Fibrenamics

INNOVATIVE APPLICATIONS OF TEXTILES/FIBROUS MATERIALS

Raul Fangueiro

Fibrous Materials Research Group/FIBRENAMICS
Center for Textile Science and Technology
Territory, Environment and Construction Research Centre

University of Minho
PORTUGAL

UMinho nas 400 melhores universidades do mundo

Coordinator| **Raul Fangueiro** | rfangueiro@civil.uminho.pt

Fibrenamics

University of Minho
School of Engineering
Guimarães, Portugal

University of Minho
Braga
Portugal

Fibre the future

Fibrenamics

Architecture

Building

Transports

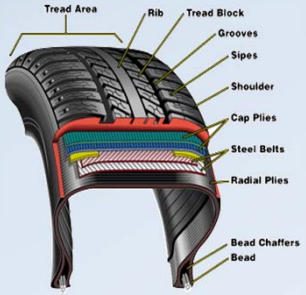
Personal Protection

Medicine

Sports

Fibrenamics

Multisectorial Platform for scientific and technical cooperation based on **Fibrous Materials**



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WWW.FIBRENAMICS.COM

180 partners

40 000 visitors (2 years)

800 users (international fibrenamics community)

200 files shared

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Dissemination

Technological survey

Knowledge transfer

Research and technological transfer

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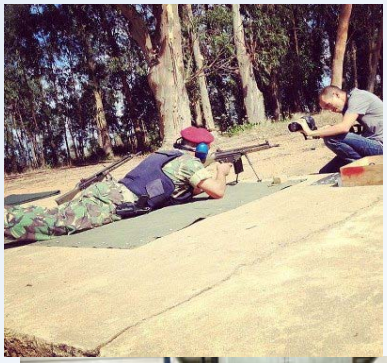
Media

- TV
- Radio
- Newspapers
- Journals
- Online



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> FIBRENAMICS Workshops

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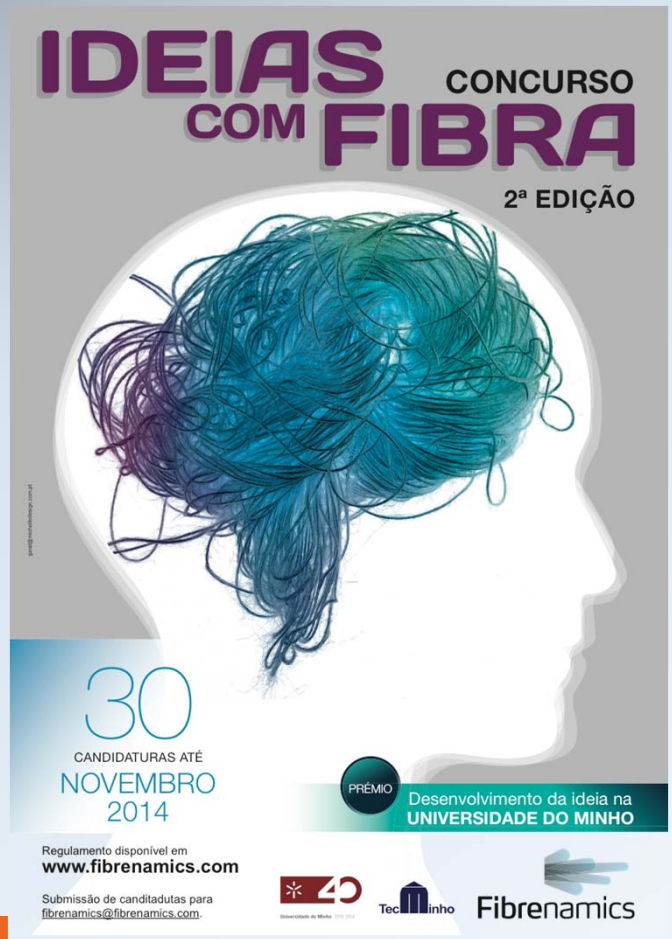
> IDEAS WITH FIBERS



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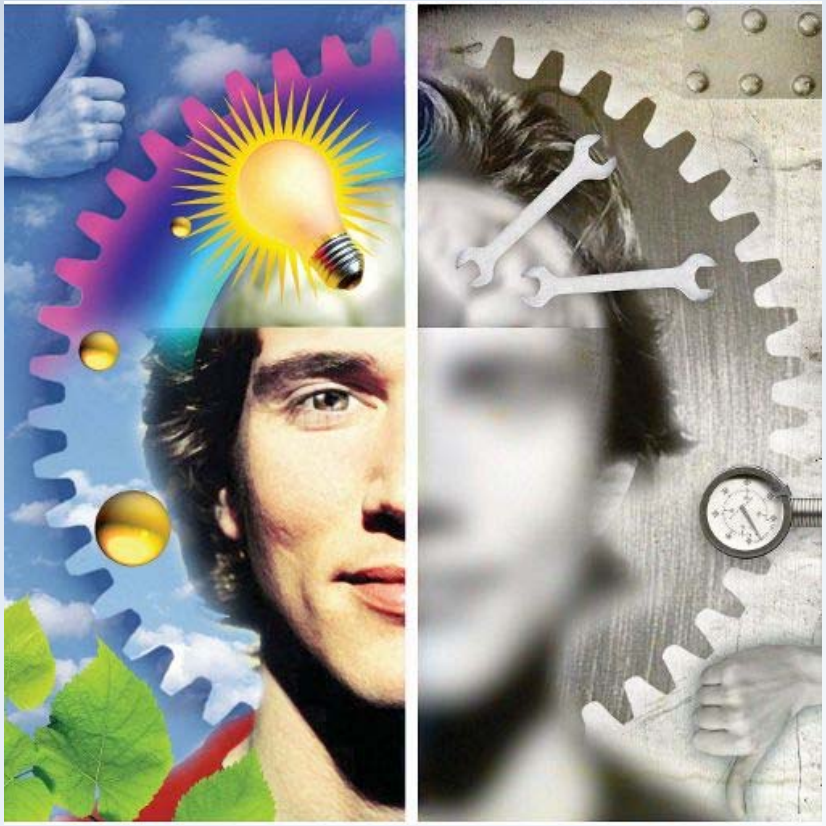
Research Projects



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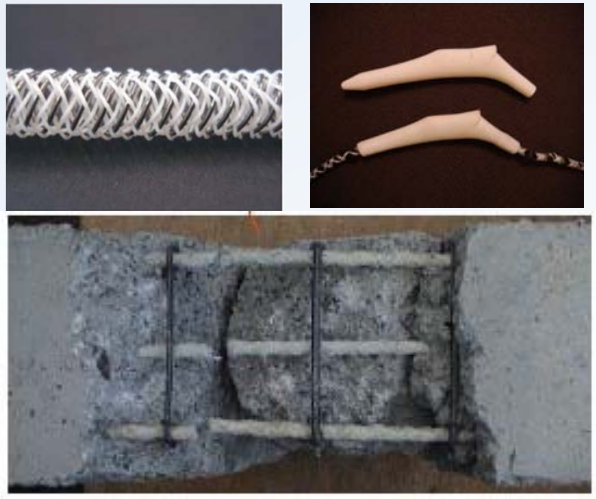
fmrg fibrous materials research group university of minho

FIBROUS MATERIALS RESEARCH GROUP

A **multidisciplinary** international **top leader research team** on the field of fibrous materials for technical applications, **producing continuous knowledge** based on high level post-graduated research works and **developing joint research projects** in partnership with companies and other industrial agents.



