Development of Rechargeable Aluminium Batteries

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OUTLINE

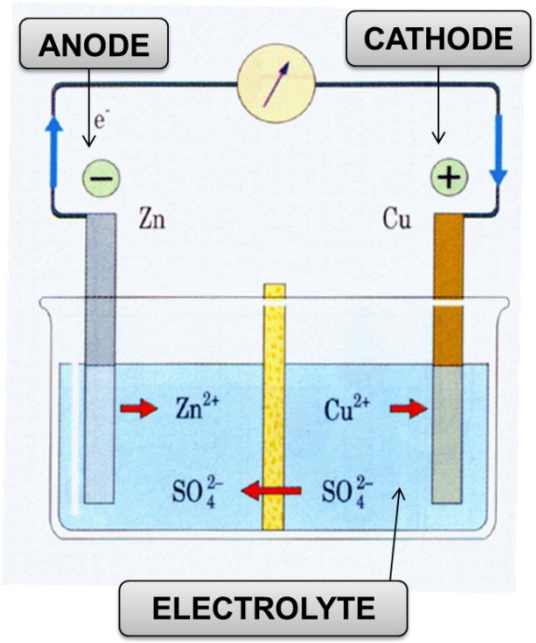
1. Context and State of the Art
2. Objectives
3. Methodology and Work plan
4. First Results

1. Context and State of the Art

PhD Context

Electrochemical E. Storage

Batteries concept & classification



PRIMARY BATTERIES

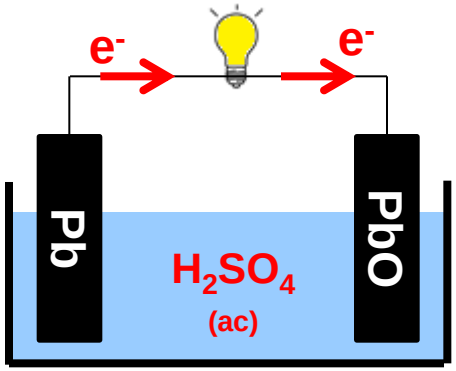
- Not electrically rechargeable
- Use, adaptability and maintenance

SECONDARY BATTERIES

- Electrically rechargeable
- Long life
- Wide range of applications
- Some technologies can be used

Batteries concept & classification

Lead-Acid Batteries



500-800 cycles

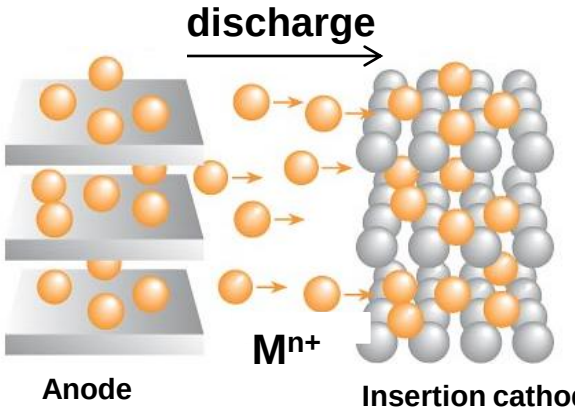
E: 50 Wh kg^{-1}

Low cost & maintenance

Poor electrochemical performance

Environmentally unfriendly

Metal-ion Batteries



Li-ion

E:120 Wh kg^{-1}
1200 cycles
90% efficiency

Electric Vehicle
Stationary Application

↑ Energy
↓ Cost

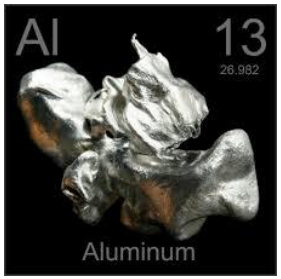
Advantages

- ↑↑ Gravimetric 3,86 Ah/g
- $E_{theo} \approx E_{gasoline}$ (11kWh/kg)

