Politecnico di Torino

Cement-based composites containing functionalized carbon nanomaterials

Luca Lavagna[a], Daniel Suarez-Riera[b], Matteo Pavese[a]

[a] Department of Applied Science and Technology, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129, Torino, Italy
[b] Department of Structural, Geotechnical and Building Engineering, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy

luca.lavagna@polito.it

Health monitoring of structures

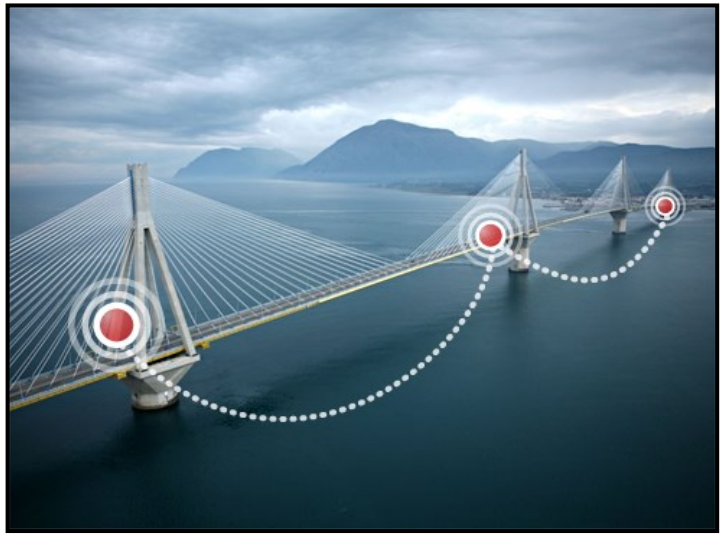
Cement is used in many structures where crack propagation is extremely dangerous

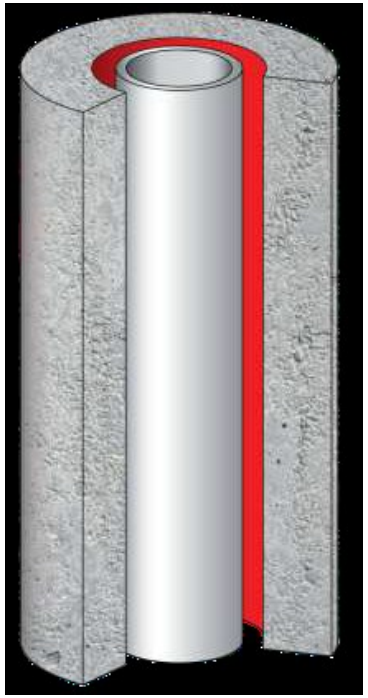
Cement/concrete integrity must be monitored to avoid

Morandi bridge, 2018

Gulf of Mexico, 2010

Carbon-based cement composites





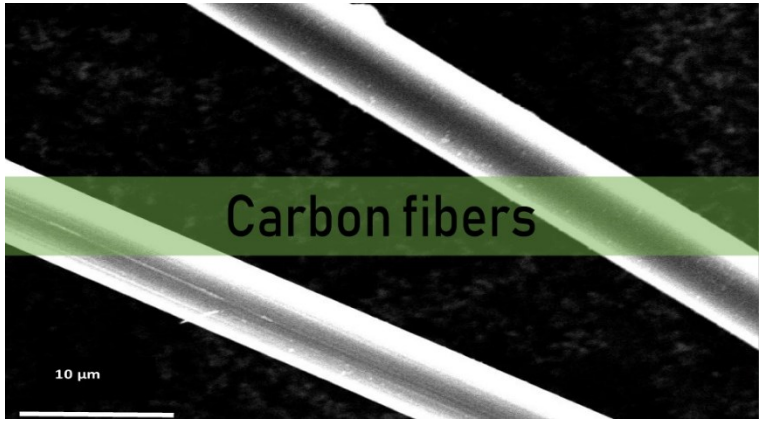
Applications:

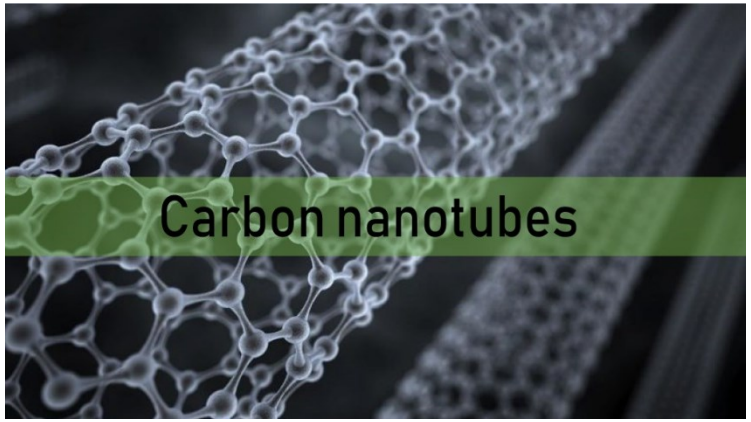
- Health on-line control for civil structures
- Experimental studies of a structure during dynamic loads (earthquakes)
- Stress sensors and structures on-line monitoring for oil&gas applications

