Polymer composites improvement by using Biochar as a filler

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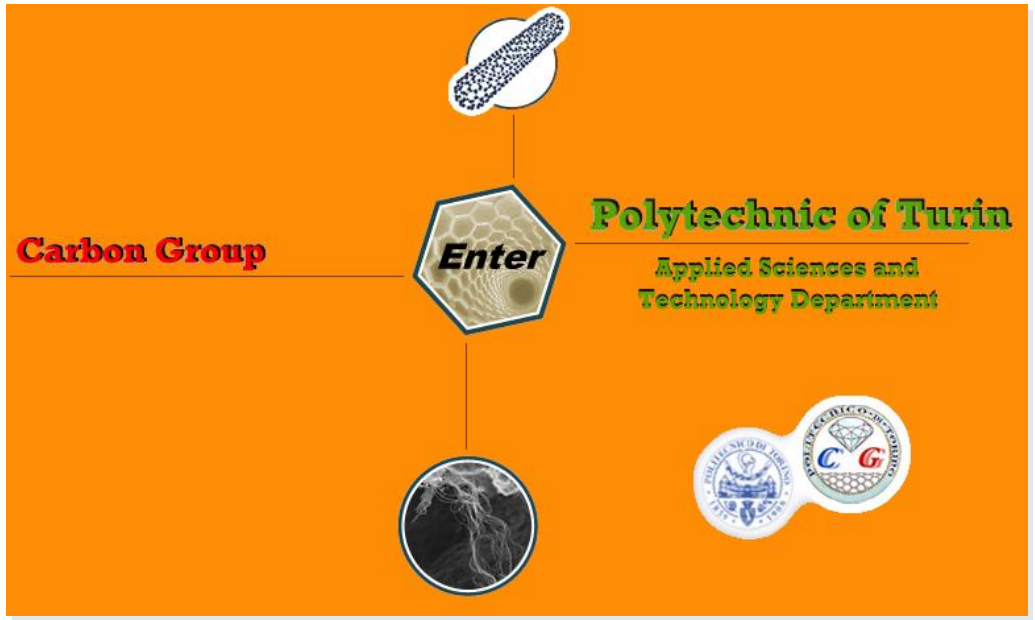
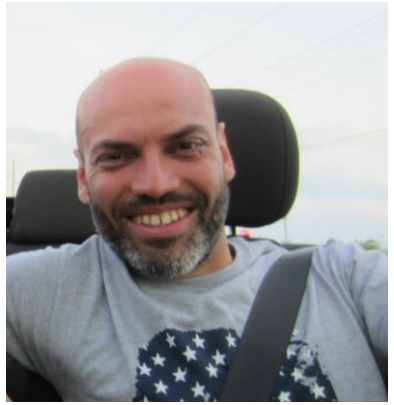
°Adjunct Professor Faculty of Science, University of Ontario Institute of Technology, Oshawa, Ontario, Canada

Turin, Oct. 5, 2021

Carbon group



www.polito.it/carbongroup


Mauro Giorcelli, Researcher


Massimo Rovere, Raman specialist


Mattia Bartali, Post. Doc


Pravin Jagadale, Researcher


Prof. Alberto Tagliaferro, Head


Prof. Carlo Rosso, Mechanical

Index

Composites based on Carbon fibers

Composites based on nano e micro carbon fillers

Biochar: a possible alternative

Our work on Biochar Composite

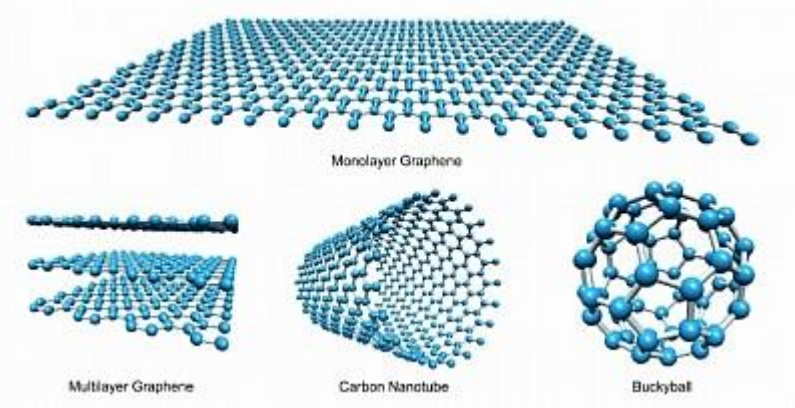
Summary

Carbon fibers composite

http://modcomp-project.eu/

- H2020 project in 4 years (2016-2020)
- 17 partners (Academy & Industry)

Type of «traditional» carbon filler: advantage/disavantage



Advantage:

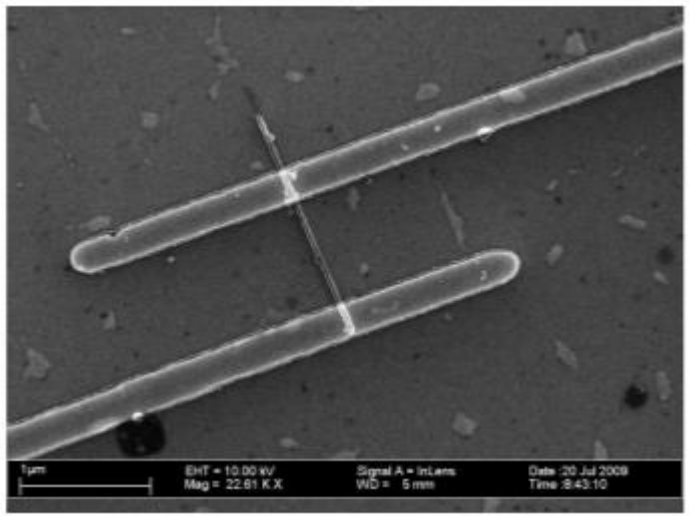
1. High performance carbon material
2. High electrical conductivity
3. High mechanical properties

Disadvantage:

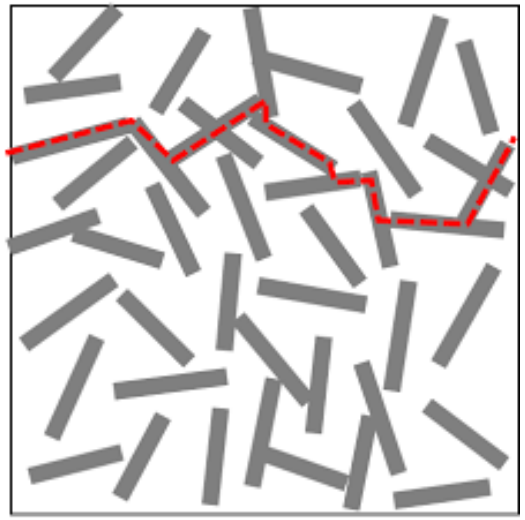
1. Not so easy to obtain a unifor dispersion
2. High cost material

Type of «traditional» carbon filler: advantage/disavantage

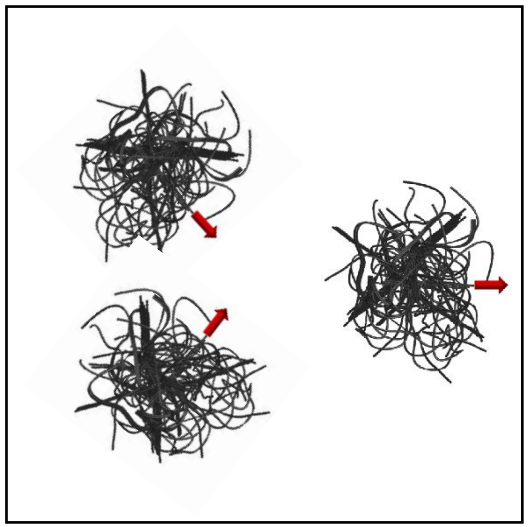
Copper electrical conductivity 10^6 S/m → CNTs electrical conductivity 10^6-10^7 S/m



Ideal

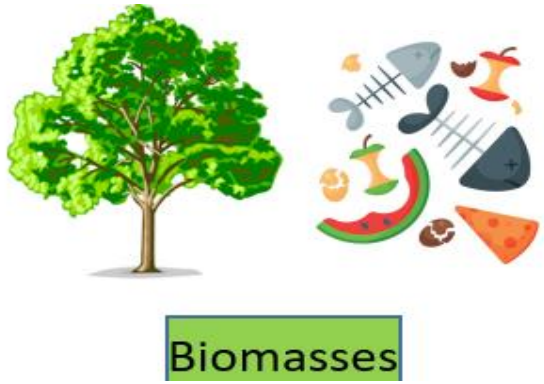


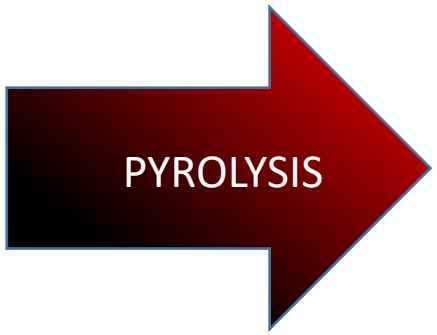
Real

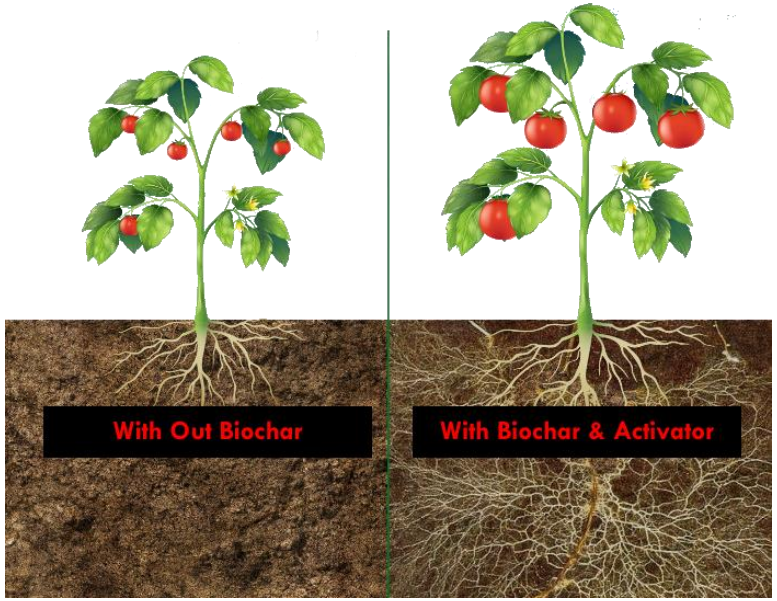


Low cost carbon filler: Biochar

- Carbon based material derived from biomasses pyrolysis







Question:

is the Biochar able to substitute expensive carbon filler?

Biochar is the new black!

But before….

To check:

1. High performance carbon material?
2. High electrical conductivity?
3. High mechanical properties?
4. Dispersion in composite?