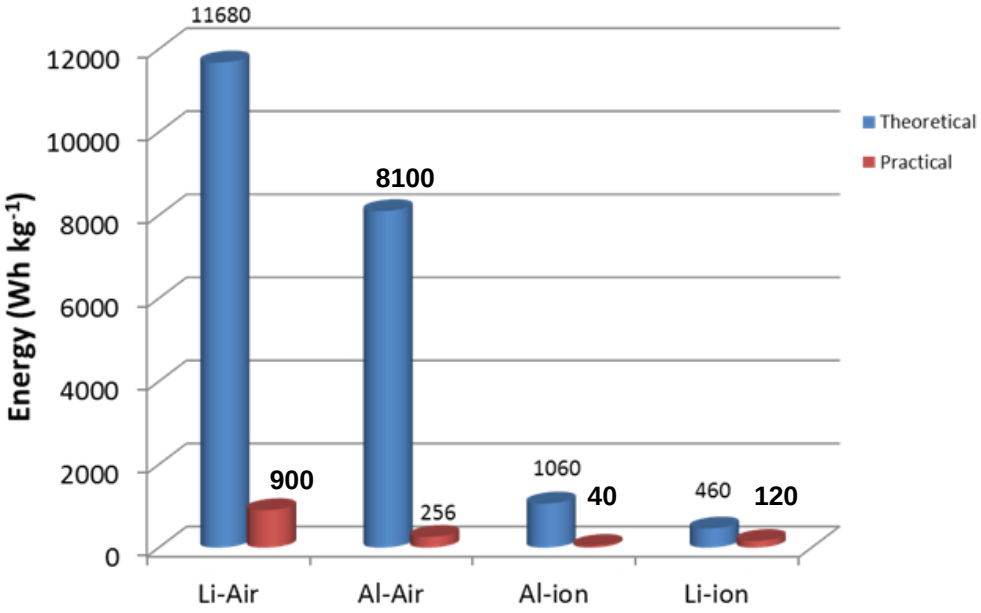
Disadvantages

- $E_{theo} >>> E_{real}$
- Production and Price
- React easily with water and oxygen in atmosphere conditions -> Li(OH)

Al-based Batteries: Al –Air & Al-Ion



- Third element most abundant in the crust earth (8,1%)
- Commercial and low cost (30 times lower than Lithium)
- Environmentally friendly
- Volumetric Energy four times more than Lithium
- Second highest theoretical energy



HIGH INTEREST IN DEVELOP SECONDARY BATTERIES BASED ON ALUMINIUM

ELECTRODEPOSITION AND ELECTROXIDATION OF ALUMINIUM IS NOT POSSIBLE IN AQUEOUS ELECTROLYTE

General objective and PhD Novelty

General Objective

To develop a Rechargeable Batteries based on Aluminium

Hypothesis

The development of non-aqueous electrolyte which can allow the electrodeposition and electroxidation of aluminium opens the possibility to develop secondary batteries based on aluminium.

PhD Novelty

Fundamental electrochemical study of each component that form the battery:

- **Novel Electrolytes : based on ionic liquids and organics**
- **Novel Electrodes:**
  - ✓ **To study different composition and geometries**
  - ✓ **Cathode electrodes for revesible intercalation and ORR/OER**

2. Objectives

OBJECTIVE 1

To develop electrolytes and to optimize electrodeposition reaction.

MILESTONE 1

To define electrolytes composition and define anode properties and characteristics.

OBJECTIVE 2

To do research on cathodes development.

MILESTONE 2

To define electrochemical properties and characteristics for cathode electrolytes.

OBJECTIVE 3

To design and to assemble prototypes.