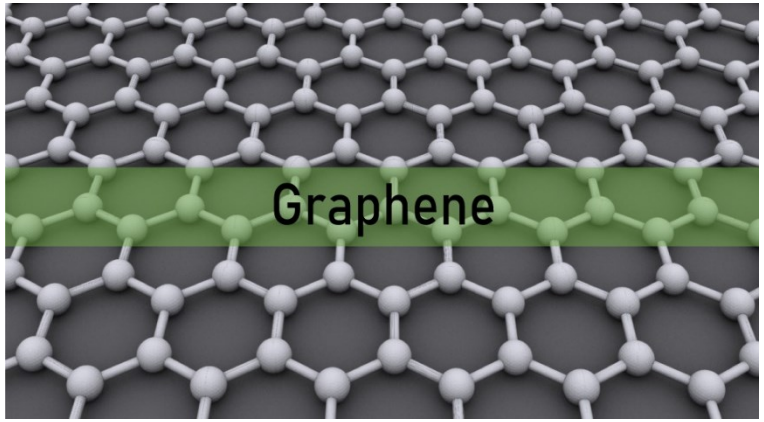
Carbon-based cement composites

Improvement of: **- Mechanical properties**
- Electrical conductivity

FUNCTIONALIZATION NEEDED

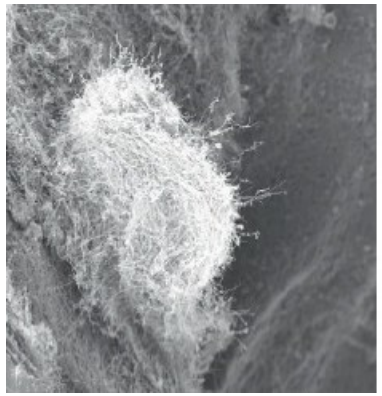




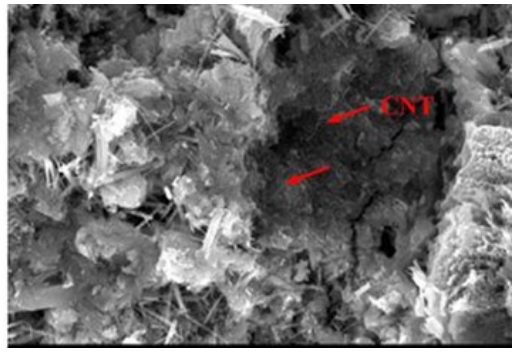


Nanocomposites issues

BAD
dispersion in water



BAD
dispersion in cement due to agglomeration

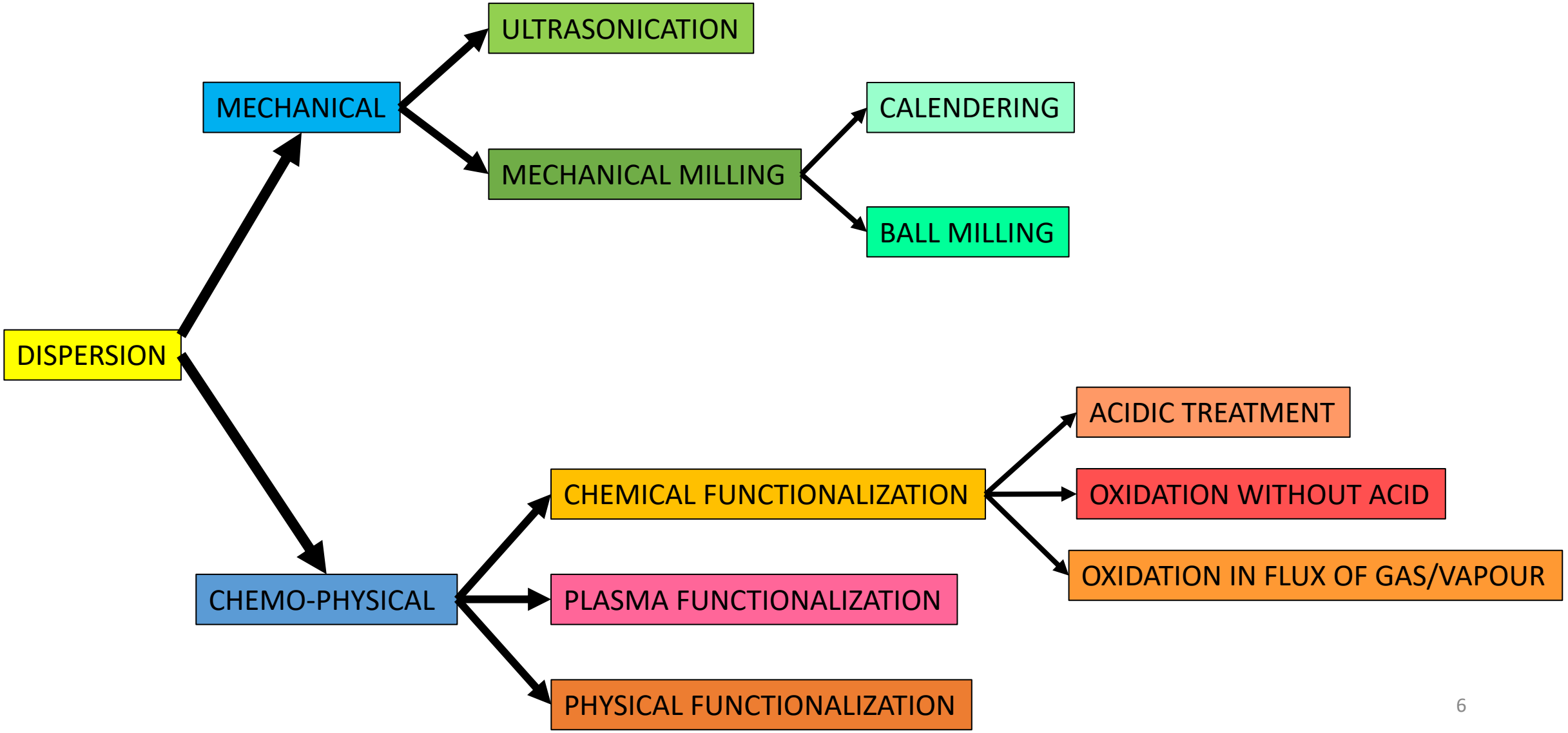


BAD
interaction with cement

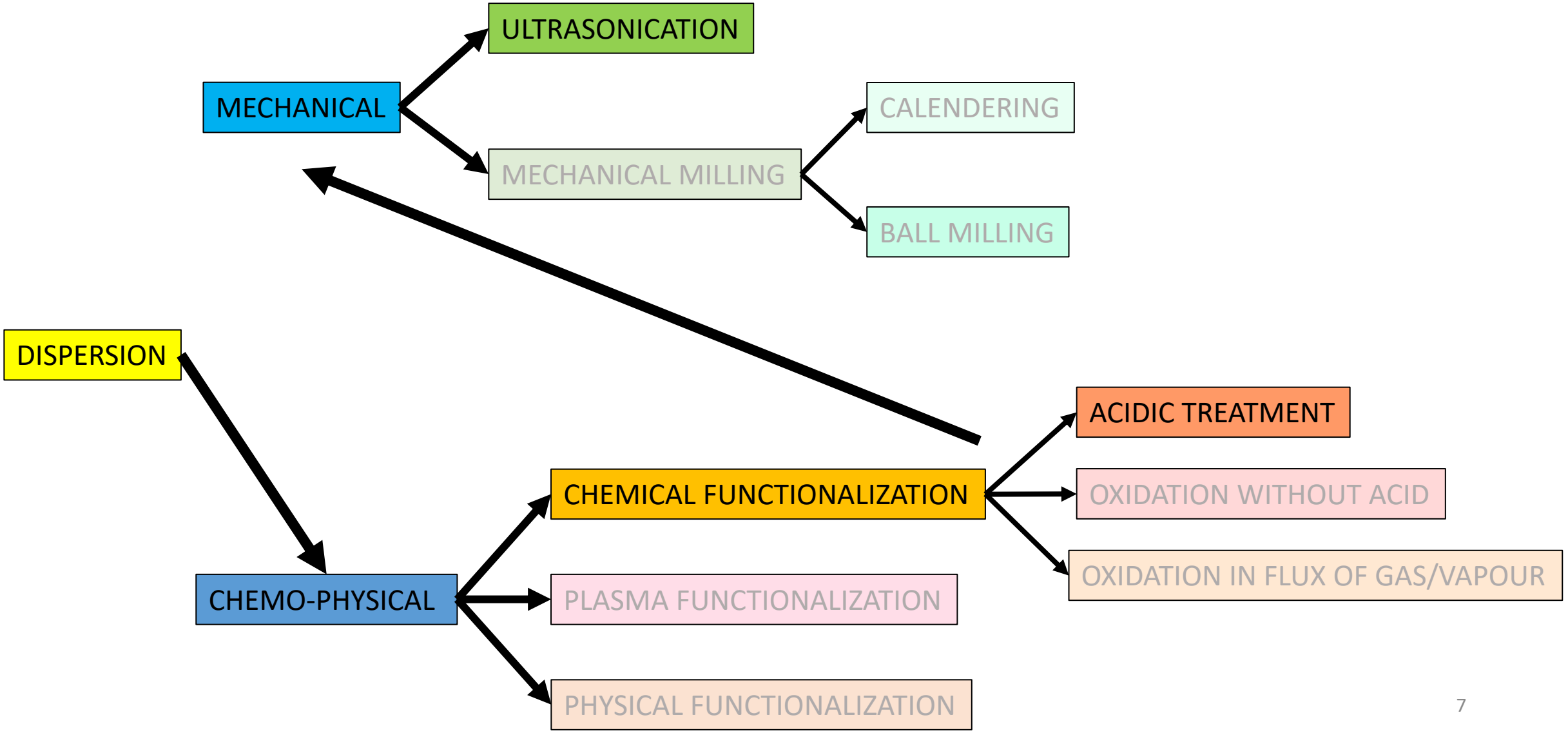
Carbon materials are apolar, and in particular they tend to aggregate so it is difficult to disperse them in water

In order to achieve a good dispersion and interaction with the matrix it is necessary to attach polar groups on the surface

Dispersion/functionalization methods

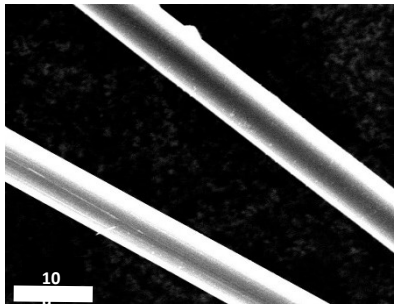


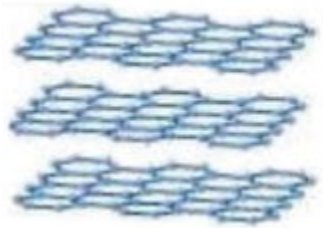
Dispersion/functionalization methods

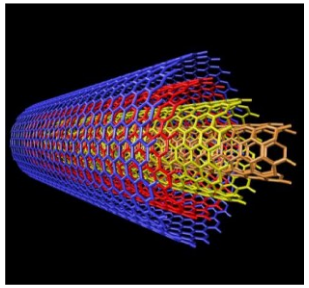


Preparation route

Chemical functionalization



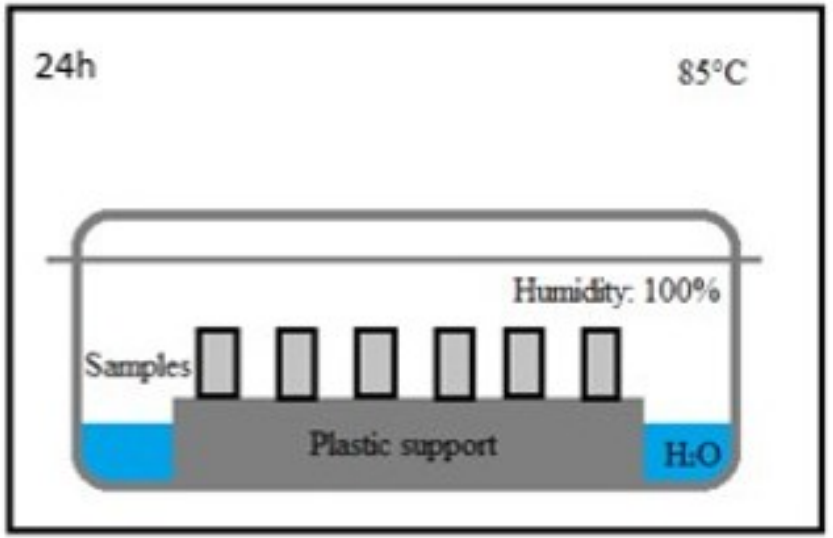




+

Homogenous solution

Cement



TESTS

Cement + carbon fibers

Taguchi design of experiment

Test	Time [min]	Temperature [°C]	Acidic mixture	Flexural strength [MPa]
1	5	0	HNO_3	12.6
2	5	30	1 HNO_3 : 3 H_2SO_4	12.6
3	5	60	3 H_2SO_4 : 1 H_2O_2	13.2
4	30	0	1 HNO_3 : 3 H_2SO_4	8.6
5	30	30	3 H_2SO_4 : 1 H_2O_2	10.5
6	30	60	HNO_3	10.8
7	60	0	3 H_2SO_4 : 1 H_2O_2	12.2
8	60	30	HNO_3	8.2
9	60	60	1 HNO_3 : 3 H_2SO_4	2.1

