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Development of composite and hybrid materials from gasification biochar and clay

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OUTLINE

I. Introduction

II. Biochar

III. Clay

IV. Applications

V. Conclusions

I. Introduction

Widespread utilization of Carbonaceous and Clay materials

- ✓ Carbonaceous materials including carbon black, carbon fibers, carbon nanotubes (CNTs) and graphenes are of great interest
- ✓ Carbonaceous materials can derive from renewable resources such as Biomass and Biogenic waste

- ✓ New momentum for clay energy based materials, clay bricks, clay geopolymer mortars, clay sorbents, clay biopolymer fillers
- ✓ Raw natural clay from deposite sites or processed by chemical/thermal/mechanical treatment with additives

- ✓ Engineered biochars / clays composites for various applications

Hybrid: mixture of two or more materials to obtain a material with new properties

Composite: mixture of carbon materials with inorganic or organic matter to produce a new material with structural and functional properties

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II. Biochar - Biochar production

BIOGREEN® introduction

Thermochemical conversion – range of applications

100- 150°C

Drying

A dehydration with the release of light hydrocarbons

GAS

250 - 280°C

Torrefaction

a mild form of pyrolysis dedicated only for biomass conversion. Torrefaction leads to obtaining dry product with higher energy content. Main product is biocoal - yield between 70 and 80%

BIOCOAL

300 - 550°C

MT pyrolysis

enables chemical conversion of products like biomass, plastic, or rubber into a solid, liquid or gas phase. Enables valorization to biooil and biochar. Yield of biooil ranges from 30 to 60%.

Yield of biochar 25 to 35%

BIOOIL, **BIOCHAR**

600 - 900°C

HT pyrolysis & gasification

conversion most of the feedstock into methane-rich syngas which can be valorized into energy by using it CHP unit or steam boiler. Yield of syngas ranges from 50 and 95%

SYNGAS

$CO+H_2$

SO_x CO_2 CH_4 PAH NO_x

Biochar is biomass dependant !

By-product for plant extract

Wood sawdust

Crop residue

Green waste

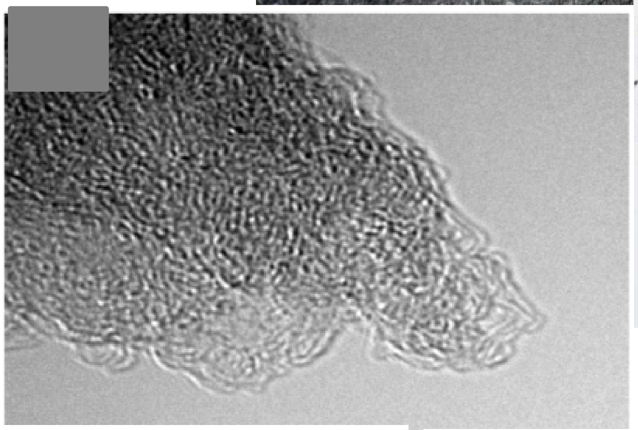
BIOCHAR PROPERTIES DEPENDS ON BIOMASS AND OPERATING CONDITIONS

II. Biochars

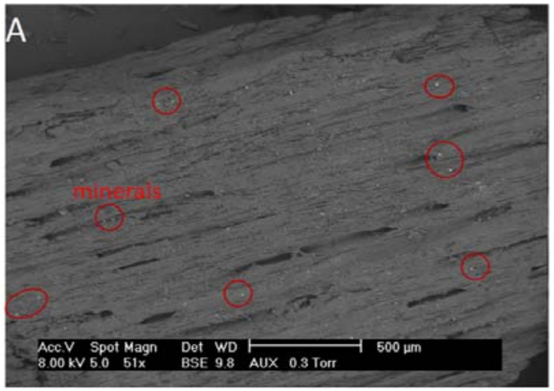
Energy
Fuel cells
photovoltaic
Supercapacitors