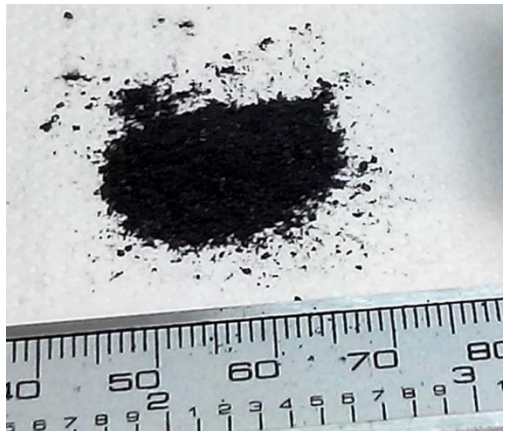
Advantage:

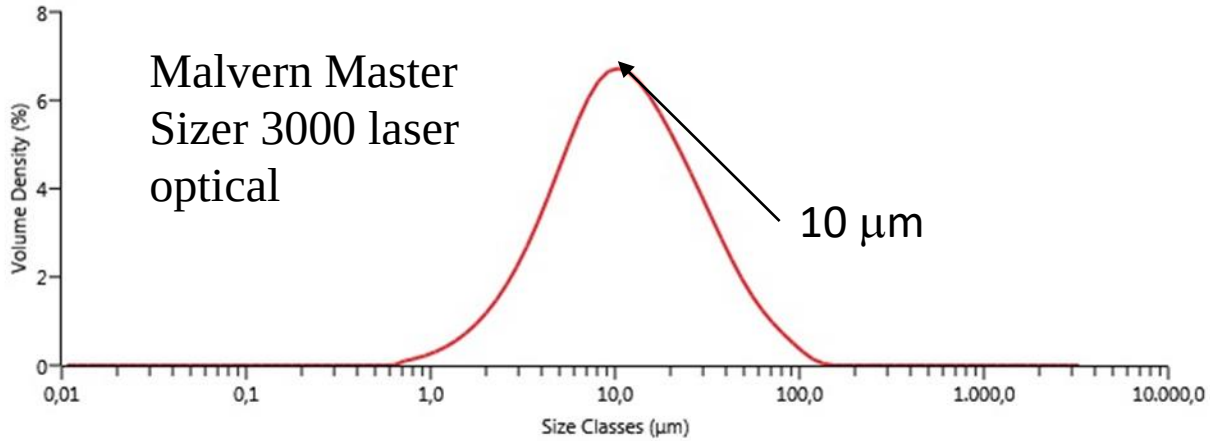
1. Low cost
2. Wordwilde aviability
3. CO_2 sequestration and «green» material

Composite based on biochar: preparation and their characterization

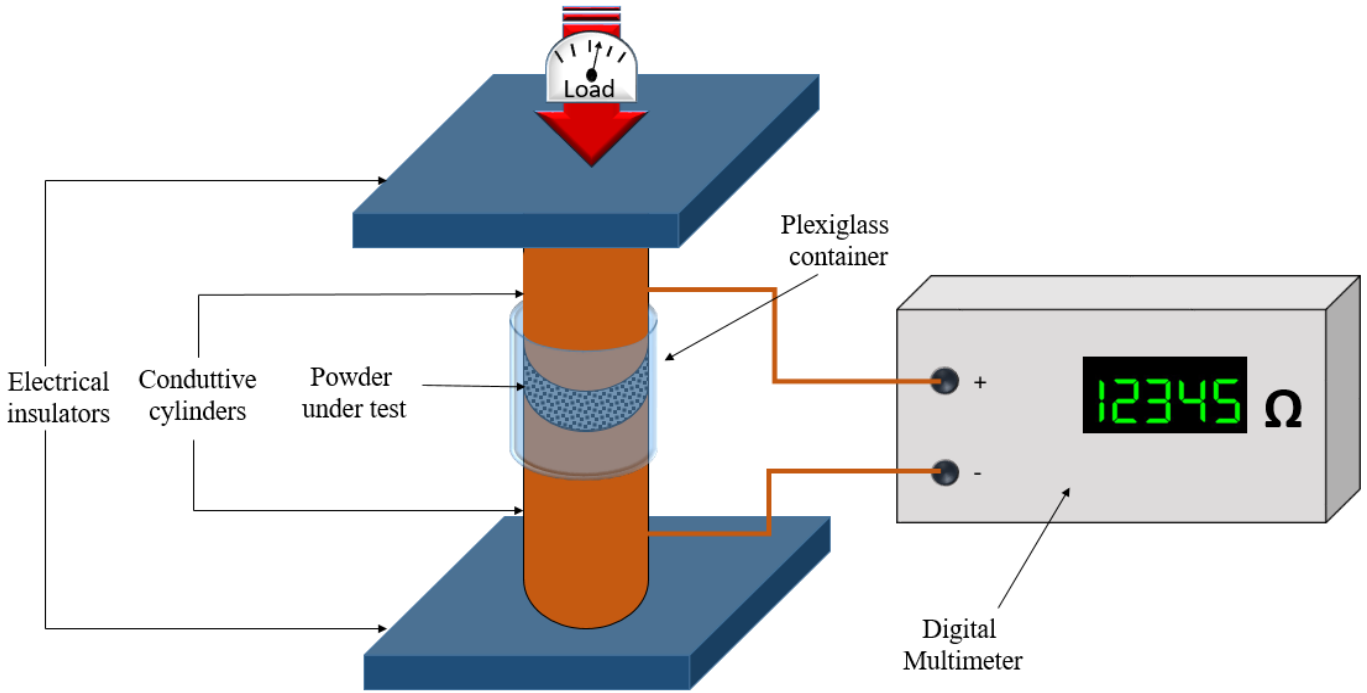
To check: Dispersion in composite?

Biochar powder is produced by using a fruit mixer

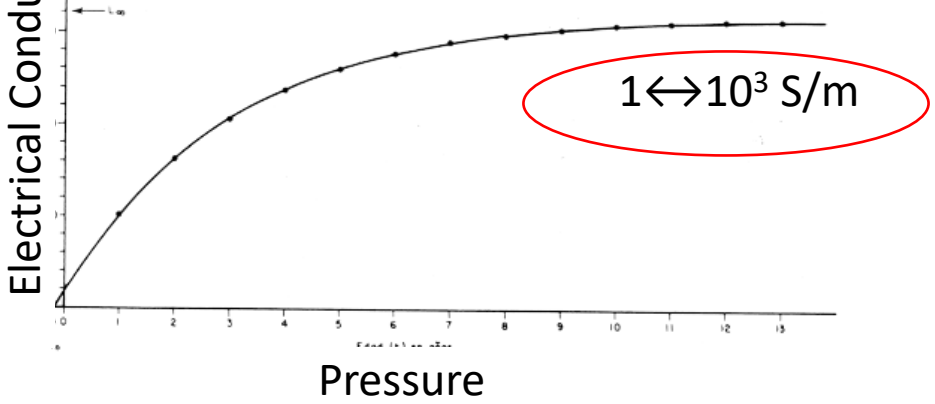




Biochar **powder** electrical characterization



$$\sigma = \left(R\frac{L}{S}\right)^{-1}$$



Biomass and Bioenergy 122 (2019) 466–471

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: www.elsevier.com/locate/biombioe

Research paper

Analysis of biochar with different pyrolysis temperatures used as filler in epoxy resin composites

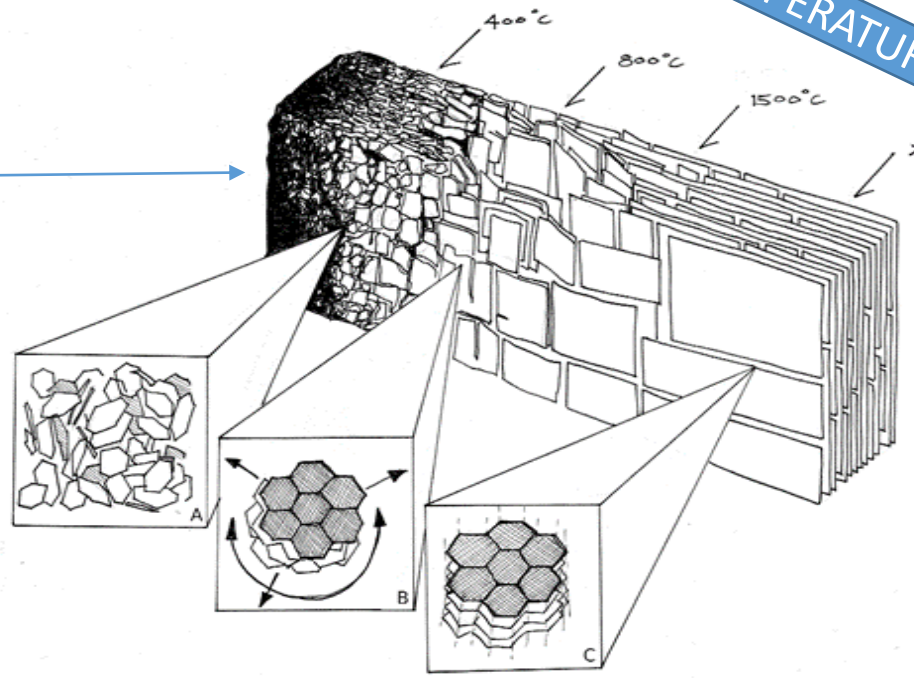
Mauro Giorcelli[a], Patrizia Savi[b,*], Aamer Khan[a,c], Alberto Tagliaferro[a,d]

Biochar: how to increase electrical properties

Thermal treatment

TEMPERATURE

Amorphous



Graphitized

Graphitilization grade cheked by **Raman Spectroscopy**

Massimo Rovere, Raman specialist

Lehman J et al, Biochar for environment management: science and technology, Routledge, 2012

Biochar: a possible alternative

- MWCNTs: ~$1/gram (→ $10^{6}/ton) [1]
- Carbon black: ~$ 1000/ton[2]
- Biochar: ~$500/ton [3]

[1] Nanocyl NC7000 Industrial grade
[2] Alibaba.com
[3] Marousek, J.: Significant breakthrough in biochar cost reduction. Clean Technol. Environ. Policy 16, 1821–1825 (2014)

Our work on Biochar

Biochar as it is

Biochar in composites

1st

Electrochimica Acta 133 (2014) 169–173

Contents lists available at ScienceDirect

Electrochimica Acta

journal homepage: www.elsevier.com/locate/electacta

Pyrolyzed bamboo electrode for electrogenerated chemiluminescence of $Ru(bpy)3^{2+}$

Muhammad Noman[b], Alessandro Sanginario[a,*], Pravin Jagdale[c], Micaela Castellino[a], Danilo Demarchi[b], Alberto Tagliaferro[c]

chemosensors

MDPI

Article

Biochars as Innovative Humidity Sensing Materials

Daniele Ziegler [1], Paola Palmero [1], Mauro Giorcelli [2], Alberto Tagliaferro [2] and Jean-Marc Tulliani [1,*]

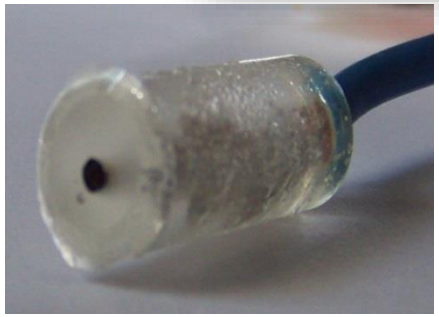
- Comparison with “traditional” carbon filler
- Specific study on “particular” biochar
  - Different feedstock
  - Different pyrolysis treatments
  - Doped Biochar (new!)