Performance:

12 Patents

27 On-going funded research projects

30 Researchers

2 Pos-doc researchers

400 Scientific publications

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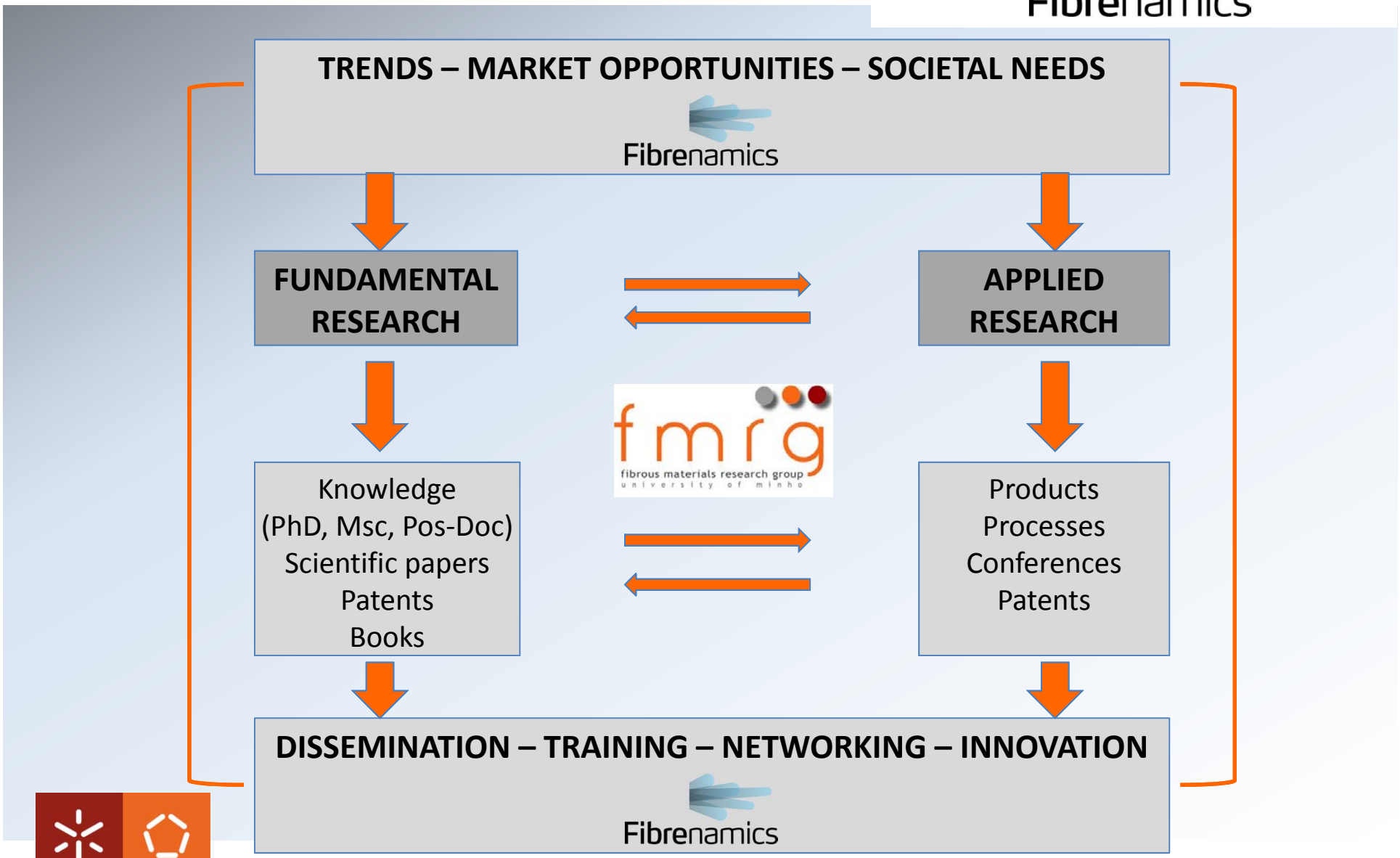


Medicine

➢ TRENDS IN MEDICINE…

- Vital signals controled by intelligent fibers;
- Development of fibers with new functionalities (ex.medicine release);
- Increase the use of fibers in implantable devices;
- Home-care.

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> Fibrenamics Projects

Braided Hybrid Smart Stent

- ✓ Biocompatibility, anti-corrosion, auto-expansion;
- ✓ Elasticity;
- ✓ Placement without damage of blood vessels;
- ✓ Depositions of nanoparticules to unable rejection;
- ✓ PP, PA, PES Monofilaments

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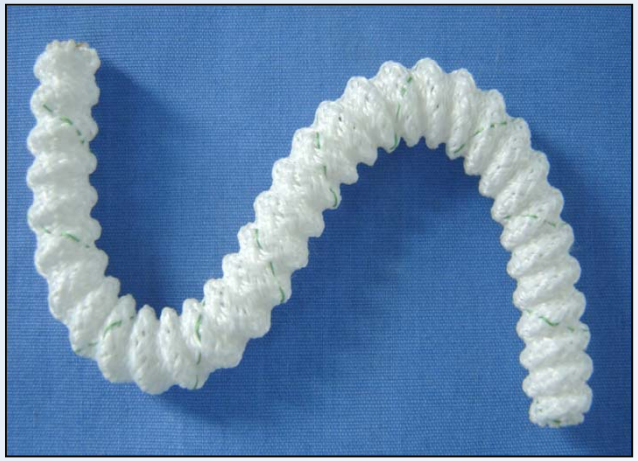
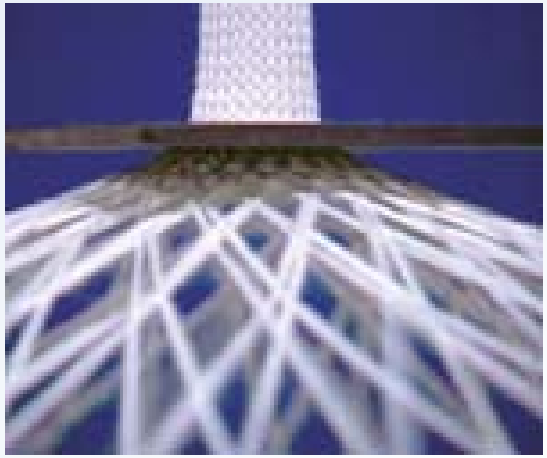
> Fibrenamics Projets

Development of hybrid vascular grafts based on PES and PLGA fibers

Braided vascular prosthesis is a medical device for blood vessel replacement characterized by a tubular shape in a crimp form and composed by at least two sorts of biocompatible yarns, being one absorbable by the human body.

Patent WO/2009/141715 A2





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> Fibrenamics Projects

IMPETUS
YOU INSPIRE US

PROTECHDRY
free and alive!

***Protech Dry*- Undewear for light incontinence**

- ✓ Patented multifunctional structure;
- ✓ High absortion capacity;
- ✓ Light;
- ✓ Used like normal underware;
- ✓ Re-usable;
- ✓ Odours neutralization;
- ✓ Improves life quality (auto-confidence).

