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Carbon Materials and Environment / Electrocatalysis & Polymer Electrochemistry : Research Activities

Ángel Berenguer Murcia

March 24th 2015

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MCMA

GEPE
Group of Electrocatalysis & Polymer Electrochemistry

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Research groups line-up

MCMA

GROUP MEMBERS

- 4 Professors
- 6 Lecturers
- 1 Senior Researcher
- 2 Post-doctoral Researchers
- 2 Research Technicians
- 16 PhD Students

GEPE
Group of Electrocatalysis & Polymer Electrochemistry

GROUP MEMBERS

- 1 Professor
- 3 Lecturers
- 1 Post-doctoral Researcher
- 1 Research Technician
- 6 PhD Students

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MAIN RESEARCH TOPICS (ENERGY)

- Preparation of porous materials
- Supercapacitors
- Fuel Cells
- Energy storage (Hydrogen, methane, etc.).
- Gas storage for environmental applications (CO_2).
- Gas purification (membranes, microreactors)
- H_2 sensors

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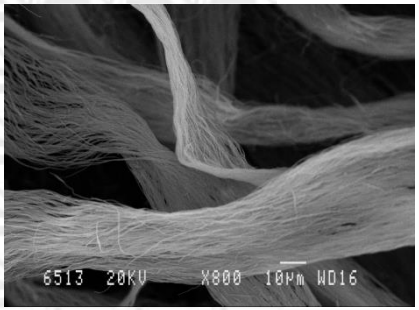
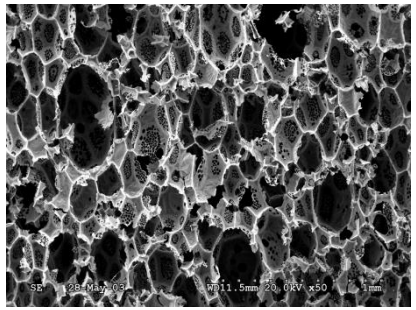
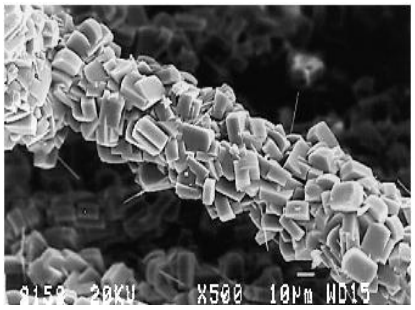
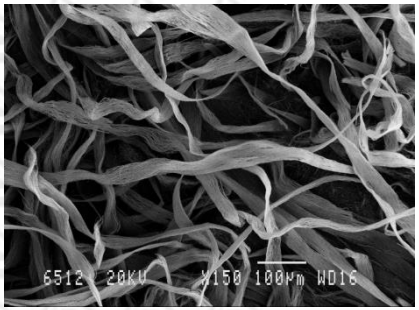
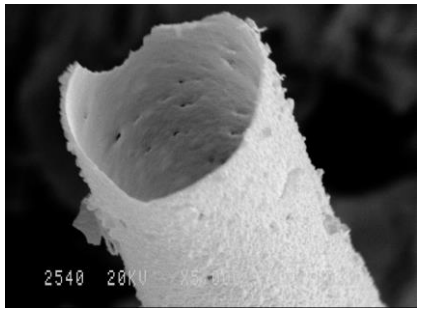
Preparation of porous materials

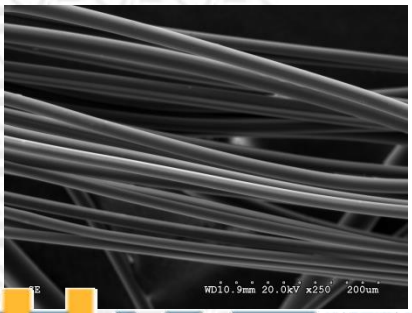


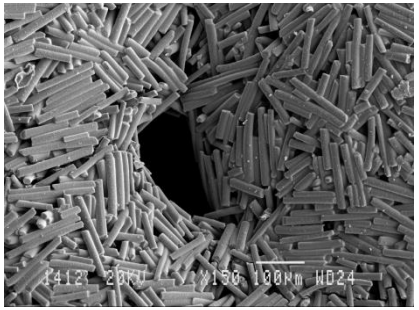












- Carbon fibres
- Carbon nanofibres
- Molecular sieves
- Activated carbons
- Composites
- Zeolites
- Ordered mesoporous materials
- Ceramics (TiO_2, Al_2O_3, SiO_2, $CeO_{2,...}$)
- Monoliths

...

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Characterization of porous materials

ASAP 2020

μSAXS of the ESRF Grenoble (France)

Autosorb 6 (Quantachrome)