With factorial approach 27 tests

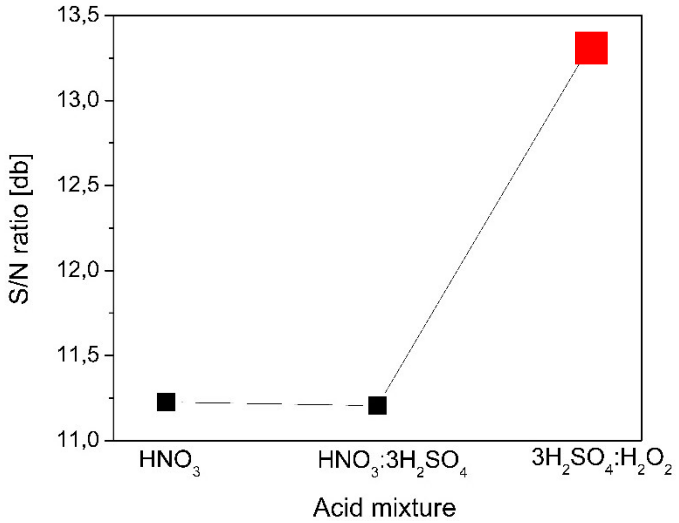
With Taguchi 9 tests

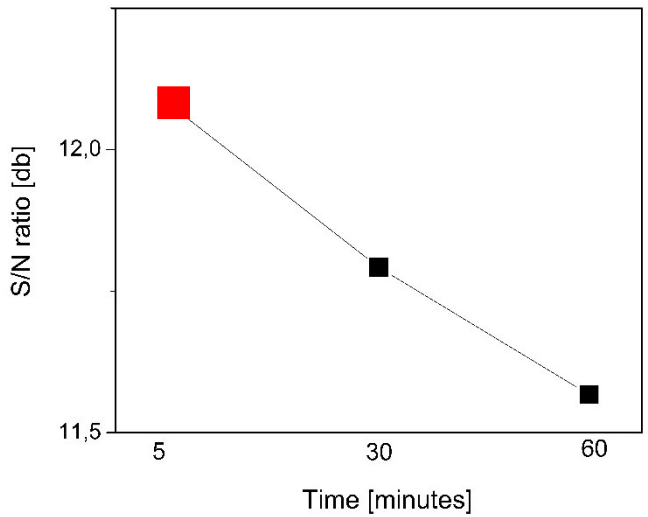
$S/N = -10 * \log(\Sigma(1/Y^2)/n)$

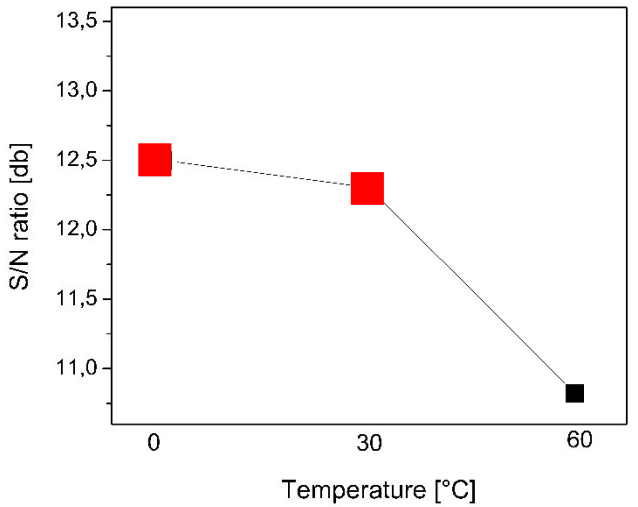
Time [min]	S/N [dB]	Temperature [°C]	S/N [dB]	Acidic mixture	S/N [dB]
5	22,1	0	20,5	HNO_3	20,1
30	19,8	30	20,1	1 HNO_3 : 3 H_2SO_4	10,9
60	10,9	60	11,0	3 H_2SO_4 : 1 H_2O_2	21,4

Taguchi DOE results:

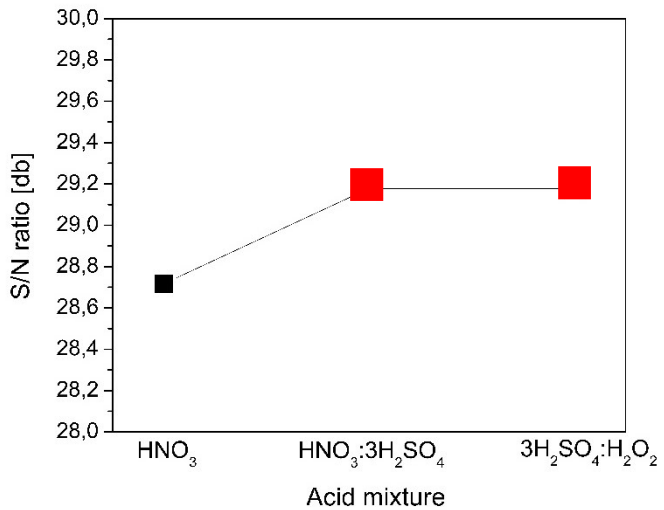
Flexural strength

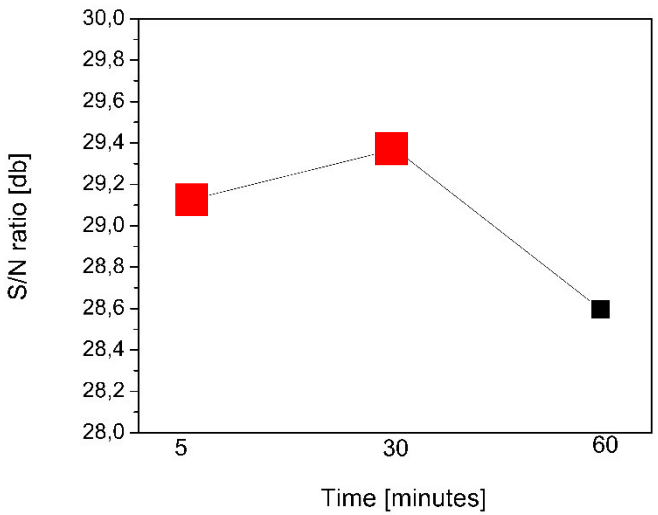


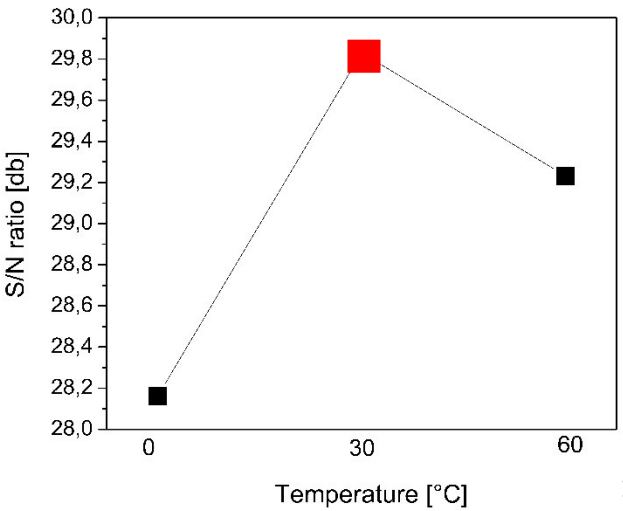




Compressive strength







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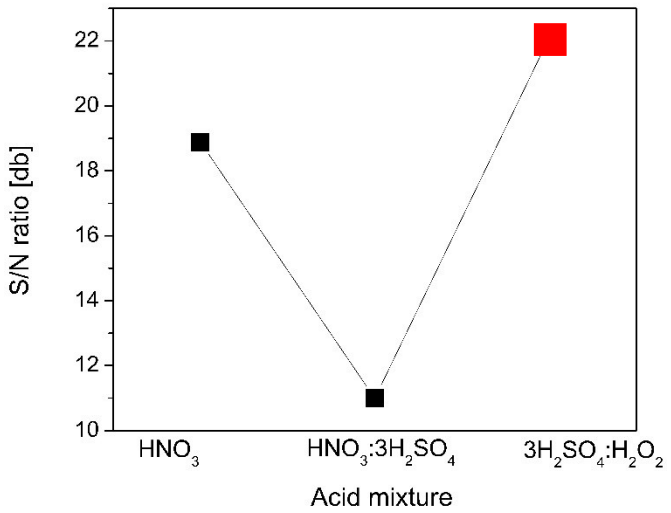
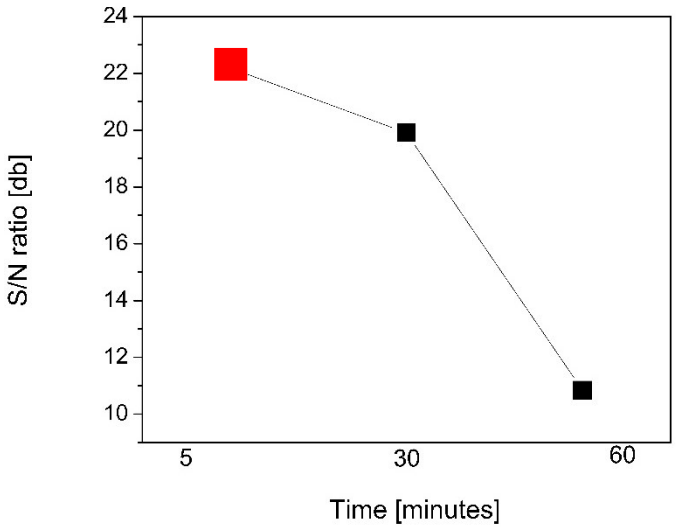
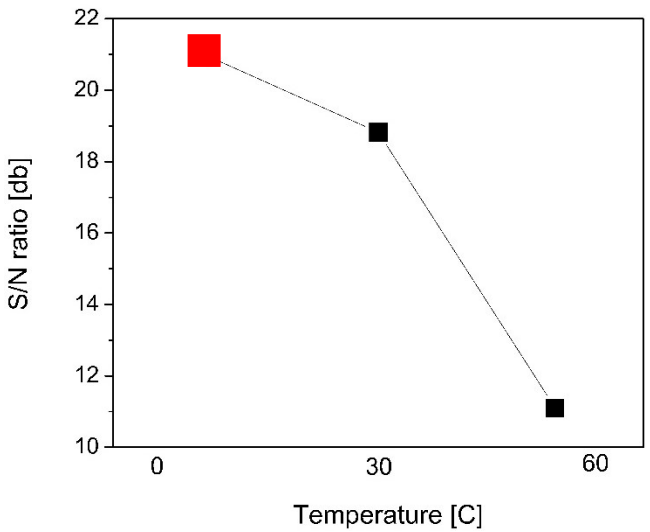
Taguchi DOE results:

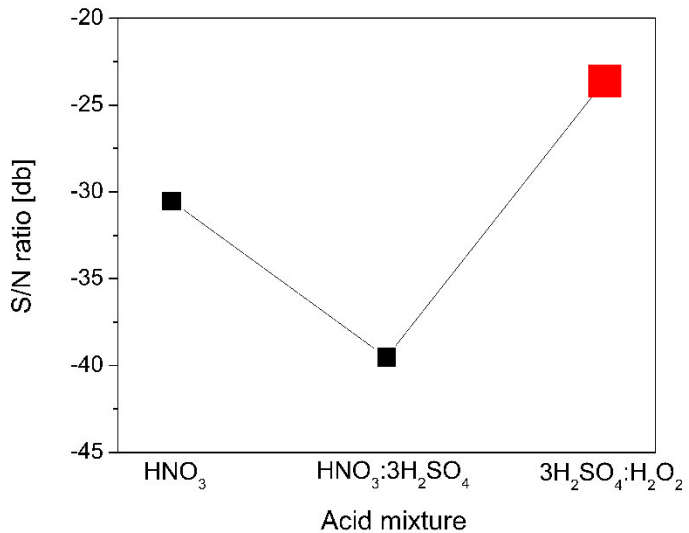
Toughness

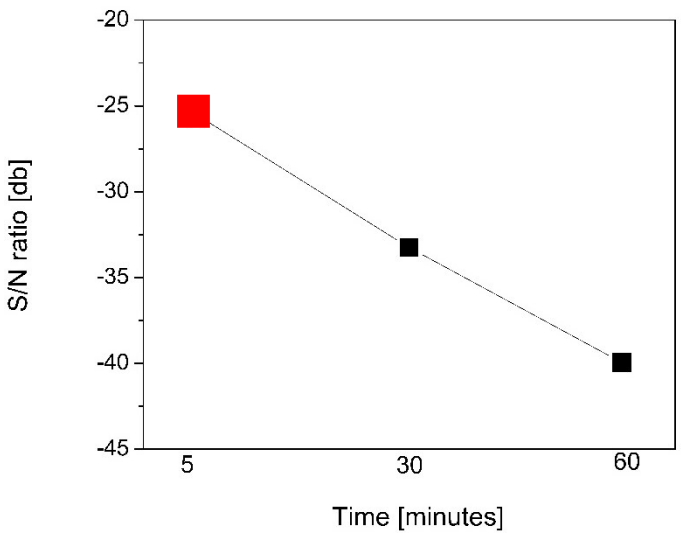


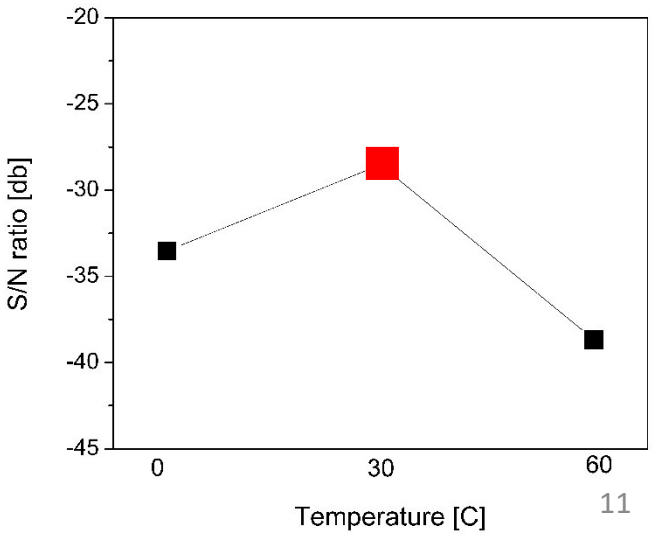




Electrical resistivity







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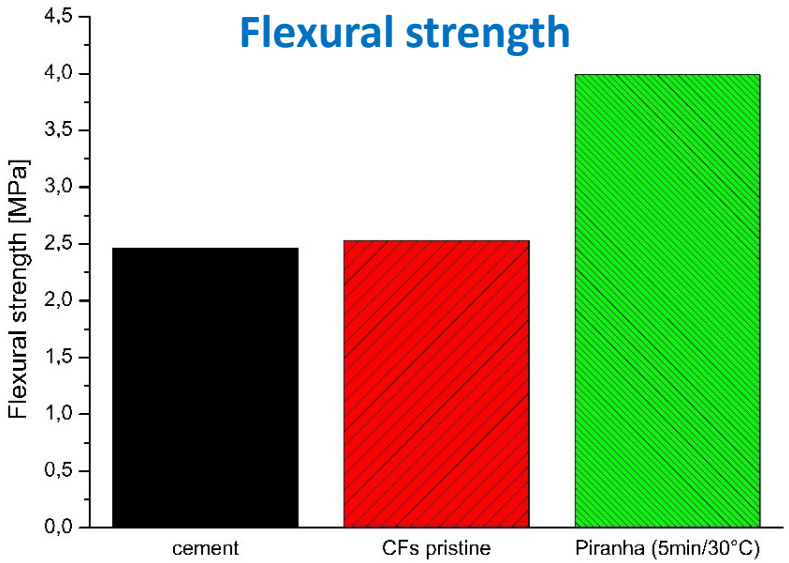
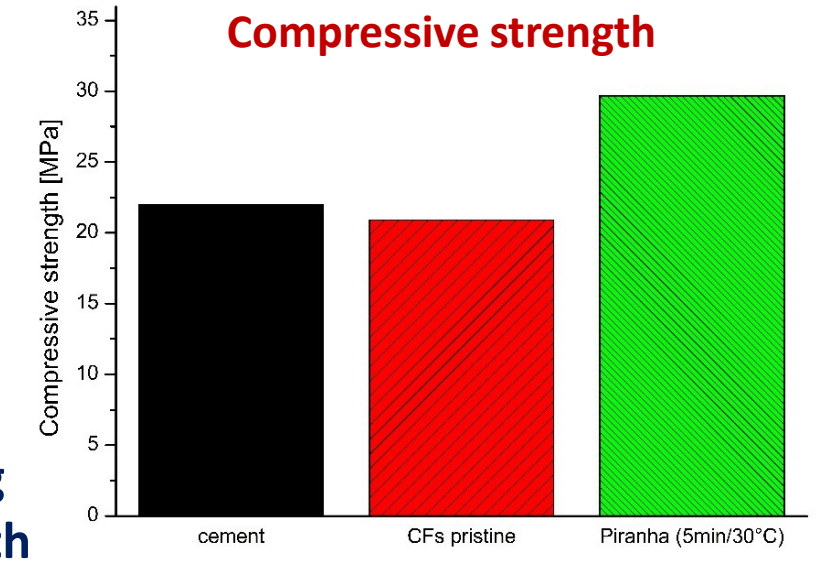
Composites performance