BAMBOO: ELECTRODES FOR ECL

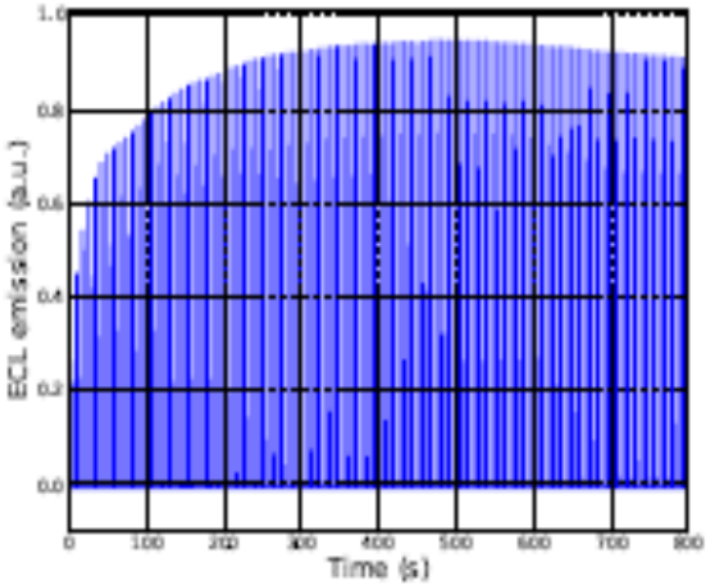
Chop ends

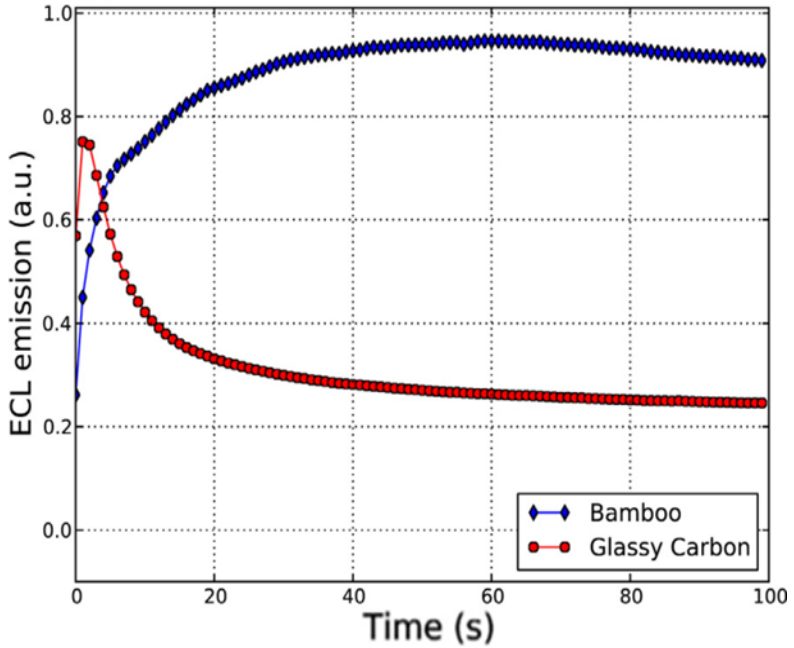
Anneal

Wrap in PDMS



ECL Signal under cyclic voltammetry excitation





1st

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[a] Istituto Italiano di Tecnologia, CSHR - Center for Human Space Robotics
[b] Electronics and Telecommunication Department, Politecnico di Torino
[c] Department of Applied Science and Technology, Politecnico di Torino

Biochar used as HUMIDTY SENSORS

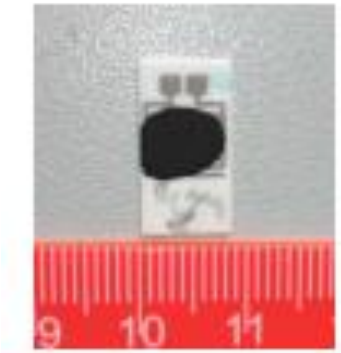


Table 6. Impedance values of SWP700-10% PVP sensor toward ozone 0.5 ppm, ammonia 50 ppm, methane 100 ppm, and carbon dioxide 500 ppm.

Gas	Z_0 (kΩ)	Z_g (kΩ)
O_3 0.5 ppm	954	954
NH_3 50 ppm	956	981
CH_4 100 ppm	958	959
CO_2 500 ppm	958	959
CO_2 600 ppm	958	959
RH40%	959	1130
CO_2 600 ppm + air RH40%	958	1120

chemosensors

MDPI

Article

Biochars as Innovative Humidity Sensing Materials

Daniele Ziegler [1], Paola Palmero [1], Mauro Giorcelli [2], Alberto Tagliaferro [2] and Jean-Marc Tulliani [1,*]

[1] Politecnico di Torino, Department of Applied Science and Technology, INSTM R.U PoliTO-LINCE Laboratory, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy; daniele.ziegler@polito.it (D.Z.); paola.palmero@polito.it (P.P.)

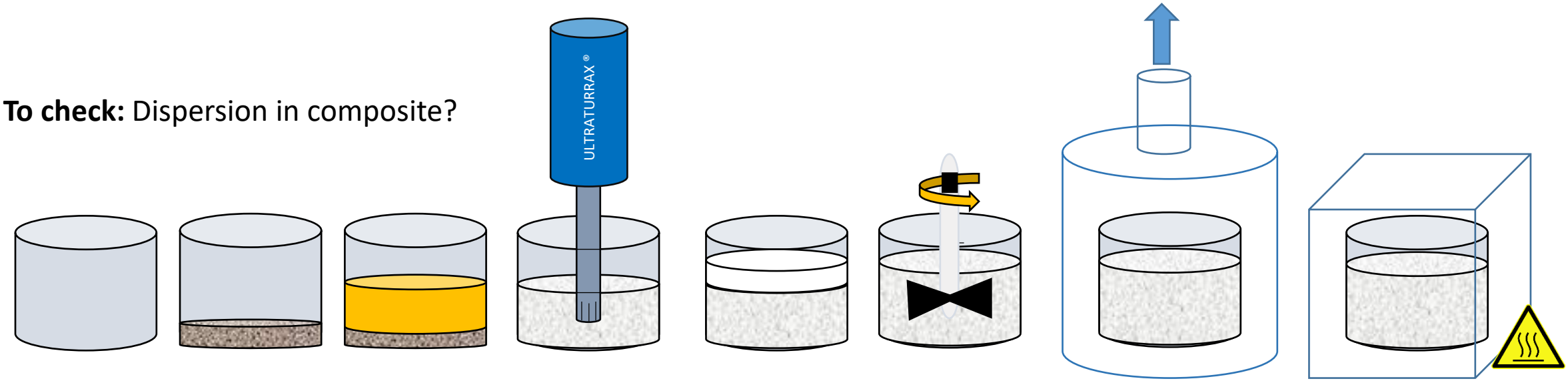
[2] Politecnico di Torino, Department of Applied Science and Technology, Carbon Group, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy; mauro.giorcelli@polito.it (M.G.); alberto.tagliaferro@polito.it (A.T.)

* Correspondence: jeanmarc.tulliani@polito.it; Tel.: +39-011-0904-700

Received: 30 October 2017; Accepted: 11 December 2017; Published: 12 December 2017

Composite based on biochar: preparation

To check: Dispersion in composite?



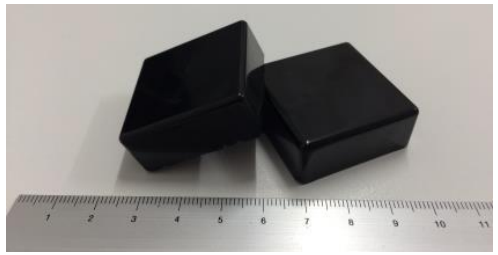
Mold BIOCHAR Resin Ultraturrax Hardener Mixing V

3000÷25000 rpm

en

ring

Composite to test



Composite matrix

- Polymer (epoxy resin, silicon, PolyPropilene,…) →good level
- Cement (collaboration with NSU Singapore) → starting level

Composite characterization

Mechanical

Electrical

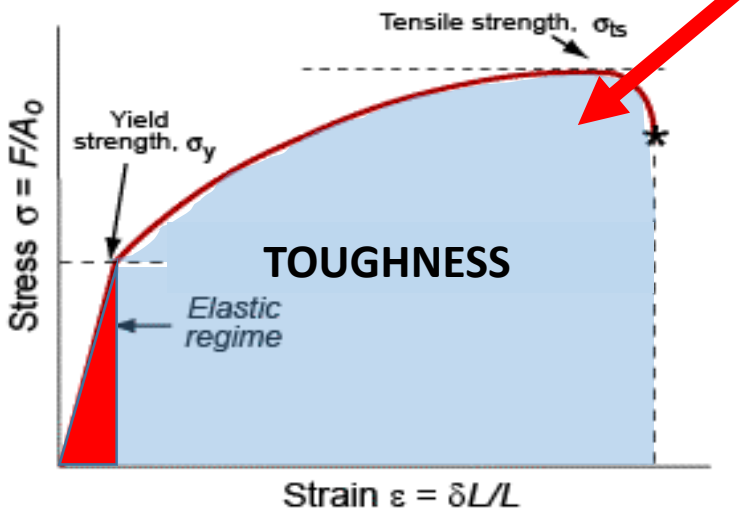
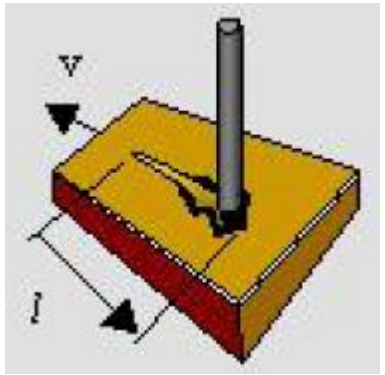
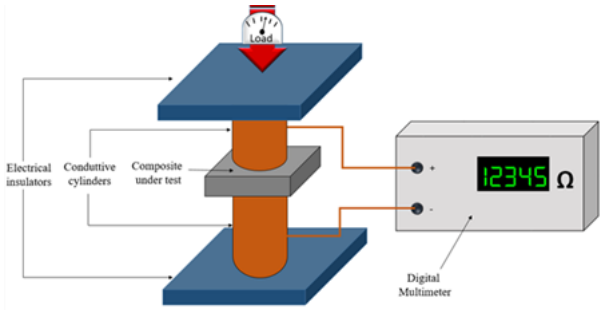


Figure 1. A tensile stress-strain curve.

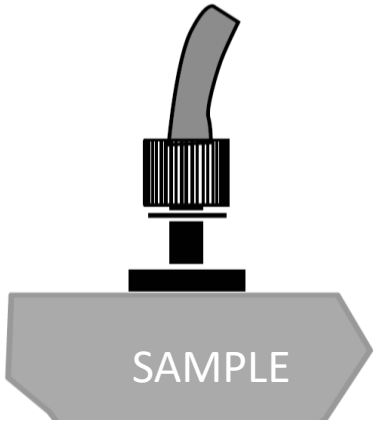
Stress/Strain curve



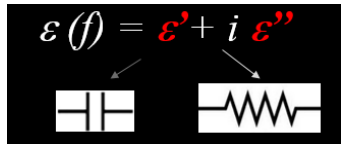
Friction coefficient study



DC Current



AC Current (up to 20 GHz)



Composite characterization (**Mechanical**)

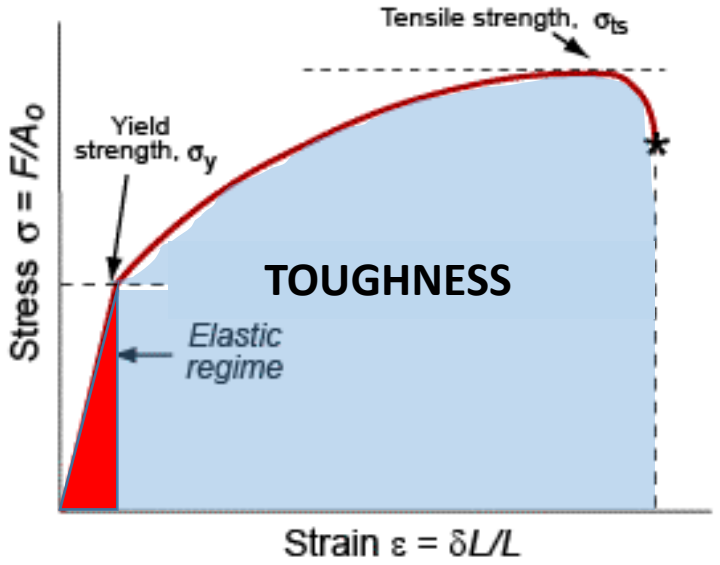
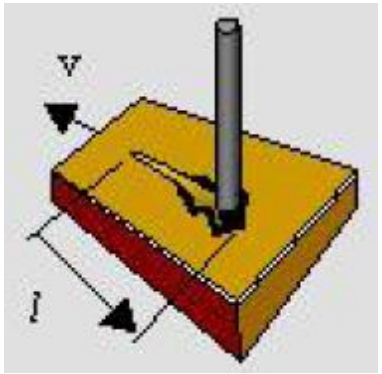


Figure 1. A tensile stress-strain curve.

