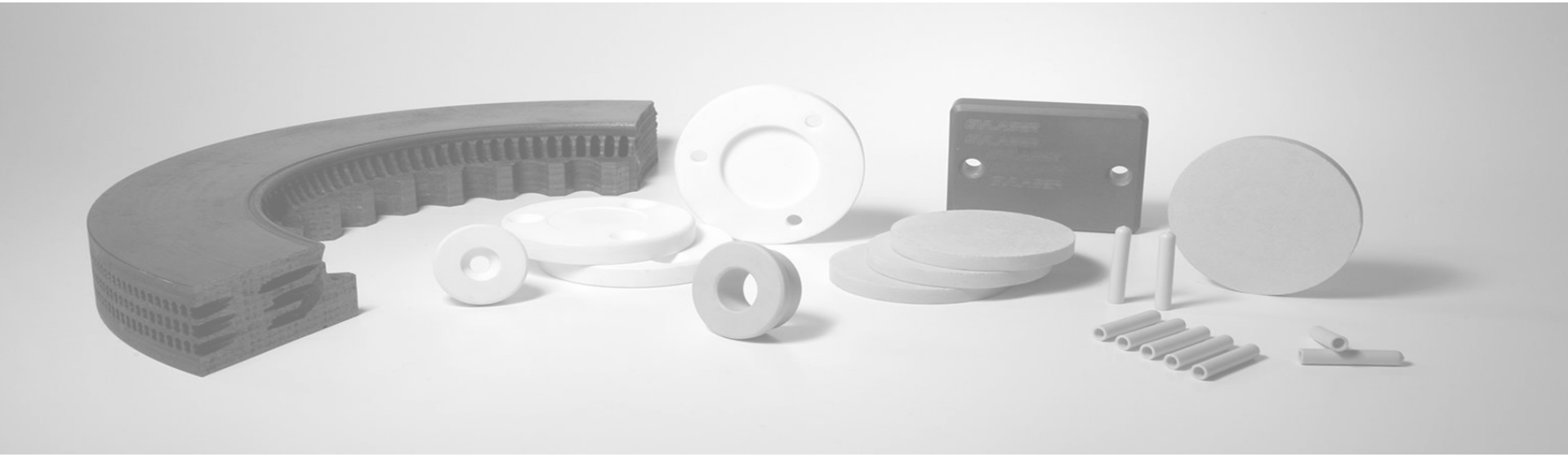
Nano Innovation 2016
Rome, 20-23 September
Conference & Exhibition

Nanostructured prepreg for high performance composite materials

Massimiliano Valle



Nano-Tech
Nano Carbon Technologies

PETROCERAMICS
Turn natural complexity into technology

Outline

Company profile

Composites for high temperature - CCM Process Flow

Nanostructured prepreg to produce polymeric preforms

kilometro rosso
parco scientifico tecnologico

Company

2003 Petroceramics was the first spin-off from the University of Milan
2007 Brembo invested in the company
2009 Settled in Kilometro Rosso

Mission

We develop ground-breaking solutions moving from knowledge in multi-component Earth systems

We offer methods and innovative technology for developing processes and advanced materials

Knowledge

PETROCERAMICS

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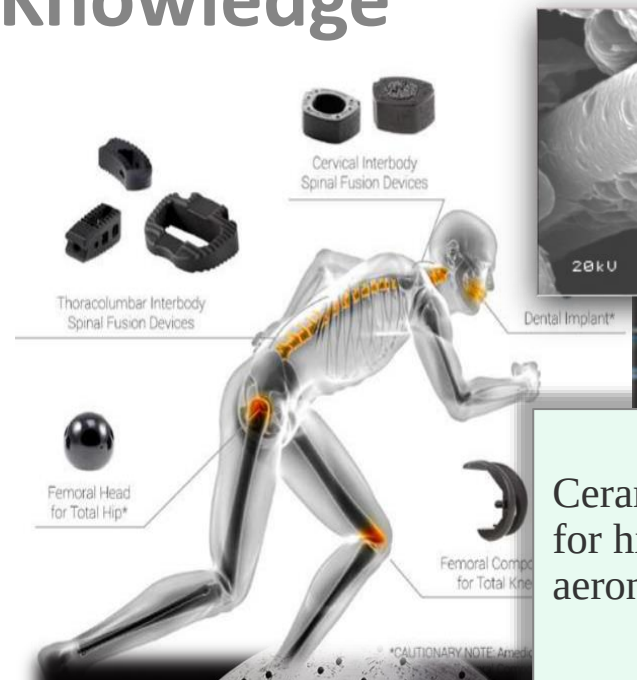