Patents:

WO 2011/108954 A1

PCT/PT2012/00022

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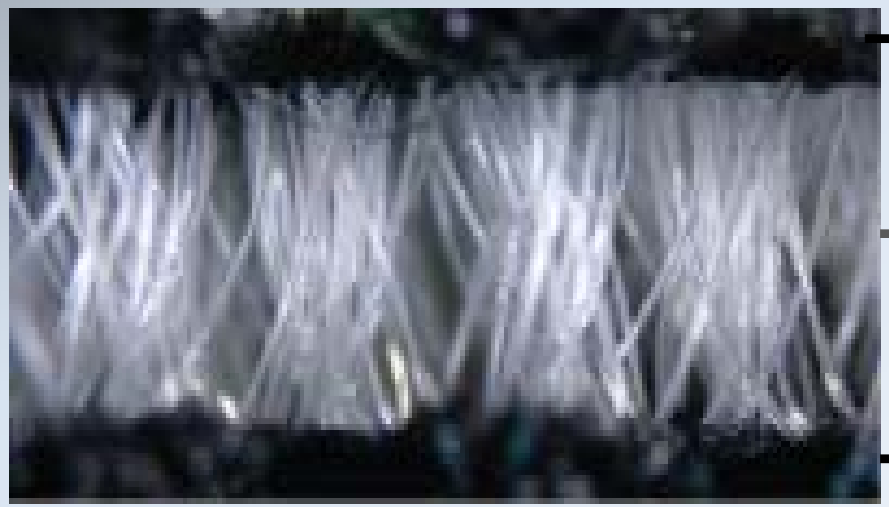
Human body



Outside

polyethylene film
coating
prevent leakage of fluid

Innerlayer
Comfort
Ultra –Absortion
Dry-feel

Midlayer
Air
Increases breathability
Liquid transportation

Outerlayer
Performance
Odour neutralization
Bioactivity
Absortion and Retention

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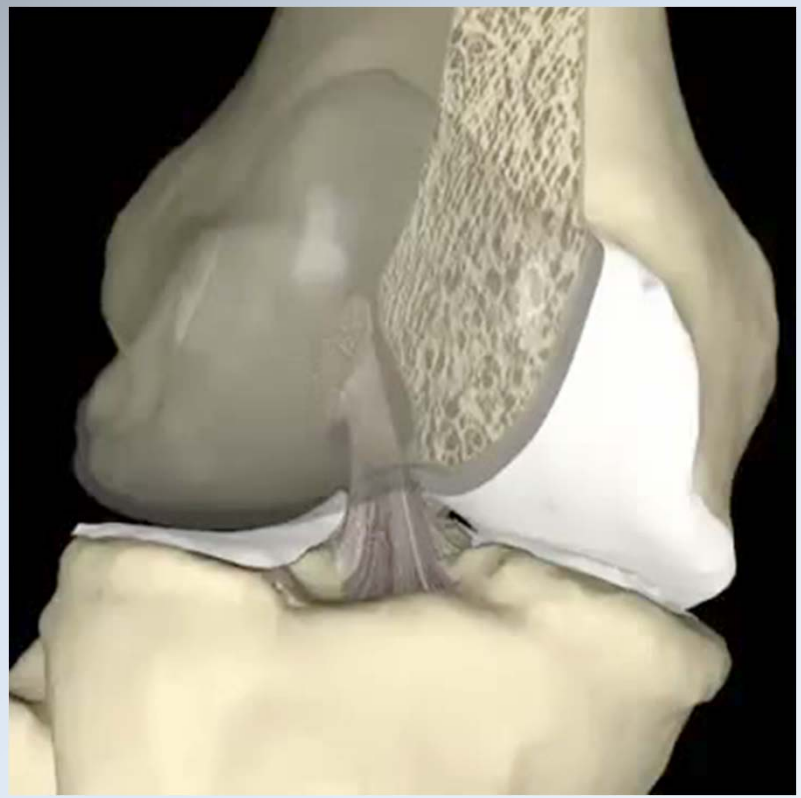
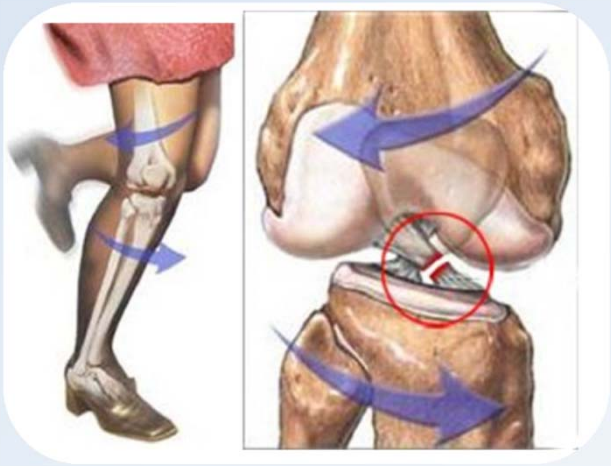
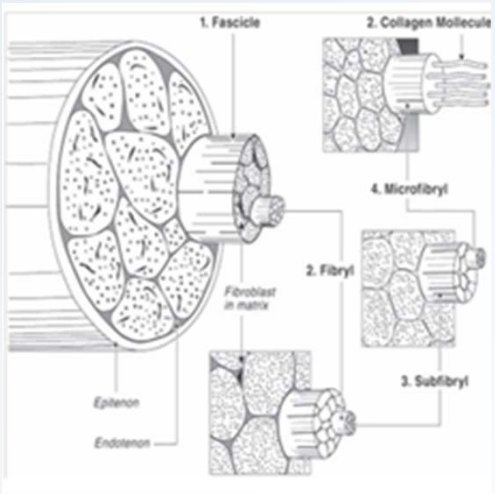
> Fibrenamics projects

FIBROUS BRAIDED FABRICS FOR LIGAMENT TISSUE REINFORCEMENTS

Knee joint and structure of ACL
Anterior Cruciate Ligament







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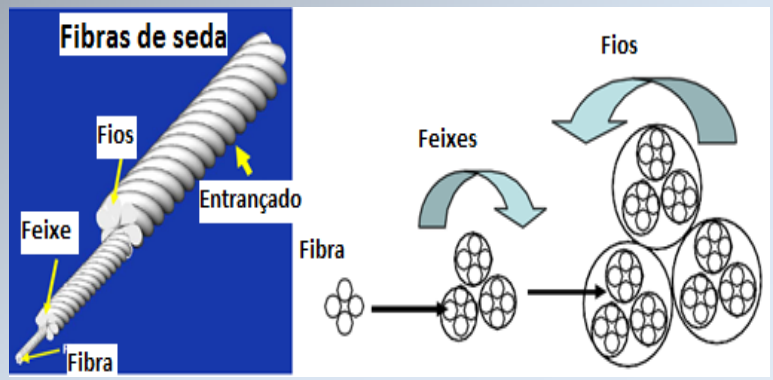
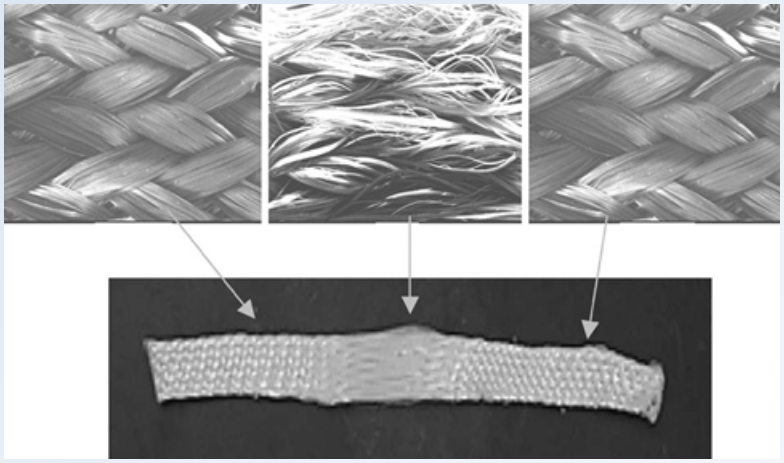
> FIBROUS BRAIDED FABRICS FOR LIGAMENT TISSUE REINFORCEMENTS