Elastic modulus = stress/strain ratio in the linear region
Young modulus = elastic modulus under tensile (compressive) stress

Yield strength (stress) = stress limit for elastic behaviour
(ultimate) **Tensile strength** = the maximum stress a material can withstand

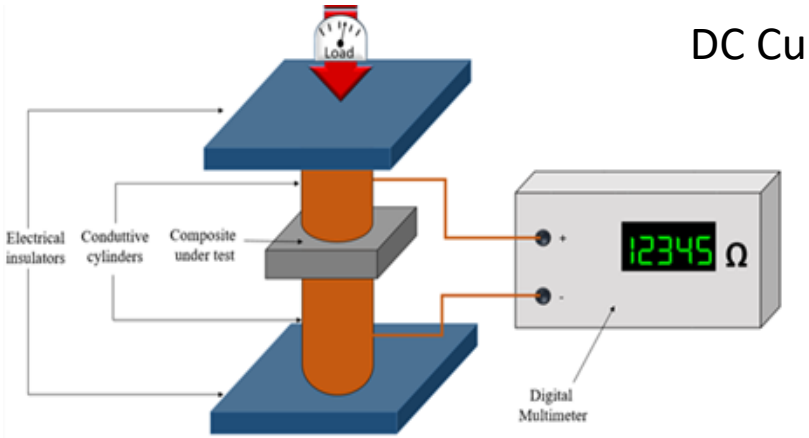
Maximum Elongation = strain at breakdown
Resilience = energy per unit volume needed to overcome the elastic behaviour
Toughness = energy per unit volume needed to break the sample



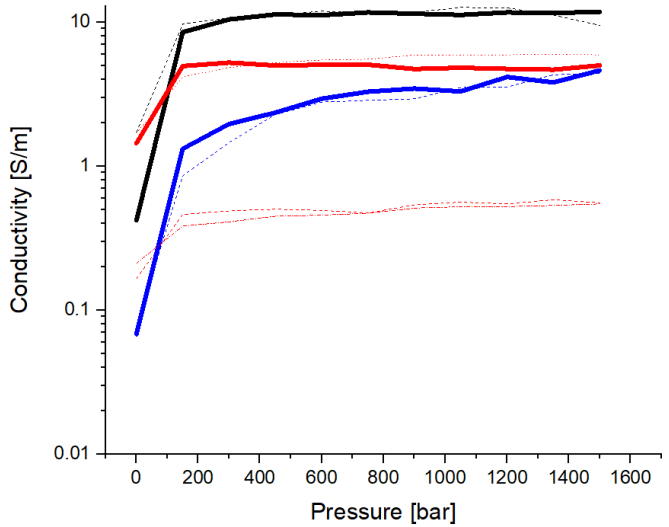
Reduction of **friction coefficient** is of high interest.

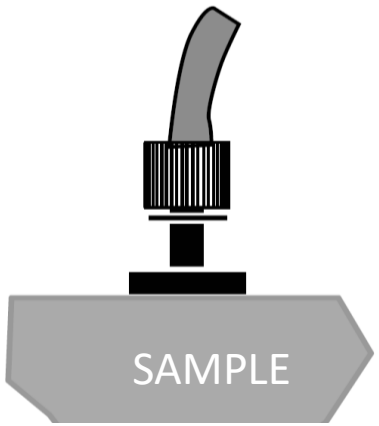
Target is to reach self-lubrication limit
(Friction coefficient = 0.08)

Composite characterization (**Electrical**)

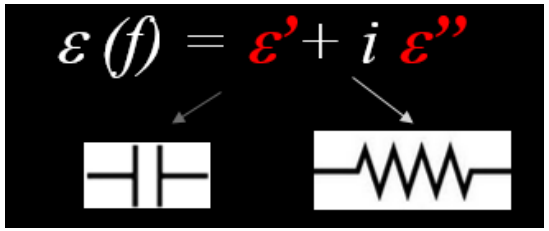


DC Current





AC Current (up to 20 GHz)



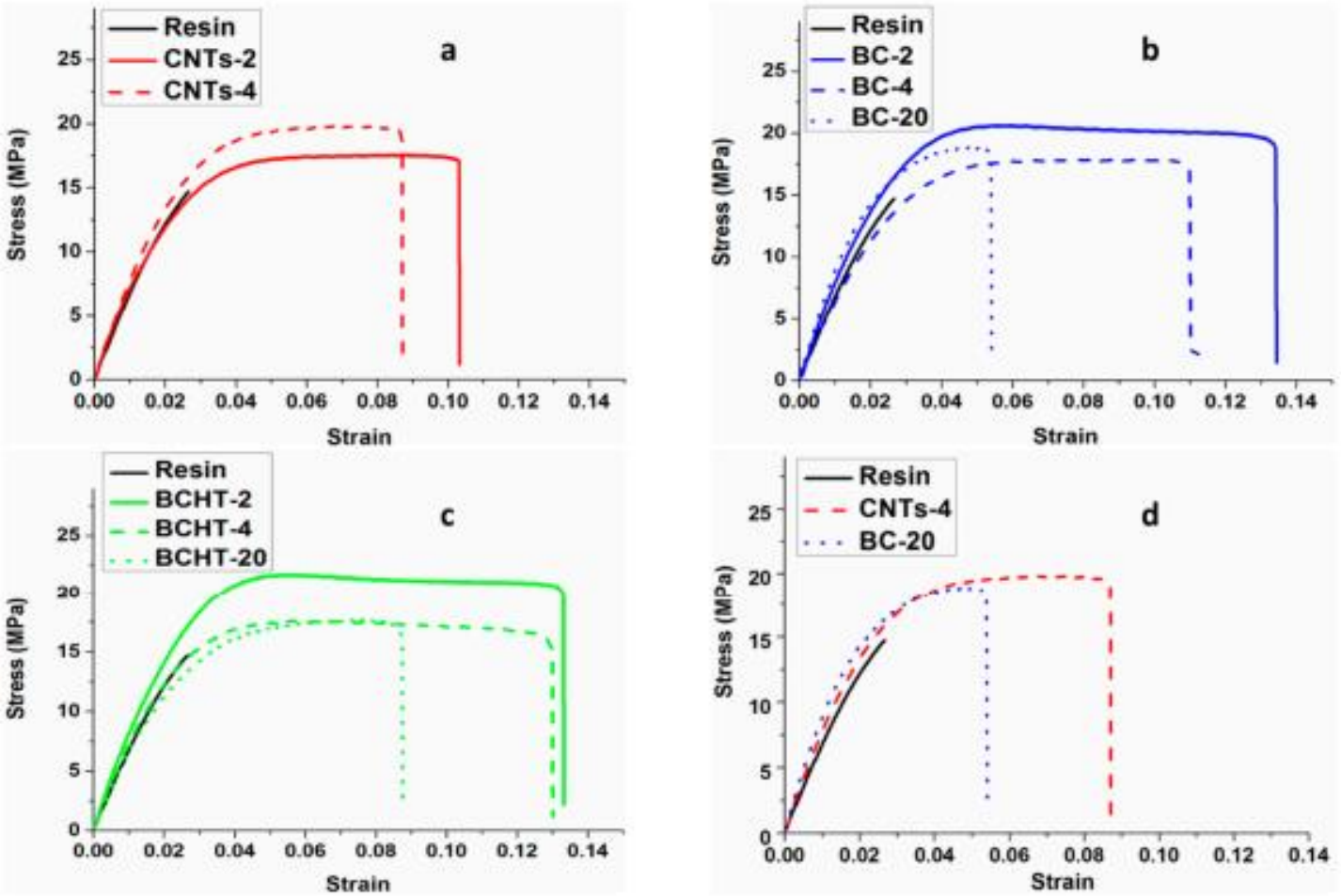
Permittivity is a complex quantity. Its **real part** describes the **ability to store energy** while its **imaginary part** describes the **ability to dissipate energy**

$$\varepsilon'' = \frac{\sigma}{2\,\pi\,f\,\varepsilon_o}$$

As electrical conductivity is related to energy dissipation a close correlation exists

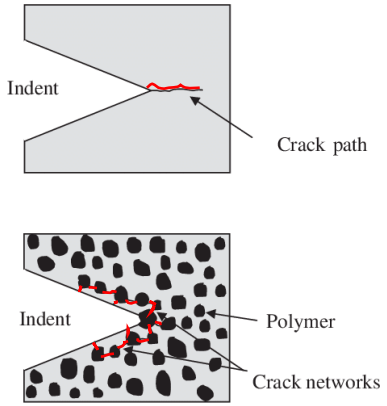
Mechanical characterization

Comparison with “traditional” carbon filler (Carbon Nanotubes, CNTs)



Results are comparable with CNTs

The best results were achieved by **2 wt.%** of Biochar



polymers

MDPI

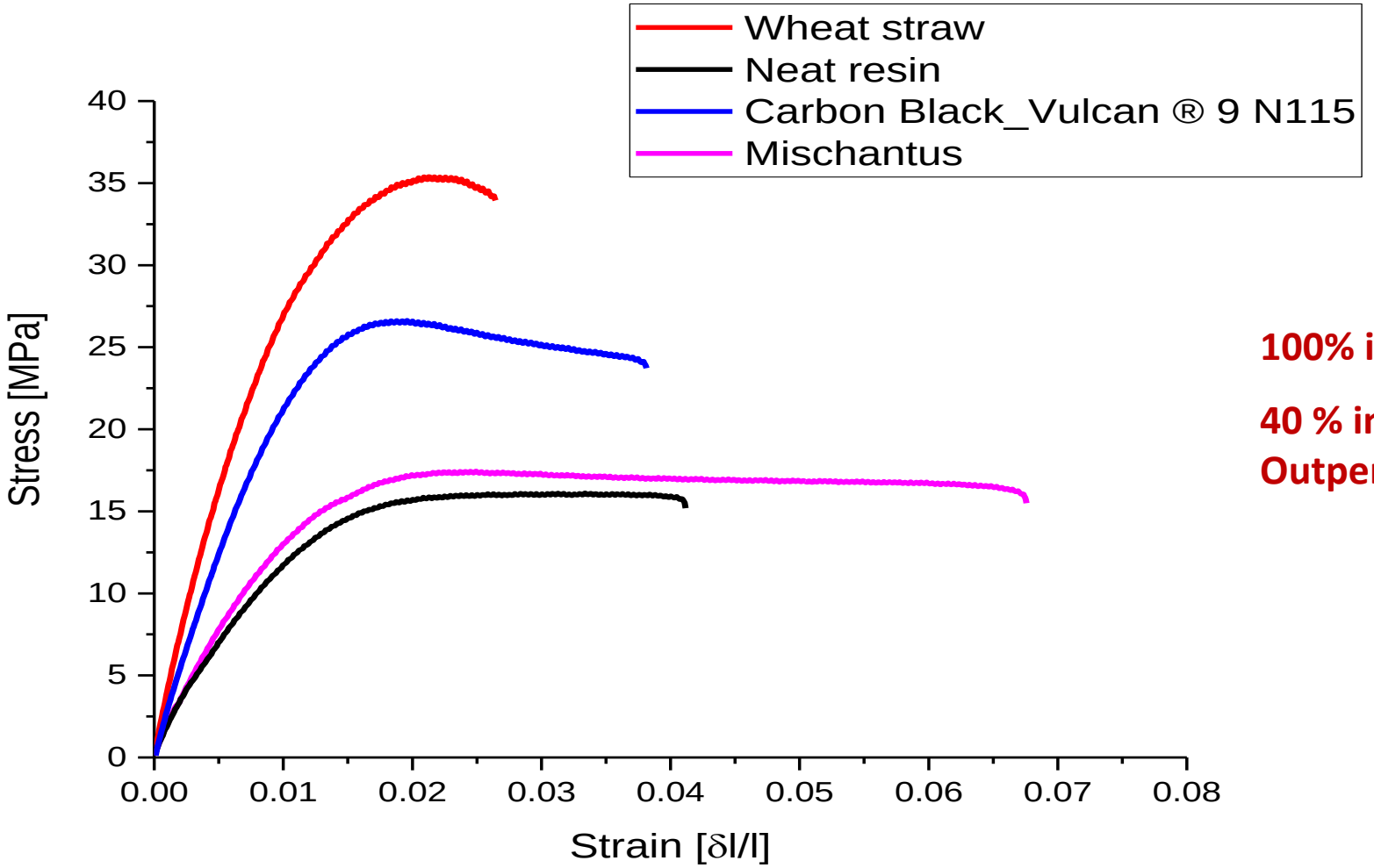
Article

Low-Cost Carbon Fillers to Improve Mechanical Properties and Conductivity of Epoxy Composites