Chemistry
Catalyst
Adsorbent
Water treatment

Environment
Carbon sequestration
CO_2 Storage
Sensors



Agronomy
Water retention
Plant nutrients
Soil conditioner

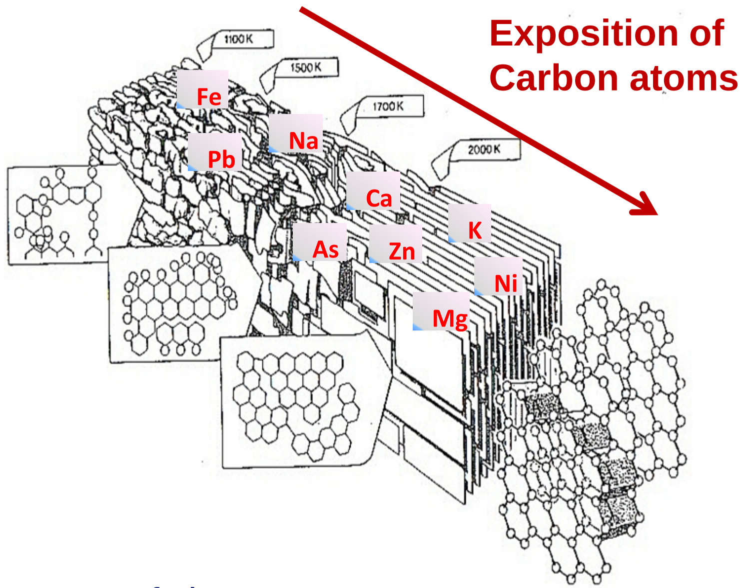


Reinforcing materials in polymer composites. Biocomposites

Other uses
Biomedical use Pharmaceutical
Gas storage

II. Biochar

Structure



Structure of chars vs temperatures towards graphitic structures

Carbonaceous matrix:

Aromatic units /

O within heterocyclic and phenolic group /

Aromatic units cross-linked by ether and olefine

Van Krevelen plot for biochar

Various material forms within the black carbon defined by the range in the oxygen to carbon (O/C) ratio :

Increasing O/C ratio ↑

Biomass (O/C > 0.6)

Biochar (0.4 < O/C < 0.6)

Charcoal (0.2 < O/C < 0.4)

Soot (0 < O/C < 0.2)

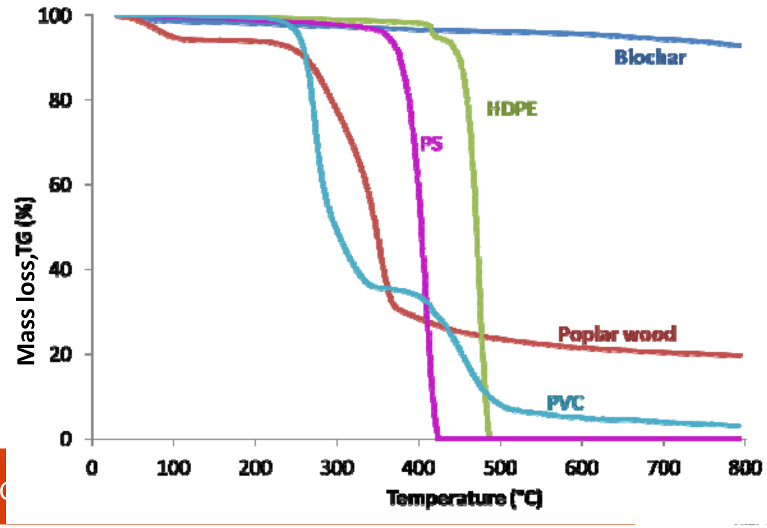
Graphite (O/C = 0)