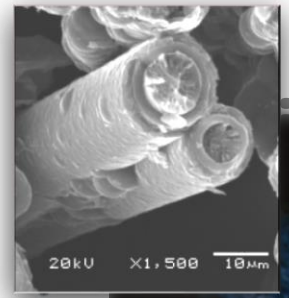

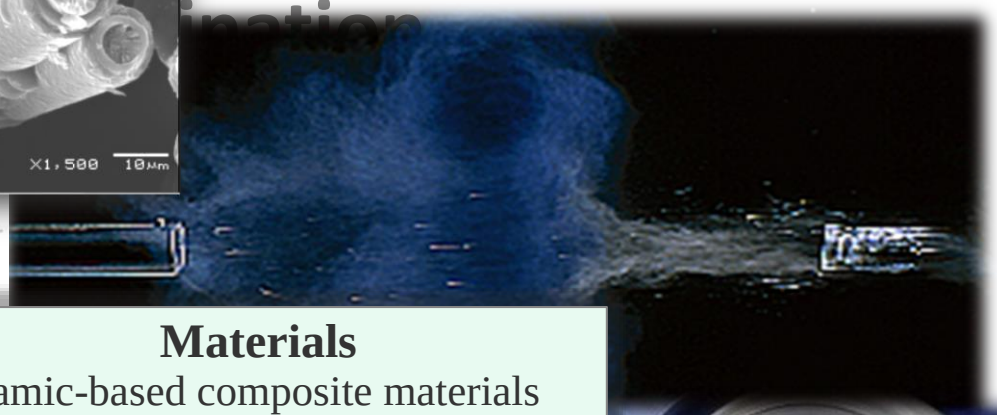

Materials

Ceramic-based composite materials for high-end applications: aeronautics, automotive, sport

Processes

Shaping and sintering of oxide and non-oxide powders and fiber reinforced materials (up to 2300°C).

Vacuum liquid metal infiltration of ceramics preforms (up to 1800°C)

Composites for high temperature

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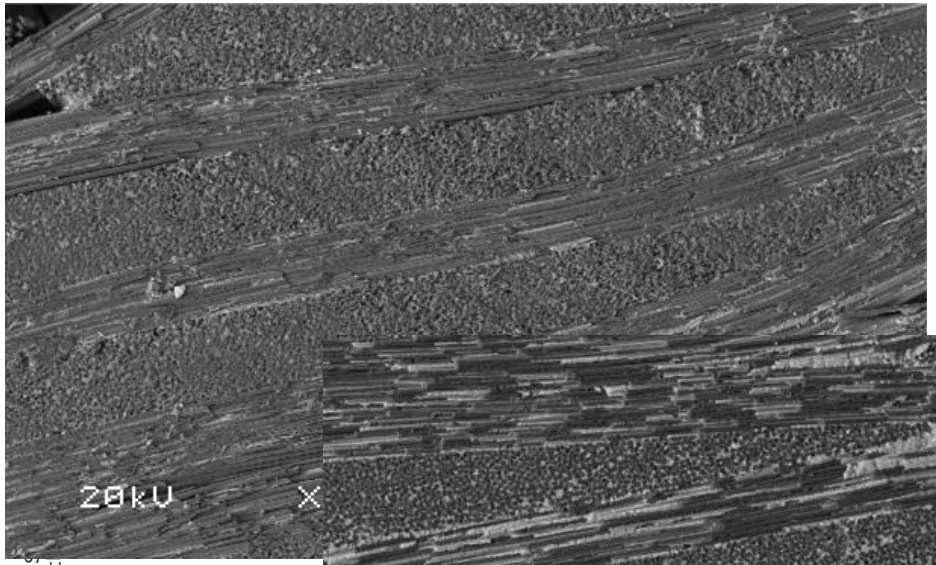
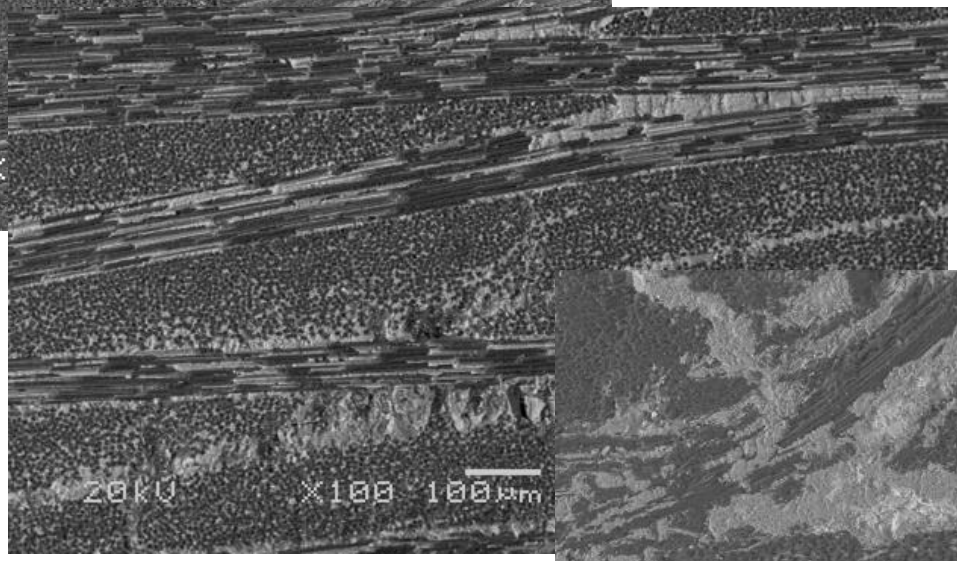
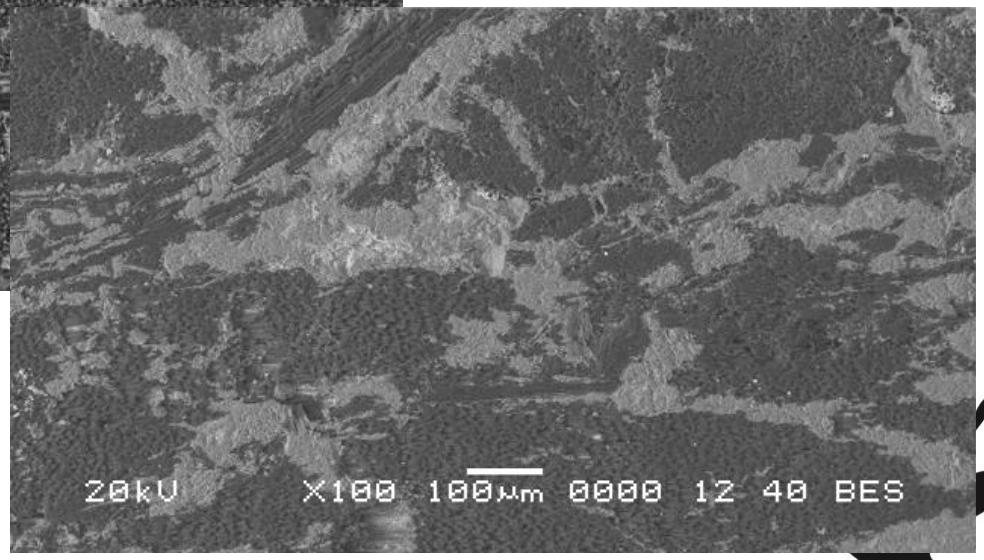


