8-20-2017

Microwave characterization and shielding properties of biochar based polymers and cements

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Microwave characterization and shielding properties of biochar based polymers and cements

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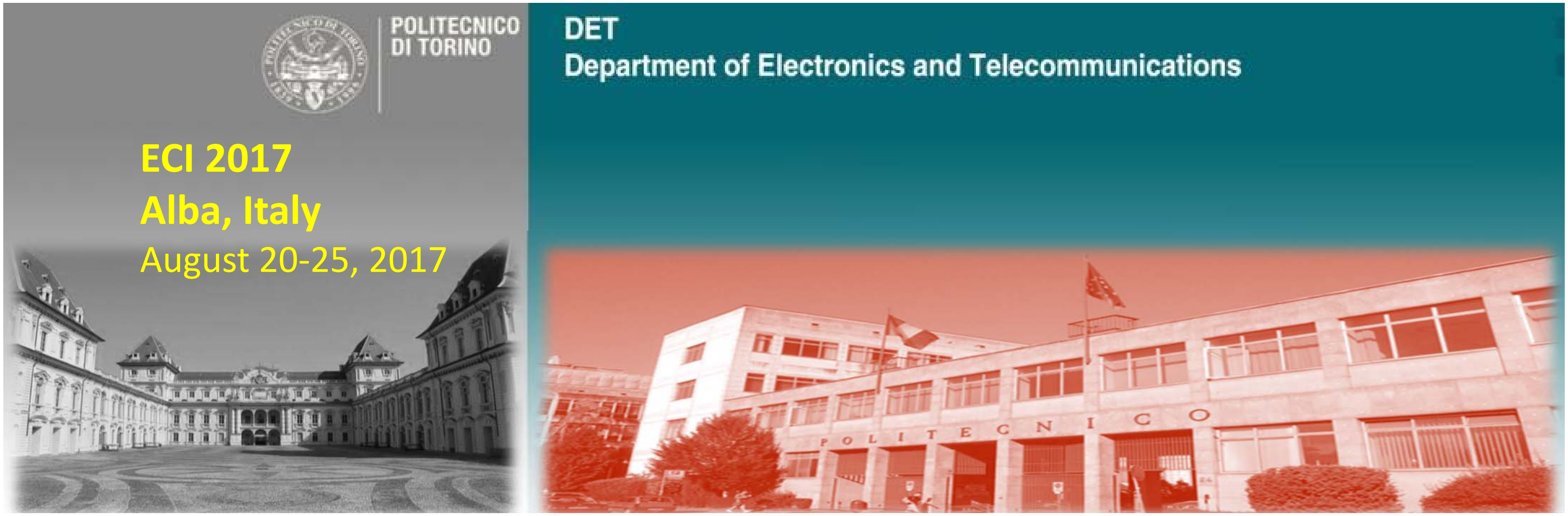

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Multi disciplinary Team

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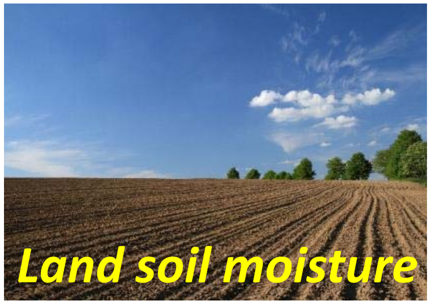
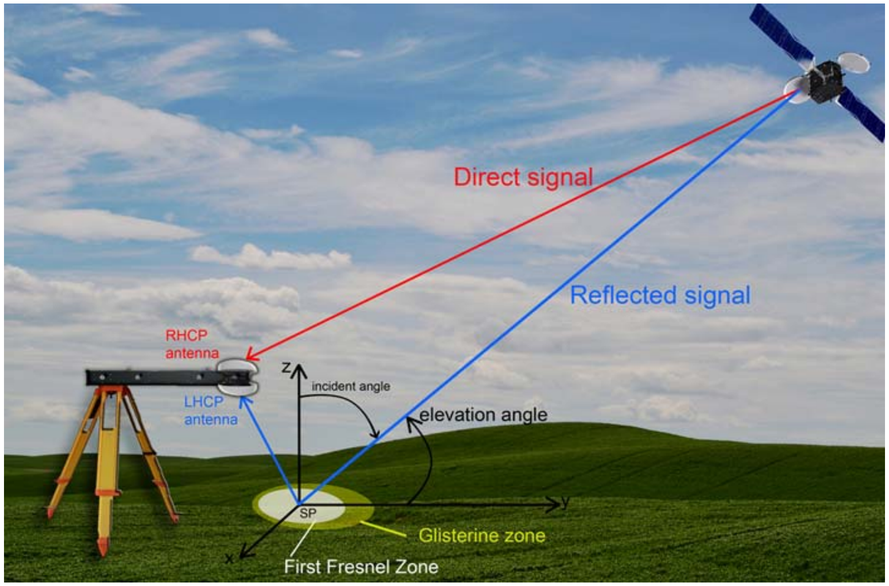
Simone Quaranta
Univ. of Ontario Institute of Technology (UOIT): Faculty of Science, Oshawa, ON, Canada.

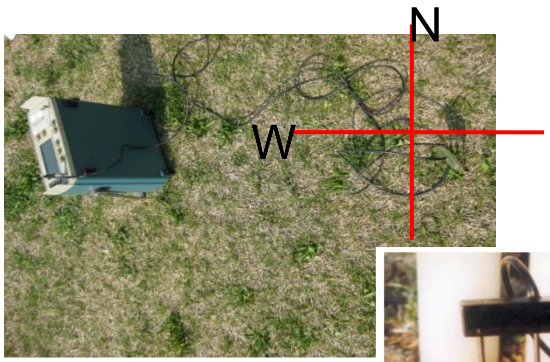
Land soil moisture





Global Navigation Satellite System Reflectometry (GNSS-R)

Time Domain Reflectometry Measurements (TDR)



Tektronix Metallic Cable Tester 1502

Three-rod sensor

Outline

1. Introduction and Motivation
2. Biochar and polymers (bulk)
3. Biochar and cement
4. Biochar and polymers – thick films
5. Conclusions

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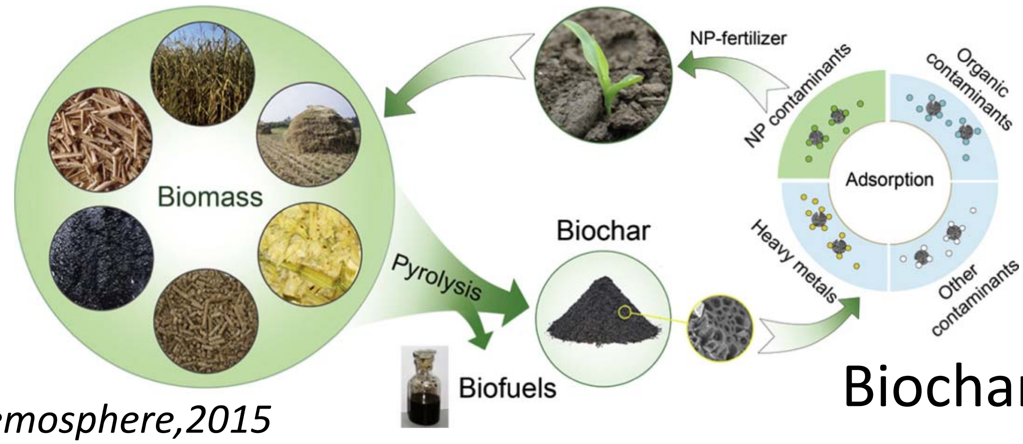
BIOCHAR

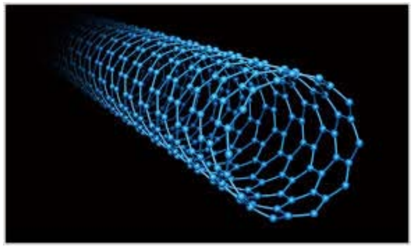
It is a by-product of thermochemical biomass pyrolysis



X. Tan et al., Chemosphere,2015

Biochar cycle

CARBON NANOTUBES



MWCNTs: $1000/Kg [1]

Biochar: $0.5/Kg [2]

[1] Nanocyl NC7000 Industrial grade

[2] Marousek, J.: Significant breakthrough in biochar cost reduction. Clean Technol. Environ. Policy 16, 1821–1825 (2014)