150°C ↓ 1000°C

T ↗

H/C ↘

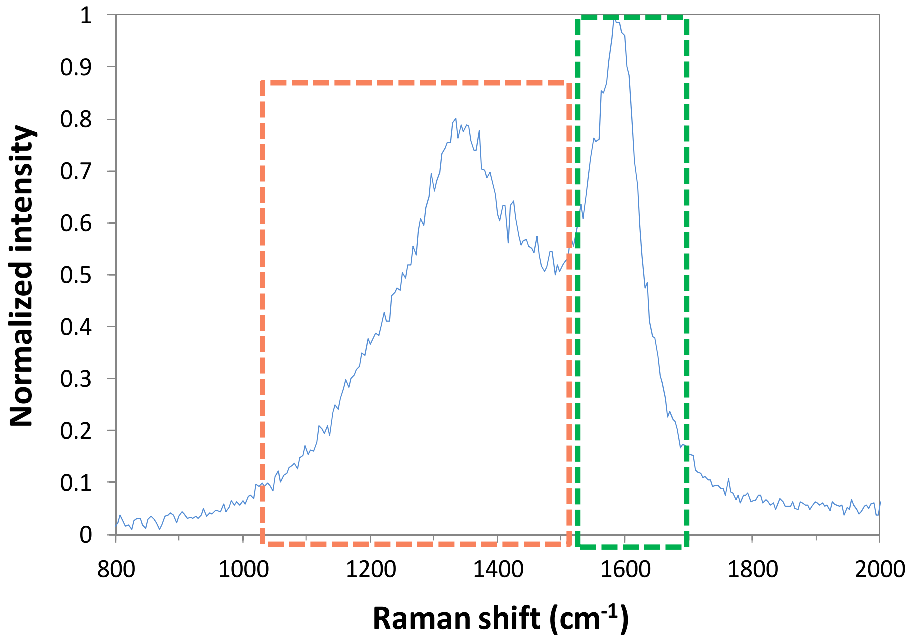
Biochar stability



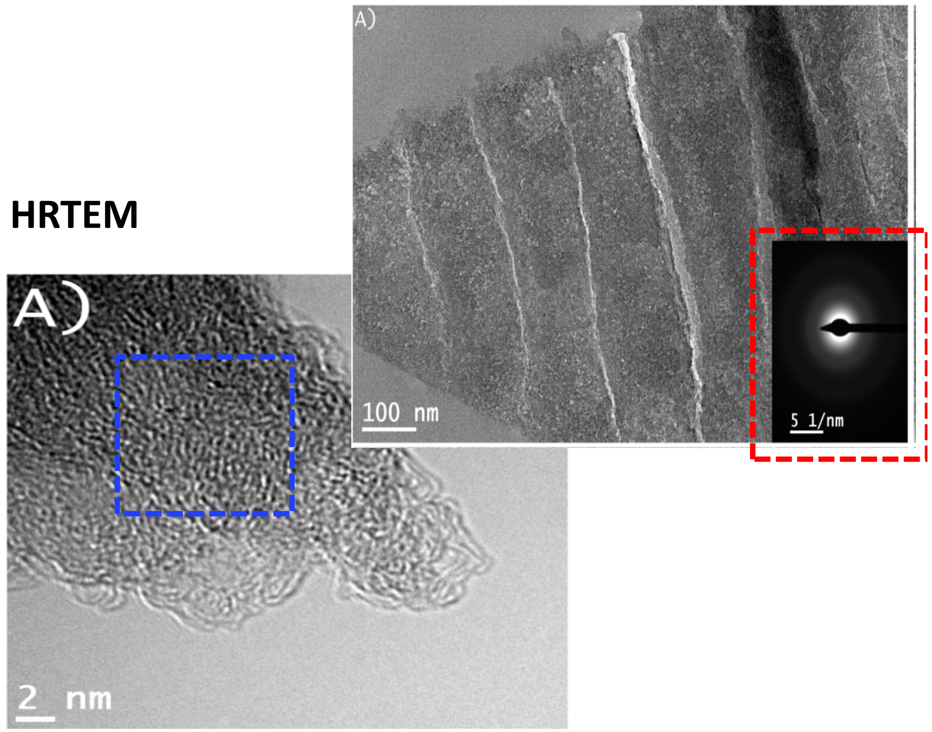
II. Biochar

Carbon structure of the raw biochar

Raman spectrum



HRTEM



- Raw biochar **complex carbon** containing:

- Ordered structures

- Disordered structures

- turbostratic carbon:

- Diffuse SAED

- No organization of the graphene layers

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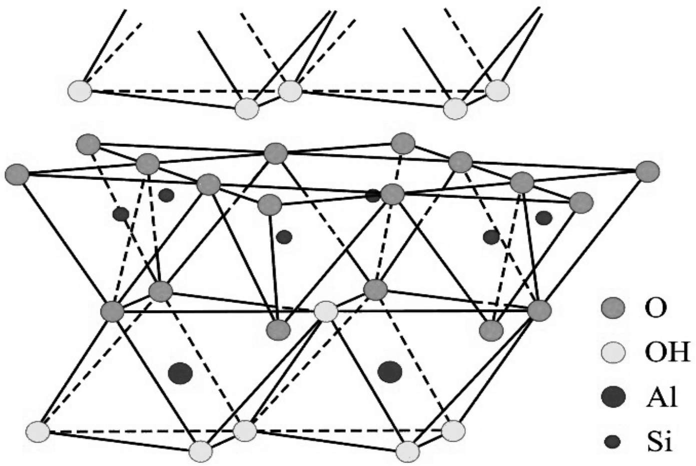
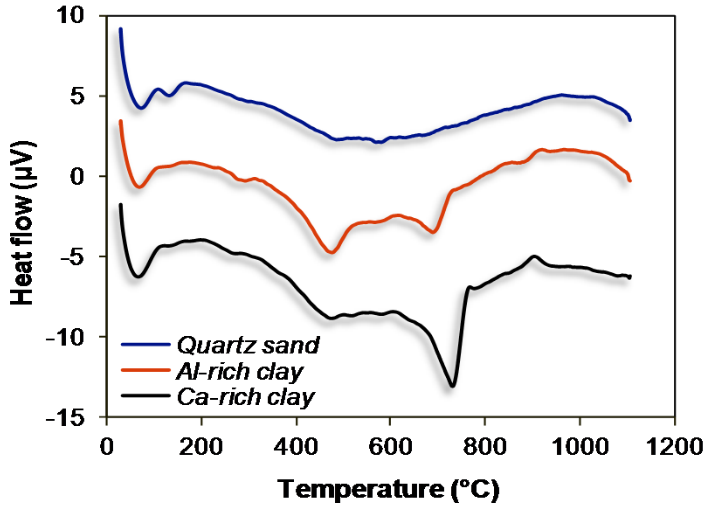
III. Clay