Polymeric composites
up to 400 ° C



Preceramics resin composites
up to 800° C



CCM materials
up to 1200° C

CCM Process Flow

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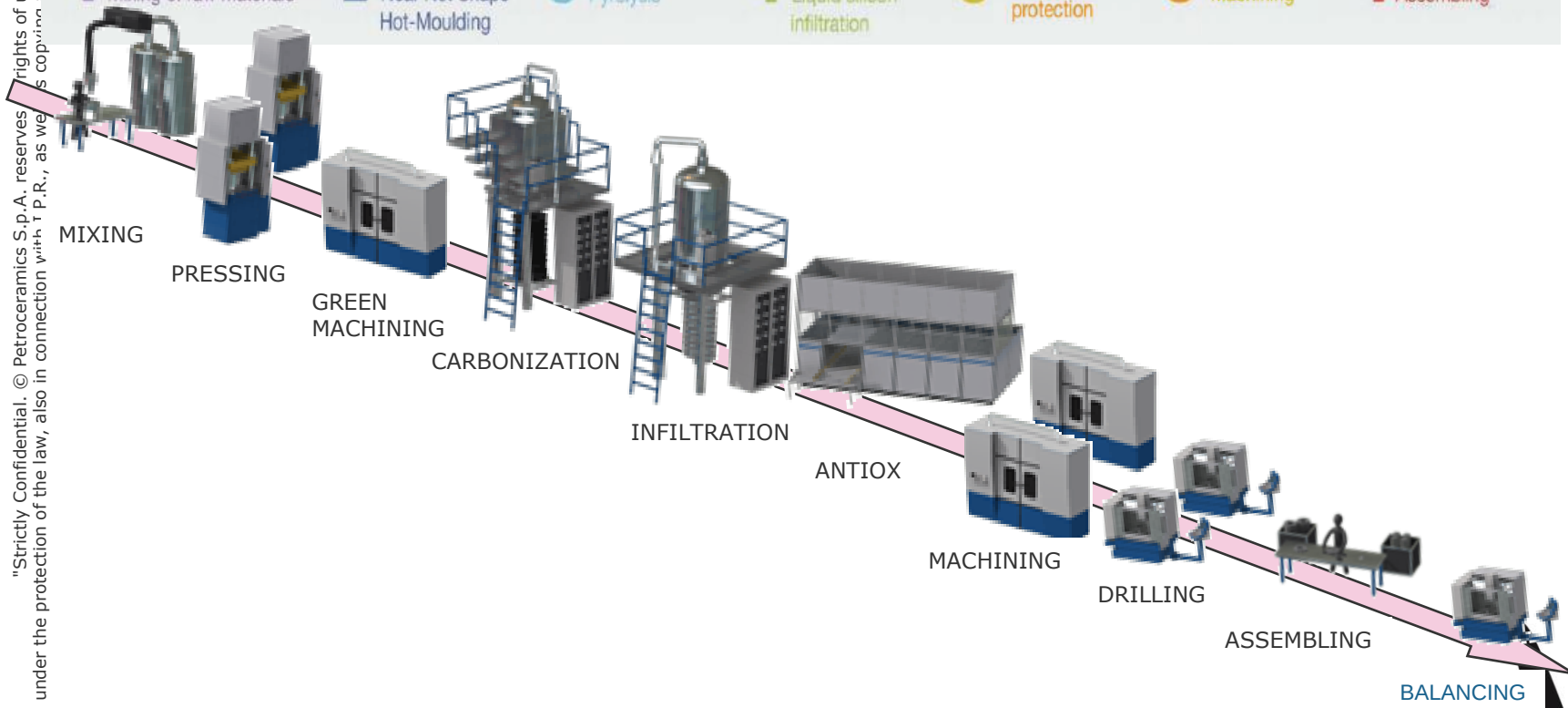