State of the art



Source : Horan *et al* (2005)



Source : Coopere *et al* (2004)

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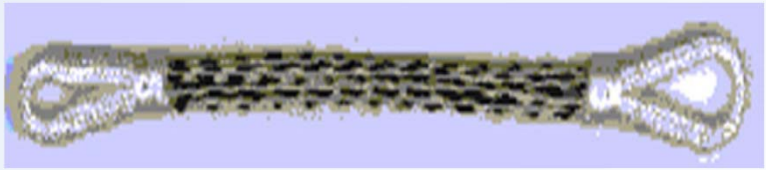

Source : Jadeja *et al* (2007)

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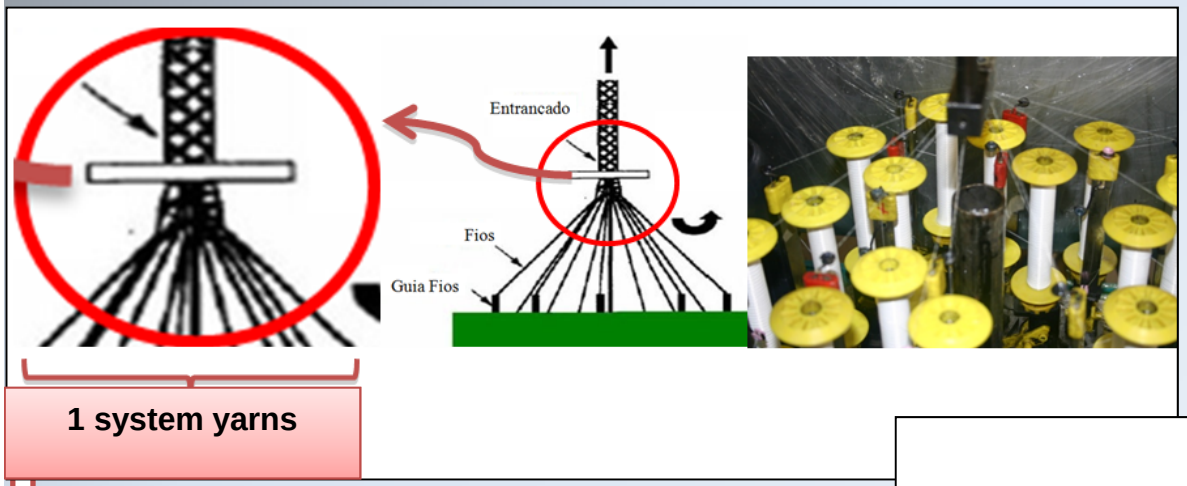
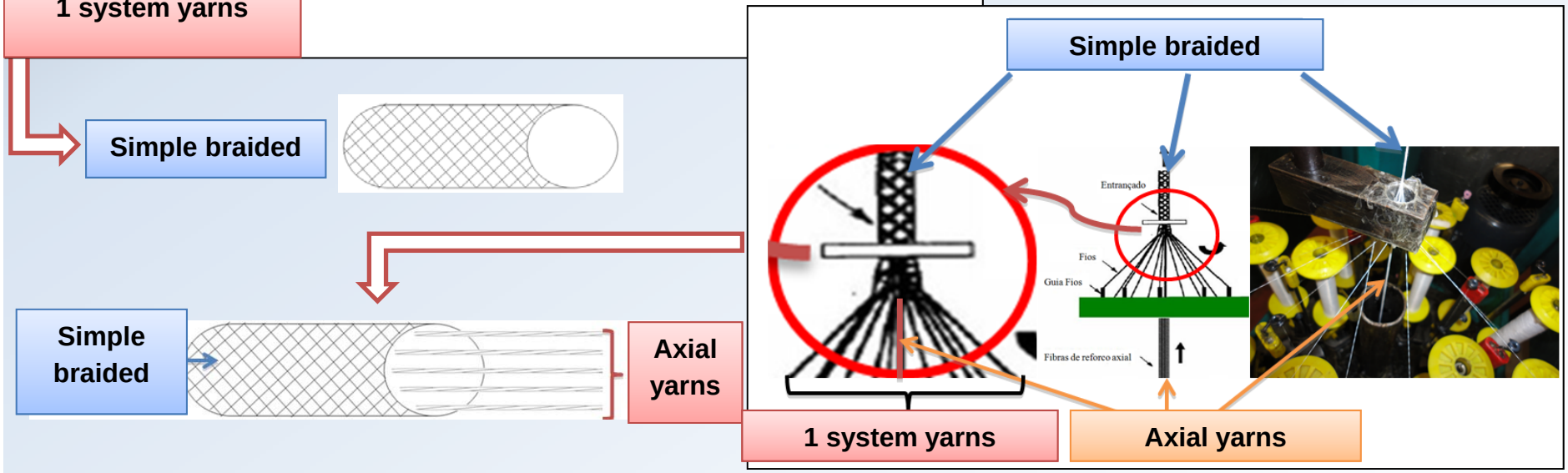
> FIBROUS BRAIDED FABRICS FOR LIGAMENT TISSUE REINFORCEMENTS

Ongoing Research





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> Fibrenamics Projects

VILLAFELPOS
PORTUGAL
SINCE 1997

Medix

***Medix* – Terry towel with heating capacity**

Patent: PPT 106457

- ✓ Towel with heating system incorporated;
- ✓ Comfortable;
- ✓ Reusable;
- ✓ Washing resistante;
- ✓ Use of conductive fibers;
- ✓ Thermoterapy.

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Development of a brain model

- ✓ Validation of HDFT (High Defenition Fibre Tracking) technique;
- ✓ Use of hollow fibers