High P adsorption equipment

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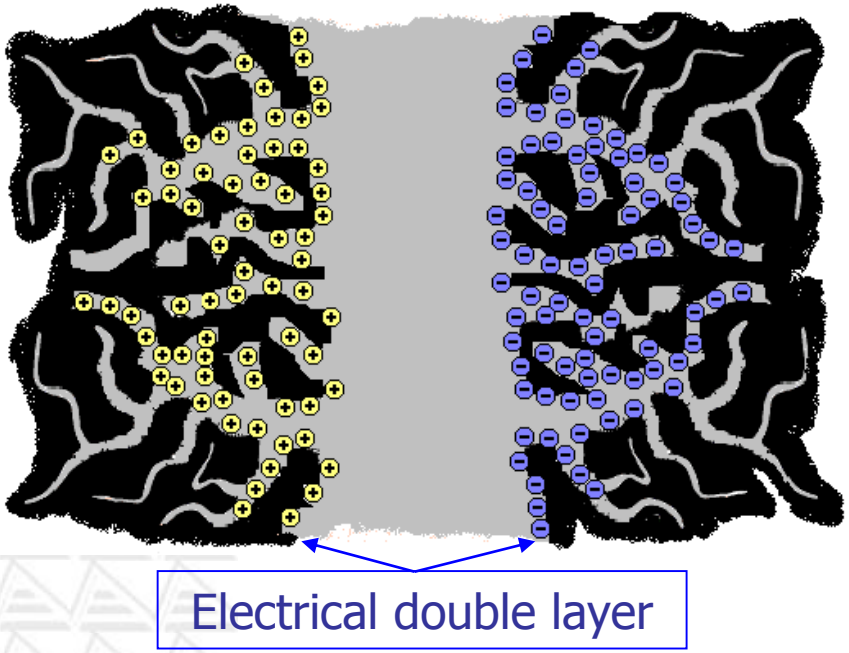
Supercapacitors: Development of Materials and Configurations

- Double-layer capacitors based on carbon materials
- Great versatility

Scheme of an activated carbon



Electrical double layer

- **Low cost**
- **Simple and established process**
- **High surface area**
- **Tunable porosity**
- **Surface chemistry**
- **High density**
- **Chemical stability**
- **Electrical conductivity**

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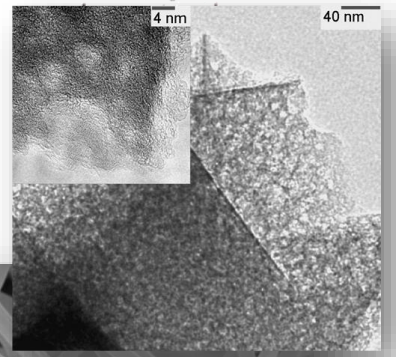
Advanced Carbon Materials for Supercapacitors

- **Highly microporous (> 3000 m^2/g) activated carbons**

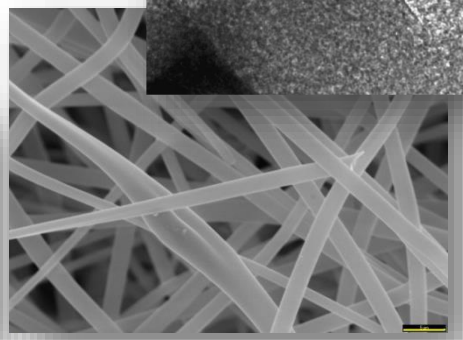
➢ Very high capacitance value in aqueous (320 F/g) and organic (200 F/g) media

- **Hierarchical micro/mesoporous nanocasted carbon from biomass residue**



➢ Enhanced ion mobility for high power density devices

- **Activated Carbon fibers and nanofibers**



➢ Microporosity is more accesible for high power applications

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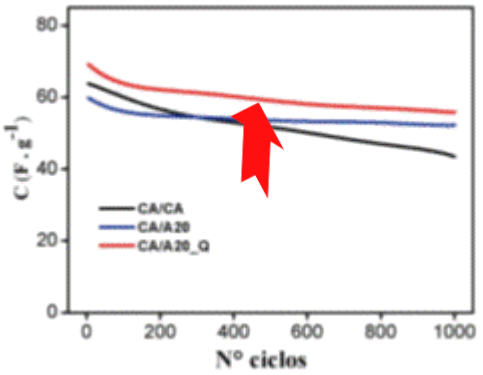
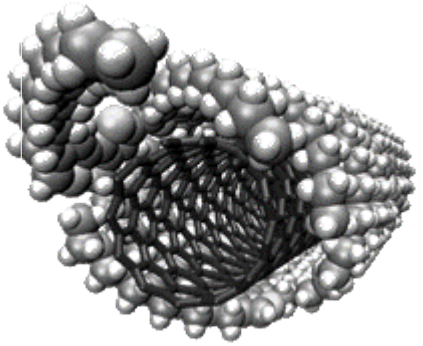
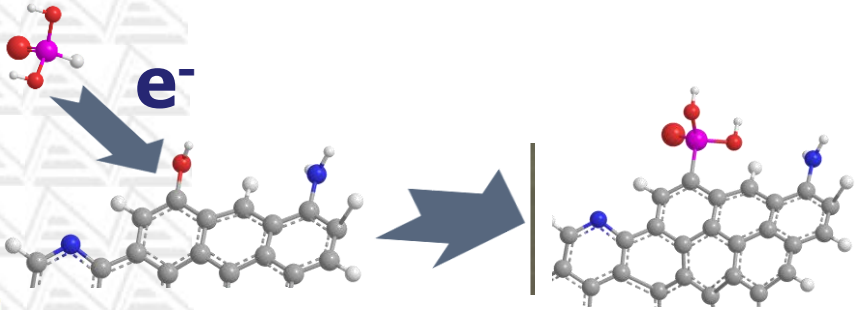
Supercapacitors: Tuning Carbon Materials

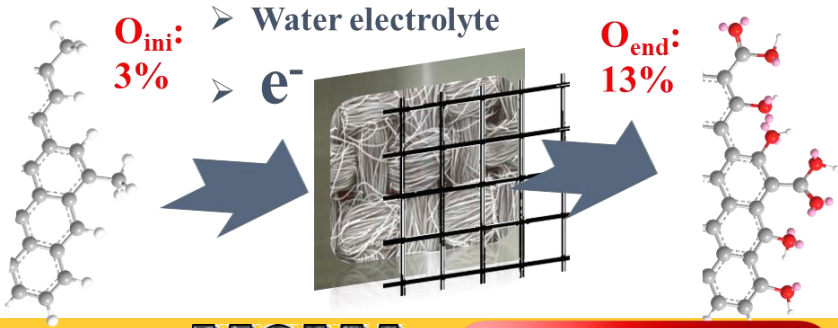
- **Carbon/Electroactive polymers hybrid materials**
  - Enhanced energy density and durability
  - Thin films inside the porosity of activated carbons or over CNT surface