Process Flow

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Raw Materials

Carbon Fibres

A disc contains carbon filaments equivalent to 36.000 Km

≈ Earth circumference

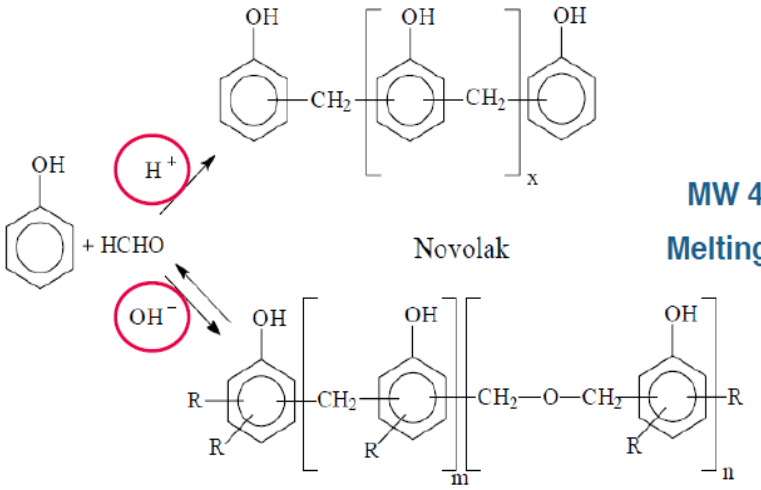
Carbon fibres are PAN based, obtained by a thermal treatment of bundles of PAN filaments.

CARBON FIBRES	
# Filament	50.000
Filament diameter	7 m
Bundle thickness – width	0,2 – 2 mm
Chop length	8 – 10 mm
Tensile modulus	250 – 500 GPa
Tensile strength	2,0 – 4,5 GPa

Raw Materials

Phenolic Resin

Phenolic resin is a Novolak obtained by formaldehyde and phenol polycondensation in acid solution.



MW 400-1000 g/mol

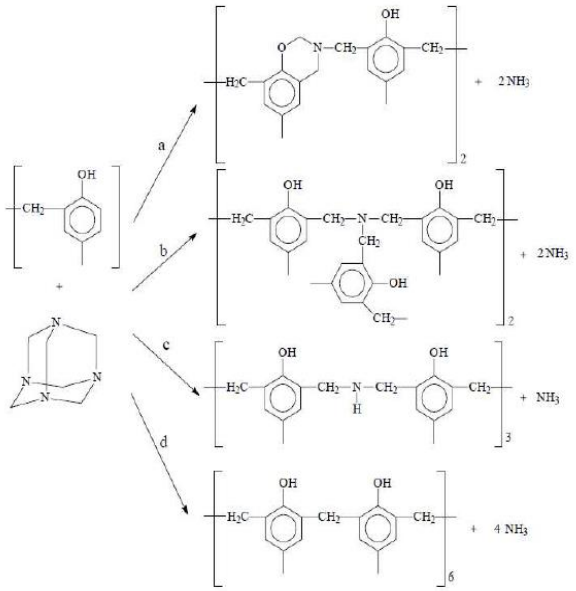
Melting area 50-100 °C

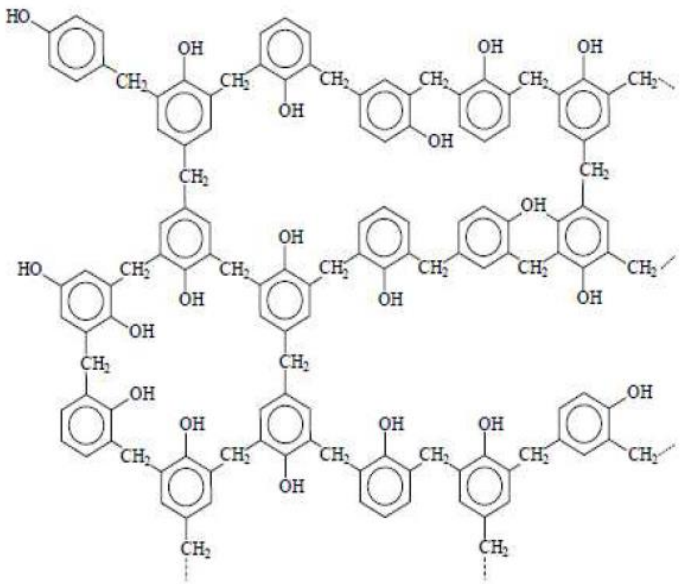
MW 150-600 g/mol

Molding

2 Near Net Shape Hot-Moulding

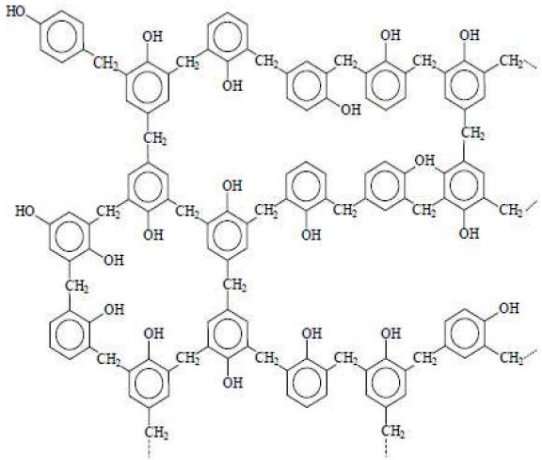
The Novolak resin is cured at temperature above 120°C by reaction with HEXA.