Flexural strength

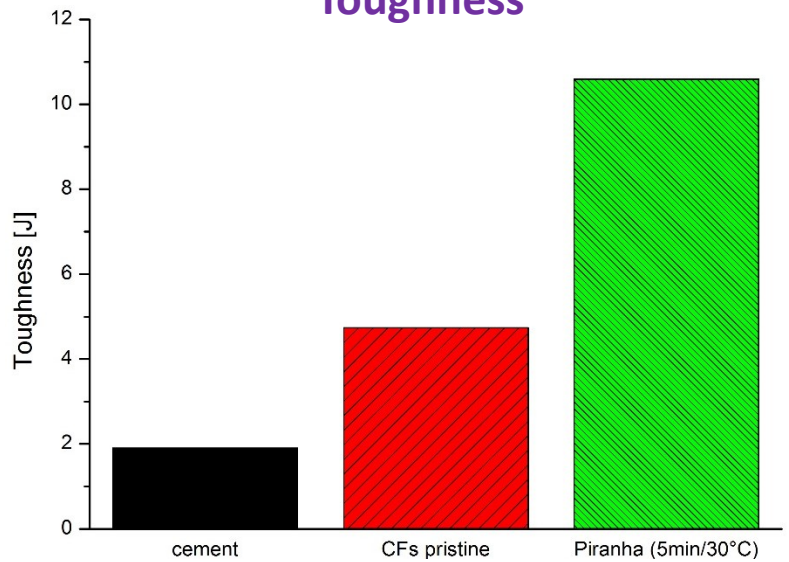


Compressive strength

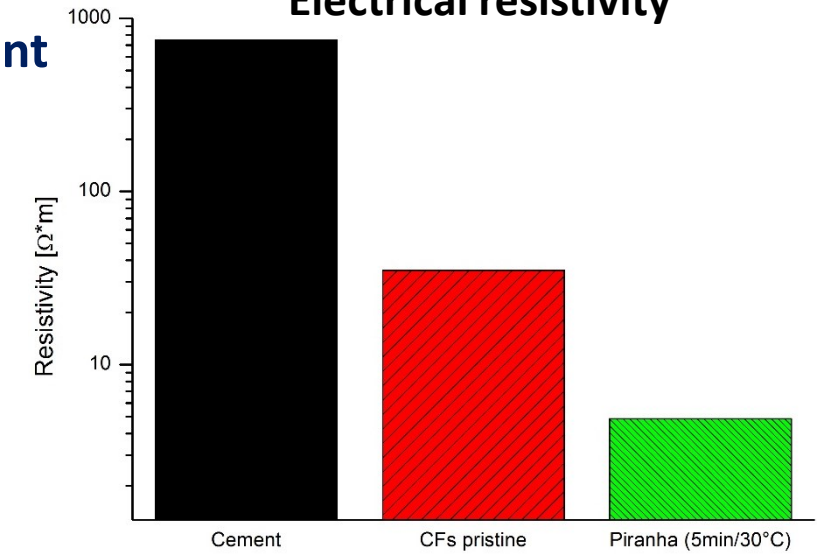


Comparing samples with 0.1% reinforcement

Toughness



Electrical resistivity



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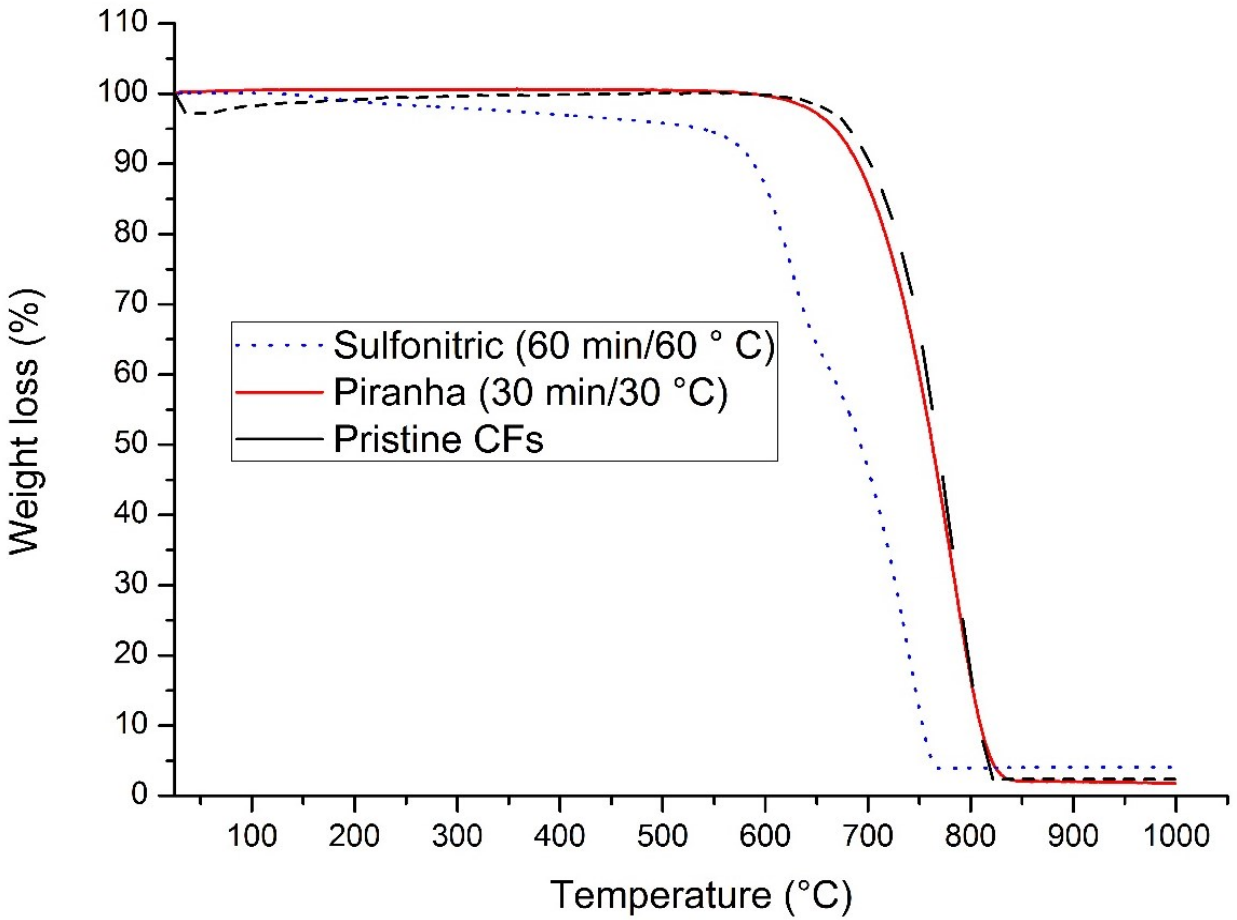
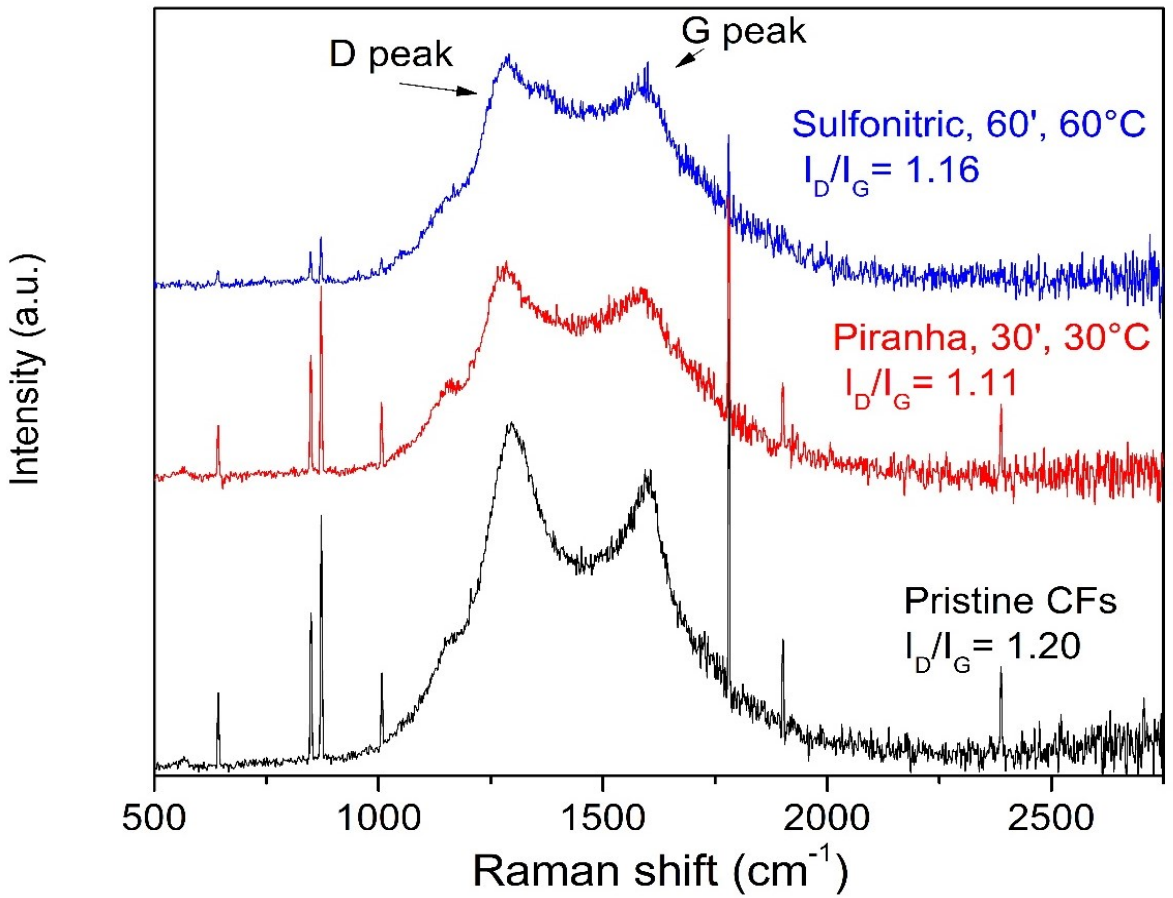
Characterization of treated CFs