- **Modification of the surface chemistry by heteroatoms**
  - Precise control of the amount and type of functionalities with low pore blockage





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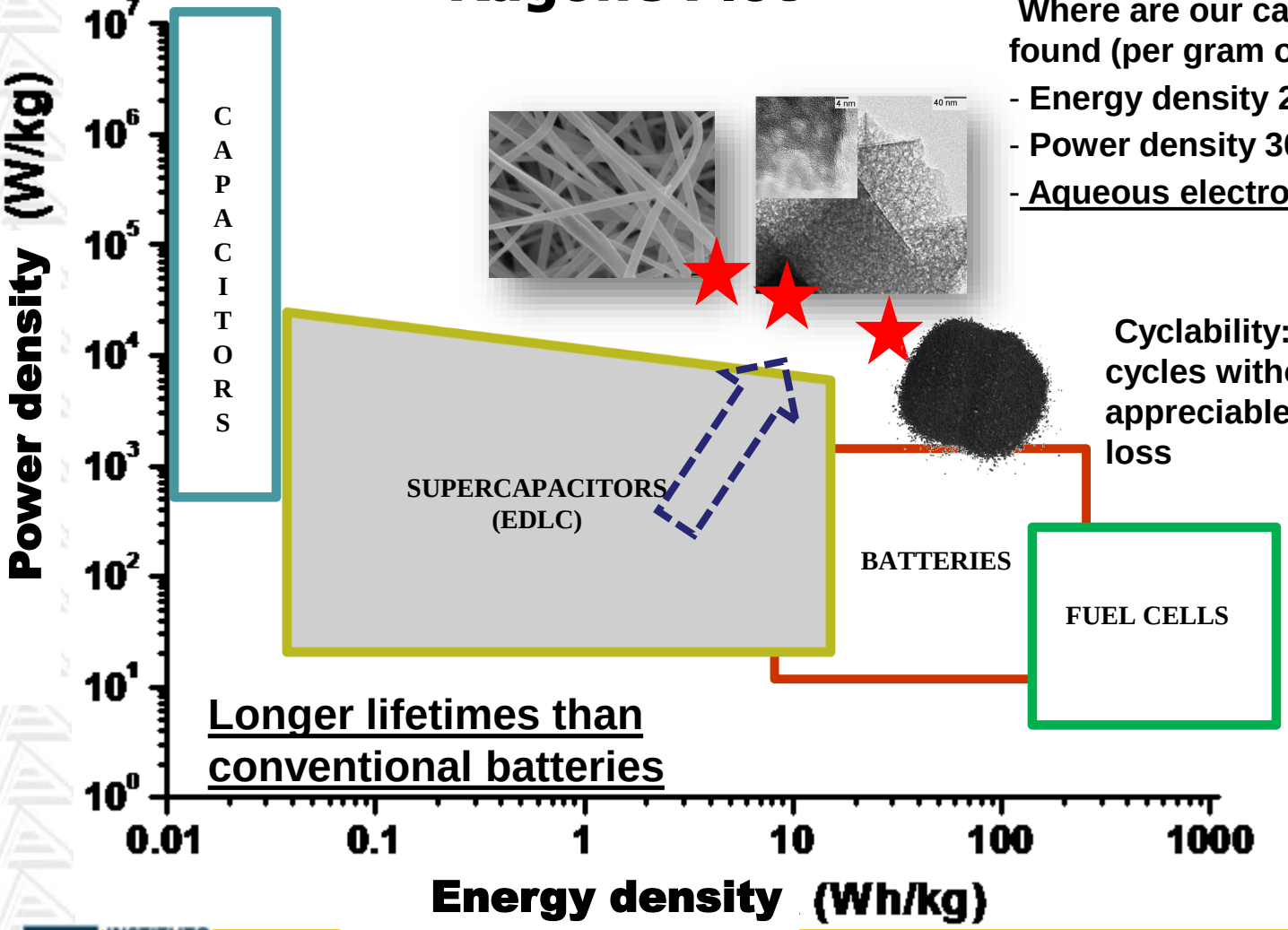
Ragone Plot



Where are our capacitors found (per gram of material)?

- Energy density 25 $W \cdot h \cdot kg^{-1}$
- Power density 30 $kW \cdot kg^{-1}$
- Aqueous electrolyte

Cyclability: >10000 cycles without an appreciable efficiency loss

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Gas and Energy storage

- Materials with tailored porosity
- CH_4 (up to 140 v/v) and CO_2 storage (up to 3 mmol/g)
- High-pressure H_2 adsorption (materials with up to 7 wt% capacity at 77K)

Spin-off company

g2m TECH

- Gas 2 Materials Technologies provides state-of-the-art adsorption equipment
- Manufacturers of Quantachrome´s iSorb HP1 and HP2, and VStar