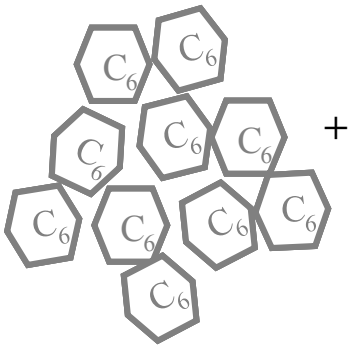


Pyrolysis

The following step is a thermal treatment in nitrogen at 900-1100°C, to transform the polymeric matrix into carbon matrix, obtaining a Carbon/Carbon composite. Open porosity is formed and will be used in the following step to introduce into the part free liquid silicon to react with Carbon and create the ceramic matrix.



Pyrolysis Furnace

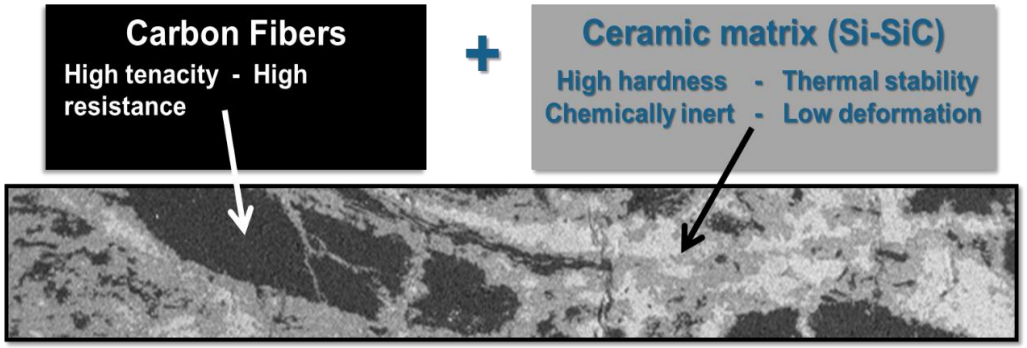


+ porosity

Liquid Silicon Infiltration

The Liquid Silicon Infiltration (LSI) is a thermal treatment in vacuum at 1500-1700°C, to transform the Carbon matrix into ceramic matrix (Silicon Carbide), obtaining a carbo-ceramic composite (C-SiC).
Free Silicon will remain in the matrix, filling the porosity and the capillarity lead to a quite low porous material.

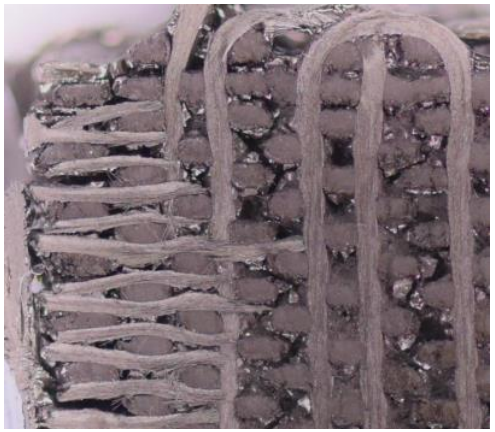
High Temperature Vacuum Furnace



$C_{matrix} + Si \xrightarrow{T = 1500\text{-}1700} SiC$

Polymeric composites structure and properties

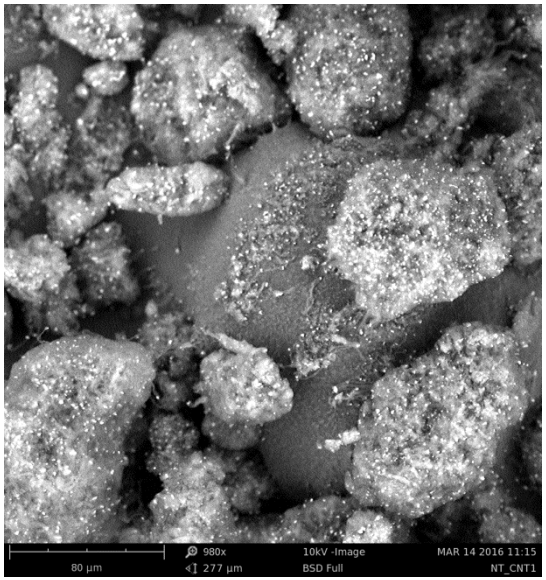
- ✓ To produce Polymeric, Preceramics and Ceramics composites the starting point is a Poymeric preform
- ✓ The structures and architectures can be different (UD; layers; 2D; 3D)
- ✓ The processes can be different (PIP; LSI; CVI; CVD)