Stability and structure

Stacking of alumina and silica sheets





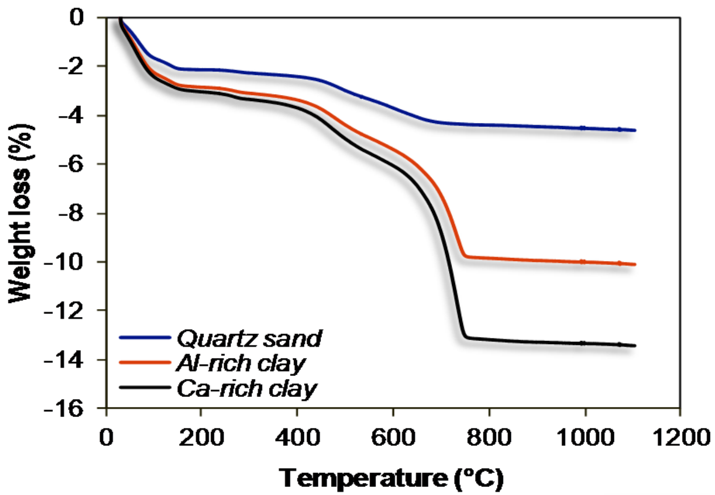
Dehydroxylation of clay minerals at 500°C:

$$KAl_3Si_3O_{10}(OH)_2 \rightarrow KAl_3Si_3O_{11} + H_2O$$

Degradation of calcium carbonates at 700°C:

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$$

Combination as stable silicates up to 1200°C



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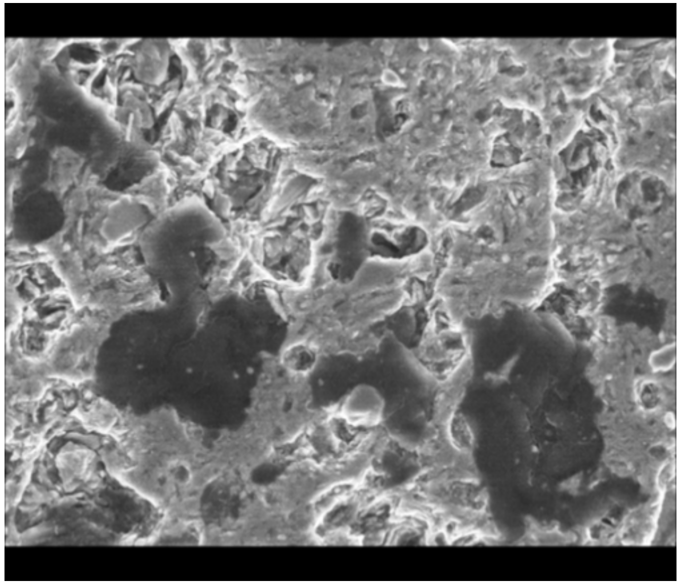
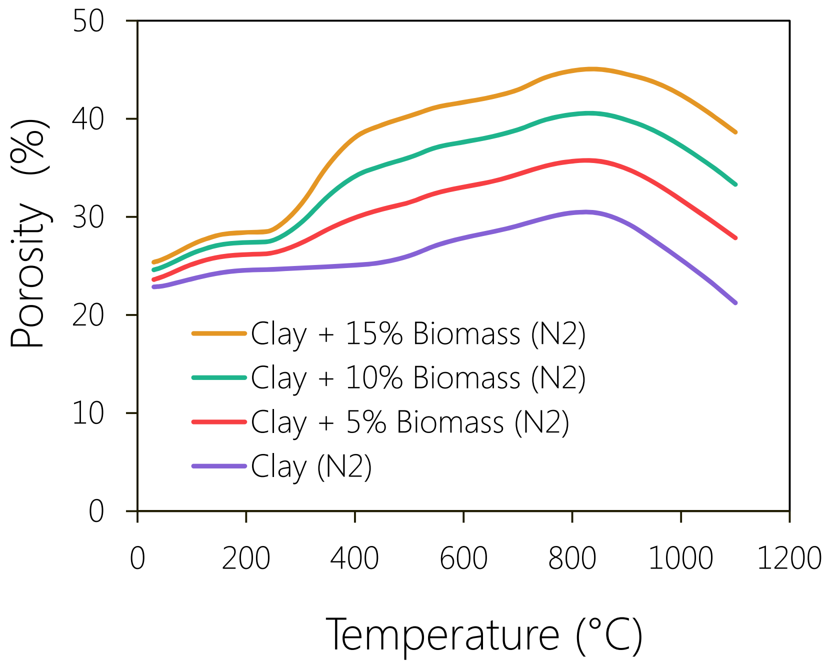
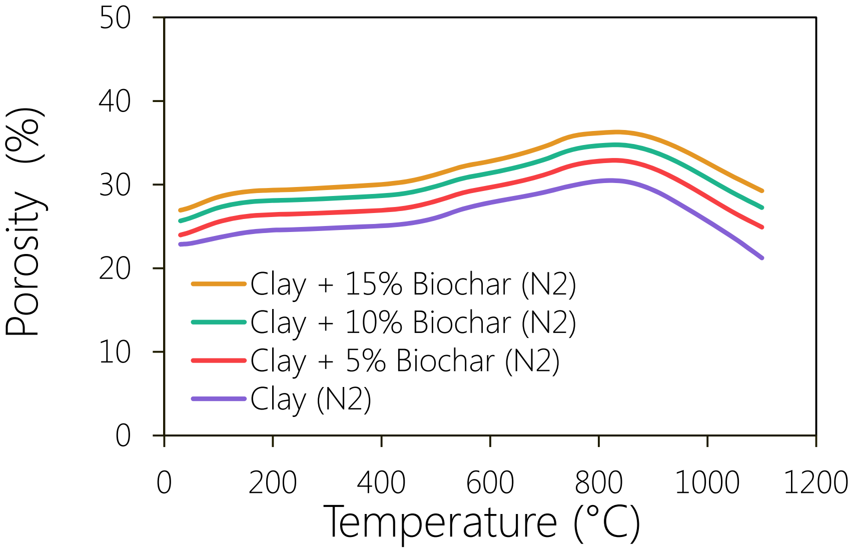
❖ **Control of the porosity rate and morphology of the composites**