Comparing the best and the worst of Taguchi DOE

Thermogravimetric analysis



Raman



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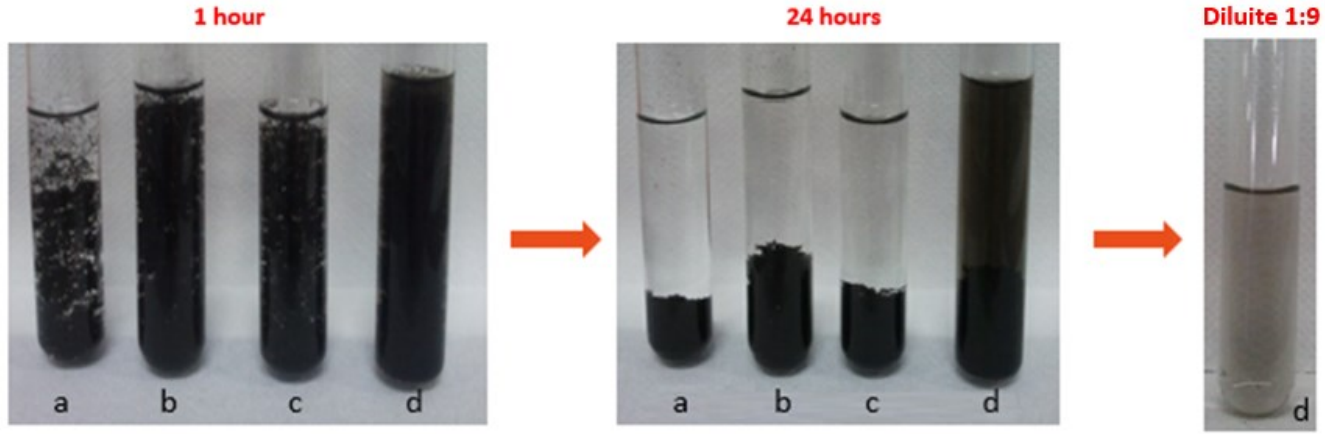
Cement + carbon nanotubes

Chemical functionalization

Experiment	Acid type	Time [min]	Temperature [°C]
A	Aqua Regia	30	30
B	Nitric	30	30
C	Piranha	30	30
D	Sulfonitric	30	30



Acid	Time [min]						
Sulfonitric	15	30	45	60	75	90	120

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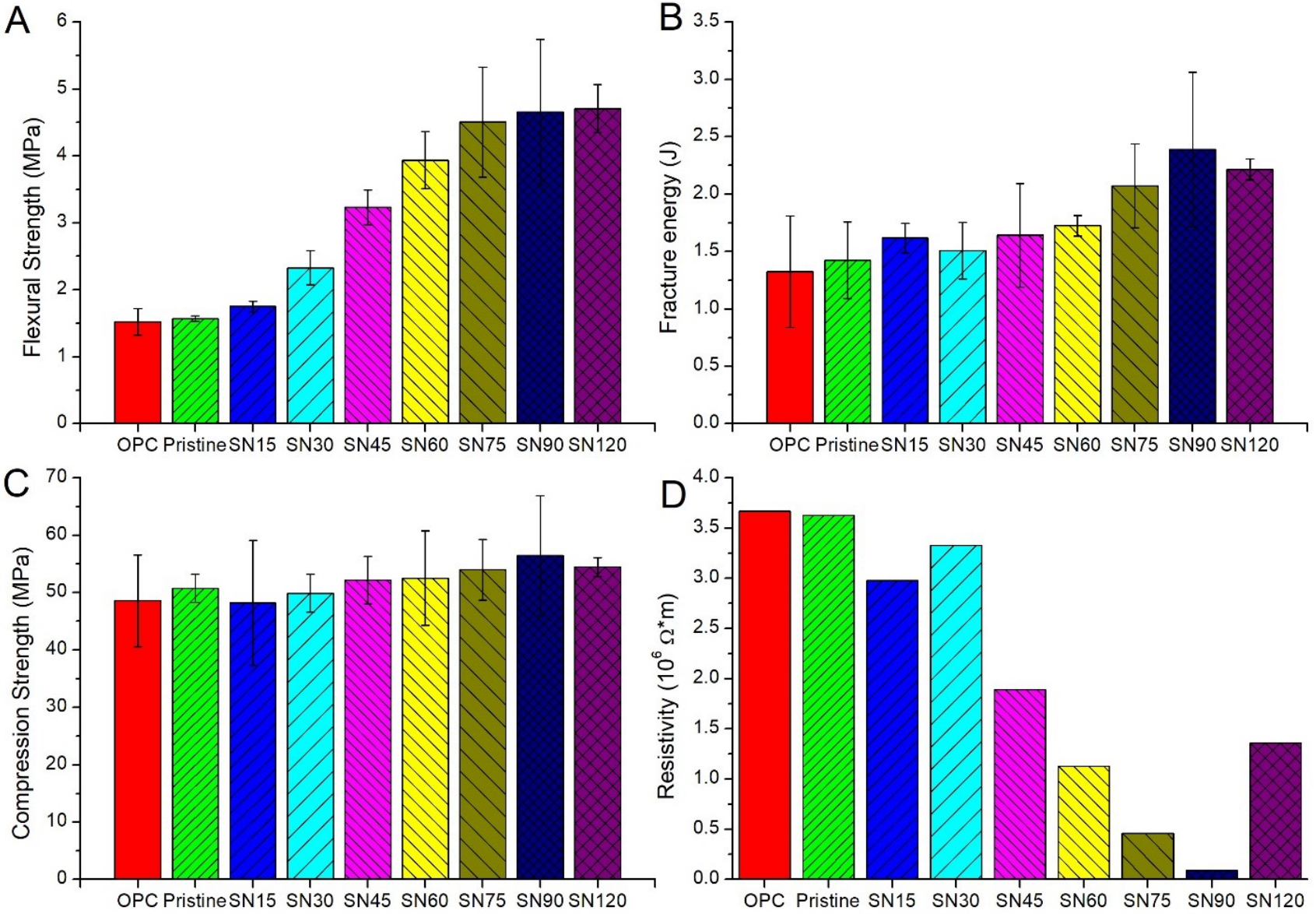
Composites performance