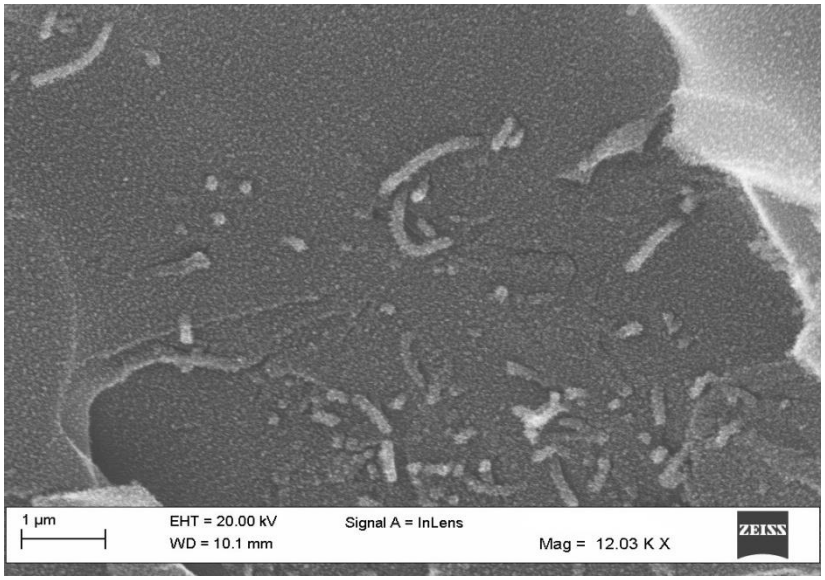
Can Nanostructured Prepregs be usefull to increase the meccanical properties of Preceramics and Ceramics Composites ?

Dispersion Techology & Know How

Patented dispersion technology that uses high shear force (patent n. 0001420824). The fluid is forced to pass through different surfaces in relative motion with a gap between them from 5 mm to 5μm, creating therefore a complex 3D motion field.



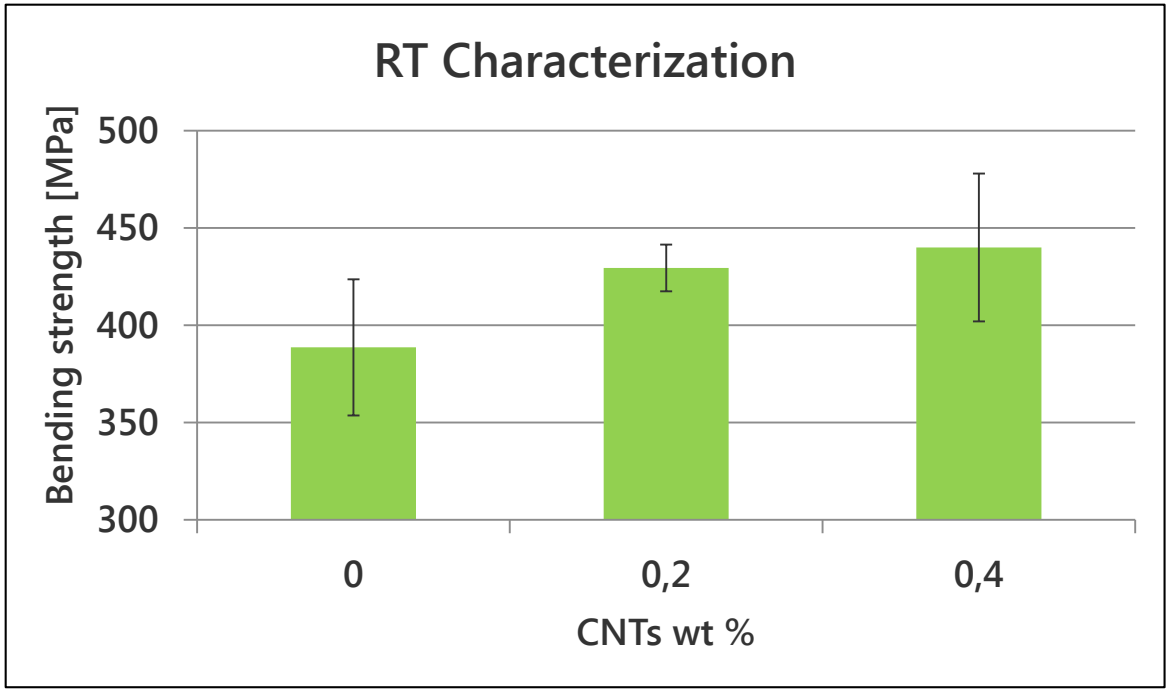
Before dispersion



After dispersion

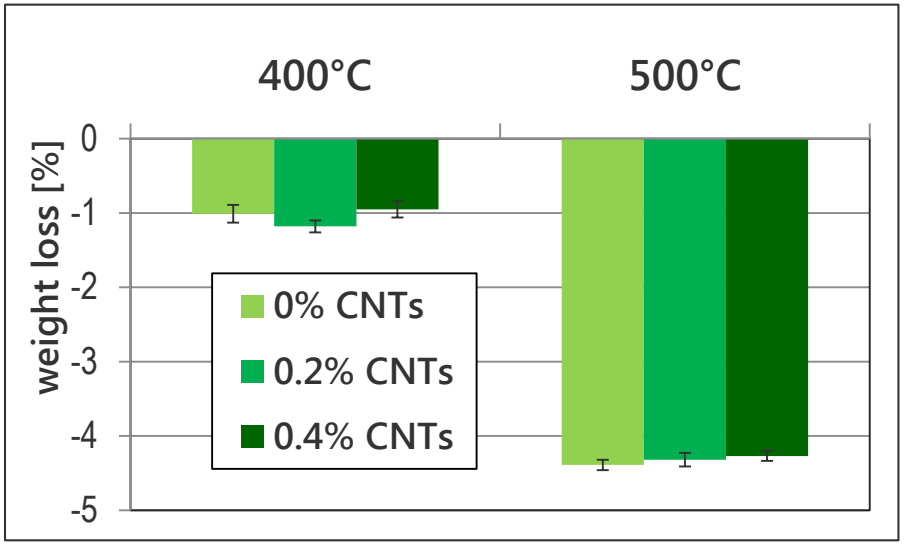
As cured polymeric composites properties

