New Concept of Metal-Air Battery for Automotive Application based on Advanced Nanomaterials

FP7-2012-GC-MATERIALS

GA 314159

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Post Lithium Ion Batteries for electric automotive applications

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TECNALIA

Objective of the project

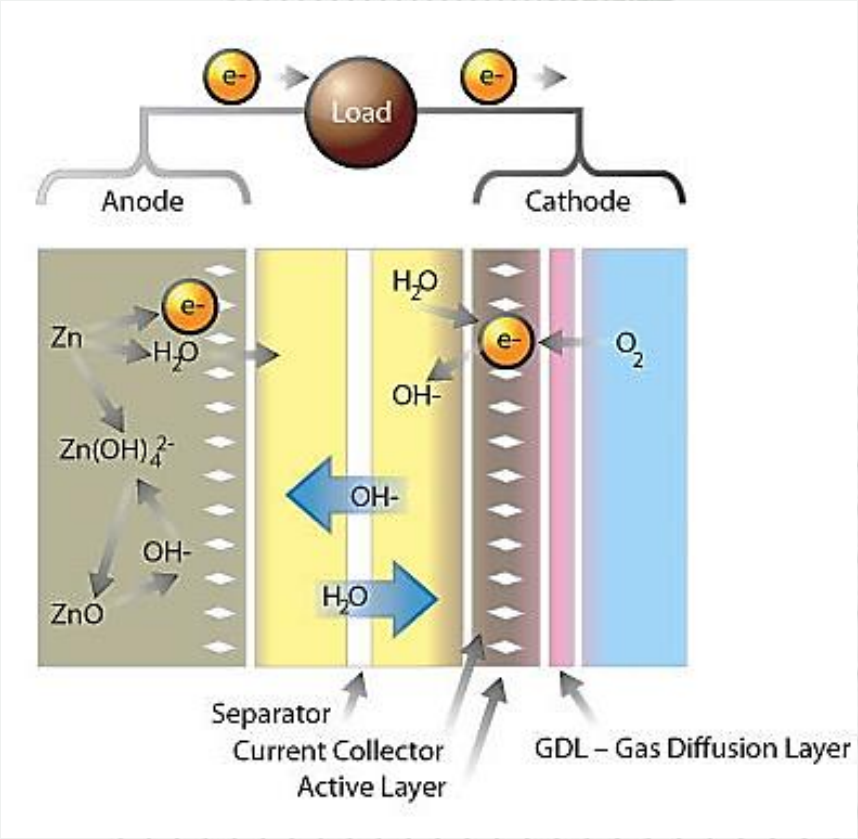
The general objective of NECOBAUT project is the following:

To develop an **innovative and scalable iron-air cell for automotive electrochemical storage:**

- with a target **cost** lower than 100 €/kWh,
- with **energy density** above 400 Wh/kg at cell level and
- With **durability** higher that 3000 cycles at 80% DoD.

This cell is demonstrated as proof of concept, but safety, environmental life-cycle analysis (LCA) and scalability are proved **taking into account the automotive specifications.**

Metal/air batteries



- Based on the reaction of a metal with atmospheric air

  Metallic negative electrode and air breathing positive electrode

- <u>Advantages</u>:
  - Theoretical high energy densities (> 10000 W·h/kg for Li-air)
  - Can be based on common and abundant materials: Zinc, Iron, Aluminium, Magnesium…
  - Potential for low cost

Iron/air batteries

- **Components:**

  - Negative Iron electrode
  - Positive Air-Breathing electrode
  - Aqueous Alkaline (KOH) electrolyte

Overall Cell reaction:

$$Fe + H_2O + \tfrac{1}{2} O_2 \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} Fe(OH)_2$$

Negative electrode:

$$Fe + 2OH^- \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} Fe(OH)_2 + 2e^-$$

Positive electrode:

$$\tfrac{1}{2} O_2 + H_2O + 2e^- \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} 2OH^-$$

- **Advantages:**

  - Availability of raw materials: iron and air with KOH electrolyte
  - Low cost: <100 €/kWh
  - Light: >80Wh/kg proved in the 80s, theoretical : 1000 Wh/kg
  - No dendrite formation or electrode shape changes (Advantage vs. Zn-air!)
  - Does not require membranes
  - Feasibility both for automotive and stationary application
  - Demonstrated but not commercial technology