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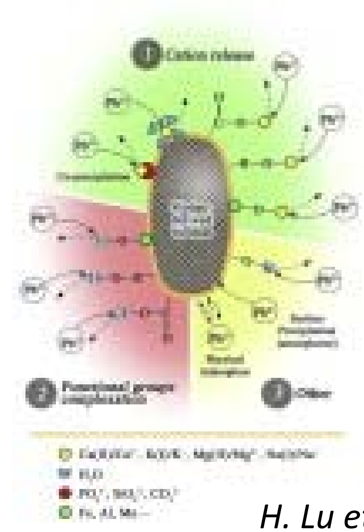
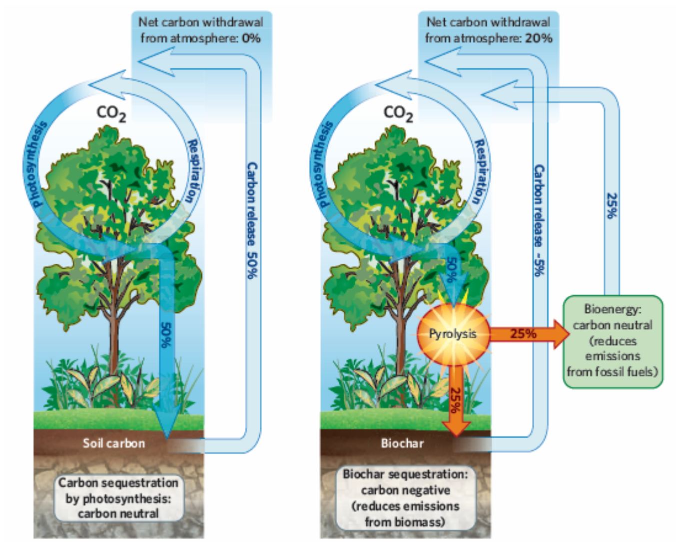
BIOCHAR applications

Removal of pollutants



H. Lu et al., Water Research,2012

Biochar in soil …



… and in construction material

ELECTROMAGNETICS WAVES

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Radiofrequency SHIELDING

Shielded measurements enviroments

Electronic equipment

Space applications (grounding rail tracks)

Wireless frequency 2.5GHz and 5GHz

Copper or new materials ?

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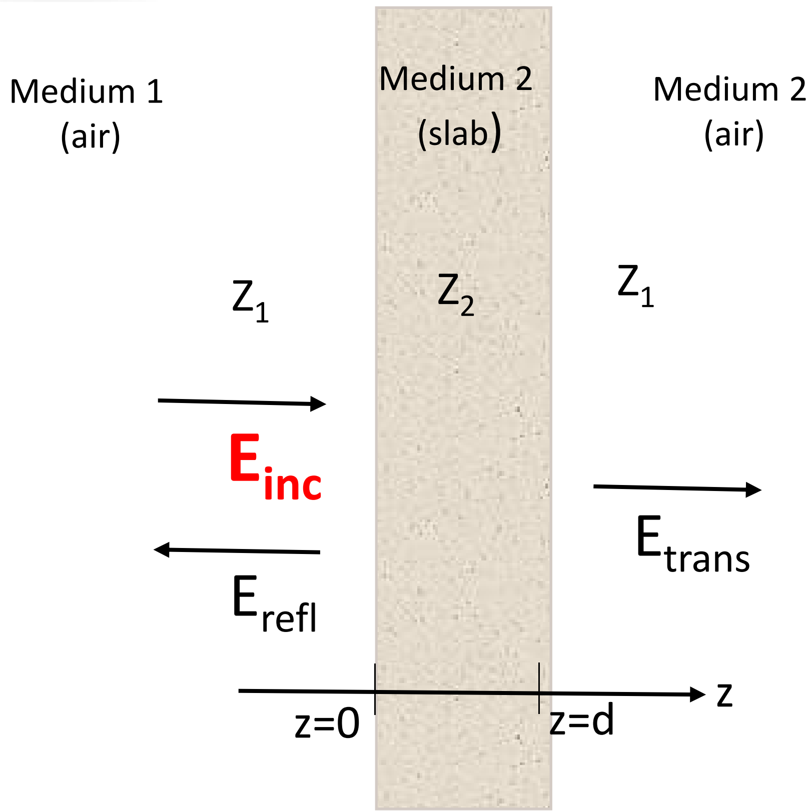
Shielding effectiveness (SE) definition



$$SE_{dB} = 20\ Log \frac{E_{inc}}{E_{trans}}$$

$$SE_{dB} = R_{dB} + A_{dB} + M_{dB}$$

R_{dB}	Reflection loss
A_{dB}	Absorption loss
M_{dB}	Multiple reflection loss

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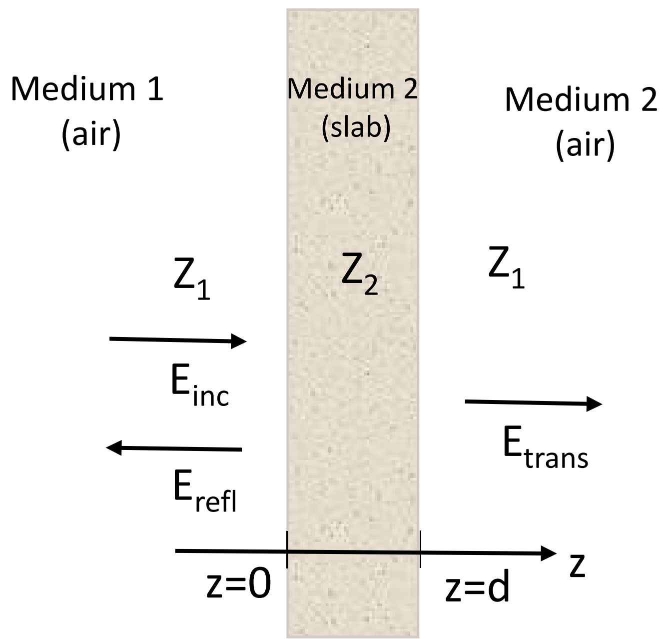
Shielding effectiveness (SE) definition



$$SE_{dB} = 20\ Log \frac{E_{inc}}{E_{trans}}$$

Z impedance of the medium

depends on complex permittivity

SE_{dB} depends on complex permittivity

10^{-6} V/m smallest detectable field strengths

10^{6} V/m largest realizable field strengths

$$20\ Log \frac{10^6}{10-6} = 240\ dB$$

Maximum dynamic range of test equipment around 80 - 120 dB

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Complex permittivity definition

It is the measure of resistance that is encountered by an electric field in a particular medium

It is the measure of a material's ability to resist an electric field

Lowest value ε_0 =8.857 10^{-12} F/m vacuum permettivity or dielectric constant

Relative permettivity $\varepsilon_r = \dfrac{\varepsilon}{\varepsilon_o}$

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Complex permittivity definition

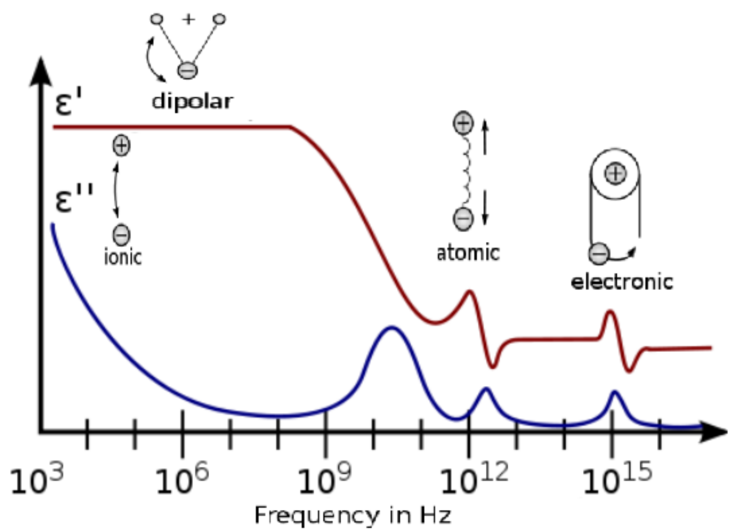
$$\varepsilon = \varepsilon' + j\,\varepsilon''$$

