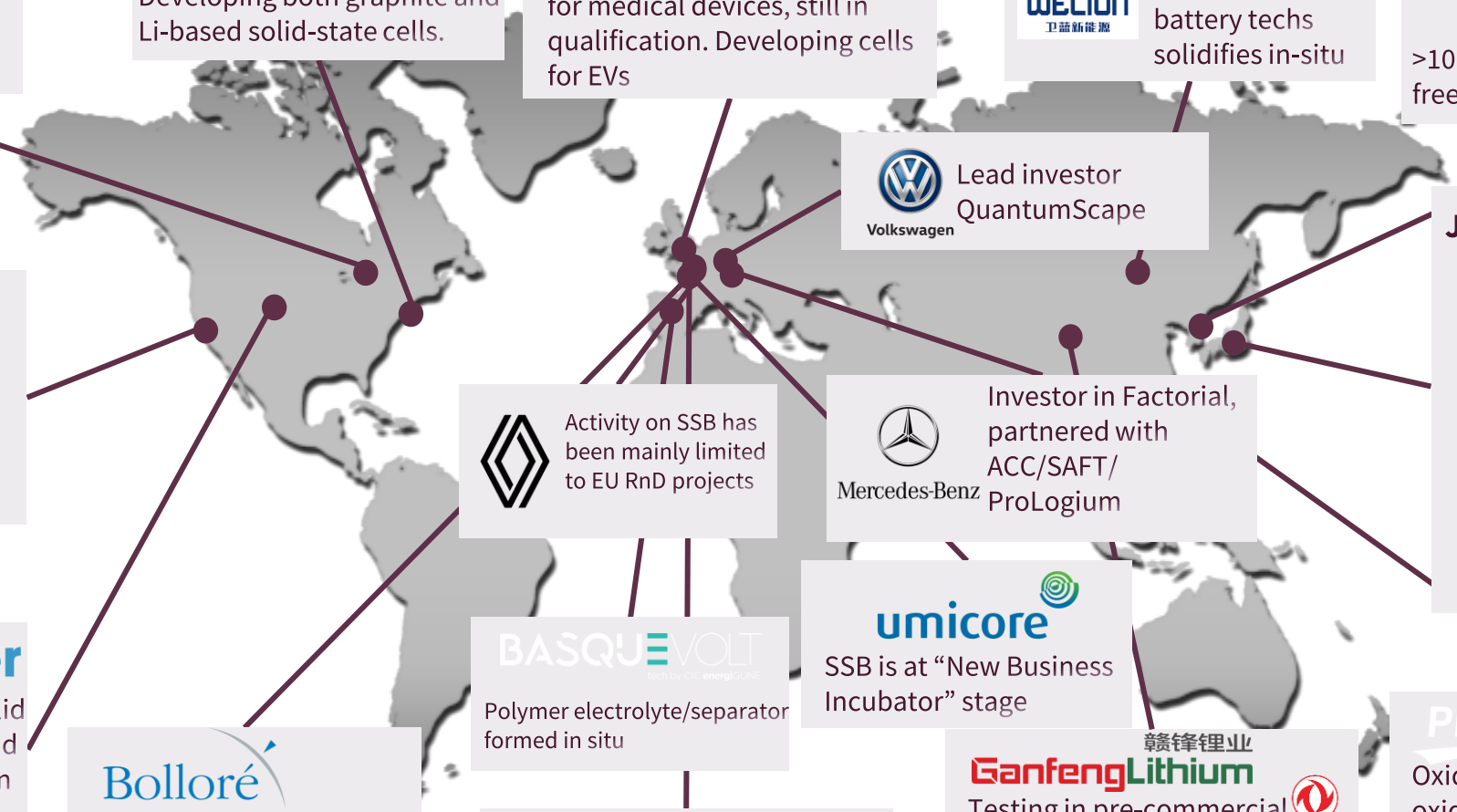
- **TOPIC: Investigation of the $Li_3PS_4$ – $Li_4SiS_4$ thio-LISICON system**
- **FUNDING:** Region Hauts-de-France (CPER MANIGEST/A2U, Projet Collaboratif)
- **PROJECT TYPE:** Master Thesis (February – July, 2024)
- **RESEARCH TEAMS :** **LRCS (UPJV, Amiens)**:
  P. GIBOT, V. VIALLET, C. MASQUELIER
  **LPCA (ULCO, Dunkerque)**:
  M. KASSEM, M. BOKOVA, A. SAMMOURY