Adsorption at 200 bar

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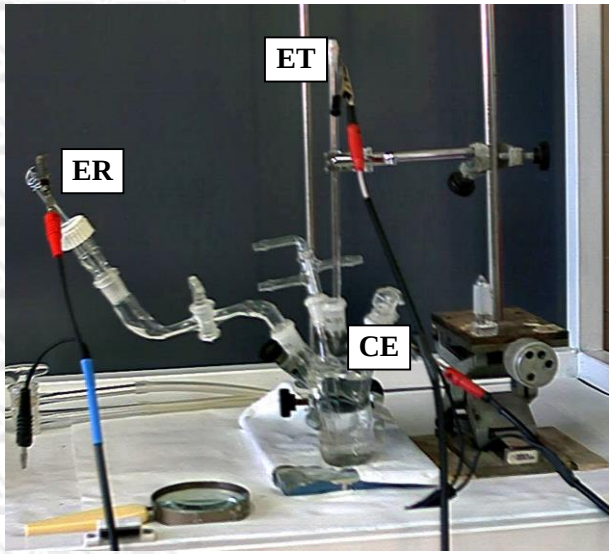
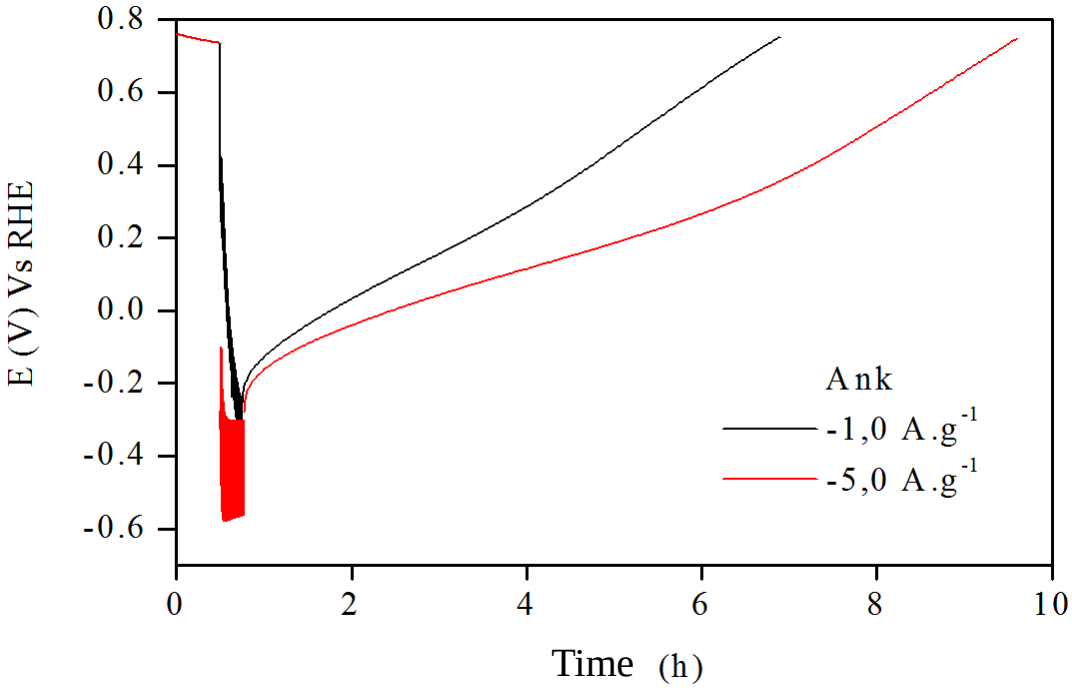
Gas and Energy storage

- Electrochemical hydrogen storage
- Storage capacity at ambient conditions (over 0.8 wt%)





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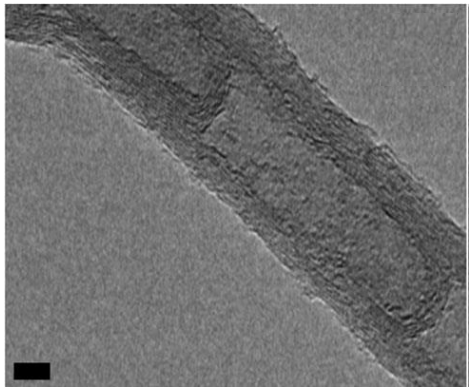
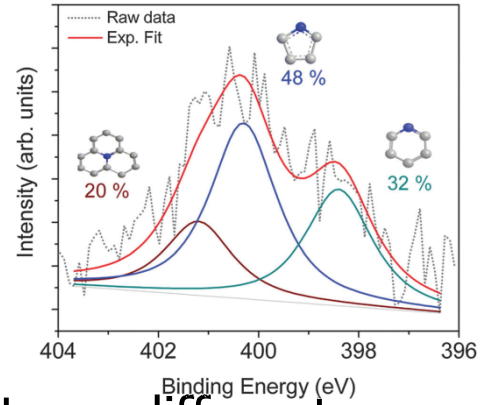
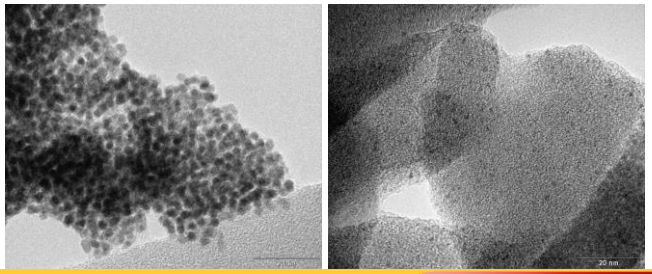
Fuel Cells

- Active materials for the Oxygen Reduction Reaction (ORR)
- Precious metal-free electrode materials
  - Heteroatom-doped tailored hierarchical carbon materials
  - Electrochemical functionalization





- Preparation of electrocatalysts on different supports
  - Conductive polymers (e.g. PANI)
  - Nanoparticle-doped materials
  - and their combinations…