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

Conductivity S/m

$\sigma = \infty$ perfect conductor

$\sigma = 0$ perfect dielectric



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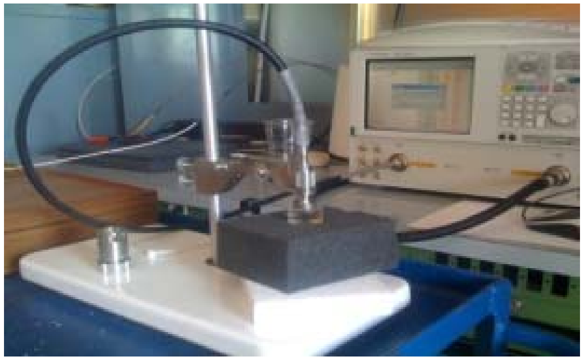
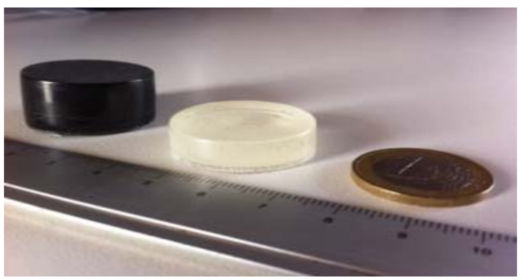
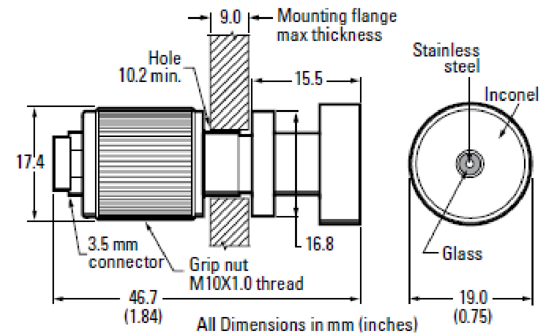
Complex Permittivity Measurements Setup

Open-ended coax sensor
(Agilent 85070D) + NA (E8361A)





Diameter 30mm
Thickness 20mm



Advantages:

- Frequency band 200 MHz – 20 GHz
- Easy calibration: air/short/water
- Fast response

Drawback:

- Flat and smooth surface required
- Minimum sample thickness

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Biochar and polymers

Pristine Biochar (BC) ✚ **Epoxy resin (LPL)**

University of Toronto (UofT), Canada

Cores Ocean

	Weight %	Resin (g)	Hardener (g)	Filler (g)
1	0wt.%	66.67	33.33	0
2	2wt.%.	65.33	32.67	2
3	4wt.%	64	32	4
4	20wt.%.	53.33	26.67	20

A. Khan, P. Savi, S. Quaranta, M. Rovere, M. Giorcelli, A. Tagliaferro, C. Rosso, Low-cost carbon filler to improve mechanical and electrical properties of polymers, submitted to Polymers

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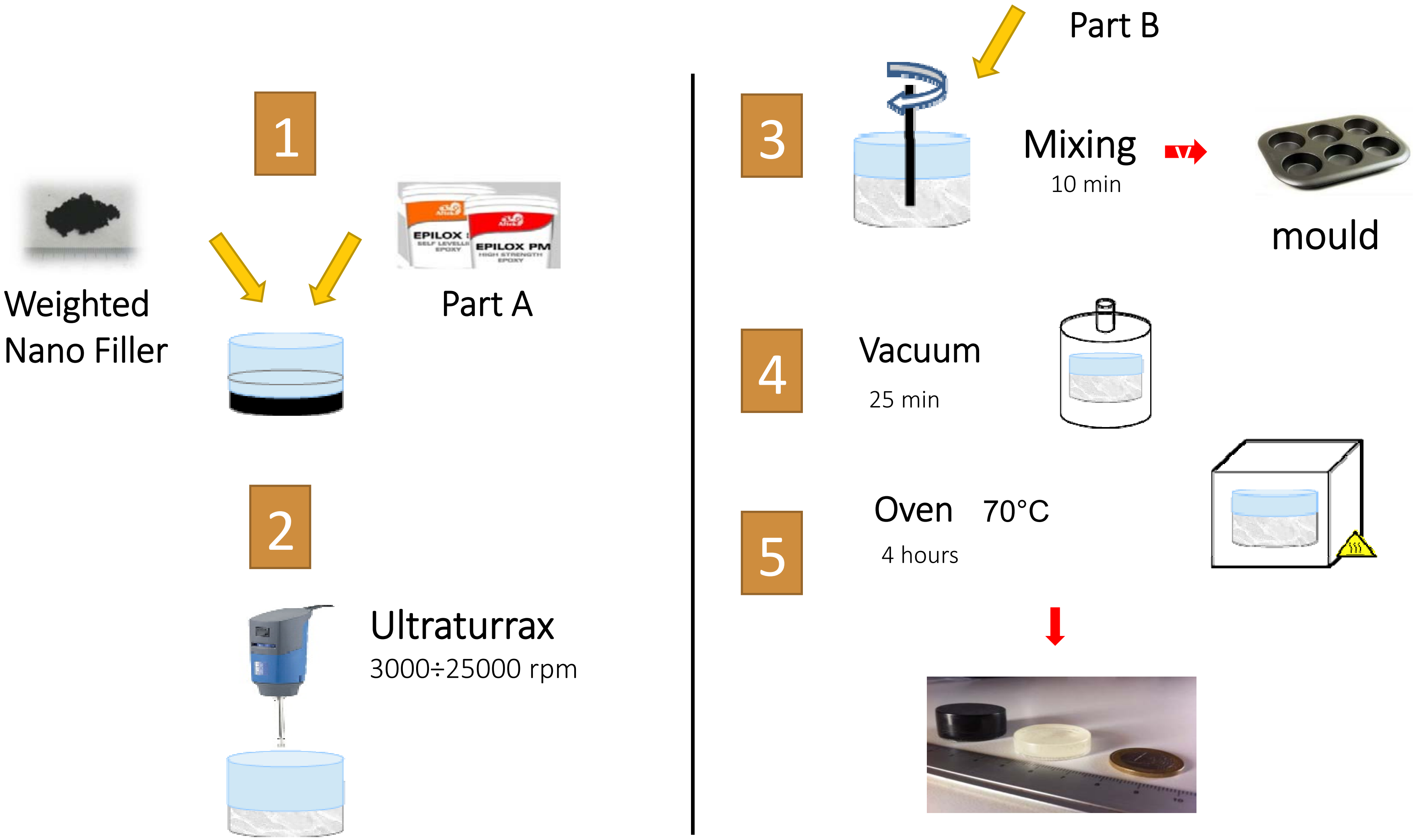
Biochar and polymers: preparation



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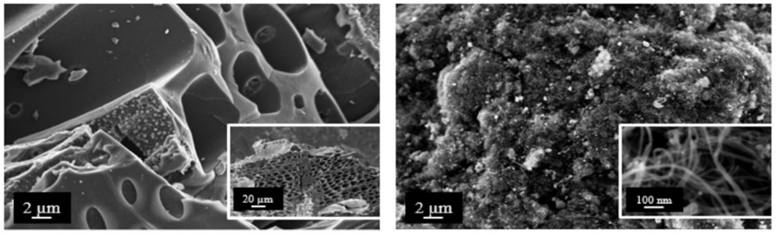
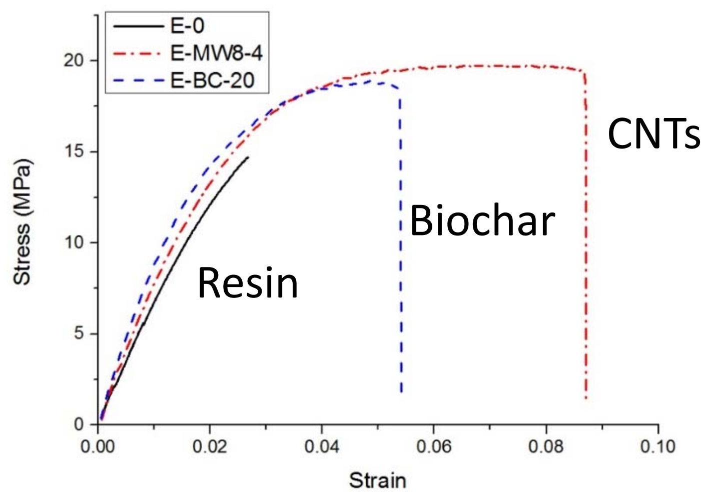
Biochar and polymers: characterization