Kudu et al.
*J. Power Sources*, 407, 31-43 (2018)
*Energy Storage Materials*, 44, 168-179 (2022)
*US Patent* 2022/0263123 A1 (2022)
US Patent 2023

- ✓ **Glassy phases** by means of a melt/quenching method => LPCA
- ✓ **$Li_{4-x}Si_{1-x}P_xS_4$ ($0 < x < 1$**, increment to be defined)
- ✓ Characterizations (ATD, RMN, air/moisture, EIS, electrochemistry…) => LPCA/LRCS
- ✓ All Solid State Batteries => LRCS

# The dawn of commercialization of ASBB



**Ford**
Lead investor in start-up Solid Power

**Factorial**
Developing both graphite and Li-based solid-state cells.

**ilika**
Oxide based thin film batteries for medical devices, still in qualification. Developing cells for EVs

**WELION**
Polymer-based, hybrid semi-solid battery techs solidifies in-situ

**SAMSUNG**
>10 yrs on sulfide SEs, focusing on free-anode concept

**Volkswagen**
Lead investor QuantumScape

**QuantumScape**
Focus on oxide-type solid electrolytes, using free anode concept and liquid catholyte. LFP and NMC

**Japanese ecosystem**
Well-developed, state-subsidied, joint industrial RnD on SSB. Toyota has more than 1300 patents. Nissan is considering in-house manufacturing. Honda is developing a proprietary tech.

Activity on SSB has been mainly limited to EU RnD projects

**Mercedes-Benz**
Investor in Factorial, partnered with ACC/SAFT/ ProLogium

**Solid Power**
Developing sulfide-type solid electrolytes with both Li and Si as (-) electrodes. Trials on metal sulfide as (+) electrodes.

**BASQUEVOLT**
Polymer electrolyte/separator formed in situ

**umicore**
SSB is at "New Business Incubator" stage

**Bolloré**
Selling high temp LFP, polymer based cell. Lower temp, high energy cells under development

**SOLVAY**
Lead investor in Solid Power, scaling up polymers and sulfide-based electrolytes. Scaling-up plant in La Rochelle

**GanfengLithium** 赣锋锂业
Testing in pre-commercial car prototypes based on semi-solid SSB, focusing on Li negative electrode

**ProLogium**
Oxide-based electrolyte, silicon oxide negative electrode. Trying to scale-up "single cell" modules and packs

**Adapted from SphereEnergy's white paper, April 2023**

Courtesy of Eunike MAHAYONI

# PROLOGIUM en Hauts de France….

L'USINENOUVELLE

Secteurs | Obsessions | Rendez-vous | Régions | Vidéos & Podcasts

AUTO | Constructeurs | Equipementiers | Innovations | Véhicule électrique | Cycles et motocycles | Les datas de l'auto

Made in France | BATTERIES | NORD | INVESTISSEMENTS INDUSTRIELS

Toutes les annonces d'investissements industriels du sommet Choose France 2023 | Sommaire

## ProLogium va investir 5,2 milliards d'euros pour produire des batteries solides à Dunkerque

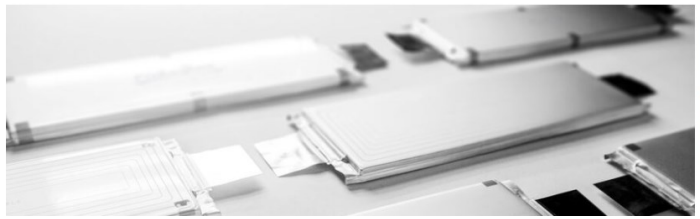
L'implantation sur le territoire français d'une quatrième gigafactory de batteries par l'entreprise taïwanaise ProLogium devrait être officialisée ce vendredi 12 mai par Emmanuel Macron, lors d'un déplacement à Dunkerque (Nord).