MILESTONE 3

To obtain a elemental cell with specific properties by mean of key-materials selection

3. Methodology and work plan

OBJECTIVE 1

Task 1.1: To select and characterize electrolytes
- **Physicochemical analysis**
  TGA, FTIR & RAMAN
- **Electrochemical analysis: Ionic Conductivity (EIS) & ESW (LSV)**

Task 1.2: Al^{3+}/Al^{0} reaction on different substrates
- **Analyse how affect composition and morphology of electrode**
  Cyclic Voltammetry (CV)

Task 1.3: To evaluate the electrodeposits
- **Composition (XRD)**
- **Morphology (SEM)**

Task 1.4: Evaluation of Al^{3+}/Al^{0} reaction
- **Efficiency and reaction potentials**
  Galvanostatic charge-discharge(CD)

OBJECTIVE 2

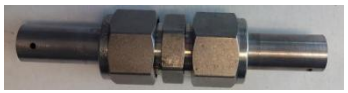
Task 2.1: To define and investigate cathode materials
- **Air-Cathode**
- **Insertion materials**

Task 2.2: To synthetize and characterize of materials
- **Physicochemical analysis**
  BET, SEM, XRD & XPS

Task 2.3: Electrochemical characterization
- **Half-cell characterization**
  CV & CD

OBJECTIVE 3

Task 3.1: To select cell components and assemble a prototype



Task 3.2: Electrochemical characterization
- **Determine battery parameters**
  EIS, CV & CD

3. Methodology and work plan

Financial support

Retos Colaboración 2015 Project

3 Companies

- Aleastur
- GFM
- Albufera Energy Storage

MINECO

Financial Support

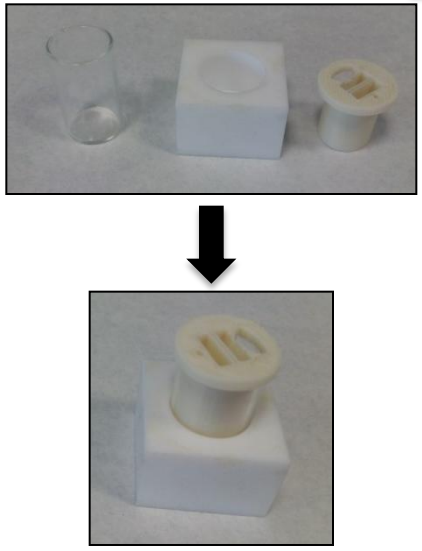
2 Research Centres

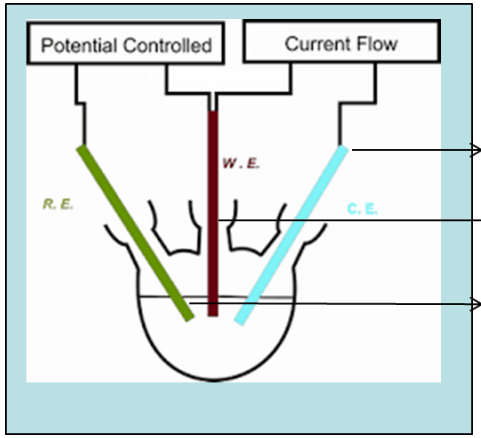
- IMTA
- IMDEA Energy Institute

Expected Impact

- To develop a future technology to store energy based in aluminium
- Low cost and environmentally friendly technology
- Application: portable devices, electric vehicles and stationary applications
- Alternative to Lead-Acid and Li-ion batteries.