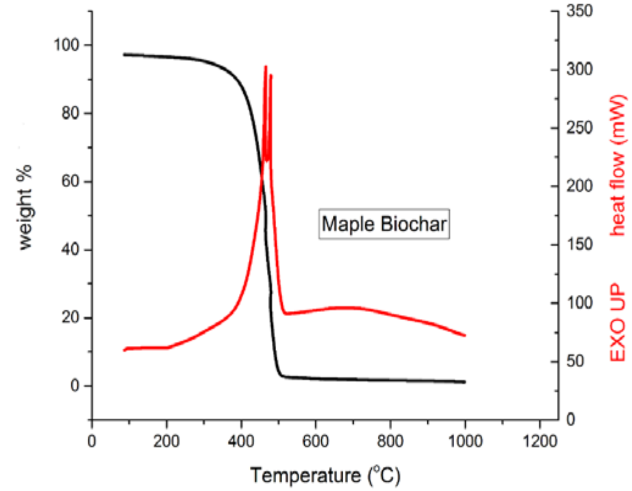
FESEM analysis



Biochar CNTs



TGA of biochar.



Biochar mm

CNTs µm

P. Savi, S. Puthoor Josè, A.A. Khan, A. Tagliaferro, Biochar and Carbon Nanotubes as fillers in polymers: a comparison, IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes (IMWS-AMP), Pavia, September 20-22, 2017

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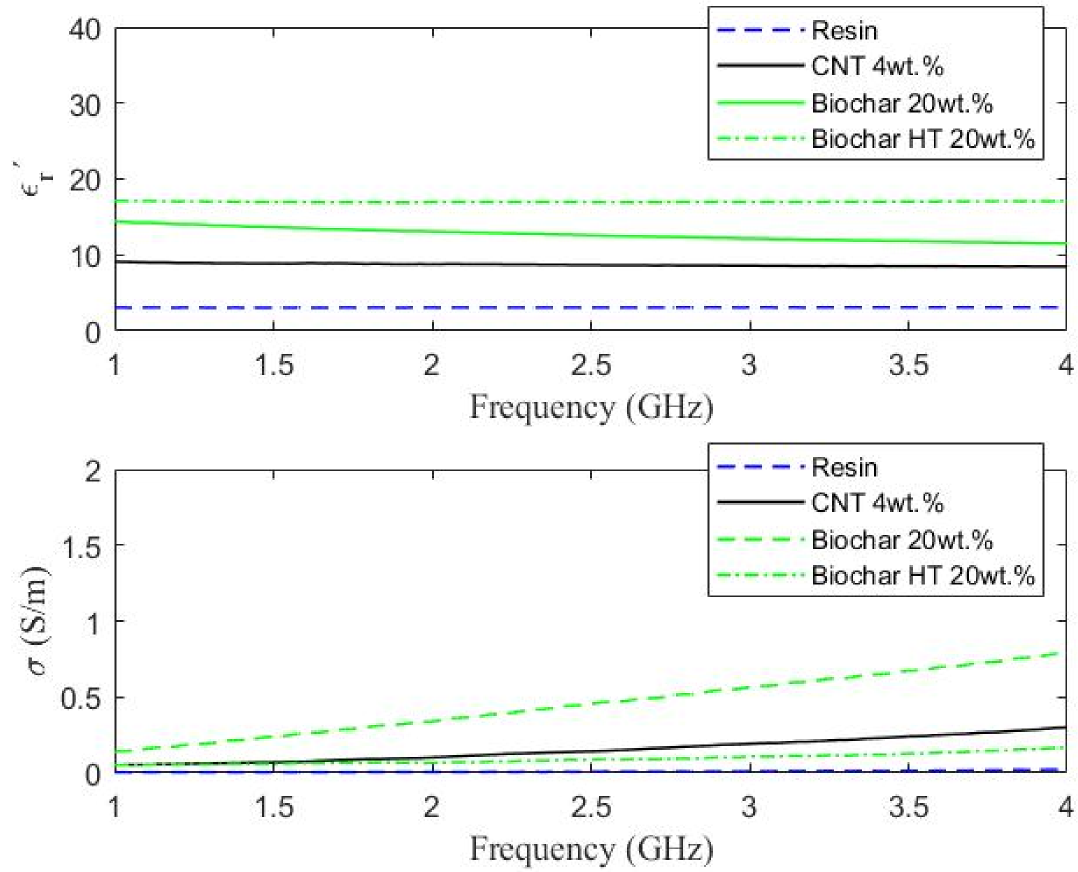
Biochar and polymers: comparison with CNTs



P. Savi, S. Puthoor Josè, A.A. Khan, A. Tagliaferro, Biochar and Carbon Nanotubes as fillers in polymers: a comparison, IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes (IMWS-AMP), Pavia, September 20-22, 2017

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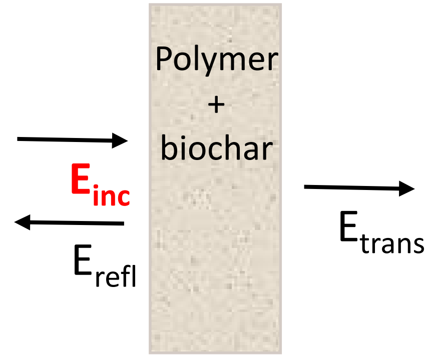
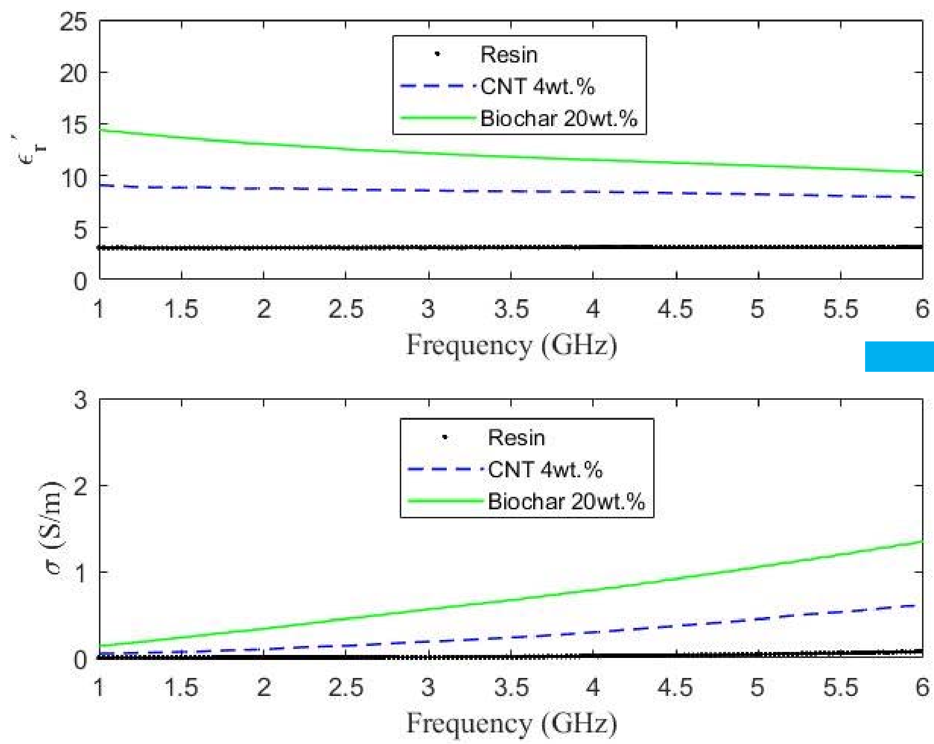
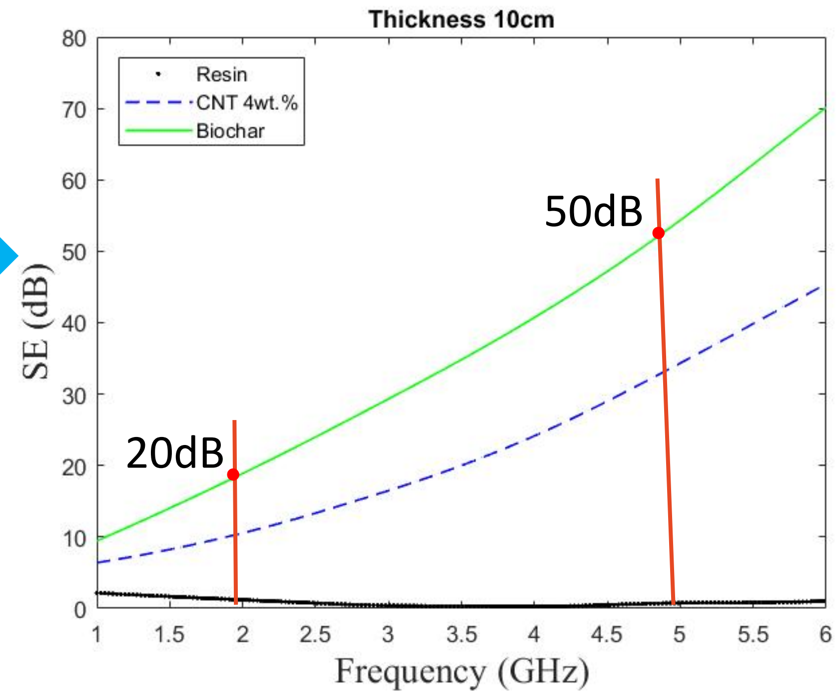
Biochar and polymers