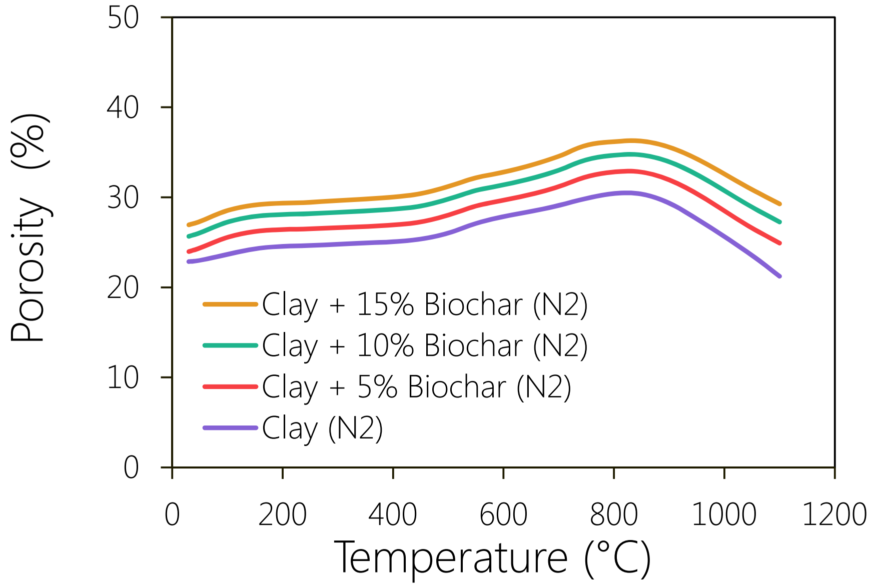
Release of H_2O and CO_2

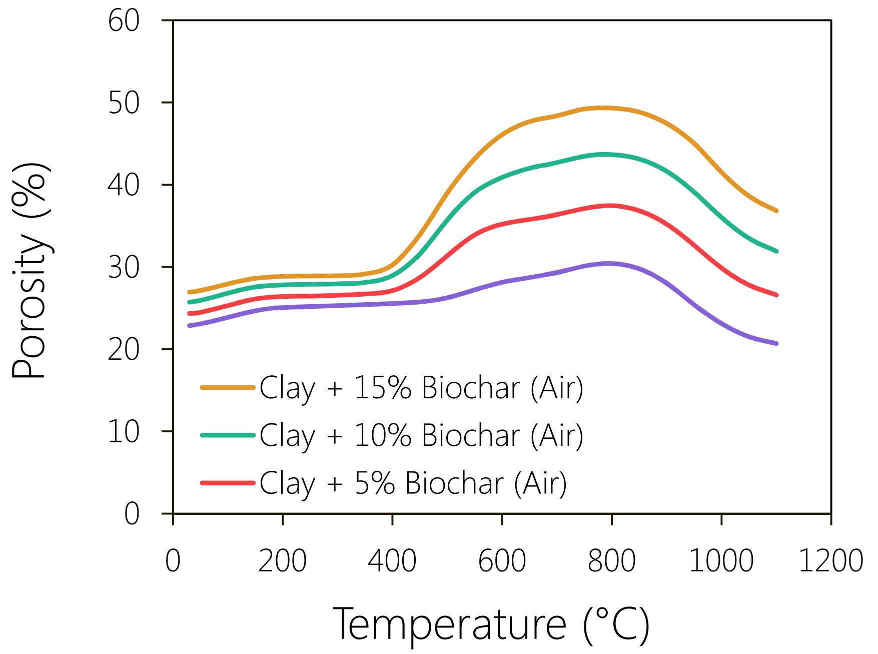




[*] Calculation of the porosity via experimental coupling between TGA and TMA

❖ Control of the porosity rate and morphology of the composites

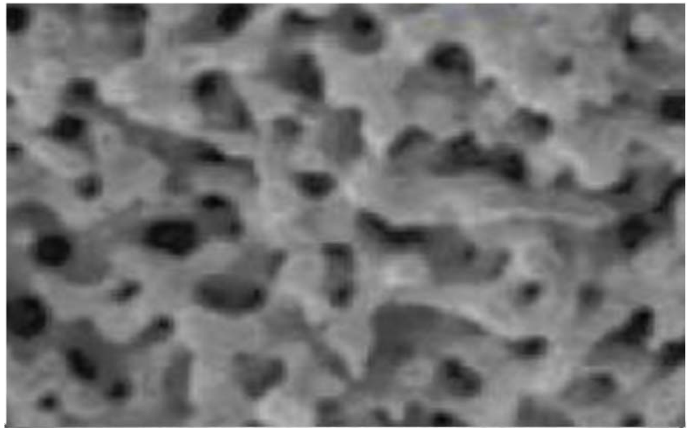


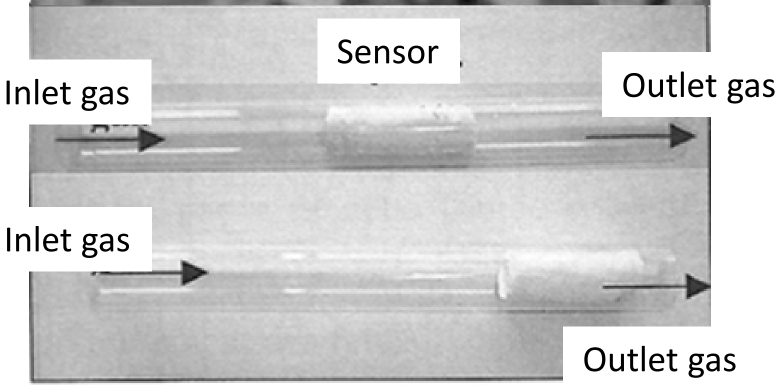