Reversibility of Al^{3+} / Al^0 reaction





CE *(Counter electrode)*: Al Foam

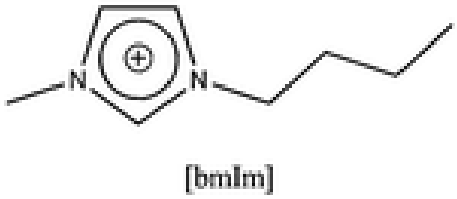
WE *(Working Electrode*

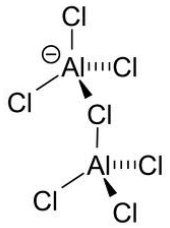
RE *(Reference Electrode)* : Al wire

Relación molar 2:1 $AlCl_3$:BMImCl

MATERIALES

- **Al Foil**
- **Stainless Steel**
- **Expanded Graphite**



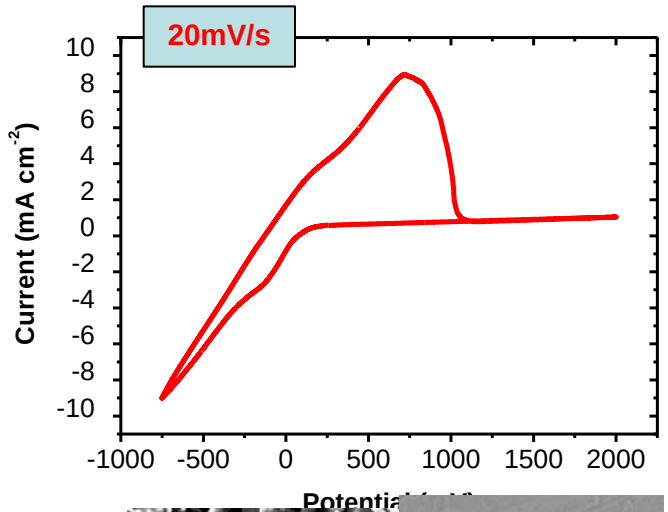


Surface & Coatings Techonology 201, 1-2, 1-9 (2006)

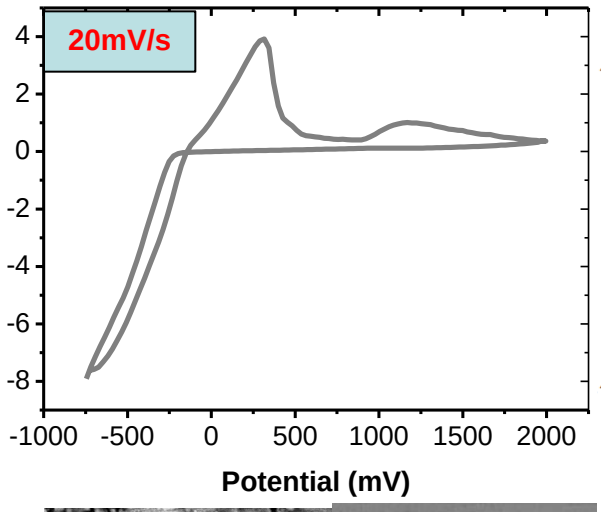
Chloroaluminate ionic liquids → **Acidic media** → **↑ Molar ratio $AlCl_3$:EMImCl**