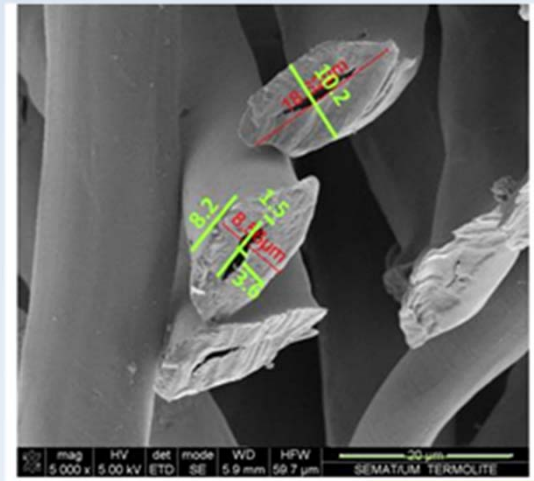
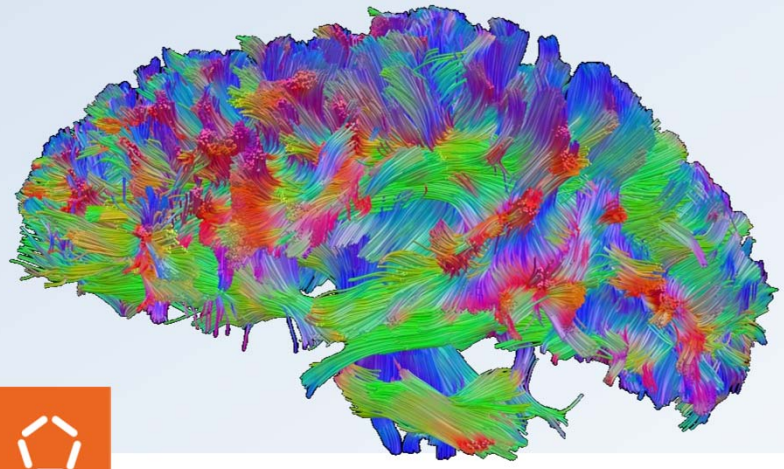
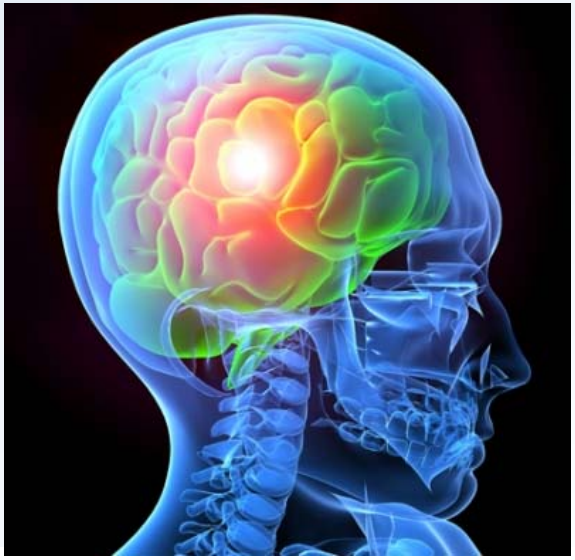


Figure 3-4 Cross section view





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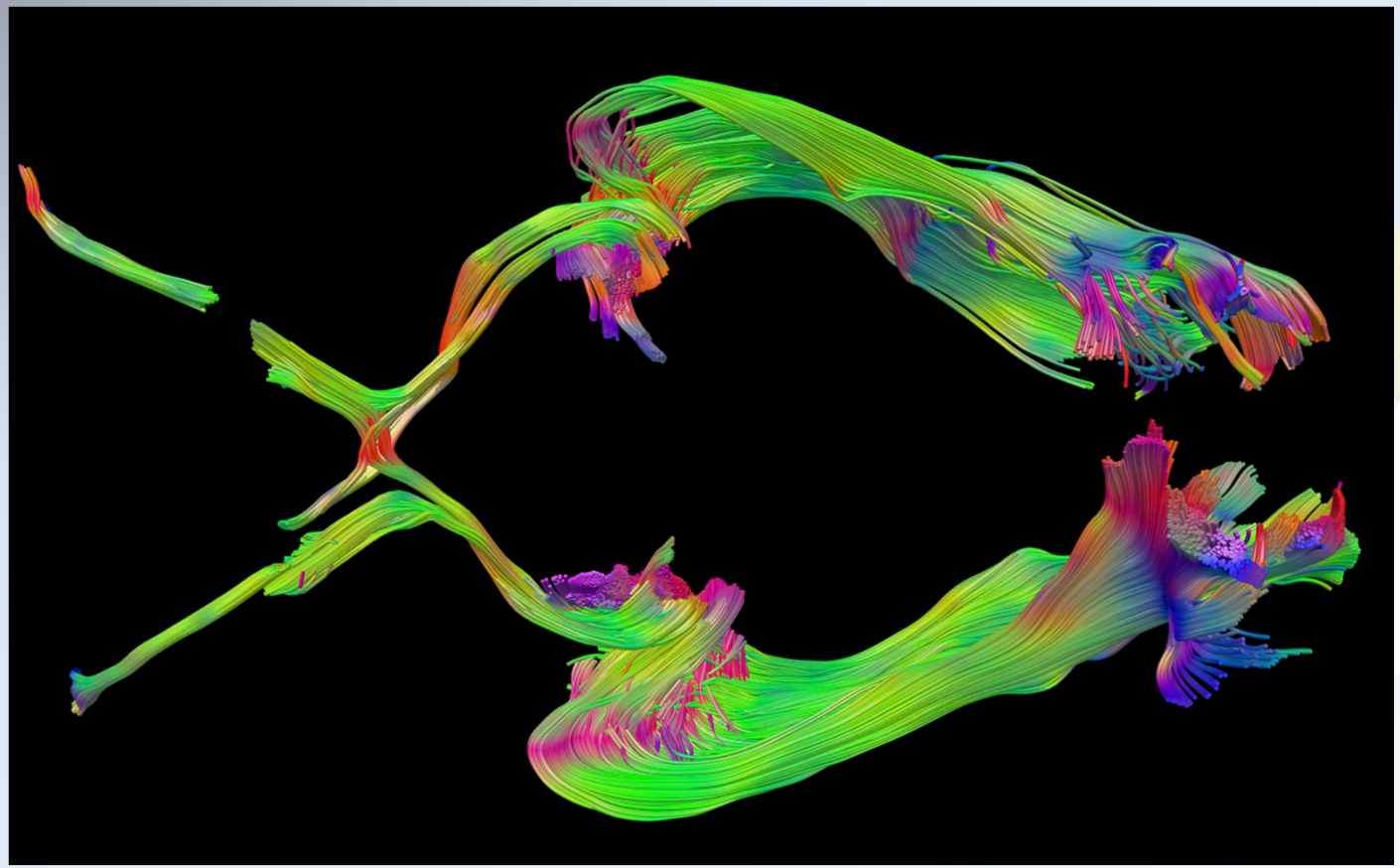
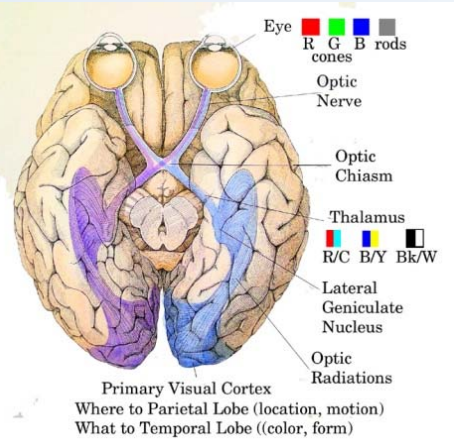
Visual System Map Fiber Direction Color





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Personal Protection

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➢ Personal protection trends…

- Use conductive fibers for heating, communication and monitoring;
- Use of nanotechnology to reduce weight and increase comfort;
- Intelligent camouflage using thermo and photo cromatic materials;
- Advanced fibrous structures