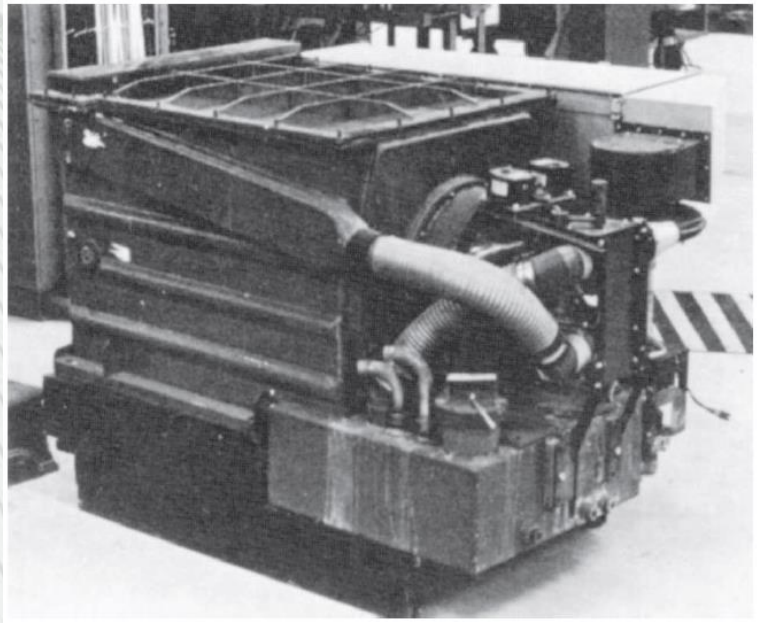
Why Iron/air?

Table 2. Comparison between Iron-air and other state of the art Metal-air batteries

Parameter	Iron-air	Zinc-air	Lithium-air
Specific Energy	80 Wh/kg[3] (theoretical: 1000 Wh/kg)	100-150 Wh/kg[4] (theoretical: 1084 Wh/kg)	600 Wh/kg[5] (objective) (theoretical: up to 11000 Wh/kg)
Cycles at 80% DoD	1000 cycles[6] (proved) **3000 cycles (NECOBAUT)**	< 500 cycles [7] (proved) (limited by Zn dendrites)	N.A. Early stage of development
Cost	< 125 €/kWh[8] (proved) **< 100 €/kWh (NECOBAUT)**	< 250 €/kWh[9] (proved) < 150 €/kWh[10] (long term)	350-700 €/kWh[11] (long term)
Safety	Good	Good	Risks associated to Lithium
Technological complexity	Medium-Low	Medium-High	Very high

Background on Iron/air batteries

- **The Fe/air battery was developed in the 80's by:**
  - ***Swedish National Development Corporation***
    - *30kWh battery for electric vehicle*
  - ***Westinghouse Electric Corporation, US*** *(1976-1992)*
    - *10kW-40kWh battery for electric vehicle.*
  - ***Matsushita, Japón***
  - ***Siemens, Alemania***



Characteristic of this Fe-air battery:

- Energy density: 80 Wh/kg
- Cycle efficiency: ~50%
- Durability: 1000 cycles

Specific objectives of the project

- To develop an **iron electrode based on nanomaterials** *(nano-oxides and nano-additives supported on nanocarbons)*
  - Higher specific surface and lower passivation will allow **higher energy densities**

- To optimize the **cell design**, by means of **modelling and simulation tools**
  - Lower ohmic losses and reduced cost of materials

- To develop an **air electrode with new nanostructured catalysts and supports**
  - **Higher current densities** by improving the Oxygen Reduction Reaction (ORR) activity
  - **Higher durability** (more stable supports)

- To assess the **scalability** of the cell designs up to automotive battery specifications.
- To assess the **safety** and **environmental impact**, (LCA) of the newly developed battery cell