4.1 Reversibility of Al^{3+} / Al^{0} reaction

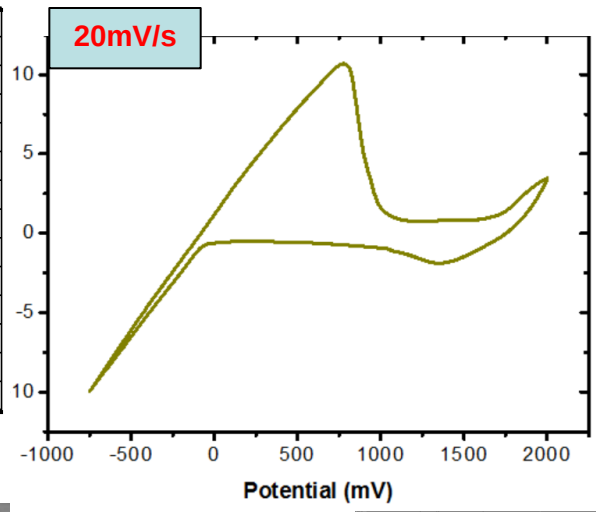
Aluminium Foil



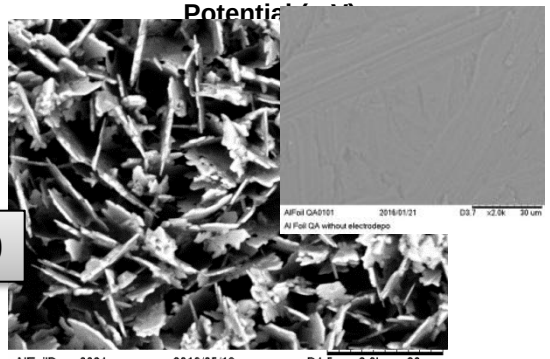
Stainless Steel

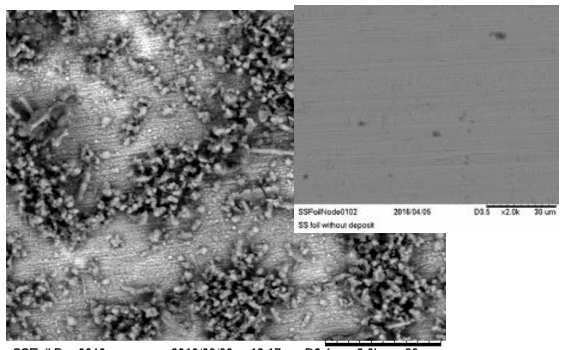


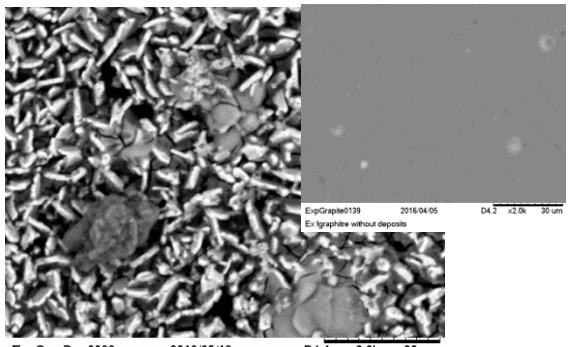
Expanded Graphite



X2000







Choloroaluminate ILs can carry out plating/stripping of Al at RT

Electropodeposition is possible on different substrate

4. First Results

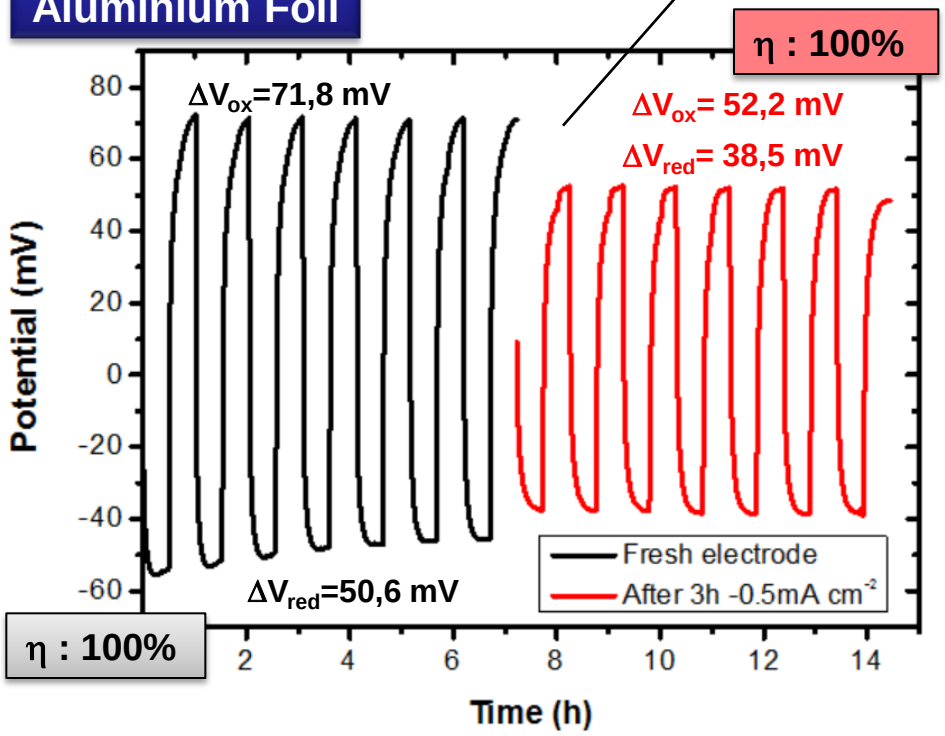
Reversibility of Al^{3+} / Al^0 reaction