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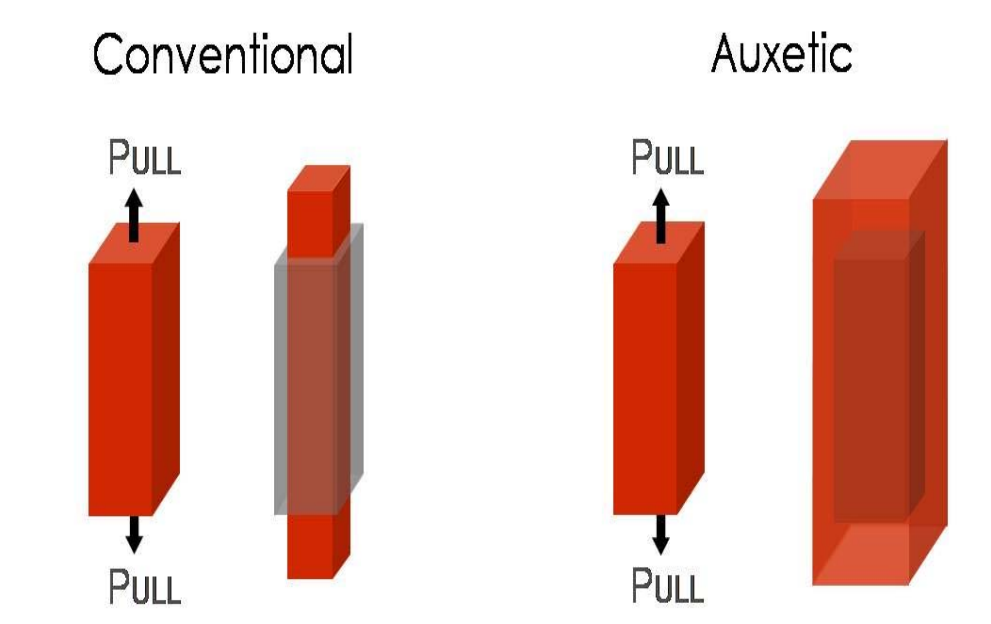
Auxetic materials

Negative Poisson ration.



$$v = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}$$

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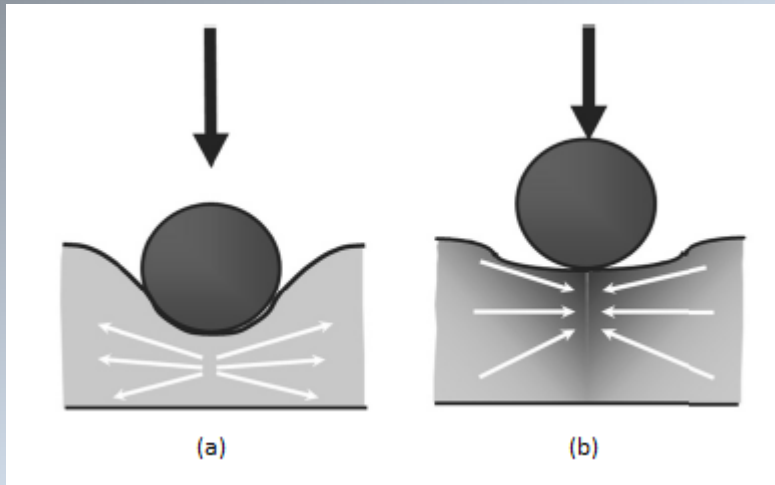

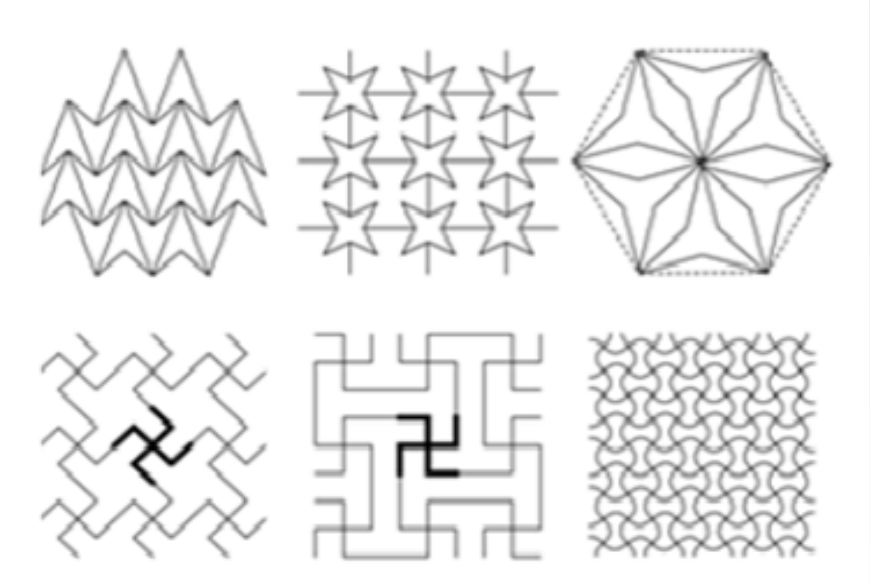

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Using High Performance Fibres to achieve high strength with superior energy absoption property

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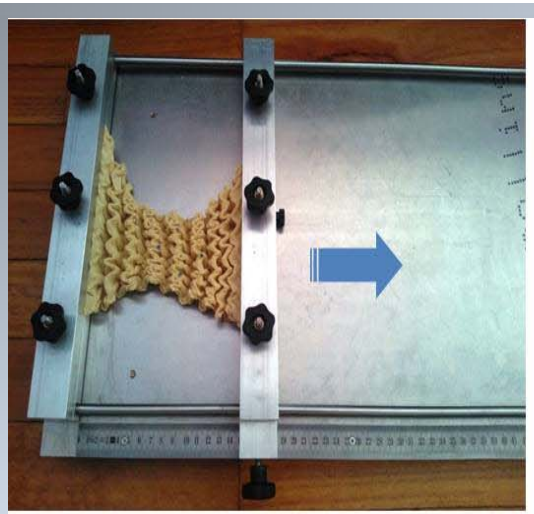