Partnership

- 3 Research institutes:
  - **TECNALIA**
  - **CNR-ITAE**
  - **INERIS**

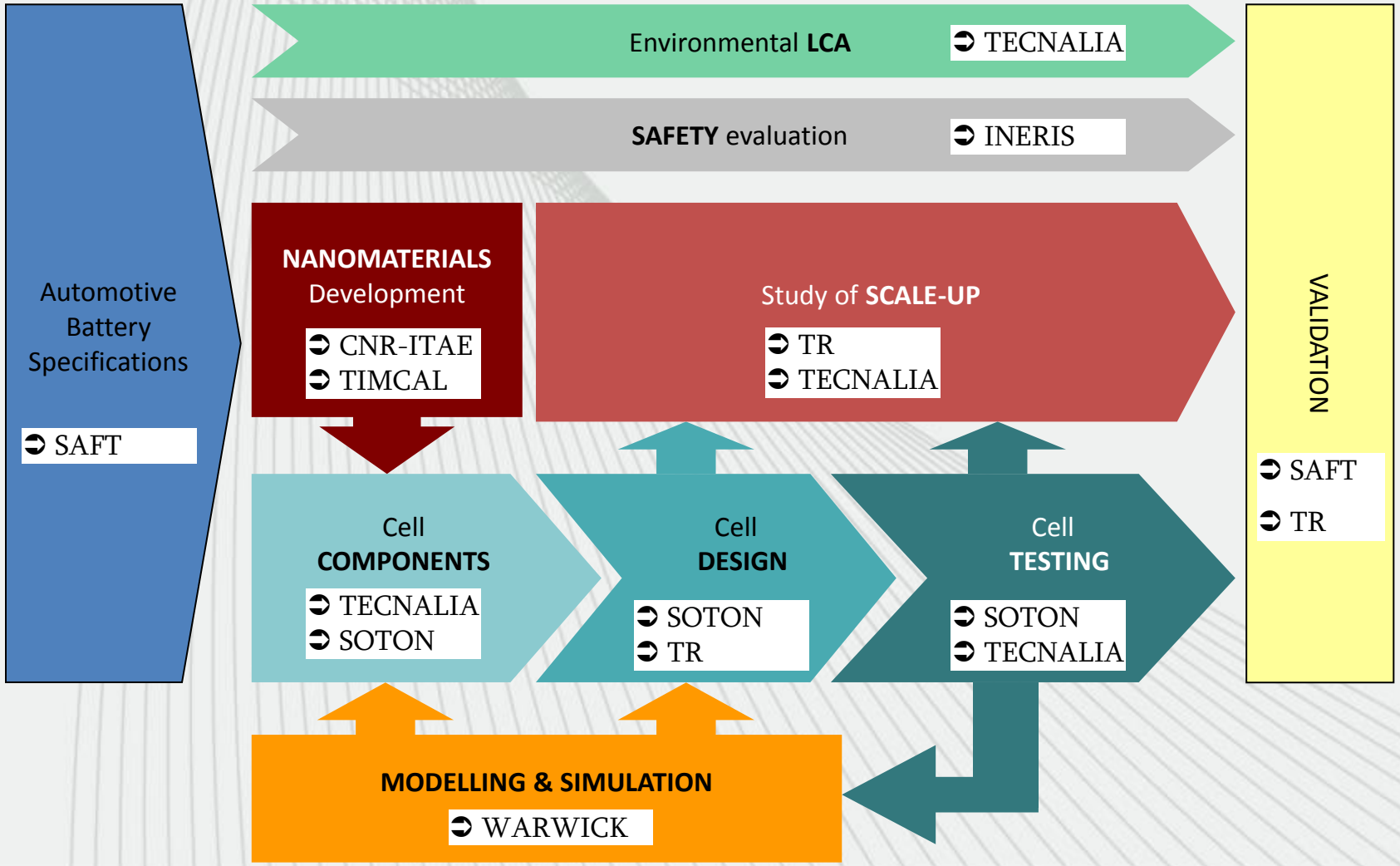
- 2 Universities:
  - **SOUTHAMPTON Univ.**
  - **WARWICK Univ.**