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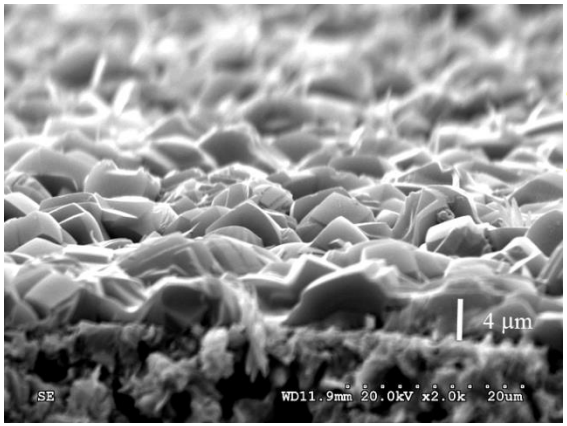
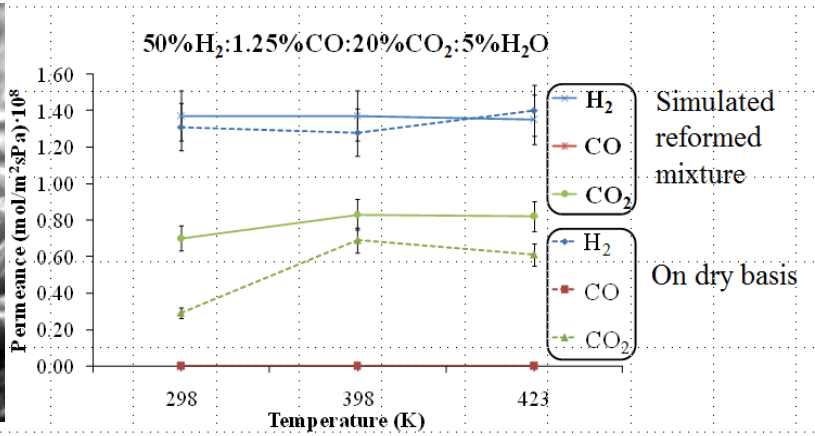
Hydrogen Purification

Inorganic composites

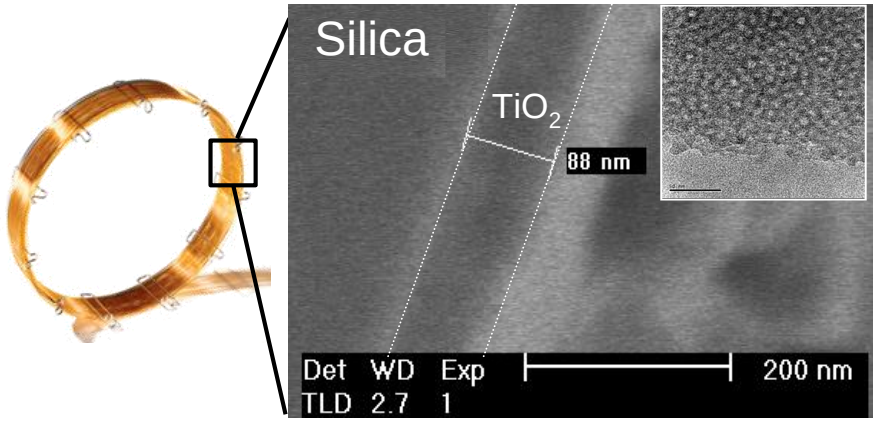
Zeolite LTA/C membrane





Hierarchical materials

PrOx microreactor



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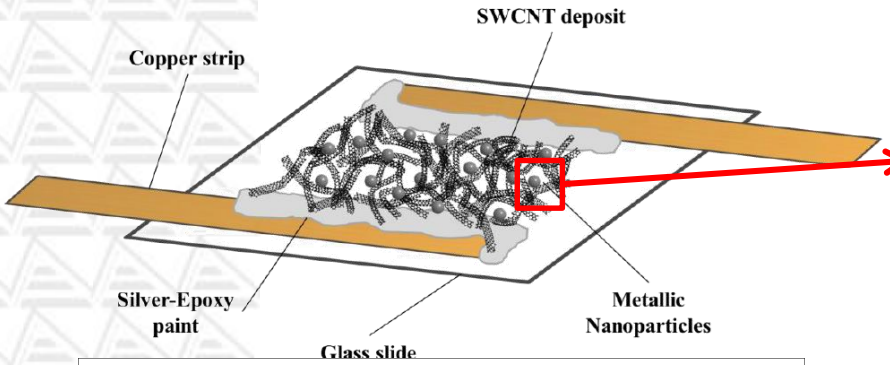
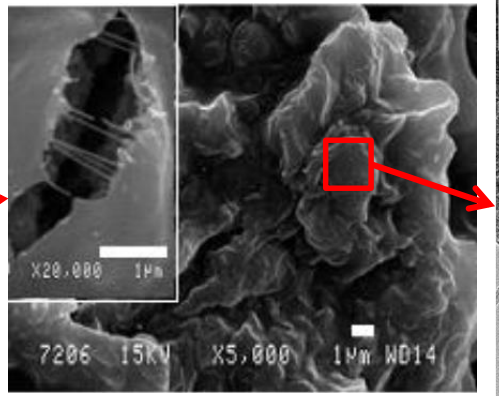
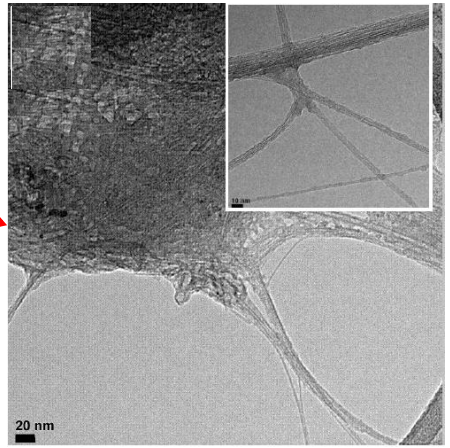
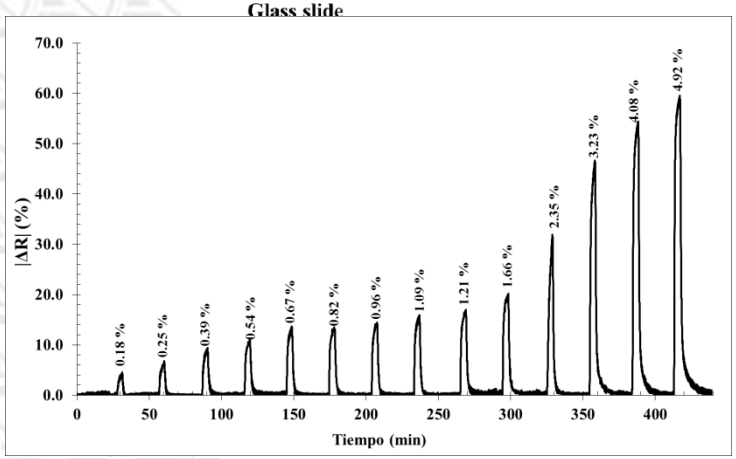
H_2 sensors (Spanish Patent ES201300598)