Permettivity measurements



SE computation



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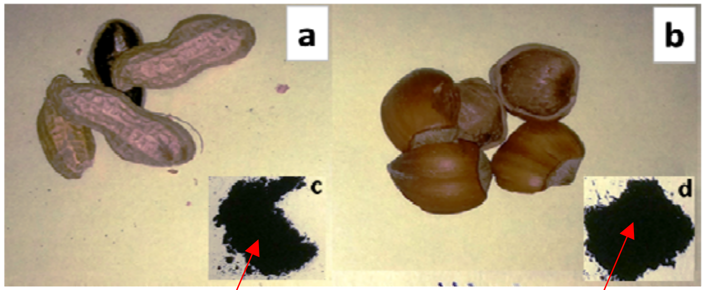
Biochar and cements

Oxides	CaO	SiO_2	Al_2O_3	Fe_3O_4	SO_3	MgO	K_2O
Content (% by mass of cement)	44	9.50	26.5	2.5	12	1.3	0.60

Portland cement Type-1 (Buzzi Unicem 52.5R)

Peanuts shells CPS



Hazelnuts shells CHS

After carbonization and grinding

	D 50 (nm)	D 90 (nm)	BET surface area (m^2/g)	Density (g/cm^3)
Carbonized peanuts shells (CPS)	600	1200	19.4	2.20
Carbonized hazelnuts shells (CHS)	750	1300	14.5	2.35

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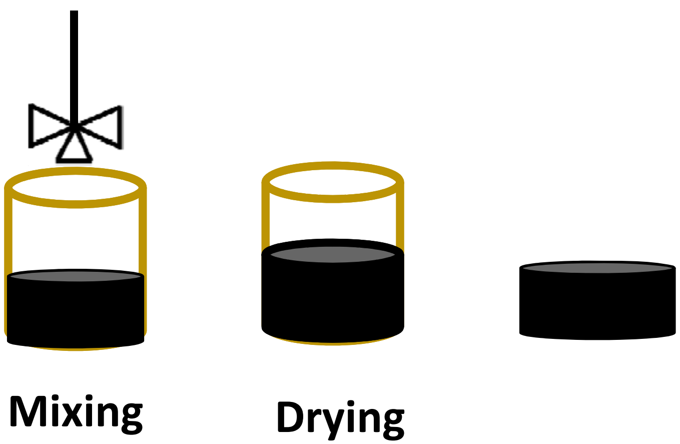
Biochar and cement preparation

i. Mixing speed was increased to 660 rpm and mixing went on for 150 s
ii. Fresh cement paste was transferred into plastic molds 65 mm in diameter and 10 mm thick.
iii. Molds were stored for 24 hours in drying chambers at 90% relative humidity.
iv. After drying the specimens were removed from molds and immersed water curing for 7 days.
v. Finally the specimens were dried at 50 ± 5 C for 72 hours in an oven.



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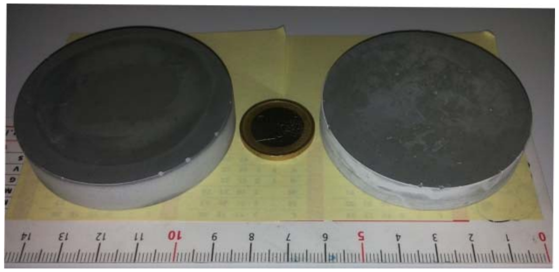
Biochar and cements

	D 50 (nm)	D 90 (nm)	BET surface area (m^2/g)	Density (g/cm^3)
Carbonized peanuts shells (CPS)	600	1200	19.4	2.20
Carbonized hazelnuts shells (CHS)	750	1300	14.5	2.35

Cement composite samples



R. A. Khushnood, S. Ahmad, P. Savi, J.-M. Tulliani, M. Giorcelli, G.A. Ferro, Improvement in electromagnetic interference shielding effectiveness of cement composites using carbonaceous nano/micro inerts, *Construction and Building Materials*, vol. 85, pp. 208-216, April 2015.

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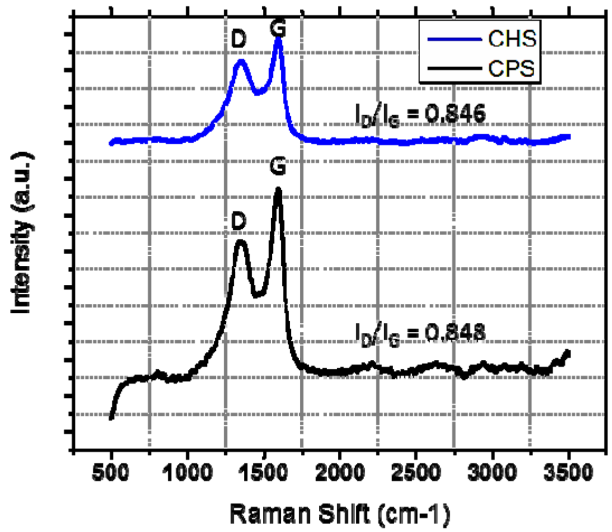
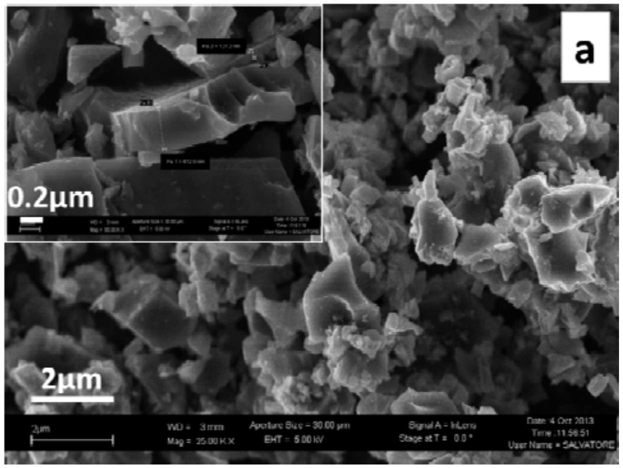
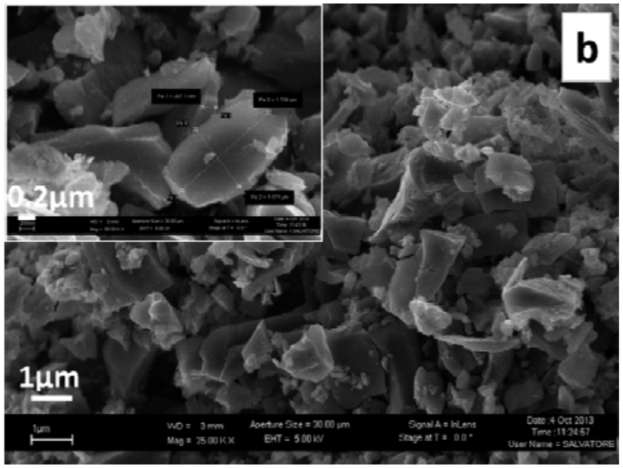
Biochar and cements