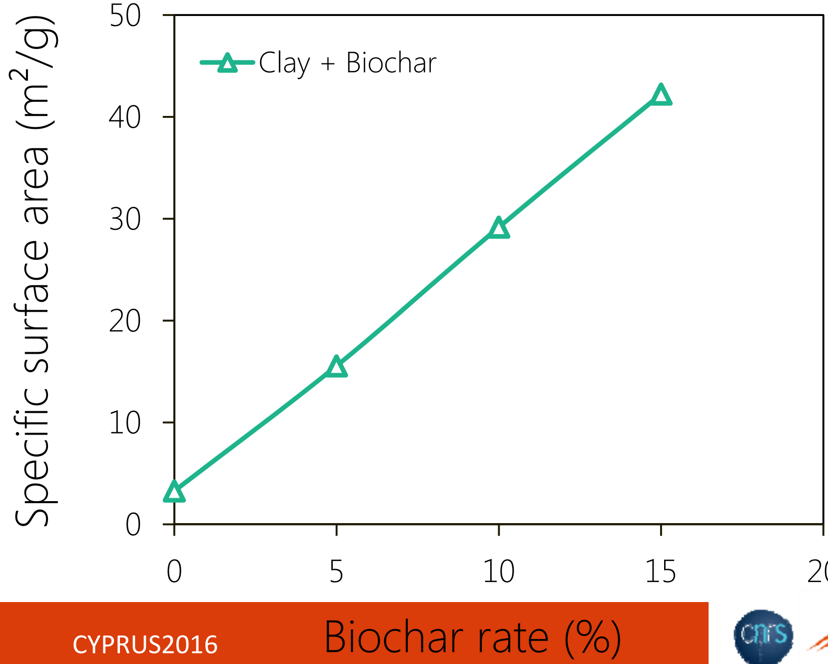
IV. Applications

Clay-Biochar composites

- ❖ **Filters for effluents treatment**
- ❖ **Sensors for pollutants removal**

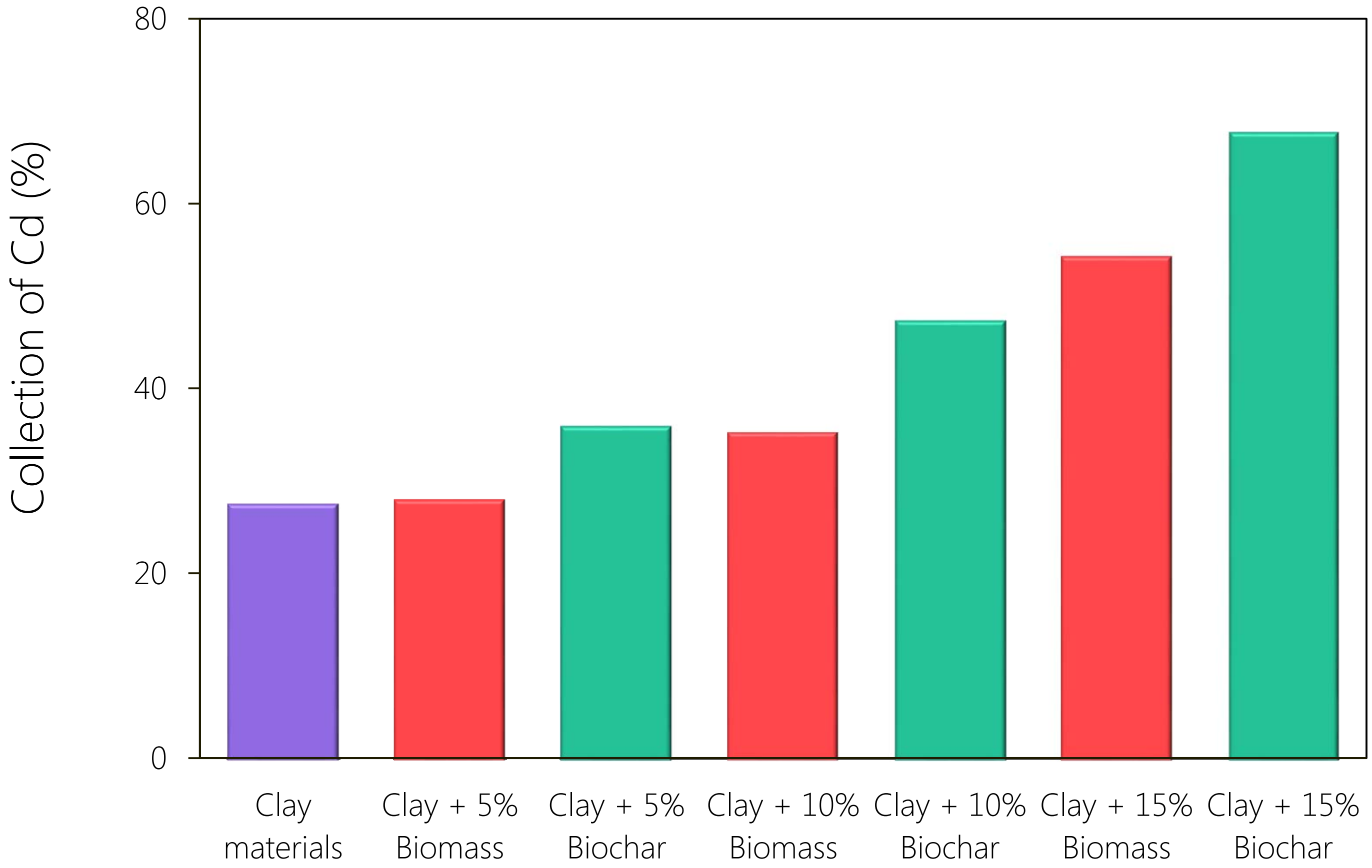






Sensors

Collection of Cadmium into the composite[*]



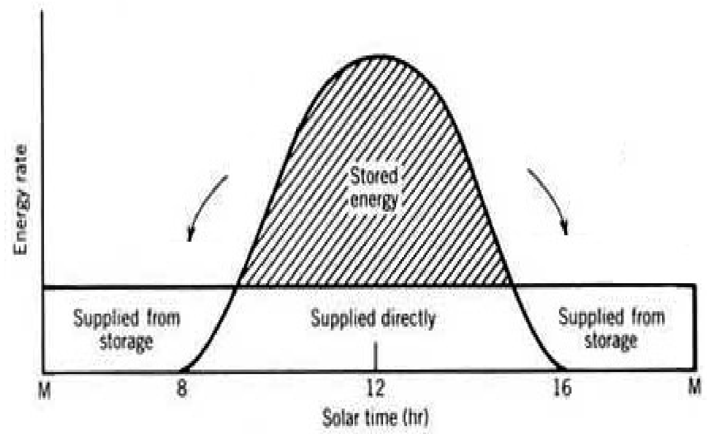
[*] Concentration of cadmium using ICP

IV. Applications – Energy storage

Intermittent nature of the renewable energy sources

- Exclusive production of energy with sun or wind ...
- Grading of the excess by means of a storage
- Storage by sensible heat (Q) of materials

$$Q = m.c_p.\Delta T$$



Require materials with a high thermal capacity (c_p)