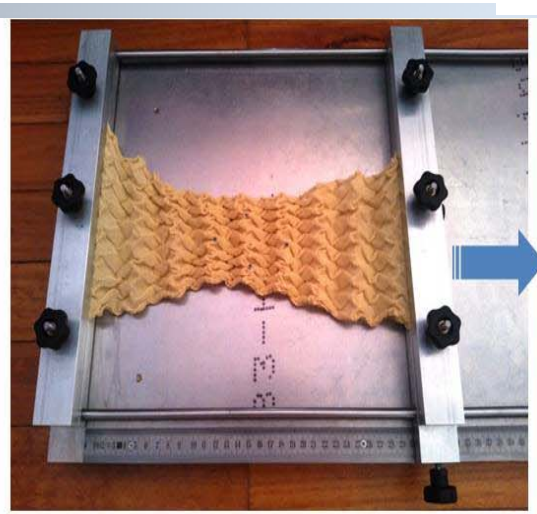

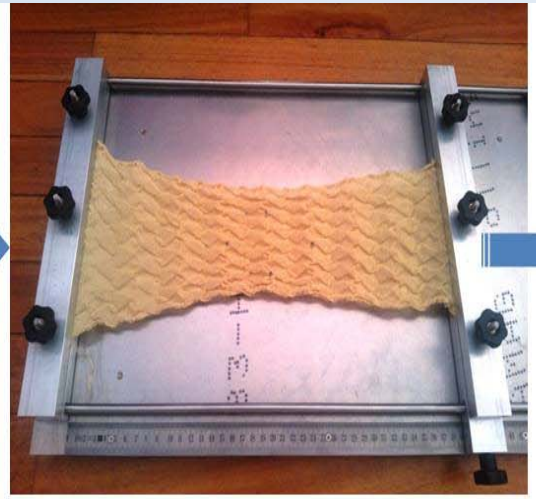

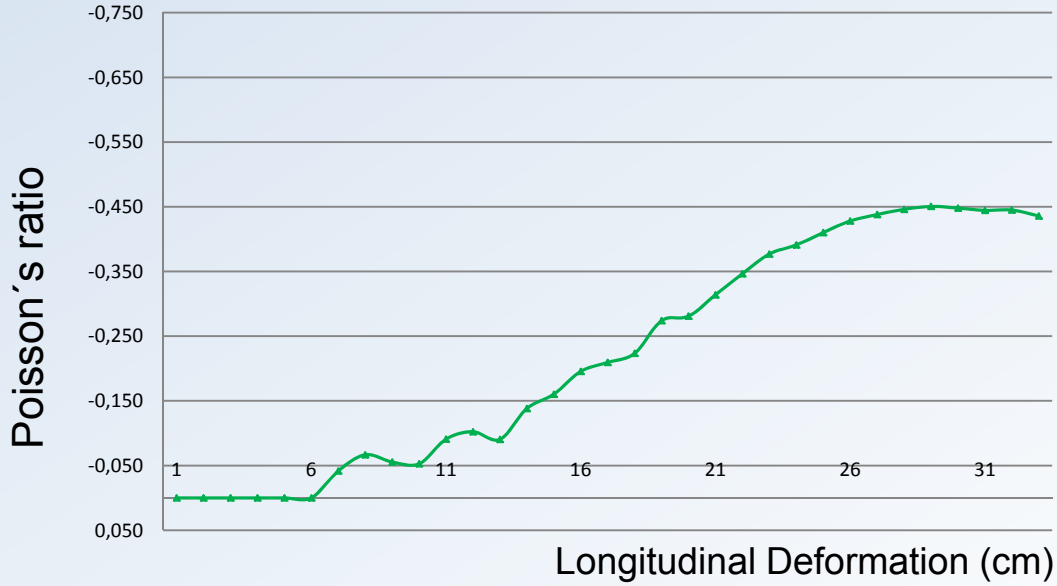


BUILDING

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TRENDS

Light-weight Construction

Sustainable Construction

Improving Durability

Alternative Materials

Structural Monitoring

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RESEARCH PROJECTS

> CARBON NANOMATERIAL BASED CEMENTITIOUS COMPOSITE <

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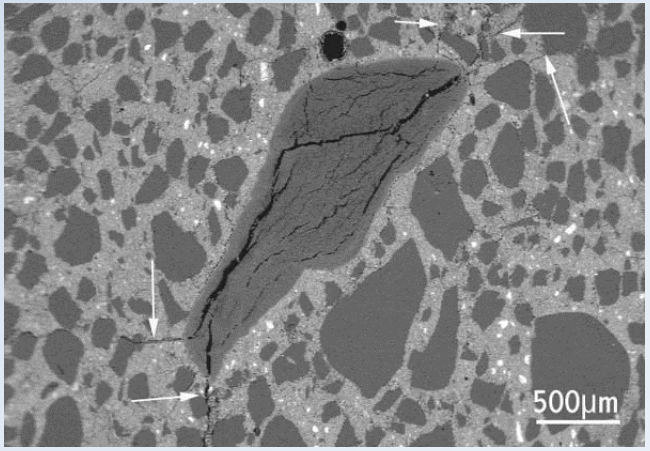
> CARBON NANOMATERIAL BASED CEMENTITIOUS COMPOSITE

Need For Nano Reinforcement In Concrete

Concrete is quasi-brittle and susceptible to cracking. The cracking process within concrete begins with isolated nano cracks, these nano cracks then conjoin to form micro cracks and in turn macro cracks.

Various degradation conditions (physical, chemical or environmental) also generate cracks in concrete.



SEM micrograph of Concrete showing cracks

Collapse of structure due to extensive cracks

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> CARBON NANOMATERIAL BASED CEMENTITIOUS COMPOSITE

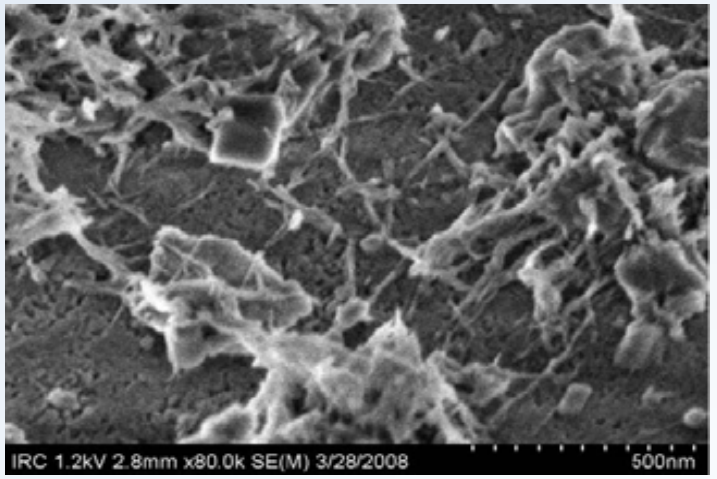
Reinforcement By Nanomaterials

➢Nanoparticles such as SiO_2 and Fe_2O_3 leads to considerable improvement in compressive strength.

➢Nanosized TiO_2 helps to remove organic pollutants from the surface of concrete which are directly exposed to UV radiation.

➢CNFs and CNTs offer the possibility to restrict the growth of nano cracks in concrete, thus creating a new generation of crack free materials.

Crack bridging by CNTs



Growth of C-S-H around SWCNT indicating strong interface

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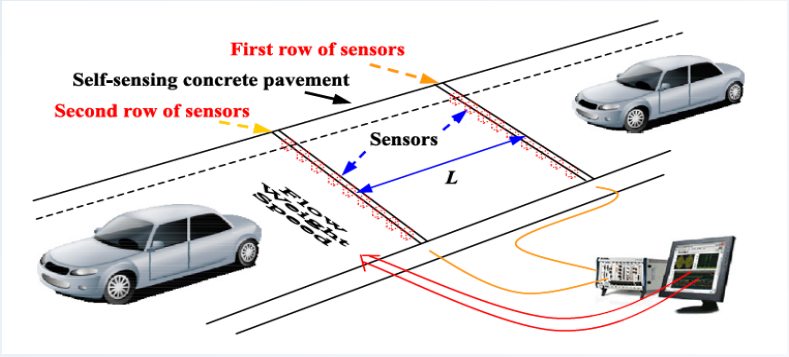
Benefits of using CNFs and CNTs

- ✓Improvement of microstructure.
- ✓Reduction of porosity.
- ✓Improvement of fracture toughness.
- ✓Improvement of mechanical properties
- ✓Introducing piezoresistive properties

a) PC paste
b) PC paste with 0.5 wt% nitric acid surface treated CNFs



Self sensing concrete pavement

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Dispersion of nanomaterials in cement is the key parameter which controls the properties of cementitious composite.

Most common approach to achieve enhanced quality concrete is proper dispersion of CNFs and CNTs in water and then using this solution in concrete .