Comparing samples with 0.1% reinforcement

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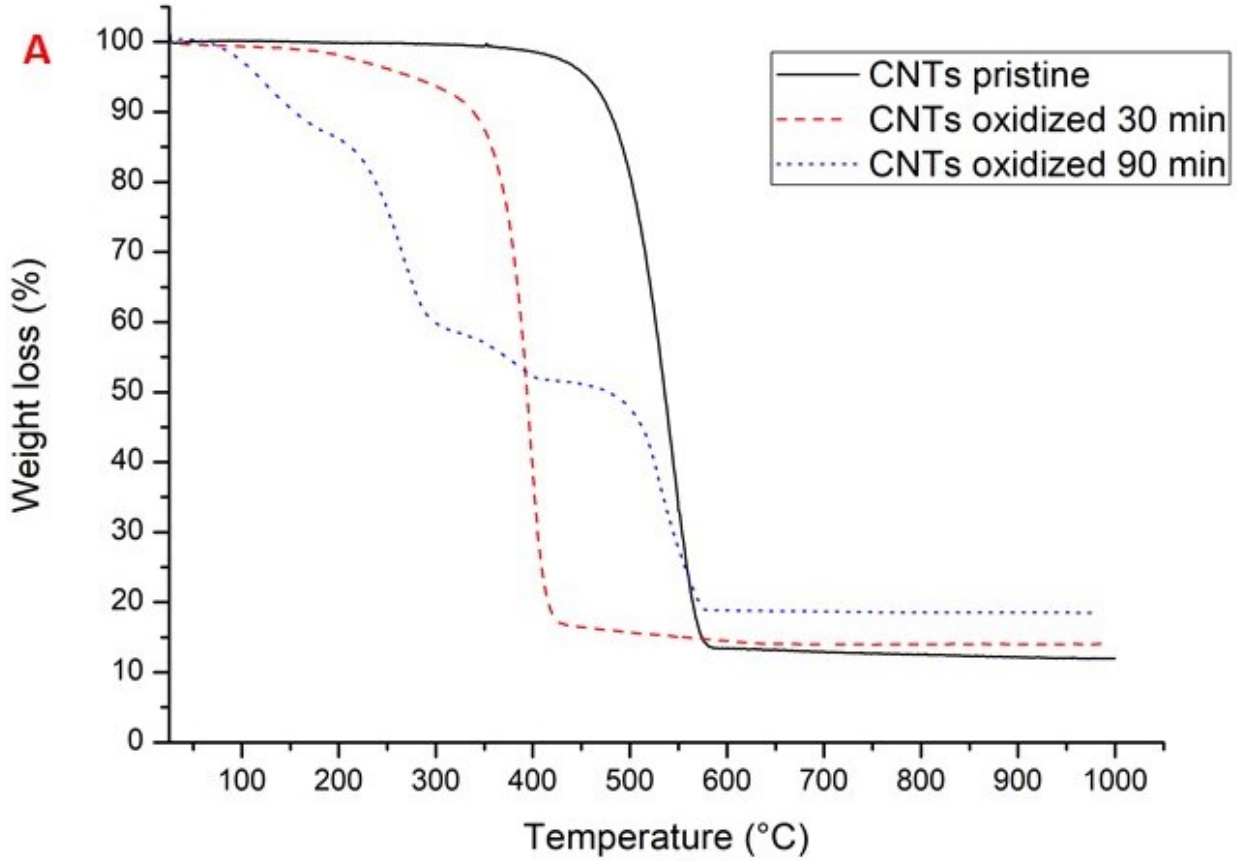
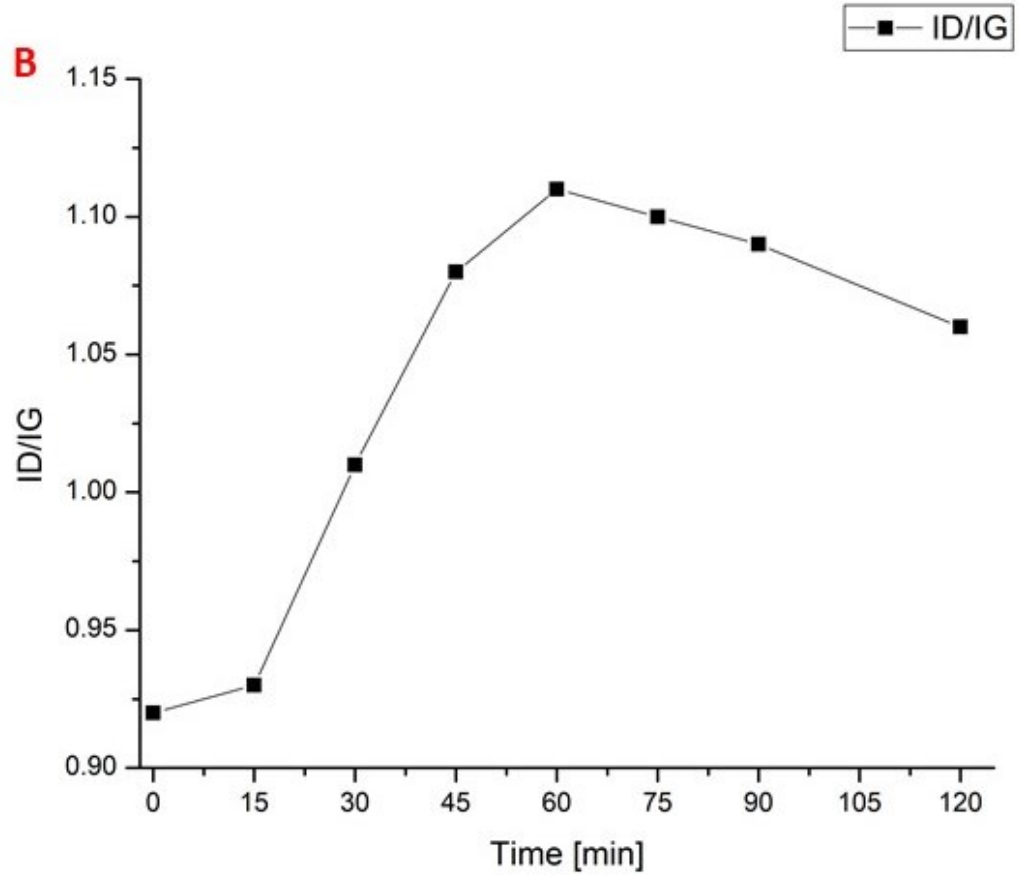
Characterization of treated CNTs

TGA



RAMAN



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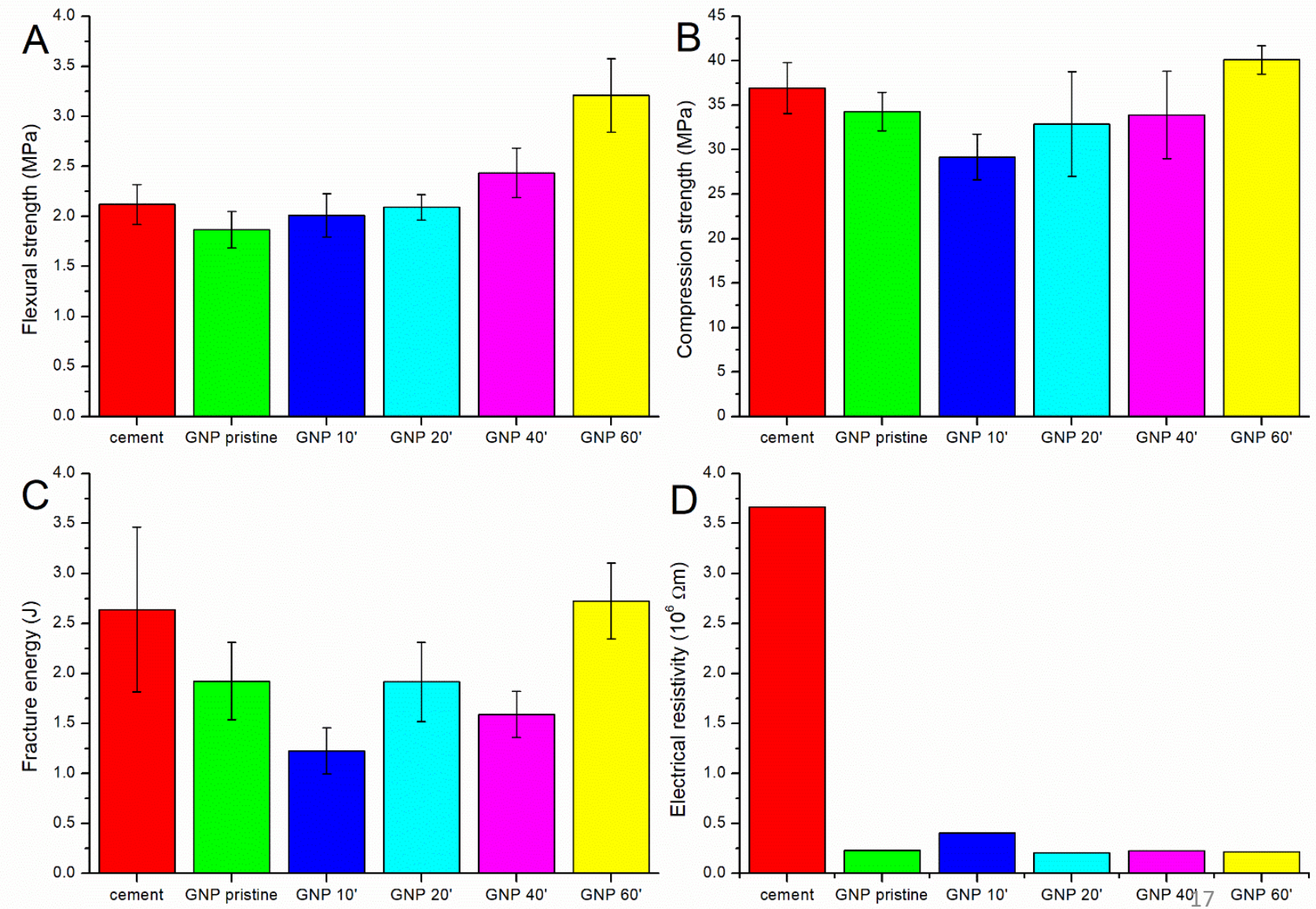
Cement + Graphene Composites performance