- Pd-doped carbon nanotubes
- Low cost, high efficiency sensors









- Low response and recovery times
- Simple preparation method
- High reproducibility

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OTHER INTERSECTING TOPICS (WATER)

- Pollutants removal in aqueous phase by adsorption
- Nanostructured electrode design for emerging pollutants removal
- Electroadsorption in porous carbon materials
- Activated carbon regeneration (thermal and electrochemical)

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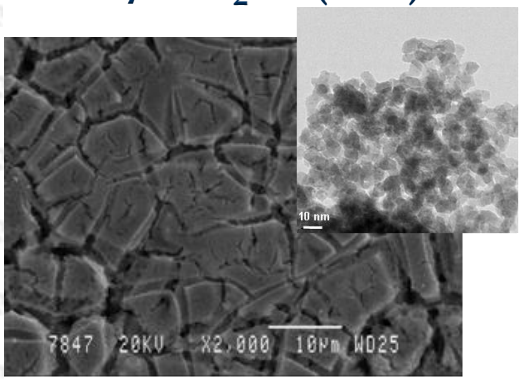
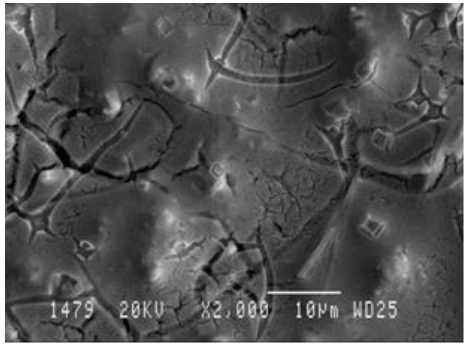
Pollutants Removal by Electrochemical Treatment

- Development of nanostructured electrode materials for pollutants removal
- Simple wet chemical approach

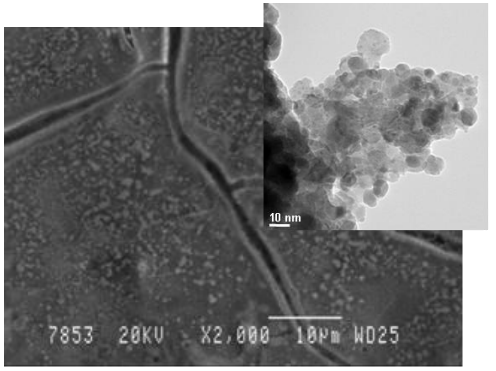
Ti/SnO_2-Sb(13%)



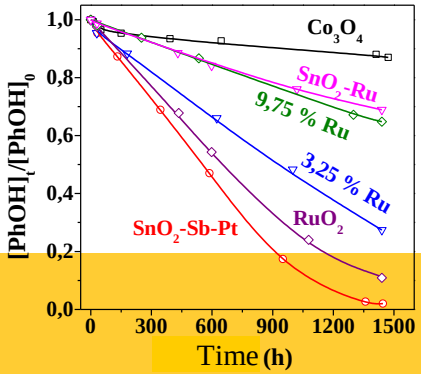
Ti/SnO_2-Sb(13%)-Pt(3%)



Ti/RuO_2



- Organic and inorganic pollutants removal
  - Phenol



  - Inorganic: Removal of cyanide anions using nanostructured $Cu_xCo_{3-x}O_4$/Ti nanostructured electrodes (≈100 removal)