- 1 industrial nanocarbon products supplier, **TIMCAL**

- 1 industrial engineering company: **TECNICAS REUNIDAS**

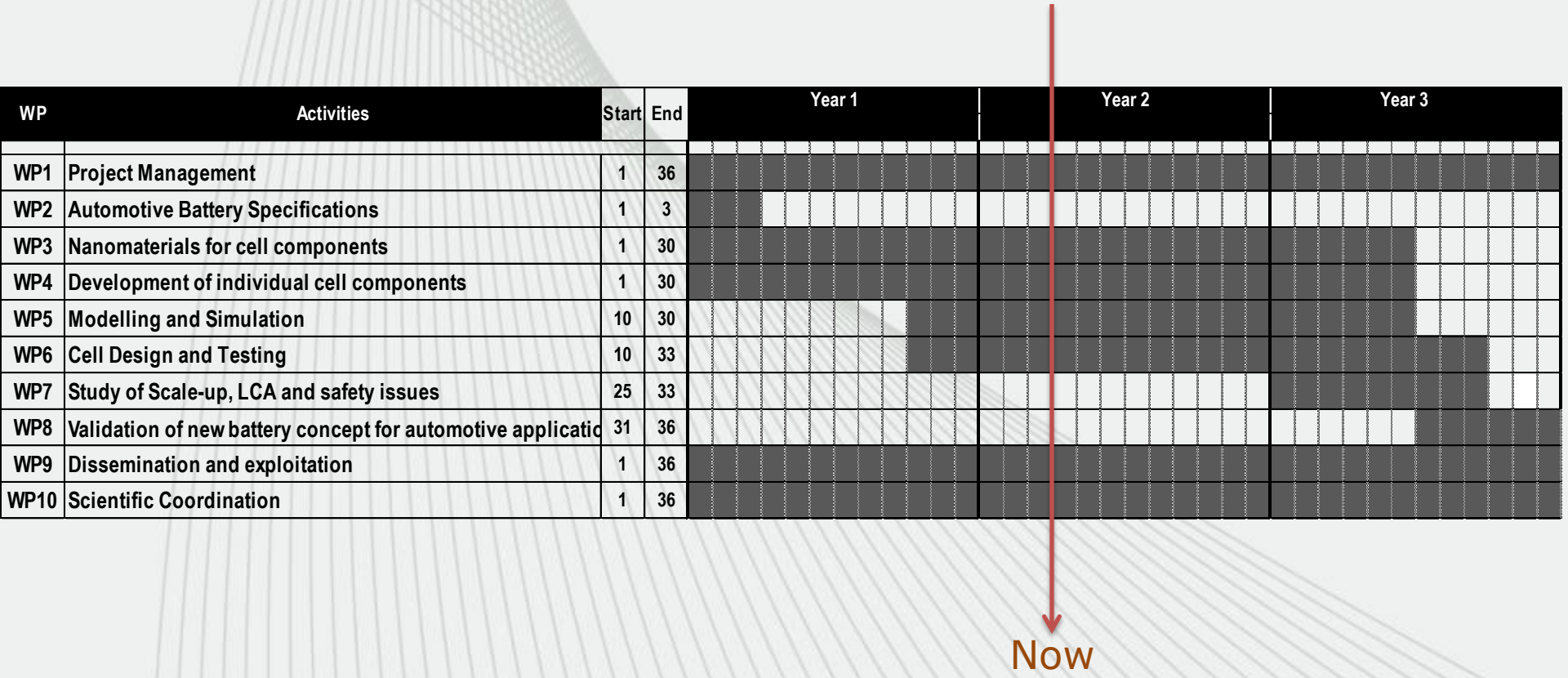
- 1 industrial car battery manufacturer: **SAFT Iberica**

RoI of each partner



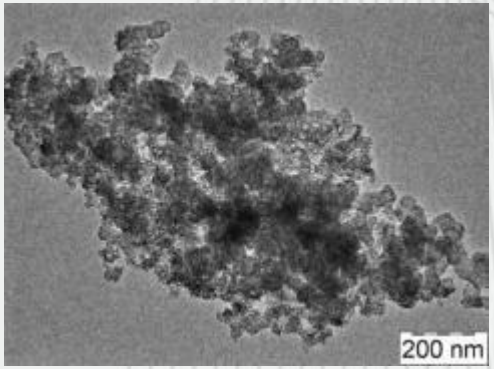
Working plan (Gantt chart)

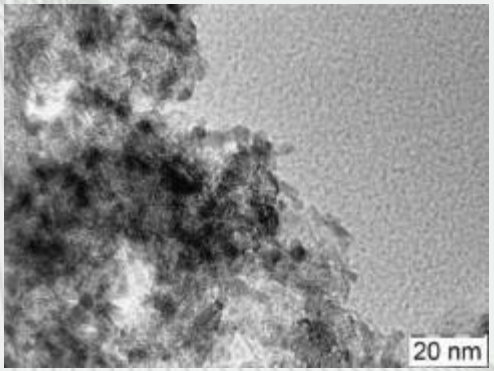
WP	Activities	Start	End	Year 1	Year 2	Year 3
WP1	Project Management	1	36			
WP2	Automotive Battery Specifications	1	3			
WP3	Nanomaterials for cell components	1	30			
WP4	Development of individual cell components	1	30			
WP5	Modelling and Simulation	10	30			
WP6	Cell Design and Testing	10	33			
WP7	Study of Scale-up, LCA and safety issues	25	33			
WP8	Validation of new battery concept for automotive applicatic	31	36			
WP9	Dissemination and exploitation	1	36			
WP10	Scientific Coordination	1	36			