Aamer Khan [1], Patrizia Savi [2,*], Simone Quaranta [3], Massimo Rovere [1], Mauro Giorcelli [1], Alberto Tagliaferro [1], Carlo Rosso [4] and Charles Q. Jia [5]

Mechanical characterization

Tunability in function of biochar feedstock



100% increase in Young modulus (wheat straw)

40 % increase in elongation (mischantus)

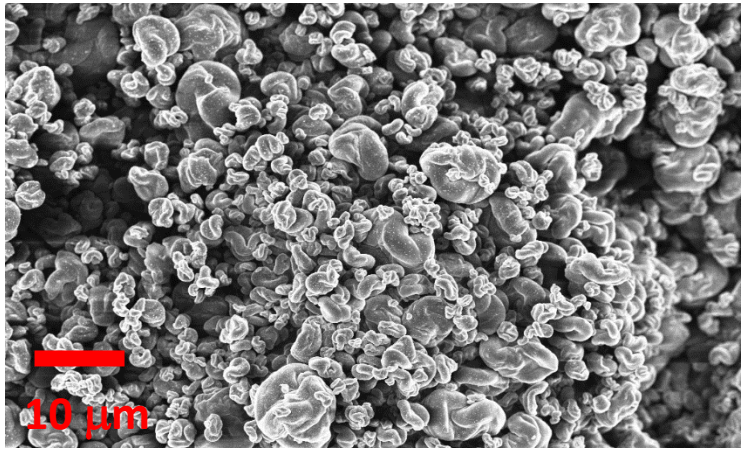
Outperfom traditional comercial carbon filler

Bartoli, M., Giorcelli, M., Rosso, C., Rovere, M., Jagdale, P., Tagliaferro, A. (2019). Influence of Commercial Biochar Fillers on Brittleness/Ductility of Epoxy Resin Composites. *Applied Sciences*, *9*(15), 3109.

Mechanical characterization

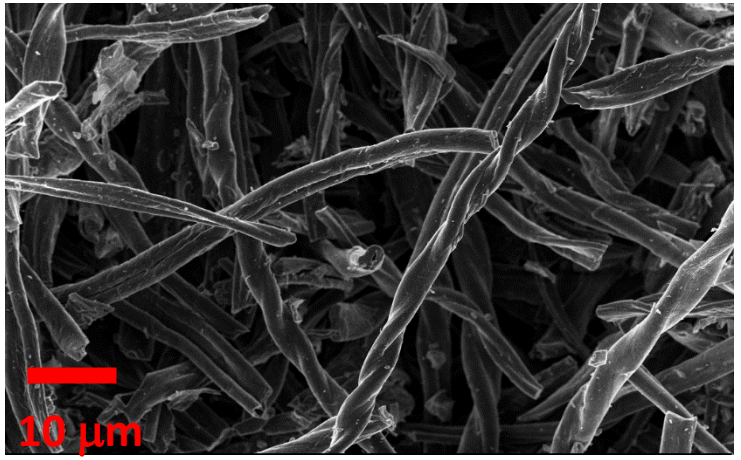
Tunability in function of biochar shape

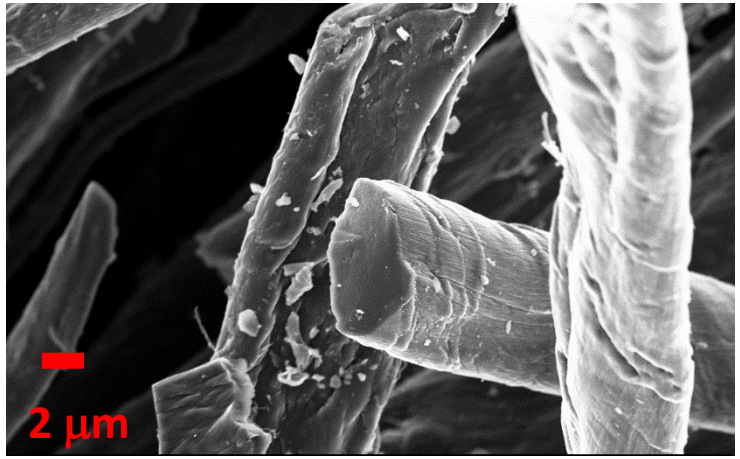
Pyrolyzed CNC



- Cellulose feedstocks: **cellulose nanorystals** (CNC) and **waste cotton fibers**
- Microstructured carbon production: *Balls and sticks*

Pyrolyzed cotton fibers

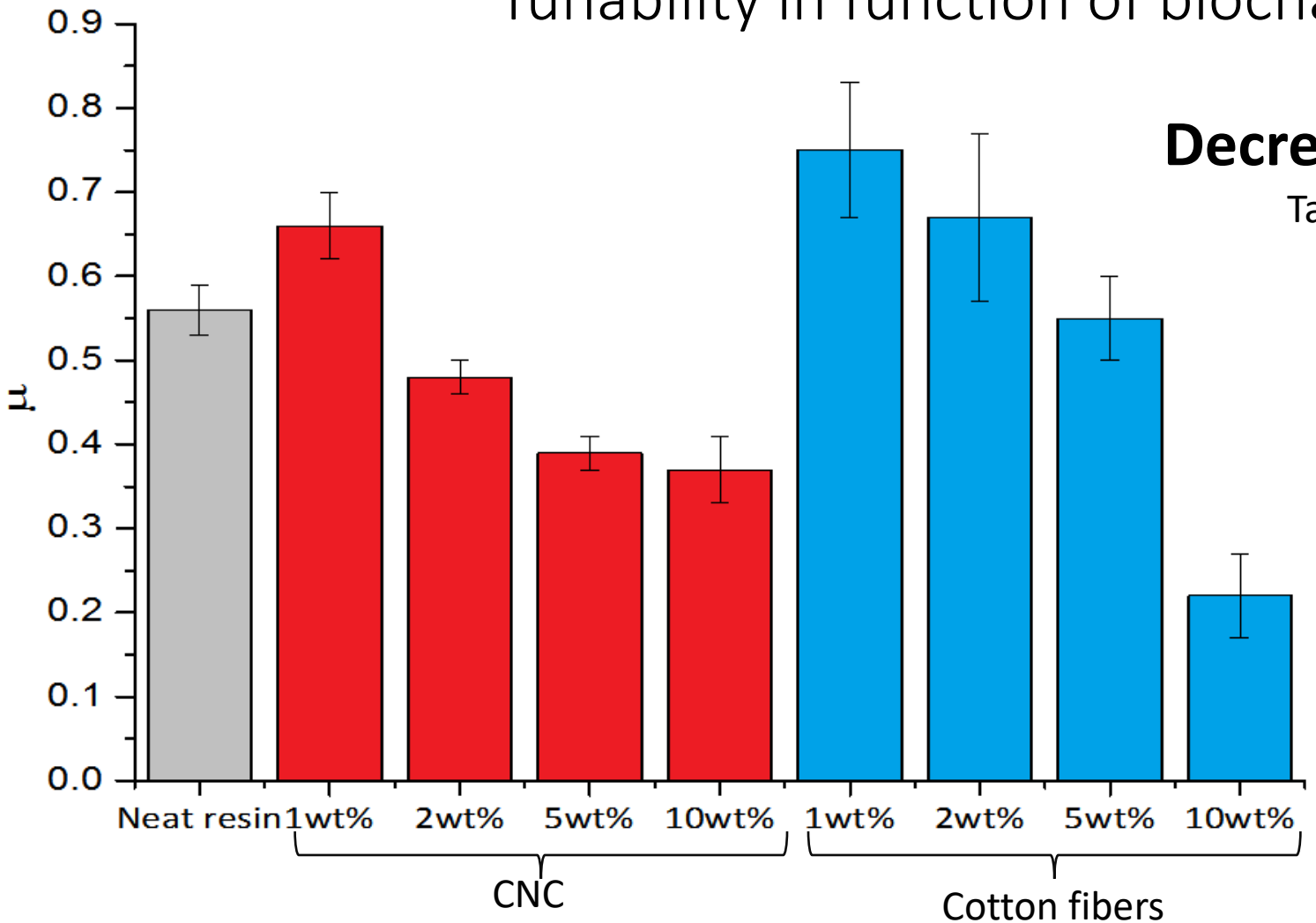




"Effect of incorporation of microstructured carbonized cellulose on surface and mechanical properties of epoxy composites"*submitted*

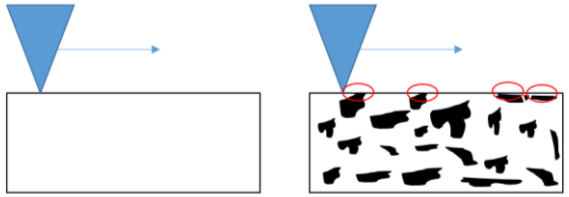
Mechanical characterization

Tunability in function of biochar shape



Decreasing of Friction coefficient

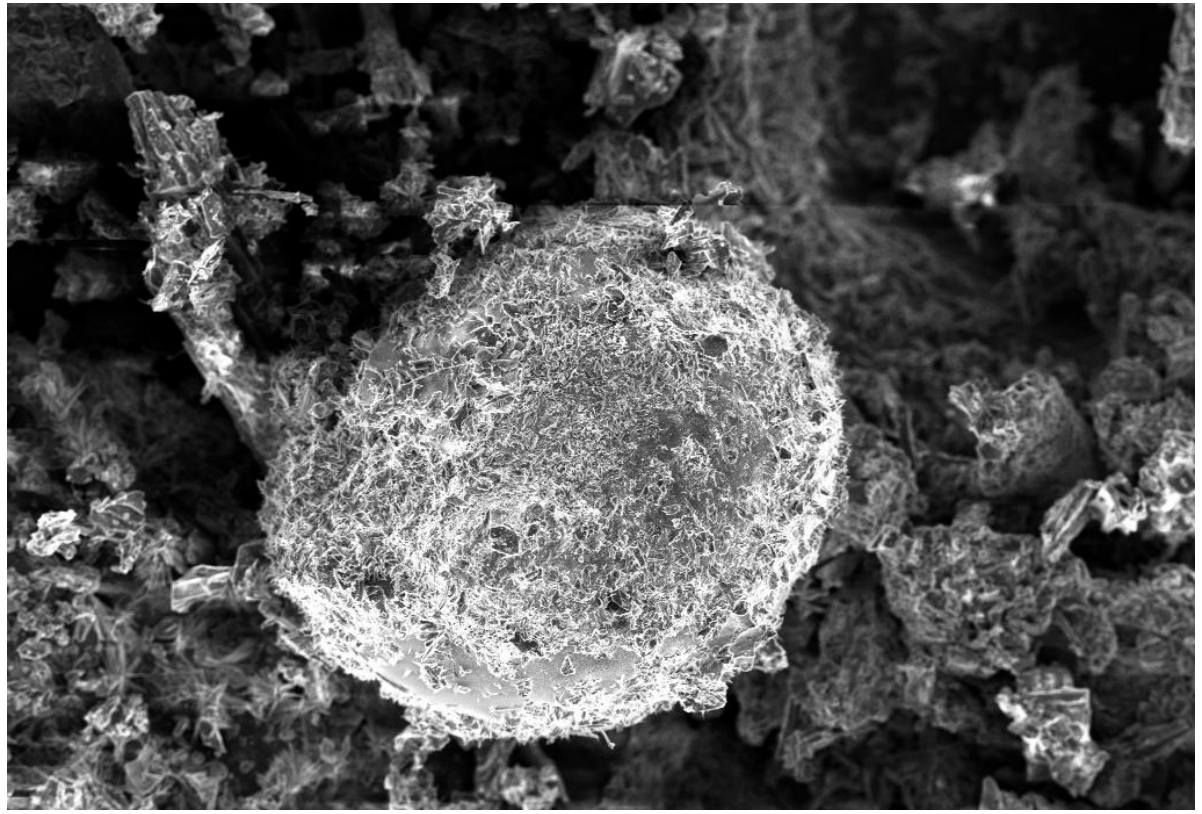
Target is to reach self-lubrication limit
(Friction coefficient = 0.08)