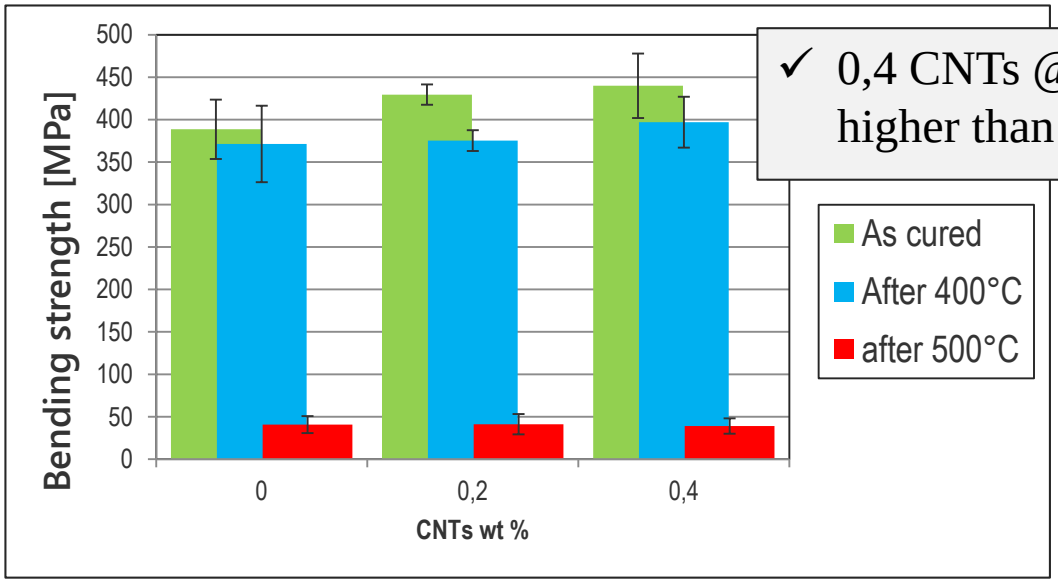
- ✓ Unidirectional oriented pitch carbon fibers
- ✓ Preceramic resins mix with CNTs
- ✓ More than 10% bending strength increasing due to 0,4wt % CNTs



Oxidation tests

- ✓ Bending strength and weight decreases after 400°C exposure for 1 hour
- ✓ Huge composites degradation after 500°C exposure for 1 hour



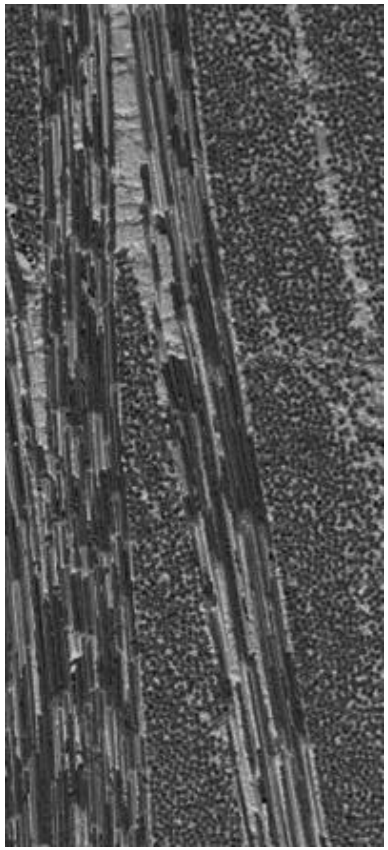


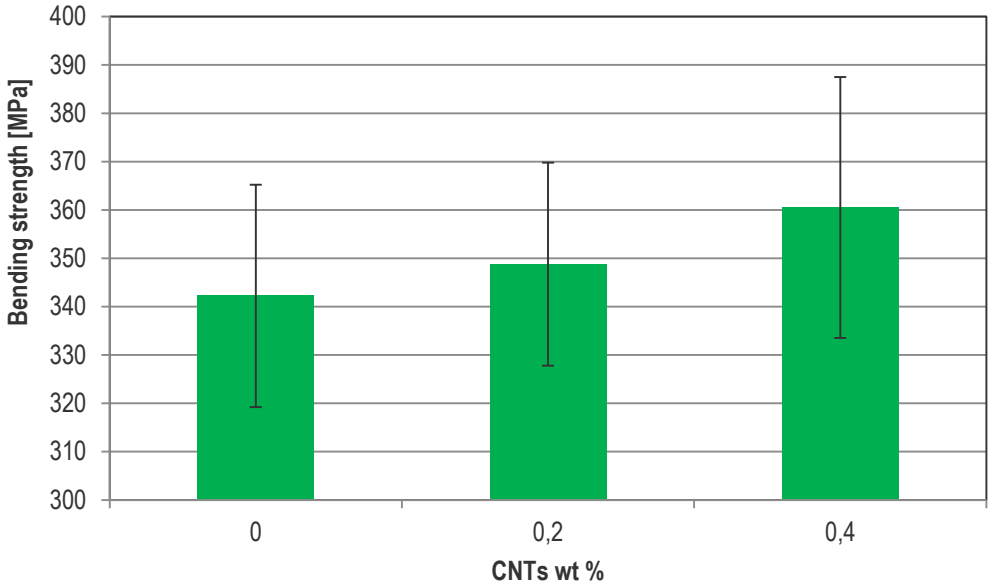
✓ 0,4 CNTs @ 400°C bending strength higher than as cured without CNTs