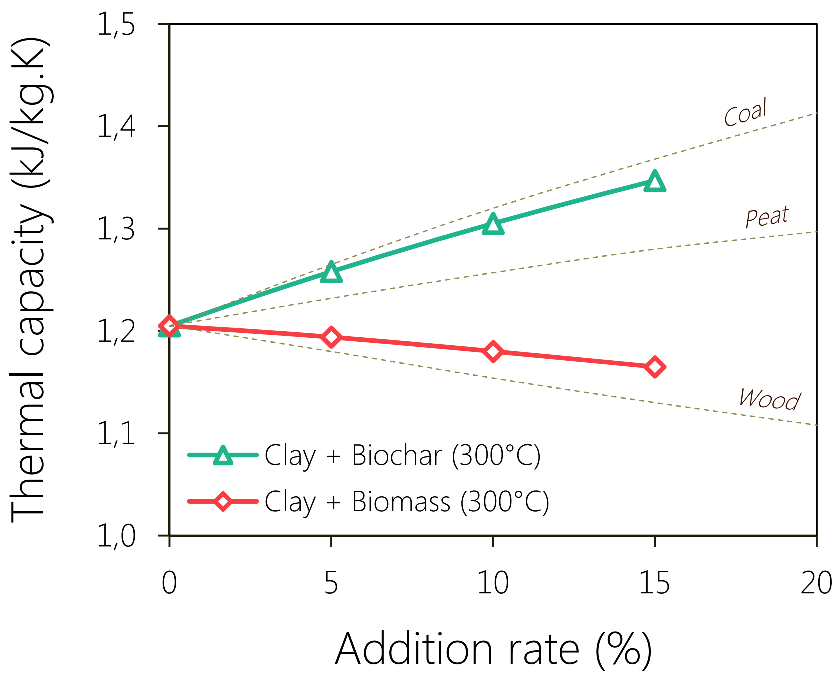
- Addition of organics and firing under inert atmosphere (N_2)
- Conservation of organics with a high c_p in inorganic structure

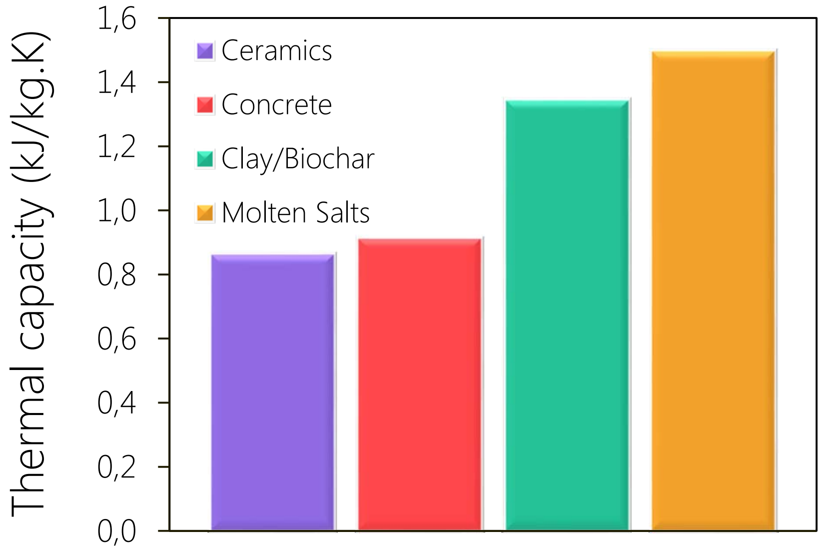
IV. Applications

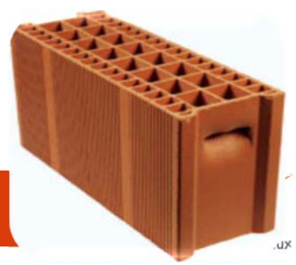
Clay-Biochar composites

❖ Materials for energy storage

Improvement of thermal capacity with biochar addition of 15%
Easy production and handling in comparison to rivals (molten salts)







[*] Thermal properties of the materials fired to 950°C using hot disk method at 300°C

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Advantages using carbon additives

- ✓ Improvement of the reactivity
- ✓ Increase of the functionnality

Motivation for further studies

Production of advanced composites from biochar and clay :

- ✓ Sensors
- ✓ Catalysts
- ✓ Materials for insulation
- ✓ Materials for energy storage
- ✓ Soil amendement

Wide range of possibilities for biochar / clay composites

ACKNOWLEDGMENTS

My group:

Thank you for your attention!

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