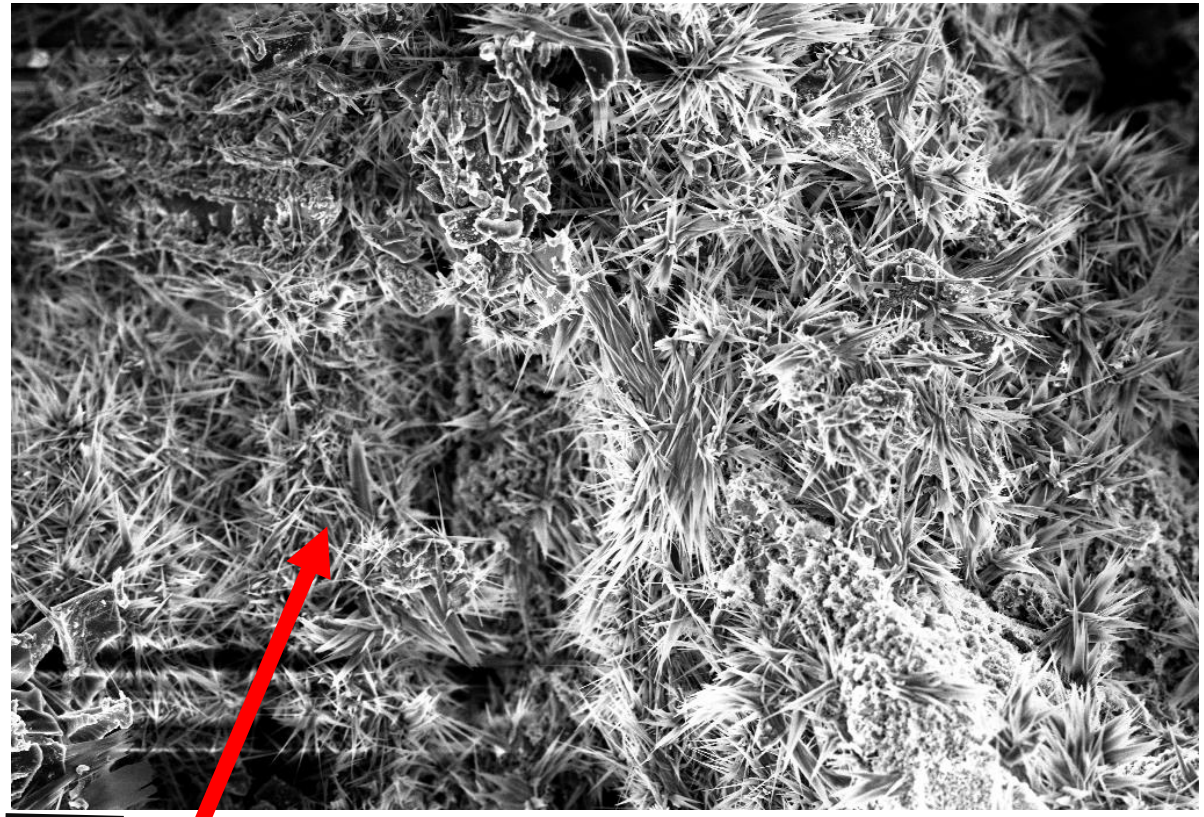
"Effect of incorporation of microstructured carbonized cellulose on surface and mechanical properties of epoxy composites» *submitted*

materials: NaOH decoration

- Based on oil seed rape biochar produced at 800°C



10 μm



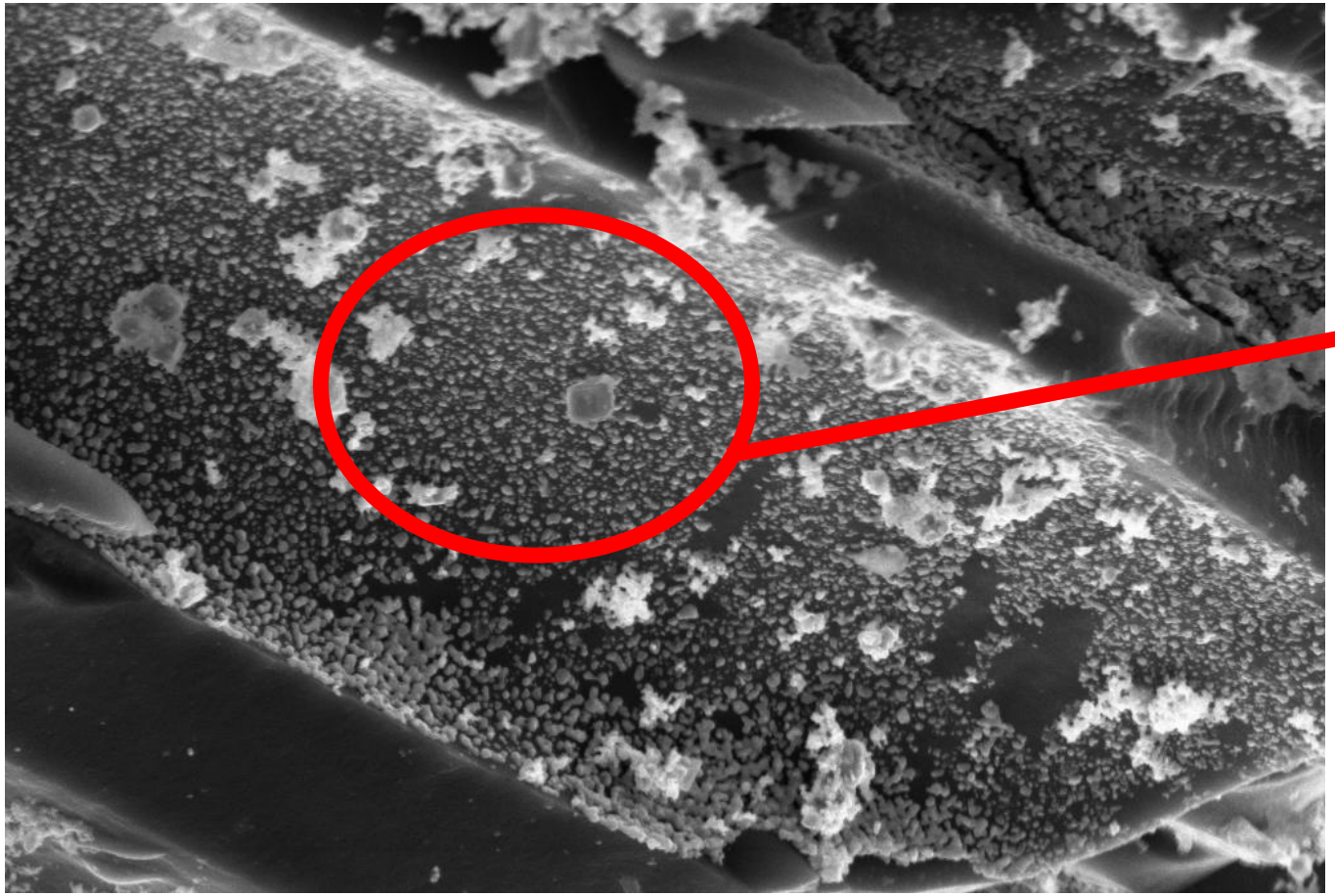
10 μm

$$Na_2CO_3 \longrightarrow Na_2O+CO_2 \xrightarrow{H_2O} NaOH$$

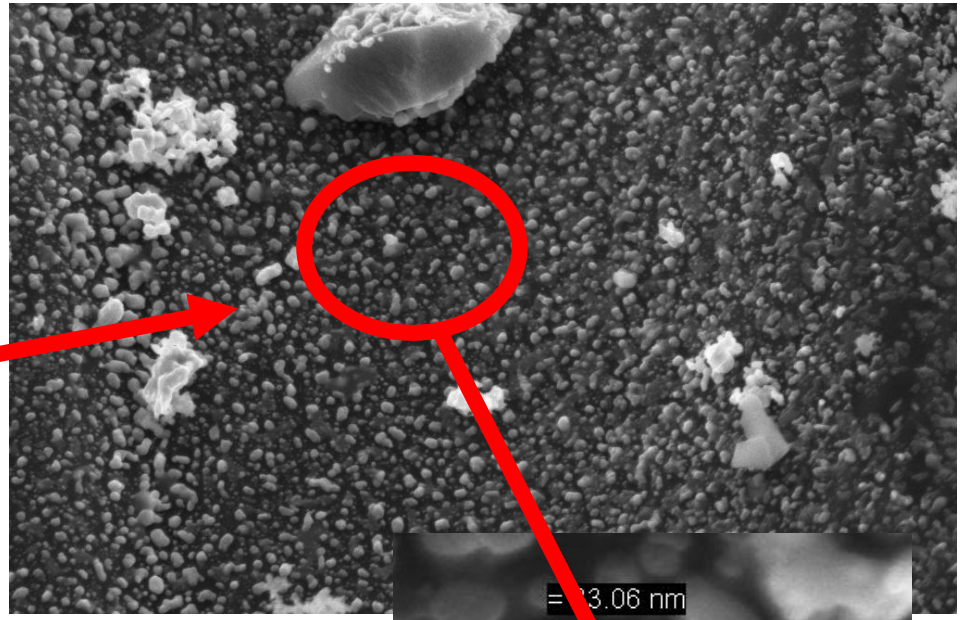
Highly basic surface !

materials:
Iron decoration

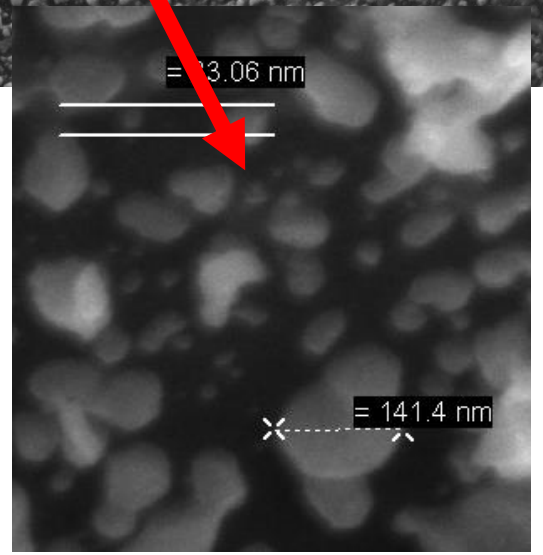
- Based on oil seed rape biochar produced at 800°C