Réservé aux abonnés

Antoine Vermeersch

11 mai 2023 \ 23h59

4 min. de lecture




# PROLOGIUM en Hauts de France….

## WITH BASIC AND ADVANCE TECH TO BALANCE CELL PERFORMANCE AND COST

Safe

High Energy Density, High C-Rate, Low Cost

Thick Separator → Thin Separator

### Liquid Type LiB

**260-280Wh/kg**

Cathode: NCM 811 (100% gel) — 85 um
Separator: (PP/PE film) — 16 um
Anode: Gr. (100% gel) — 90 um

- ☐ Safe
- ☑ Energy Density
- ☑ C-Rate: 3C
  - _ACIR: 1.5mΩ
  - _DCIR: 2.23mΩ
- ☑ Cost

### (1st LCB System)

**150Wh/kg**

LCO (100% HSE) — 110 um
(100% HSE) — 60 um
Gr. (100% HSE) — 120 um

- ☑ Ultra Safe
- ☐ Energy Density
- ☐ C-Rate: 0.2-0.5C
  - _ACIR:19mΩ
  - _DCIR:38mΩ
- ☐ Cost

### (2nd LCB System)

**225Wh/kg**

NCM 622 (90% HSE+ 10% Gel) — 100 um
(100% HSE) — 45 um
Gr. (90% HSE + 10% Gel) — 121 um

- ☑ Ultra Safe
- ☐ Energy Density
- ☑ C-Rate: 3C
  - _ACIR: 1.16mΩ
  - _DCIR: 2.54mΩ
- ☐ Cost

### (3rd LCB System + ASM)

**320Wh/kg**

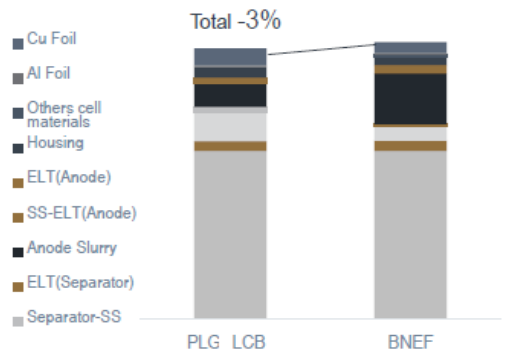
NCM 955 (100%Gel+ASM) — 91 um
(100% HSE) — 30 um
100% SiOx SiB Tech (30%HSE +70% ASM) — 43 um

**360-380Wh/kg**

NCM 955 (100%Gel+ASM) — 91 um
(100% HSE) — 30 um
100% Si Base (as left) — 20 um

- ☑ Ultra Safe
- ☑ Energy Density
- ☑ C-Rate: 5C
  - _ACIR: 0.67-0.62mΩ
  - _DCIR: 2.38-2.05mΩ
- ☑ Cost