Raman analysis



CPS 0.5wt.%



CHS 0.5wt.%

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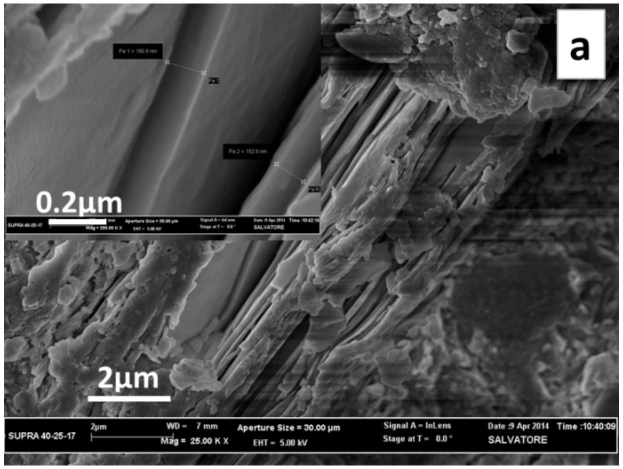
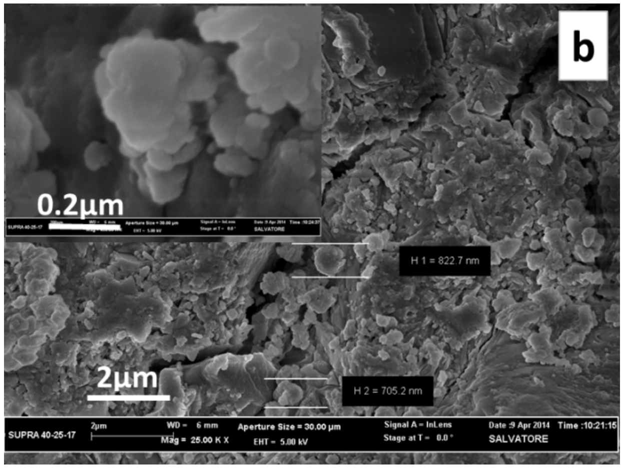
Biochar and cements

FE-SEM micrographs in cement matrix



CPS 0.5wt.%



CHS 0.5wt.%

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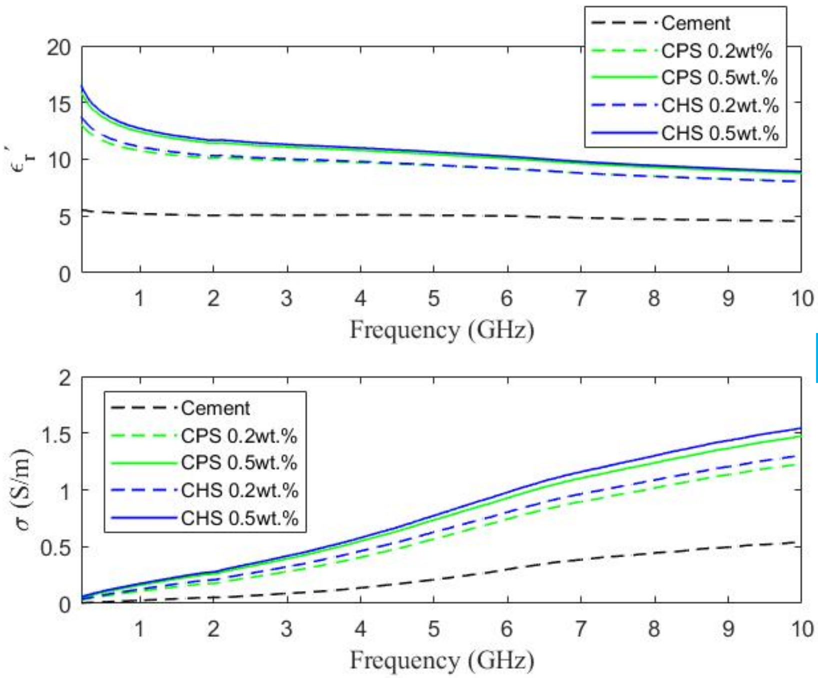
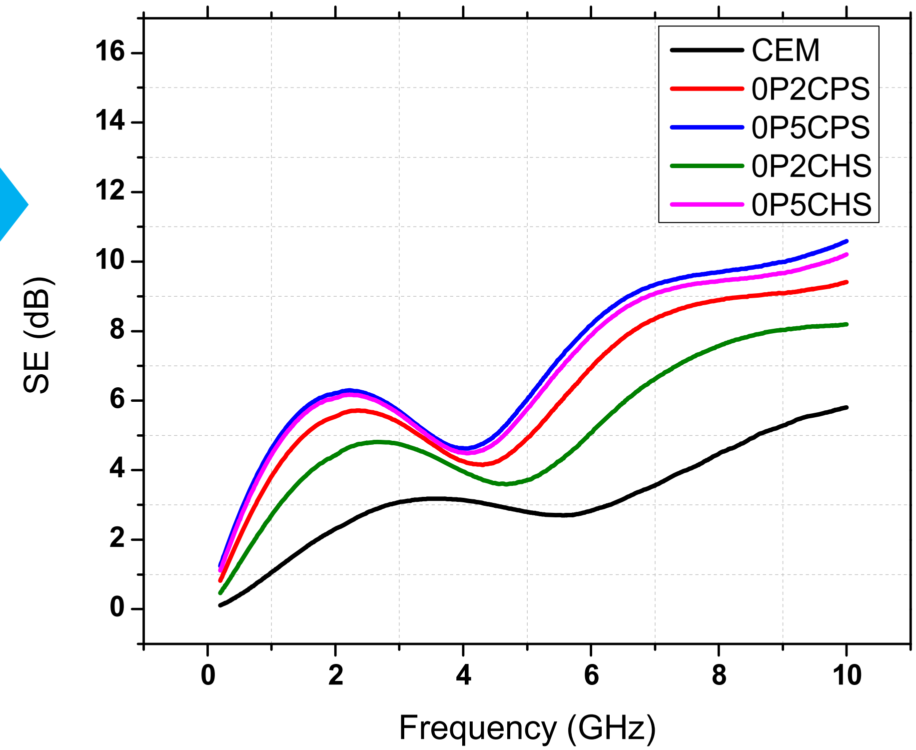
Biochar and cements

Permettivity measurements



SE computation



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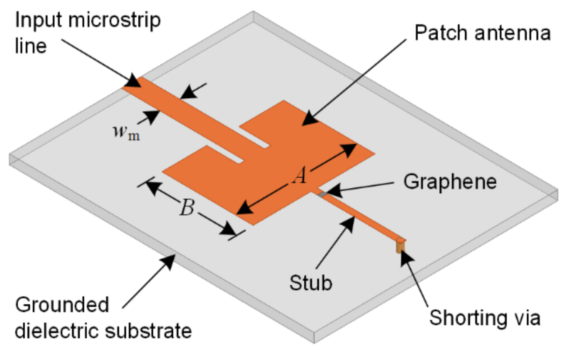
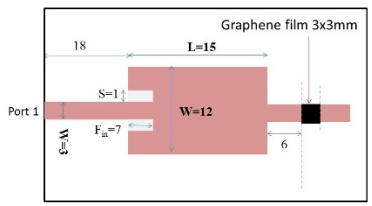
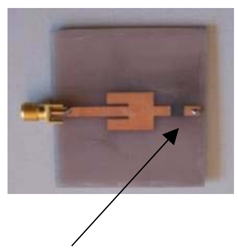
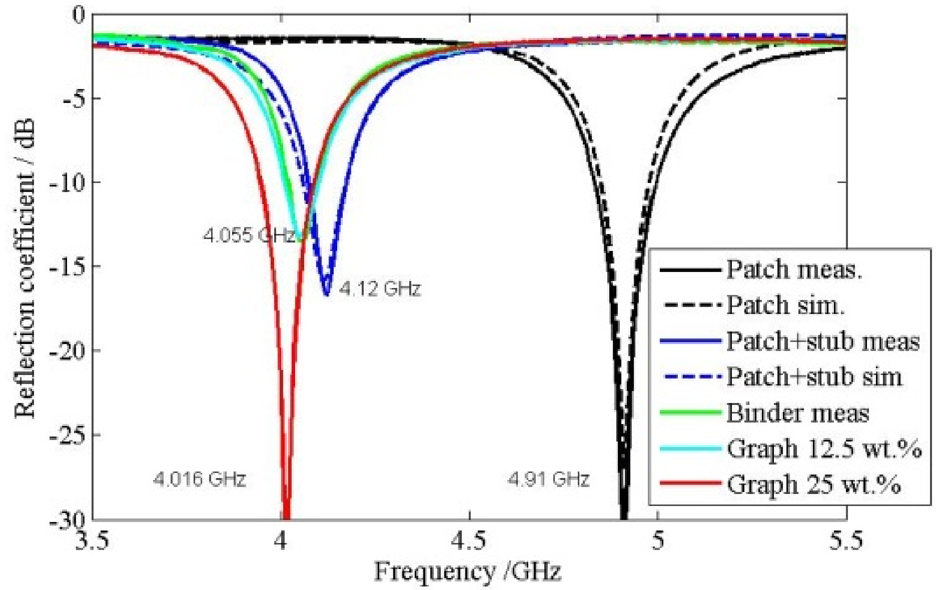
An example: wireless sensors









Resonance frequency shift of 100 MHz

Thick film, screen printing technique

Gas sensor, bio sensors ?