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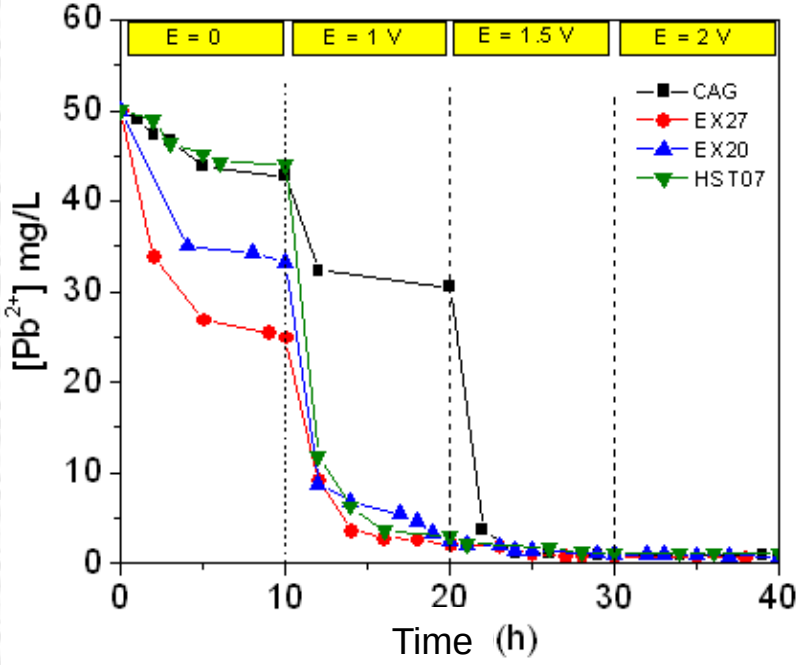
Organic and Inorganic Pollutants electroadsorption

- Removal of Lead (Pb), Arsenic (As) and herbicides (8-quinoline carboxylic acid) from industrial waste
- Electroassisted adsorption greatly improves the performance of conductive materials



- At pH=5 more than 99% of the Lead can be removed from an effluent (50% adsorption)
- At pH=8 more than 80% of the Arsenic can be removed from an effluent with 50 ppb of pollutant (39% adsorption)
- 25 mg/g AC adsorption of 8-QCA using elctroadsorption (100% improvement over conventional adsorption)

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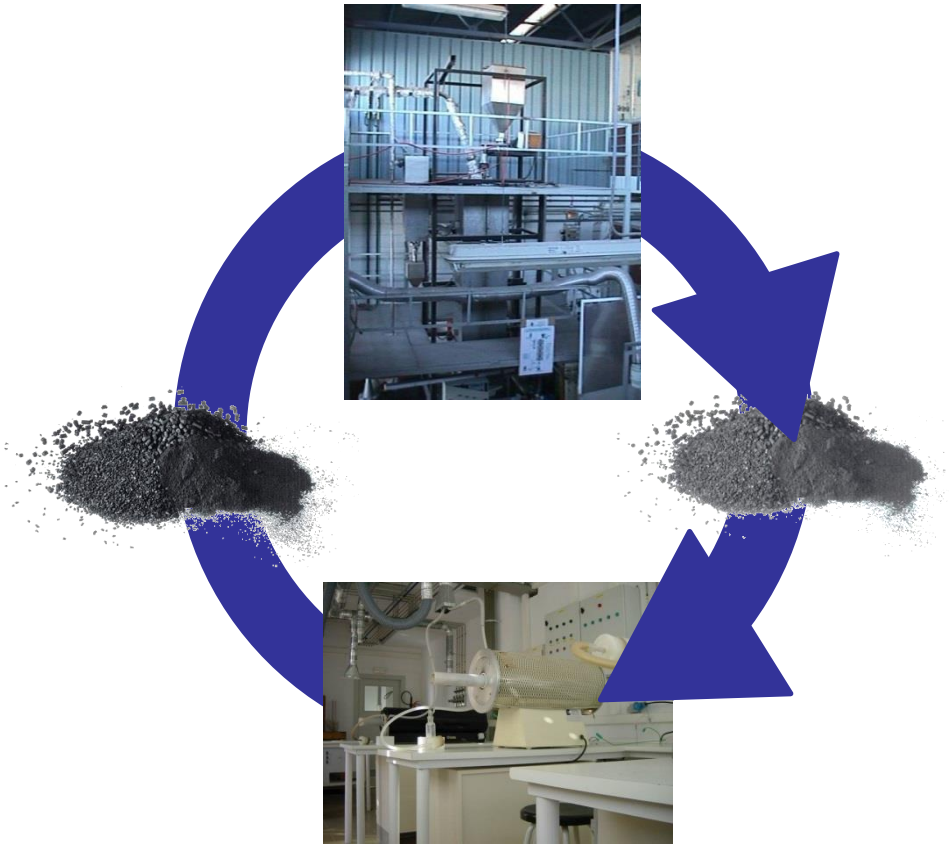
Activated Carbon Regeneration: Thermal

- Our research group has all the necessary equipment



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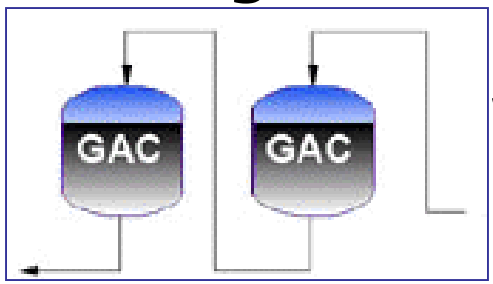
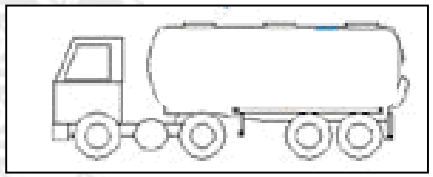
Activated Carbon Regeneration: Thermal

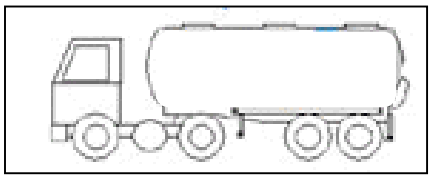
Reactivated carbon installed in adsorber