2 μm



1 μm

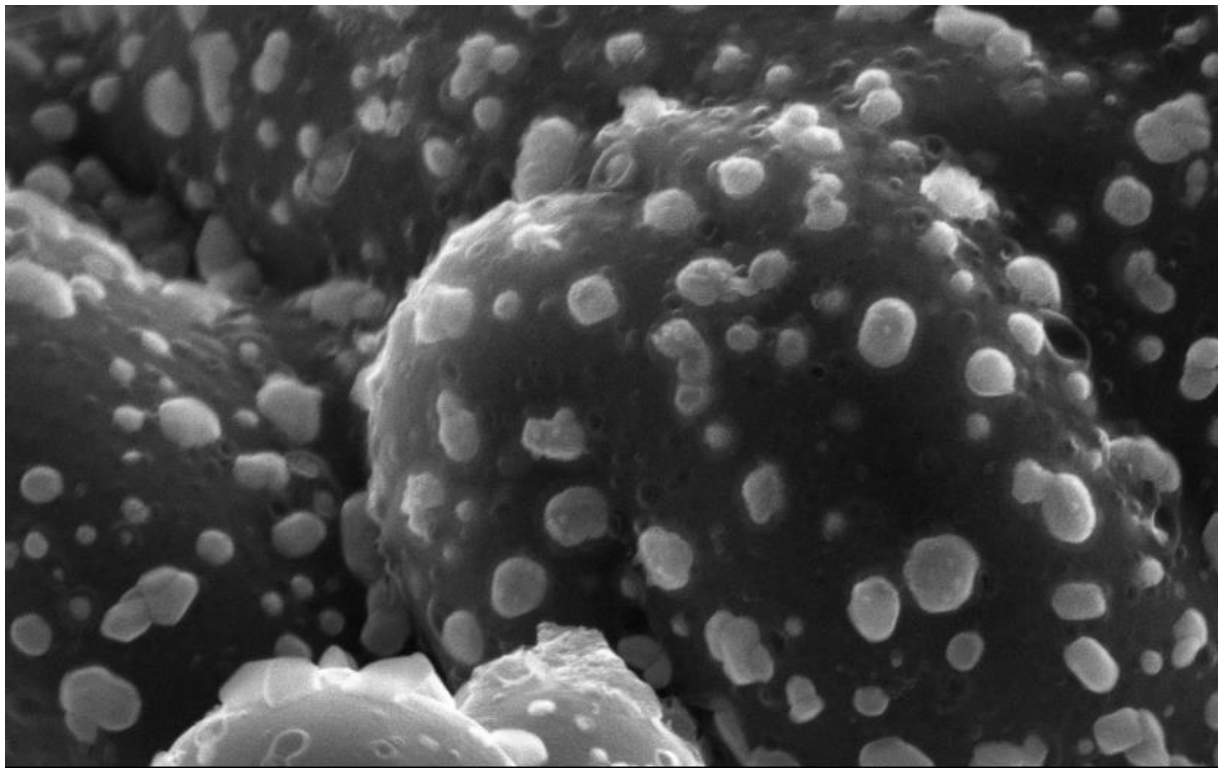


Surface are increase from 30 to 260 m^2/g after decoration!