Reduction-Oxidation
±0,5mA cm^{-2} Time 30 min

Aluminium Foil

Rv_{ox}30%

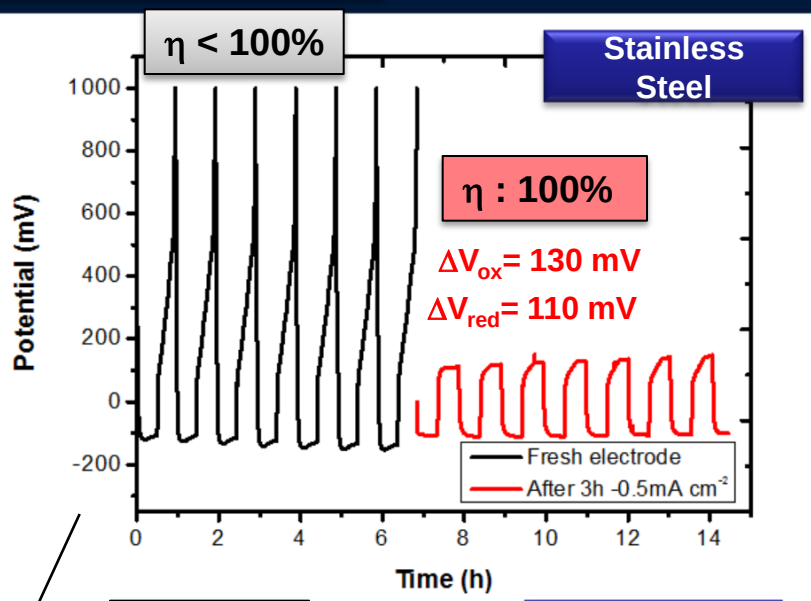
Rv_{Red}24%



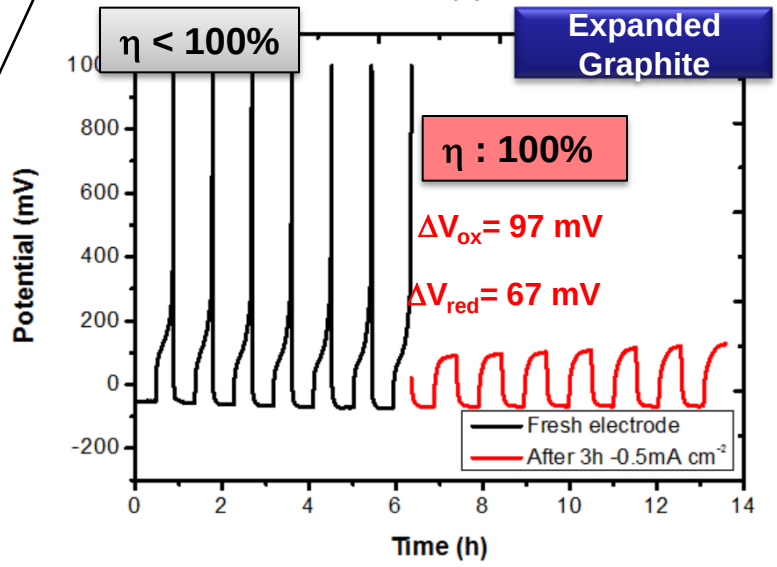
Changes in surface in Al foil reduce overpotential

Long reduction Up efficiency to 100%

Stainless Steel



Expanded Graphite



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Thank you for your attention

Comments & Suggestions are welcome

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