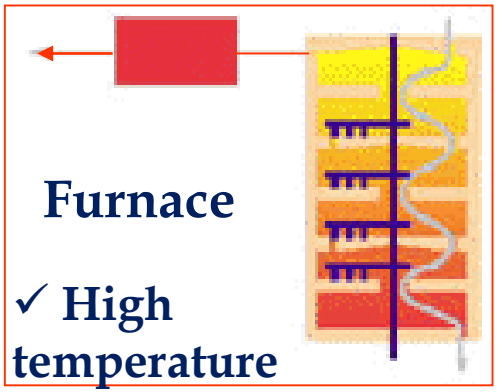
Exhausted AC removed from costumer site



Off gas treatment for complete destruction of adsorbed organic compounds



Carbon IN



Carbon OUT

Reactivated AC transported to site

Exhausted AC transported to reactivation center

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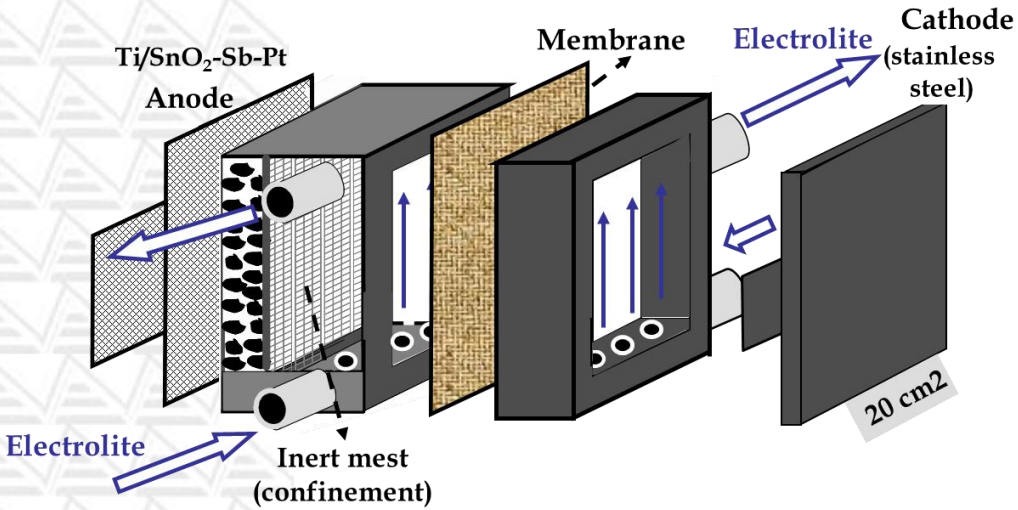
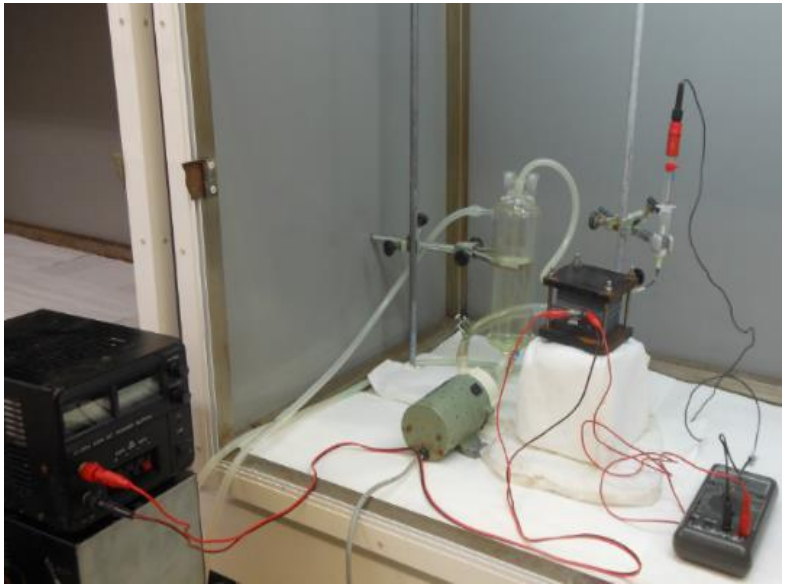
Activated Carbon Regeneration: Electrochemical

- Several advantages compared to thermal
  - In situ operation
  - Low energy consumption
  - Only one reagent required (electron)
  - Adsorbate may be removed, modified or recovered
  - Ambient pressure and temperature





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Experience in Framework Programmes

- Participation in various Joint Research Projects
- Focus on specifics calls on Nanomaterials and Energy
- Ongoing project: "INNOVATIVE ECO-FRIENDLY ACTIVATED CARBON FILTERS FOR HARMFUL VAPORS & GASES VOC PURIFICATION. (CARVOC)"
- The main challenge is the formation of a strong research consortium
- Some examples of open calls:
  - Large scale energy storage: LCE-09-2015
  - ERA-NET on Materials (inc. Materials for Energy):NMP-14-2015

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What makes a strong consortium?

- The project itself must target directly and specifically the call for which it is intended
- Multi-, Inter-, and/or Transdisciplinary character
- Involve SME and Large companies (preferably as coordinator)
- Strong application drive (Company/nies driven)
- How to build one?
  - Making a consortium takes time
  - Build up international visibility (papers, conferences, patents…)
  - Team-up in guest research stays (incoming, outgoing)
  - Develop a focused (and if possible ample) research expertise

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Carbon Materials and Environment / Electrocatalysis & Polymer Electrochemistry : Research Activities

Ángel Berenguer Murcia

March 24th 2015

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