PIP Composites properties

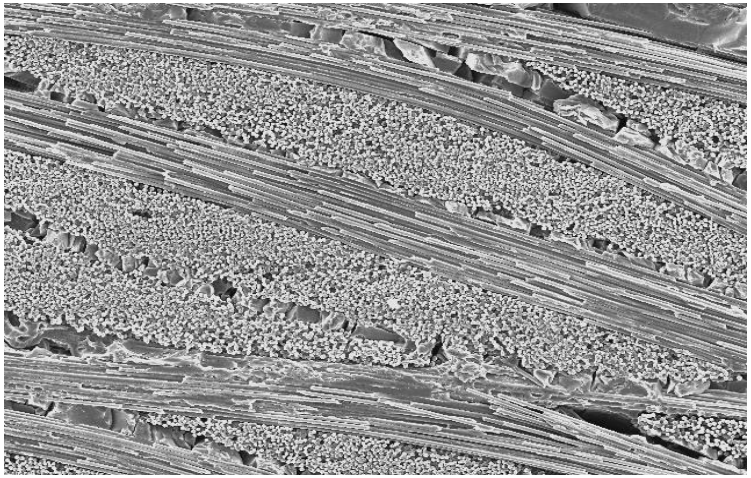
pre-preg setting → Compression moulding → Pyro N2 @ 700°C → Impr. RT 20 mbar → Pyro N2 @ 900 - 1400°C → Machining

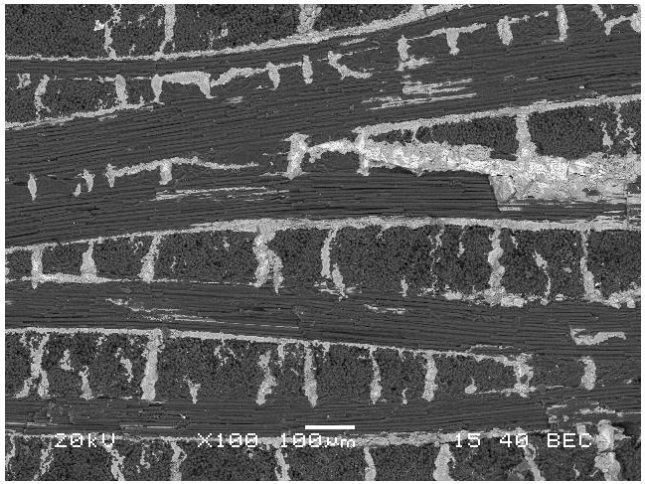
x 3

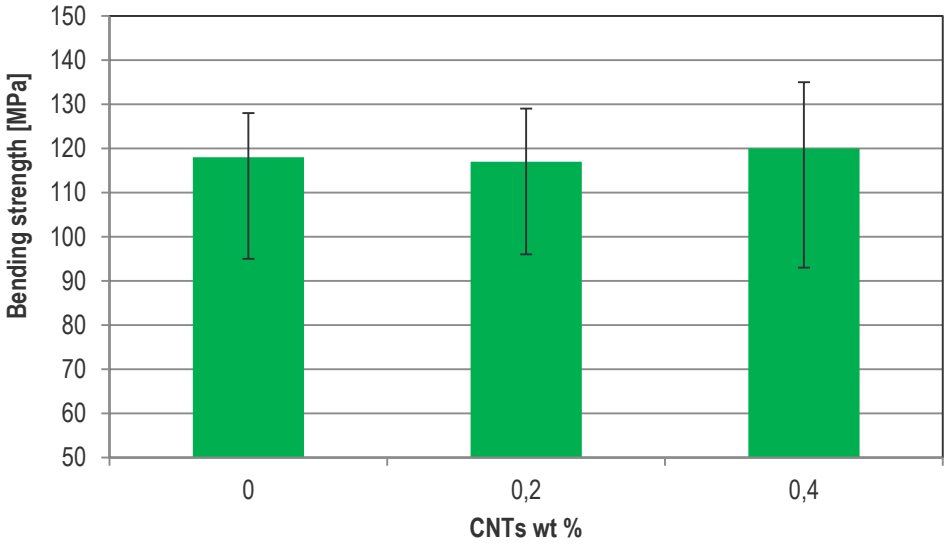




2D layered C fiber-LSI







Thanks

Marco Orlandi – BSCCB
Andrea Giovannelli – Nanotech
Lorenzo Cavalli - Petroceramics

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