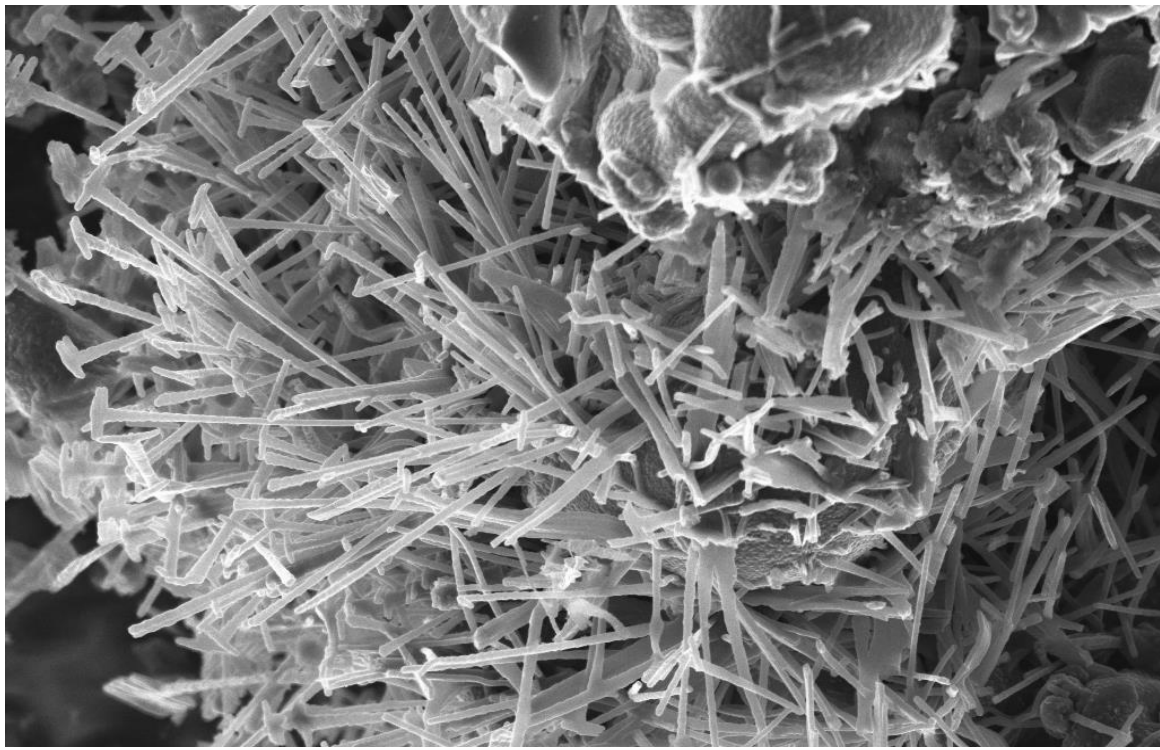
materials: Carbon decoration

- CNC based material

- Co-pyrolysis with ethanol

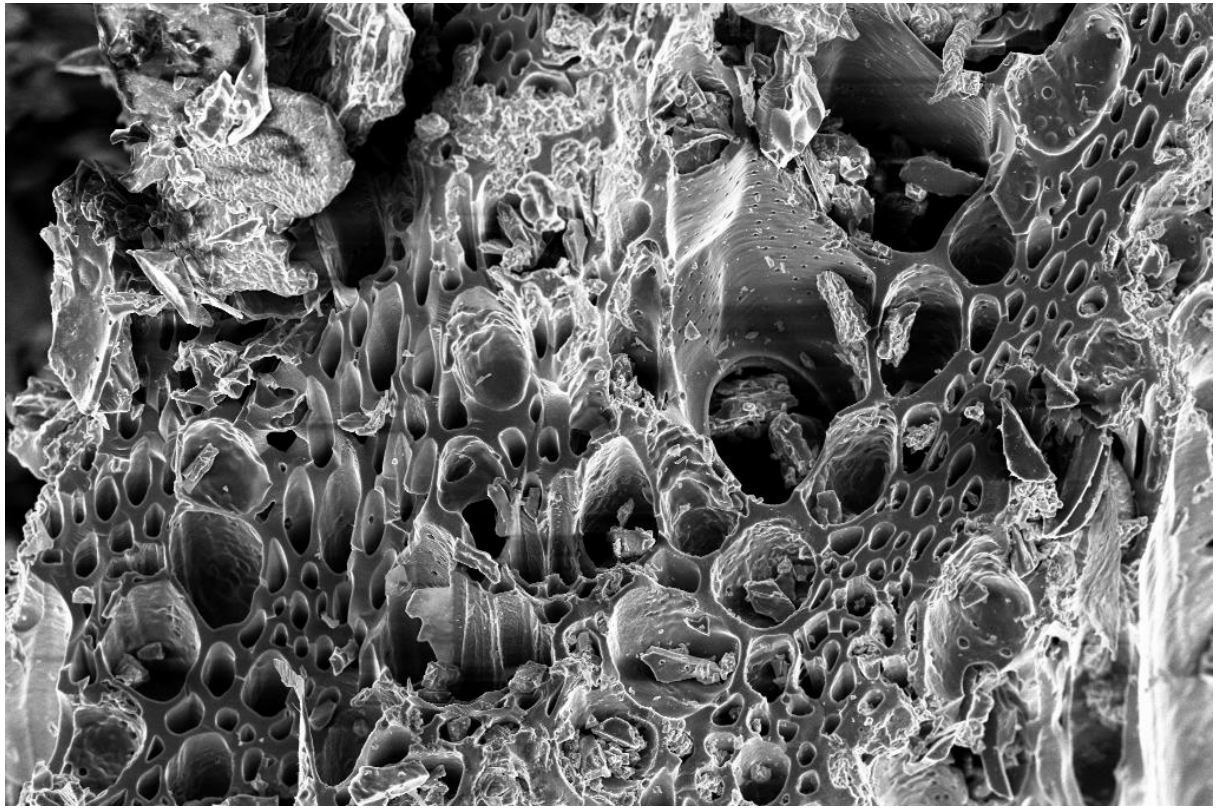


- Co-pyrolysis with fatty acids



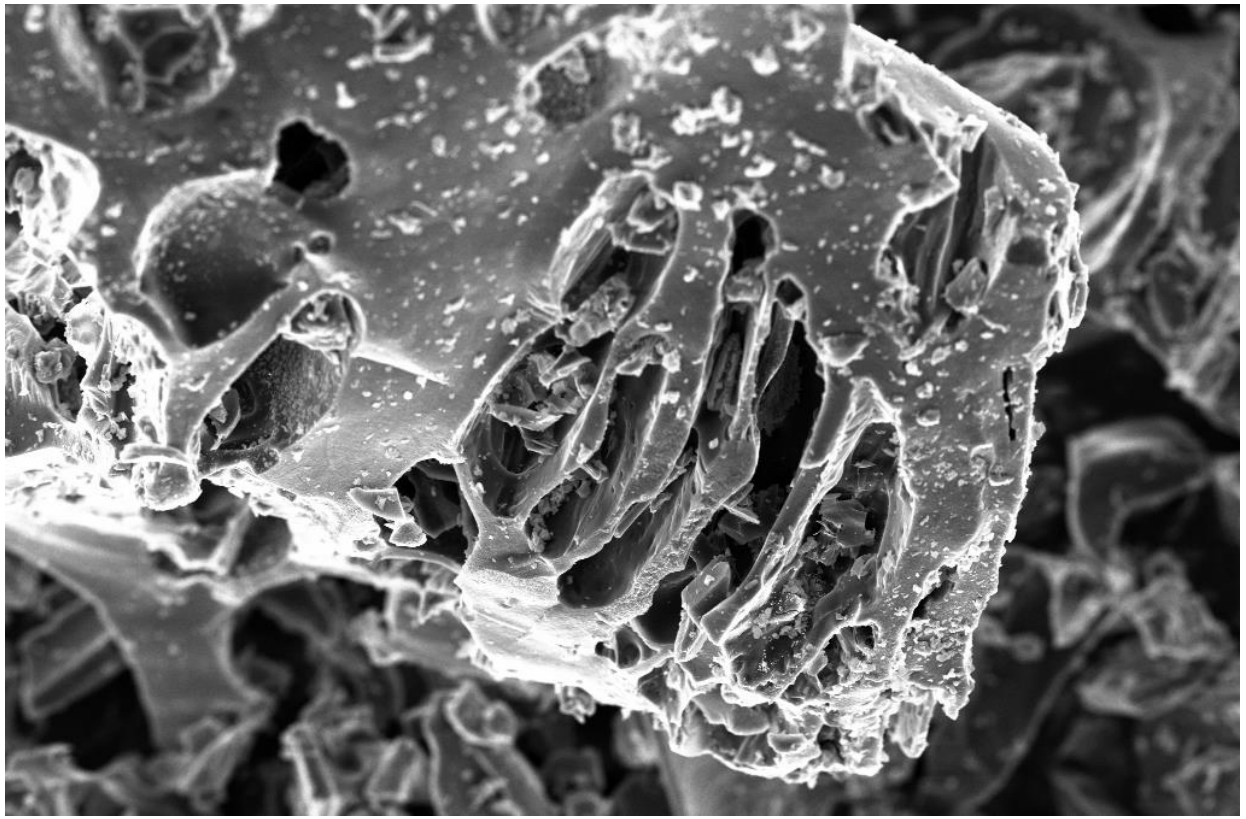
Shape tuneability: temperature effect

Wasted olive trunks



20 μm

Pyrolysis conditions: 400°C(HR:5°C/min), Ar

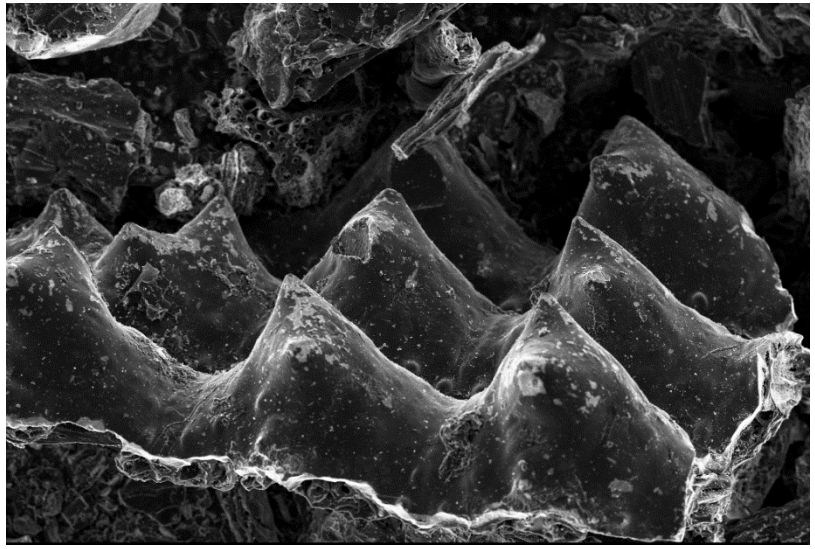


10 μm

Pyrolysis conditions: 1000°C(HR:50°C/min), Ar

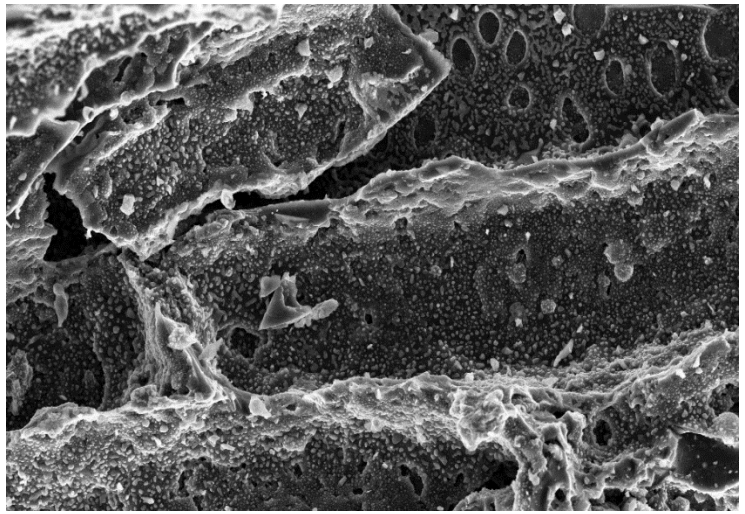
Shape tuneability: the relevance of feedstcok

Rice husk



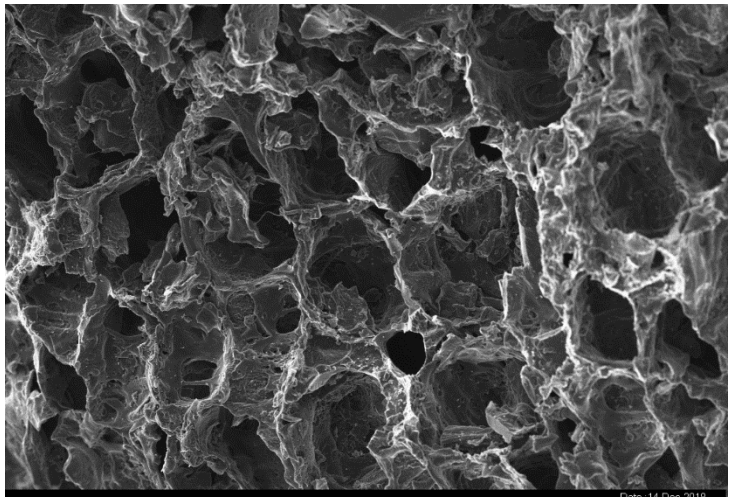
20 μm

Exhausted tea leaves



3 μm

Wasted coffee



20 μm

Pyrolysis conditions: 1000°C(HR:50°C/min), Ar

Electrical characterization

Comparison with “traditional” carbon filler (Carbon Nanotubes, CNTs)

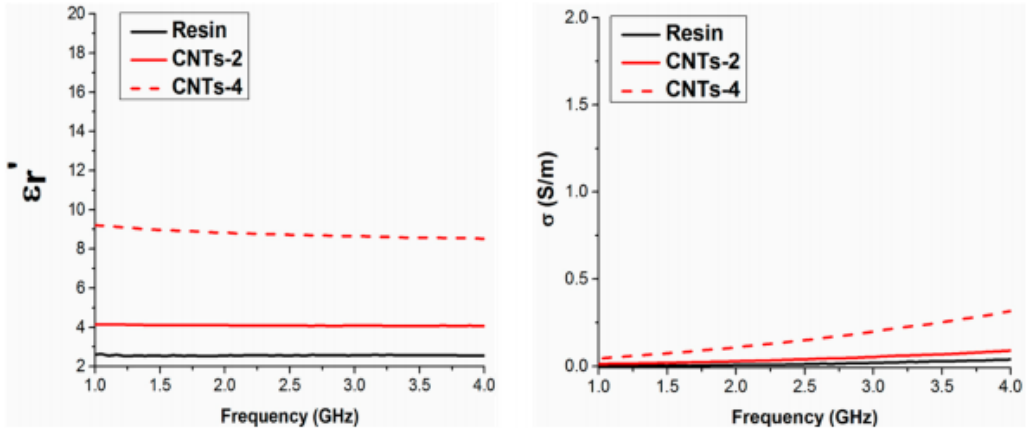
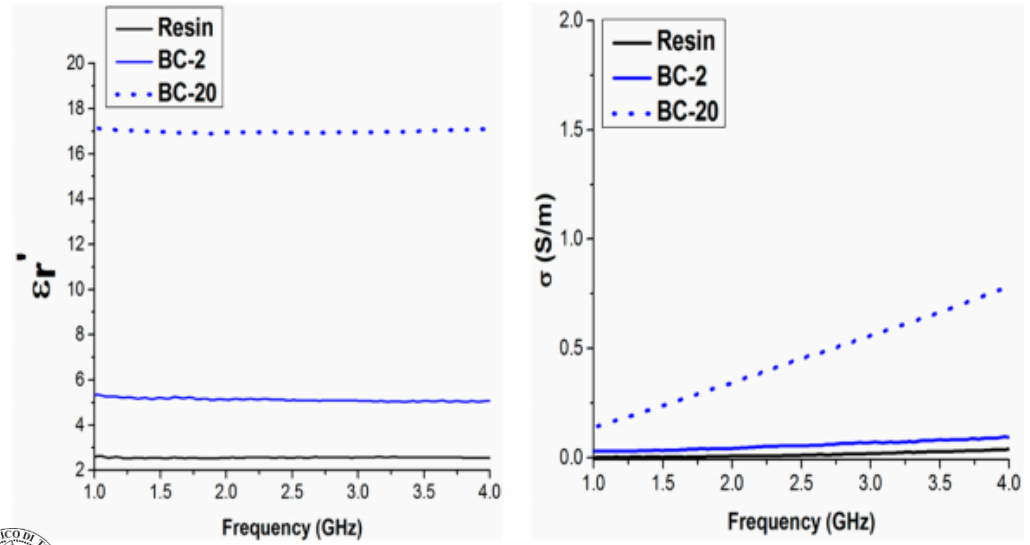
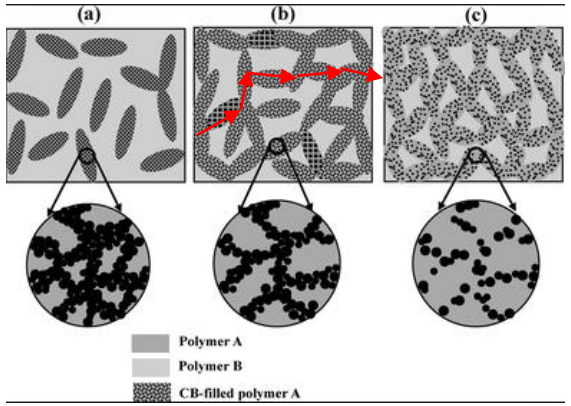


Figure 9. Real part of permittivity (**left panel**) and conductivity (**right panel**) in the microwave range for pure epoxy and epoxy composites filled with 2 and 4 wt % of MWCNTs.



Results are comparable with CNTs

The best results were achieved by 20 wt.% of Biochar



polymers

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Article

Low-Cost Carbon Fillers to Improve Mechanical Properties and Conductivity of Epoxy Composites

Aamer Khan [1], Patrizia Savi [2,*], Simone Quaranta [3], Massimo Rovere [1], Mauro Giorcelli [1], Alberto Tagliaferro [1], Carlo Rosso [4] and Charles Q. Jia [5]

Last selected pubblications

Biomass and Bioenergy 122 (2019) 466–471

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Research paper

Analysis of biochar with different pyrolysis temperatures used as filler in epoxy resin composites

Mauro Giorcelli[a], Patrizia Savi[b,*], Aamer Khan[a,c], Alberto Tagliaferro[a,d]

Biomass and Bioenergy 120 (2019) 219–223

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Research paper

Biochar as a cheap and environmental friendly filler able to improve polymer mechanical properties

Mauro Giorcelli[a,*], Aamer Khan[a,g], Nicola M. Pugno[b,c,d], Carlo Rosso[e], Alberto Tagliaferro[a,f]

polymers

MDPI

Article

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Open Access Article

Waste Coffee Ground Biochar: A Material for Humidity Sensors

Pravin Jagdale [1,2,*], Daniele Ziegler [2,3], Massimo Rovere [2], Jean Marc Tulliani [2,3] and Alberto Tagliaferro [2,4]

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Summary

Biochar is a promising candidate for composite applications

- as substitute of “traditional” carbon filler
- improvement of mechanical properties of composites
- improvement of electrical properties of composites

Advantages of Biochar:

- High carbon content
- Low cost filler
- Help to the reduction of waste disposal needs and costs
- worldwide available

Drawbacks of Biochar:

- feedstock variability
- not fashion enough to raise research funds …

Main collaborations

UNIVERSITY OF ONTARIO INSTITUTE OF TECHNOLOGY

icfar

Western
Institute for Chemicals and Fuels from Alternative Resources (ICFAR)

UK Biochar Research Centre
reducing and removing CO_2 while improving soils: a significant and sustainable response to climate change

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Next Biochar Conferences partecipations

Bio-Char II: Production, Characterization and Applications

An ECI Conference Series

September 15-20, 2019
Grand Hotel San Michele
Cetraro (Calabria), Italy

AUSTRALIA NEW ZEALAND BIOCHAR CONFERENCE & STUDY TOUR 2019 ANZBC19

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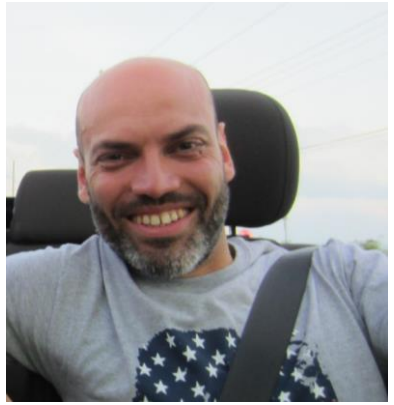
Mauro Giorcelli, Researcher


Massimo Rovere, Raman specialist


Mattia Bartoli, Post. Doc


Pravin Jagadale, Researcher


Prof. Carlo Rosso, Mechanical


Prof. Alberto Tagliaferro, Head