Cost is lower than Liquid LiB @10GWh

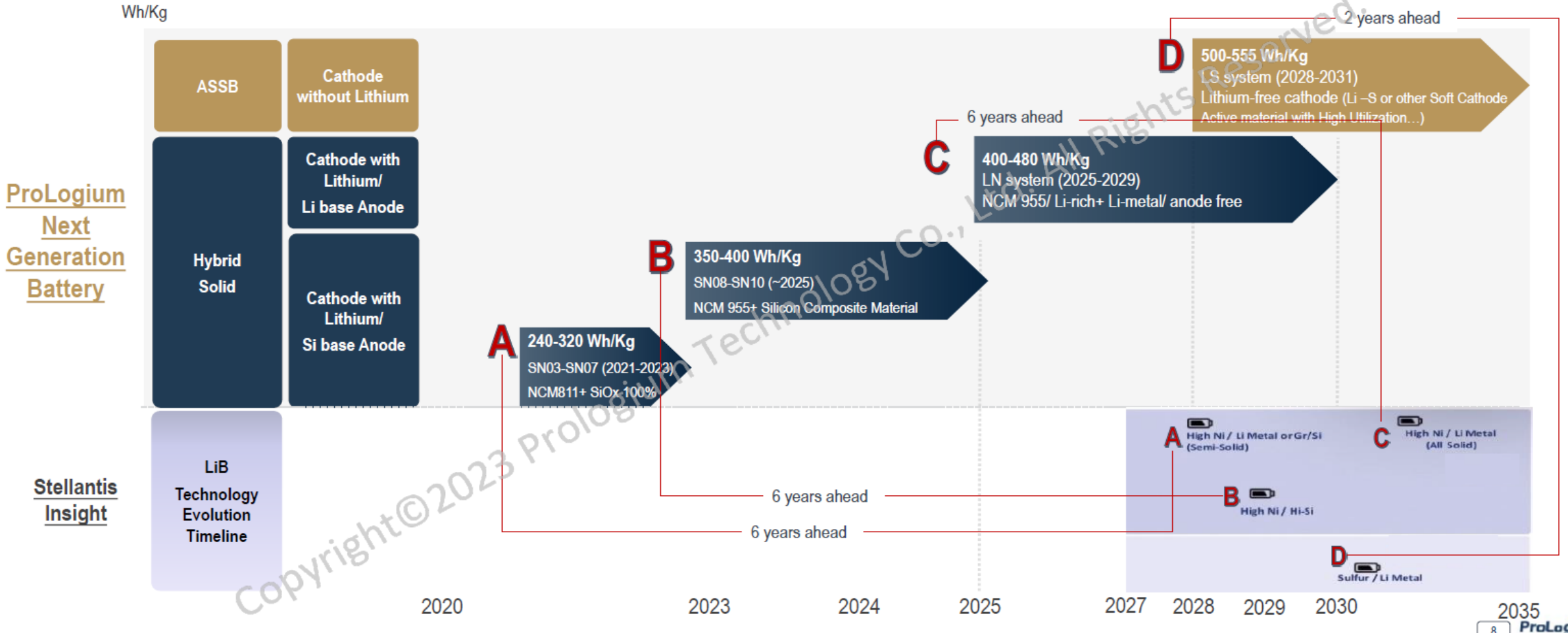



**Balance Performance and Cost**

# PROLOGIUM en Hauts de France….

## PROLOGIUM'S CHEMICAL ROADMAP TO MEET THE MARKET REQUIREMENT

2-6 years ahead of LiB technology Evolution Timeline.



# Les Projets “Stockage” Financés par MANIFEST

- **TRANSITION** : **Postdoc et M2 – 2022**, porté par J. Belhadi (LPMC) et A. Ferri (UCCS)
  « *Ingénierie des domaines ferroélecTRiques dans des superréseaux sANs plomb pour des dispoSITifs de conversION et de stockage d’énergie électrostatique* »

- **THE FORCE** : **Post-Doc** porté par A. Ferri (UCCS) et L. Dupont (LRCS)
  *« Apport des Techniques de Microscopie à Force Atomique, …, microstructures d’électrodes de batteries… »*

- **OPACPEC** : **Stage de M2 – 2022**, porté par J. P. Bonnet (LRCS), V. Bonnet (LG2A) et A. Sayede (UCCS)
  *« Optimisation d'accumulateurs au lithium à base de pectines comme liant anodique »*

- **AGROLATH** : **Stage de M2 – 2023**, porté par J. Page (LGCgE) et G. Promis (LTI)
  *« Elaboration d'AGROmatériaux à base de Liants Alkalins pour le confort Thermique de l'Habitat »*

- **ATASET** : **Stage de M2 – 2023**, porté par M. Depriester (UDSMM) et L. Zaelwski (LGCgE)
  *« Analyse thermophysique appliquée au stockage d'énergie thermique »*

- **COLIBRHIS** : **Stage de M2 – 2023**, porté par P. Gibot (LRCS) et M. Kassem (LPCA)
  *« COnducteurs ioniques au LIthium issus du BinaiRe tHIo-LISICON $Li_3PS_4$ - $Li_4SiS_4$*