Preliminary results

First nanomaterials for iron anode (FeOx) by different routes

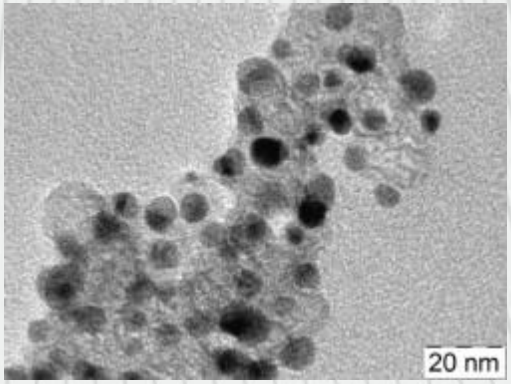




Manufacturing of first anodes

Increased discharge capacity

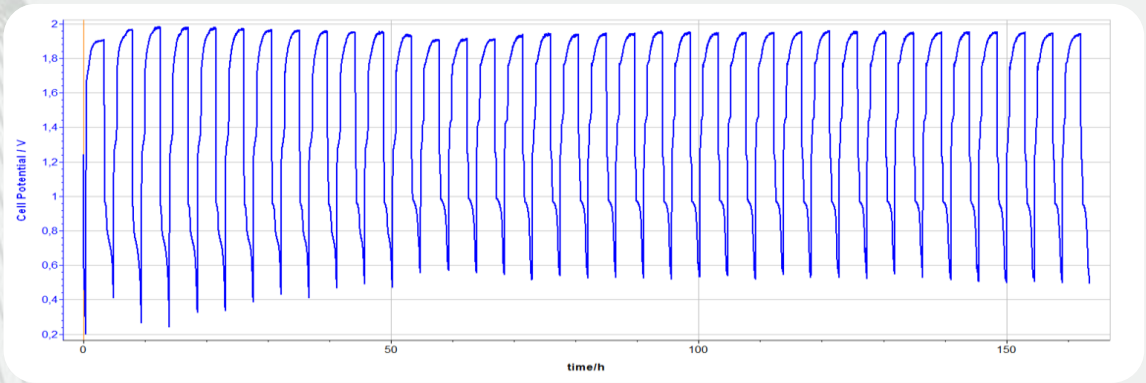
First nanomaterials for air cathode

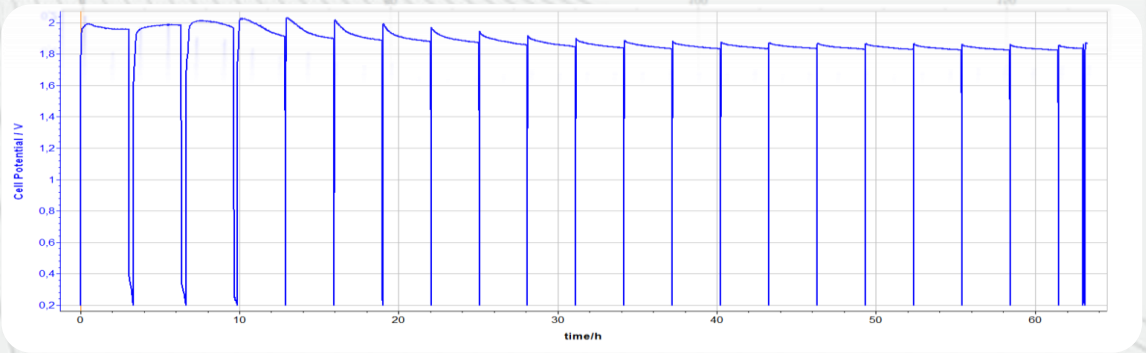


Manufacturing of first cathodes

Preliminary results

Manufacturing and testing of an iron/air cell made from commercial materials and components





Degradation of the air electrode (carbon based) after a few charge-discharge cycles

CONCLUSIONS

- NECOBAUT project focuses in the iron/air battery for automotive application
- Improvements on materials (use of nanomaterials) are planned to increase energy density and durability of the cell.
- The use of modelling and simulation will help to optimise the cell design
- The developed Fe-air cell will be tested according to automotive specifications
- Metal-air is seen as one of the future technologies to replace present Li-ion batteries
- Different metal-air batteries are under development, but they need to demonstrate their feasibility regarding performance, durability and cost.

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Thank you for your attention

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