P. Savi, K. Naishadham, A. Bayat, M. Giorcelli, S. Quaranta, "Multi-Walled Carbon Nanotube Thin Film Loading for Tuning Microstrip Patch Antennas," *10th European Conference on Antennas* (EuCAP), Davos, Switzerland, 10-15 April 2016.

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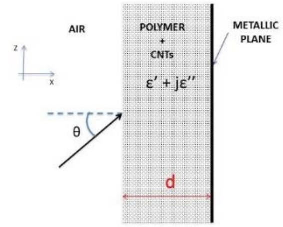
Conclusions and Future work

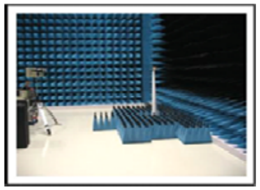
Biochar seems to be a good candidate for shielding applications

- Modeling: oblique incidence

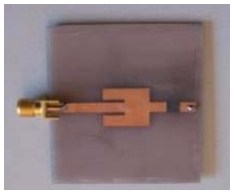


- Modeling: multilayer structure
- Modeling: new types of biochar
- (Paola: heavy metal, Franco: miscanthus)

- Measurements of SE



- Thick films and wireless sensors



Inset-feed antenna

Ring resonators

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Thanks for your attention !

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QUESTIONS ?

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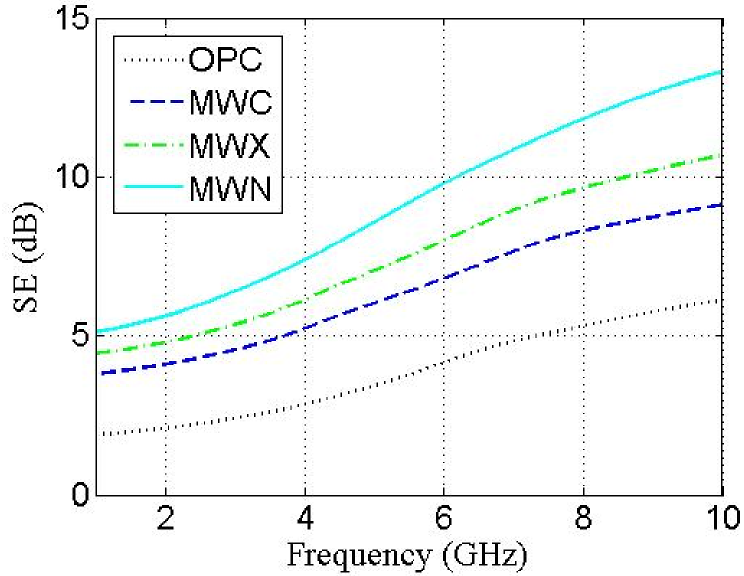
Biochar and cements: a comparison with MWCNT

Designation	Avg. outer diameter (nm)	Avg. length (µm)	Purity (%)	BET surface area (m^2/g)	Aspect ratio
MWX	8.00	10.0	90.00	300	1250
MWN	9.50	1.50	90.00	275	158
MWC	40.0	1.25	95.00	60.0	31



S. Ahmad, R.A. Khushnood, P. Savi, M. Giorcelli, G.A. Ferro, A. Tagliaferro, Effects of Multiwalled Carbon Nanotubes on the Complex Permittivity of Cement Composites, *IET Brunei International Conference on Engineering and Technology,* Brunei, Darussalam, November 1-3. pp. 1-5, 2014.

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Biochar and polymer (bulk) articolo Pavia e Polymer, qual è l'applicazione ???

Biochar and cement articolo Rao, calcolo SE con formule Paul
(stiamo aspettandobiochar Berruti todo similar analysis)

SOLO POSTER Biochar and polymer (thick film), screen printing, caratterizzazione Mario, come usare
thick film nei circuiti elettronici, copertura di componenti o scatole?

Controllare bioohm and bioohmHt sono biochar di Jia o di Franco Berruti ???

$$SE_{dB} = R_{dB} + A_{dB} + M_{dB}$$

$$R_{dB} = 20 * \log_{10}\left|\frac{(Z_O + Z_m)^2}{4 * Z_O Z_m}\right|$$

$$A_{dB} = 20 * \log_{10}\left|e^{\frac{t}{\delta}}\right|$$

$$M_{dB} = 20 * \log_{10}\left|1 - \left[\left(\frac{Z_O - Z_m}{Z_O + Z_m}\right)^2 * e^{-\frac{2t}{\delta}} * e^{-i*2*\beta*t}\right]\right|$$

$$\sigma = \varepsilon'' \omega \varepsilon_o$$

$$\mu = \mu' \mu_o$$

$$\varepsilon = \varepsilon' \varepsilon_o$$

$$Z_O = \sqrt{\mu_O/\varepsilon_O}$$

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Biochar and polymers – thick films

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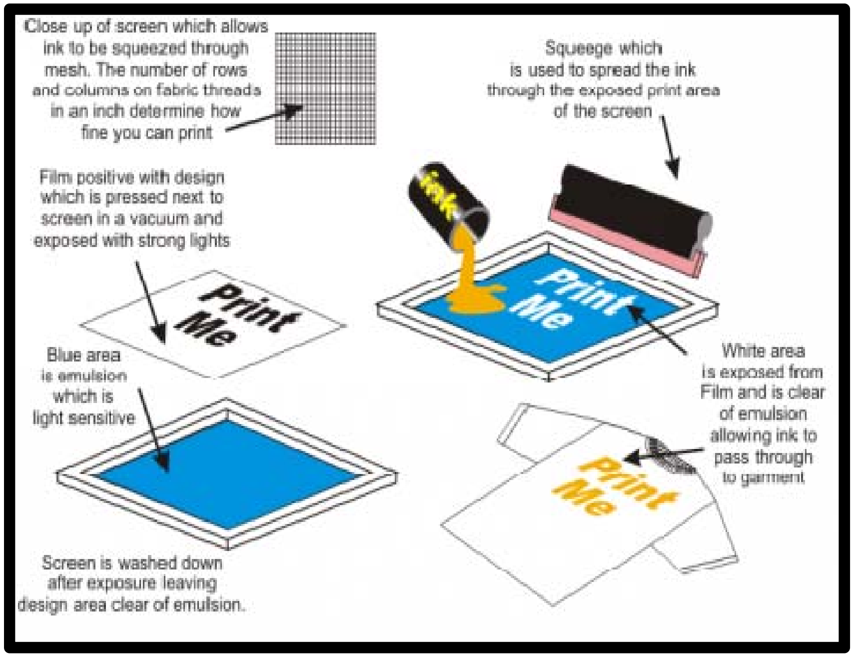
Thick films preparation

Manual screen printing

"The process of forcing ink through a porous fabric and the open areas of a stencil to produce an image".



"Hot pink Marilyn Monroe print from Andy Warhol".