- **PASTIS** : **Stage de M2 – 2023**, porté par G. Pourceau (LG2A), S. Saitzek (UCCS) et F. Sauvage (LRCS)
  *« Vers l'utilisation de matériaux de type Pérovskites hAlogénées Stables en milieu aqueux comme phoToanodes de piles alimentées à la biomaSse »*

# CPER MANIFEST

## Stockage de l'Energie

## THANK YOU FOR YOR ATTENTION

# Equipments behind ASSB Research

## Synthèse

Solid-solid synthesis

Sol/gel, solution, precipitation

Ball milling

## Caractérisations

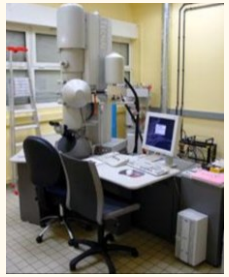
Thermal analysis

X-Ray diffraction

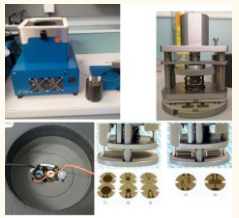
HT Cell

RT Cell

Electrochemical testing



Microscopy



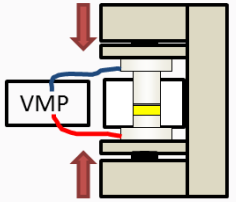
Impedance measurements / interface stability

## Mise en forme

SPS

Pressage à chaud

Pressage à froid



# Volet formations

Techniciens de maintenance et qualité : LPRO Amiens (30/an)

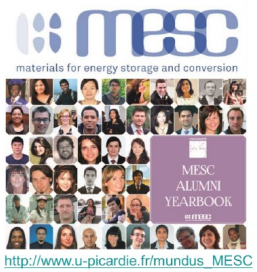
MESC : ouverture à 45 étudiants/an avec bourses

COFUND DESTINY : 50 thèses
E-Sense : 42 demi-thèses
Industrie : 8 thèses/an
MAIA

*Bac* — *Bac +3* — *Bac +5* — *Bac +8*

Coordonné depuis 2005 par UPJV Amiens

- 250 diplômés de plus de 40 pays différents !!!!
- Irrigue nos Laboratoires de doctorants d'excellent niveau
- Nombre d'entre eux à des postes clé en Industrie




http://www.u-picardie.fr/mundus_MESC

# Le LRCS: un laboratoire international avec une forte culture des réseaux

**Master Erasmus Mundus**

**dédié à la conversion et au stockage de l'énergie (MESC):**

**renouvellement du label en 2018**

**Coordonné depuis 2005 par UPJV Amiens**

materials for energy storage and conversion


http://www.u-picardie.fr/mundus_MESC

- 250 diplômés de plus de 40 pays différents !!!!
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**Programme COFUND DESTINY (fév. 2020):**

**50 thèses vont être financées par l'Europe**

**piloté par le réseau ALISTORE et le LRCS**

**20 universities + 12 Research centres, networks, large scale facilities & National Agencies + 8 companies**

| | | | | |
|---|---|---|---|---|
| UPJV Amiens | UoB Bath | UB Bordeaux | CU Cambridge | DTU Copenhagen |
| TU Delft | CHALMERS Göteborg | TU Graz | FSU Jena | LU Lancaster |
| UM Montpellier | UN Nantes | OXF Oxford | CDF Paris | UPPA Pau |
| USTAN St Andrews | UPS Toulouse | UT Twente | UU Uppsala | WUT Warsaw |
| ALISTORE | CEA Grenoble | CICe Vitoria | CIDETEC San Sebastian | ELETTRA Trieste | ICMAB Barcelona |
| IEK Jülich | ILL Grenoble | NIC Ljubljana | RS2E | SOLEIL Evry | Région Pays de la Loire |
| BASF | FCT SYSTEM | PKN ORLEN | RENAULT | SAFT | SOLVAY | TIAMAT | UMICORE |