Chemical functionalization

Acid	Time [min]
Sulfonitric	10
	20
	40
	60

Comparing samples with 0,1% by weight of cement



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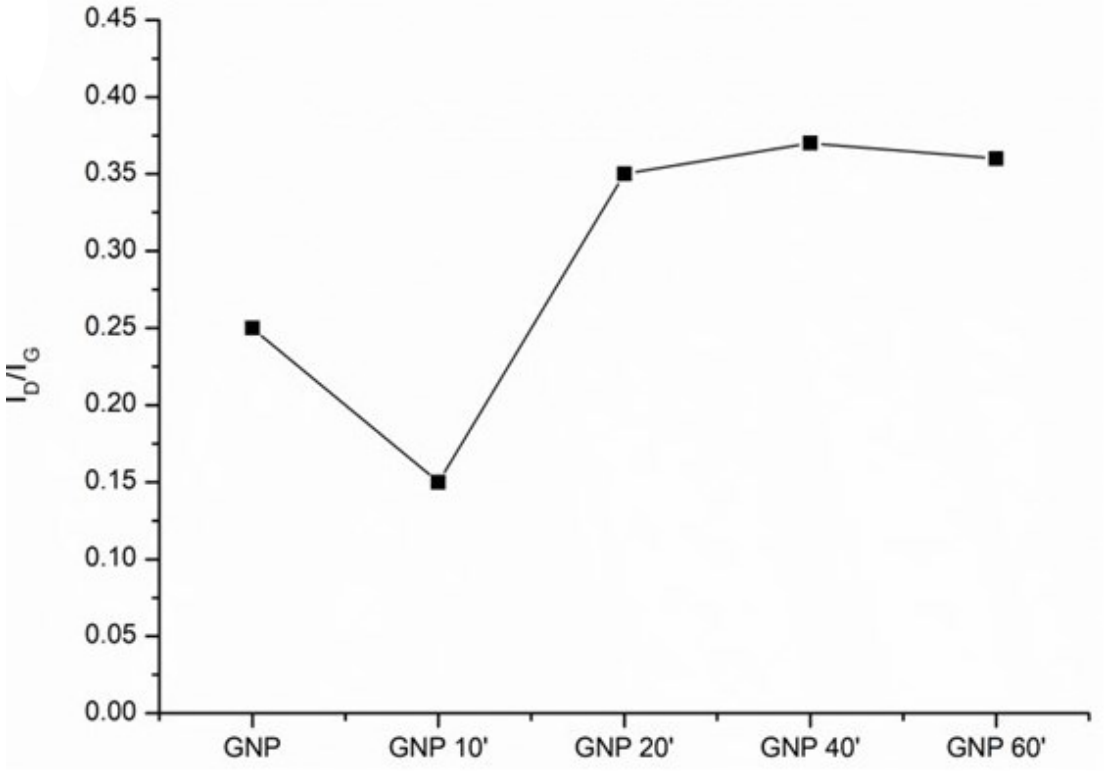
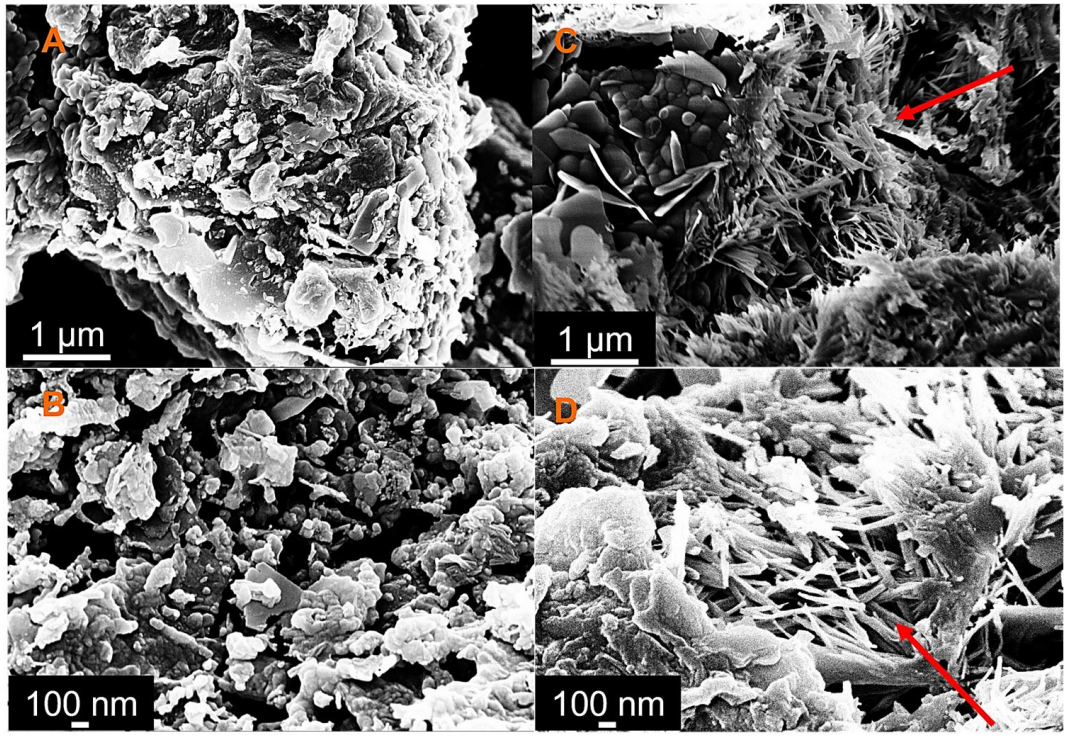
Characterization of treated CNTs

RAMAN



FE-SEM



A,B cement
C,D GNP 60’

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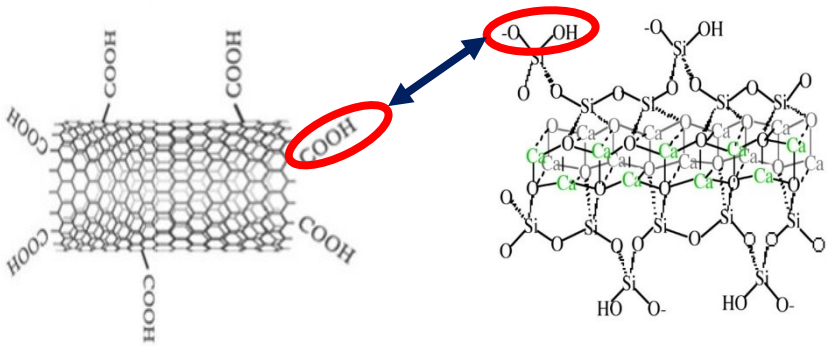
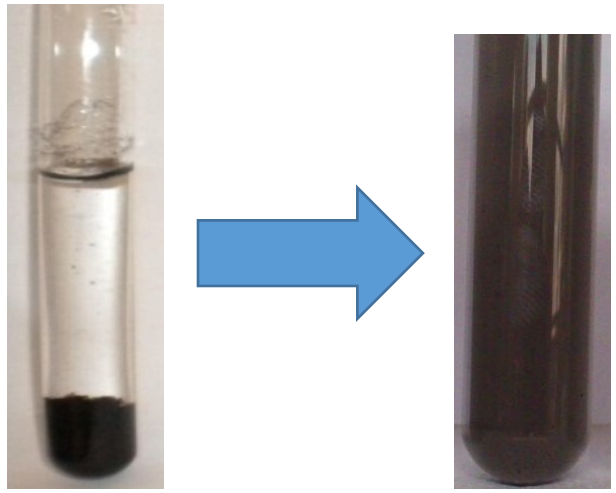
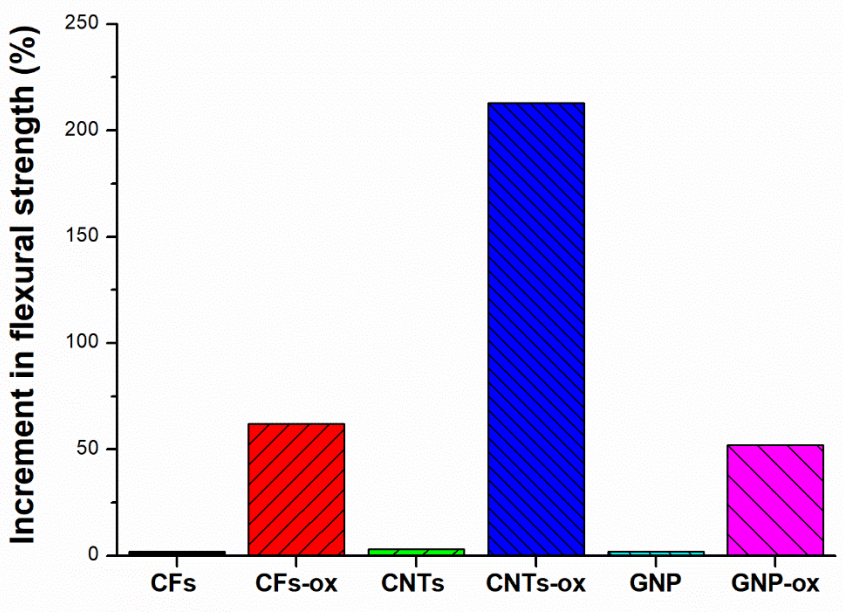
Final remarks

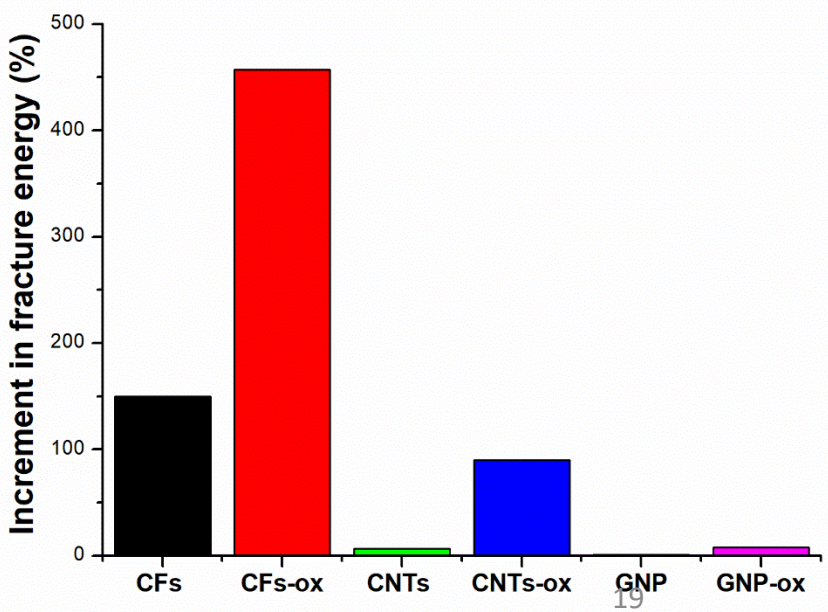


Functionalization

- ✓Key role of dispersion in water and in matrix
- ✓Enhancement of composites mechanical properties
- ✓Conductive cement







Thank you for your kind attention