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Inserire foto di esempi screen printing

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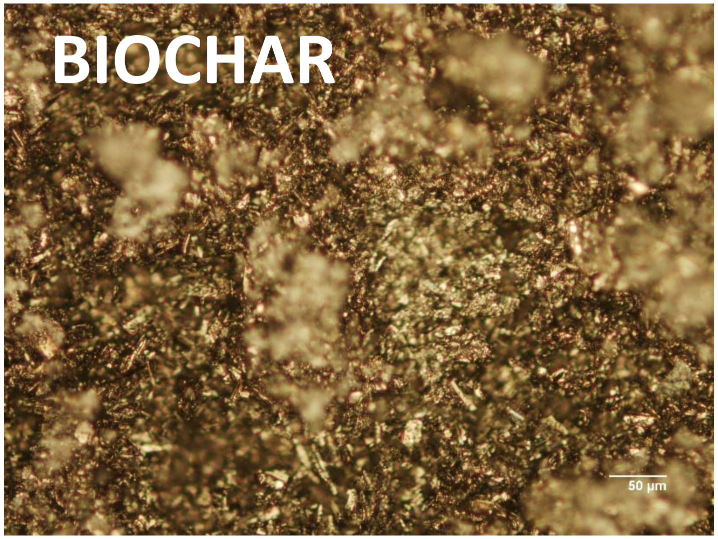
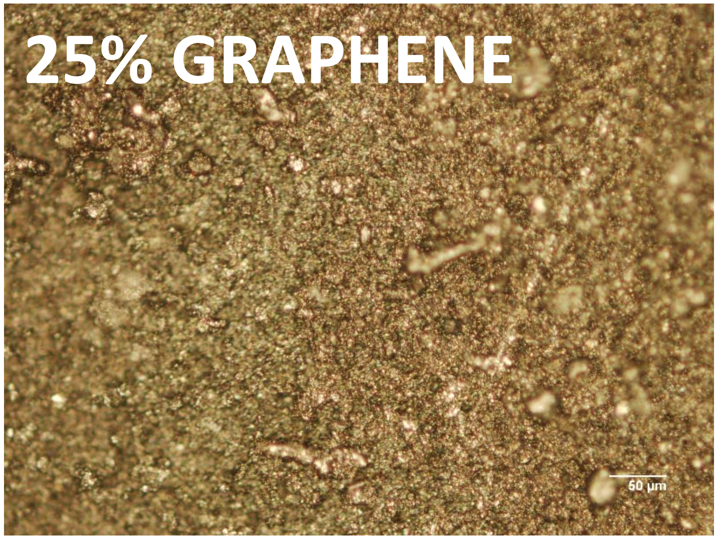
Thick films characterization





Optical Images 20 x Magnification

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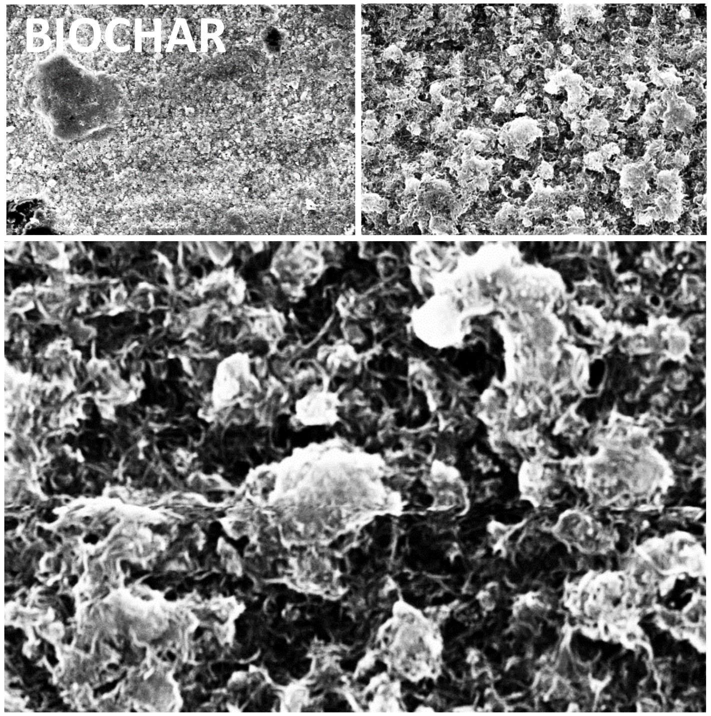
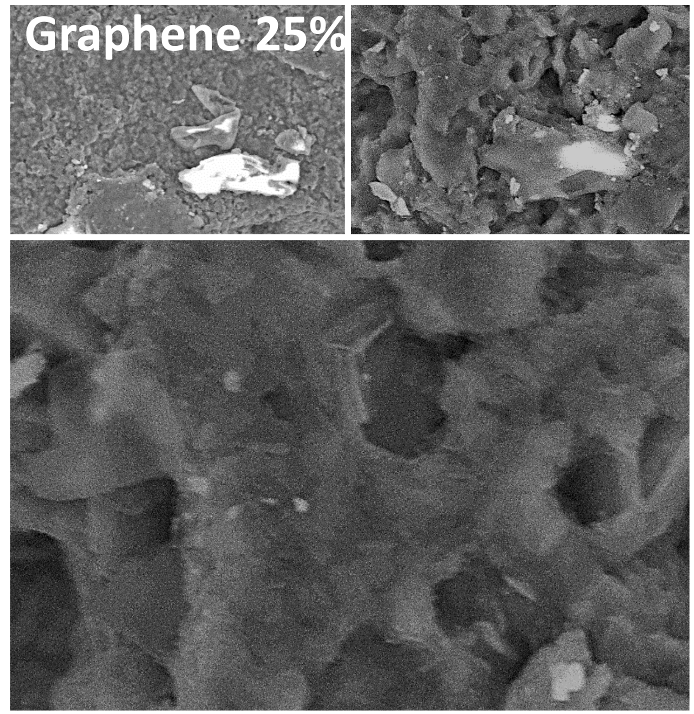
Thick films characterization





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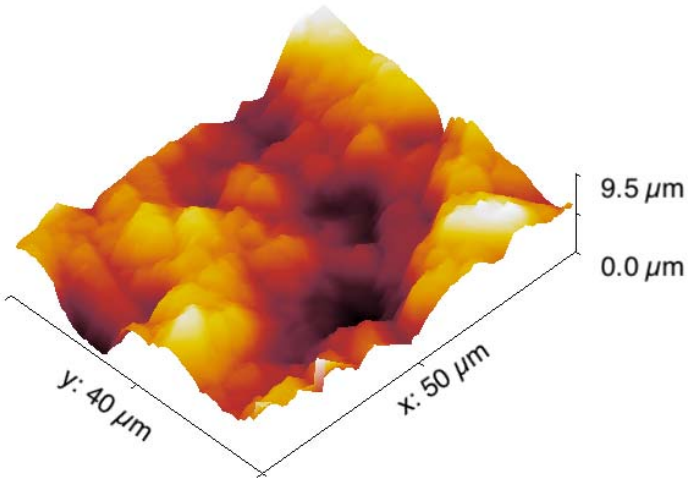
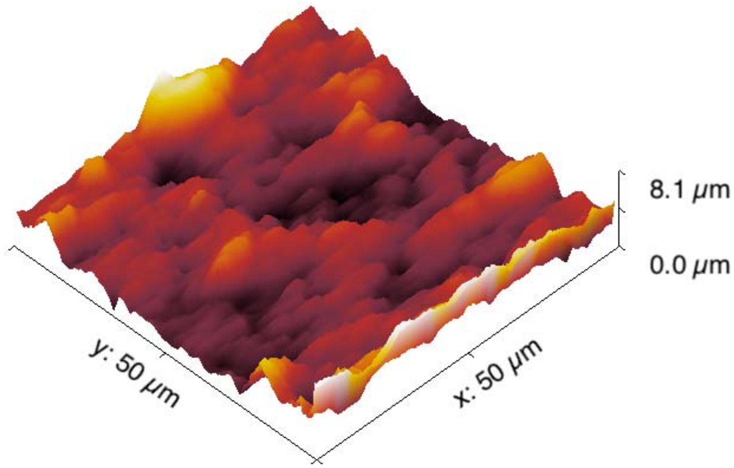
Thick films - applications



BIOCHAR



25% Graphene

AFM Characterization

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Ha senso usare film sopra i componenti elettronici?

O come protezione di scatole ?

Controllare cosa ho come antenne con biochar. Potrebbe funzionare meglio come sensore essendo molto più grotoluto

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