Dispersion Technique

Chemical method
Functionalization
Surfactant
Polymers and admixture

Physical method
Ultrasonication
Mechanical stirring
Adsorption

Combination of chemical and physical method

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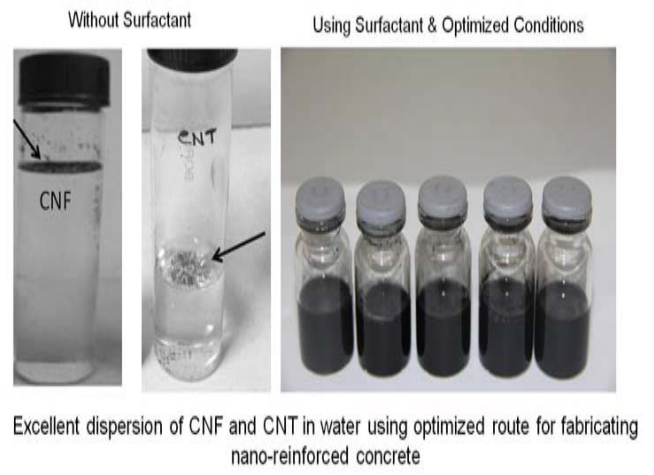
> CARBON NANOMATERIAL BASED CEMENTITIOUS COMPOSITE

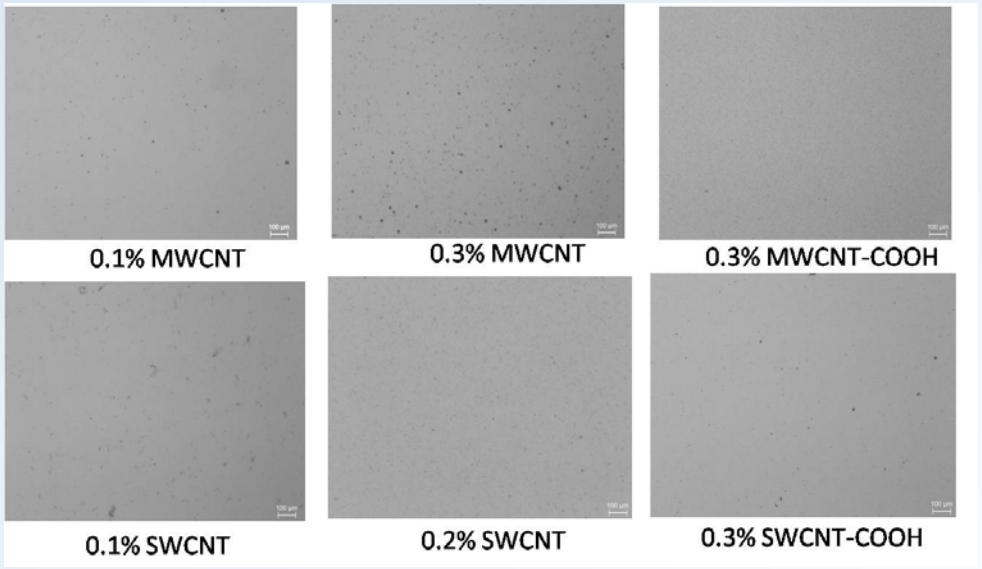
Ongoing Research By FMRG

- Emphasis on exploring physical route that minimizes the damage to CNTs and CNFs.
- Use of combination route for achieving excellent dispersion as well as dispersion stability.
- Development of **crack free** and **piezoresistive** concrete



Excellent dispersion of CNF and CNT in water using optimized route for fabricating nano-reinforced concrete

Optical Micrographs



Excellent homogeneous and stable aqueous dispersion of CNTs and CNFs in water has been achieved through our dispersion approach.

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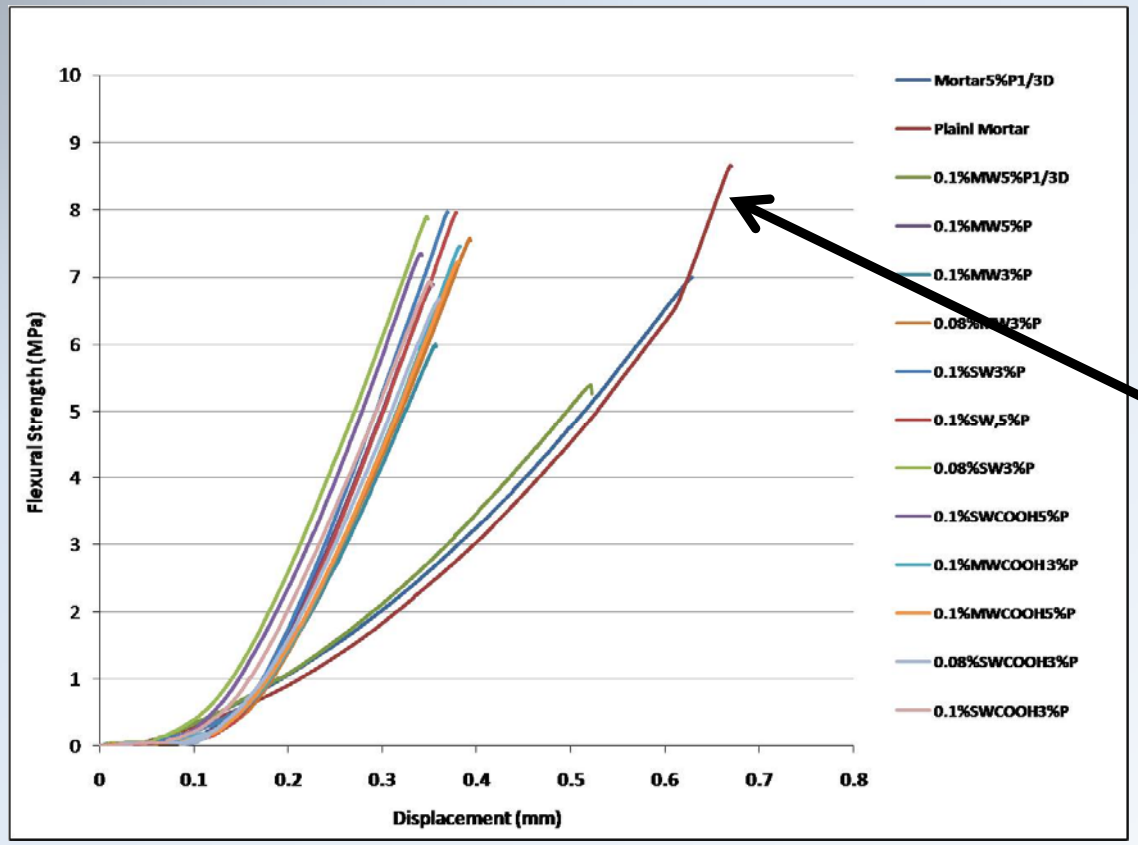
Flexural Testing



Plain mortar

- ✓ Addition of CNT to cement mortar improved the stiffness significantly and reduced the ductility
- ✓ Flexural strength reduced only slightly after addition of CNT

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RESEARCH PROJECTS

> MULTISCALE COMPOSITE MATERIALS <

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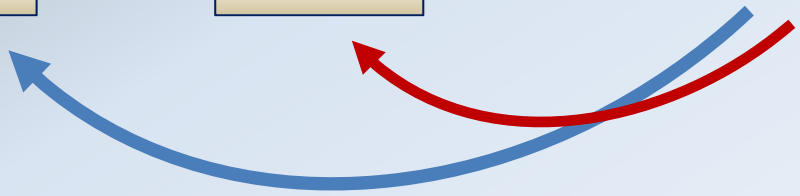
What are Multi-scale Composites ?

Fibre + Matrix ⇒ Conventional Composite

Fibre + Matrix + Nanomaterial ⇒ Multi-scale Composite

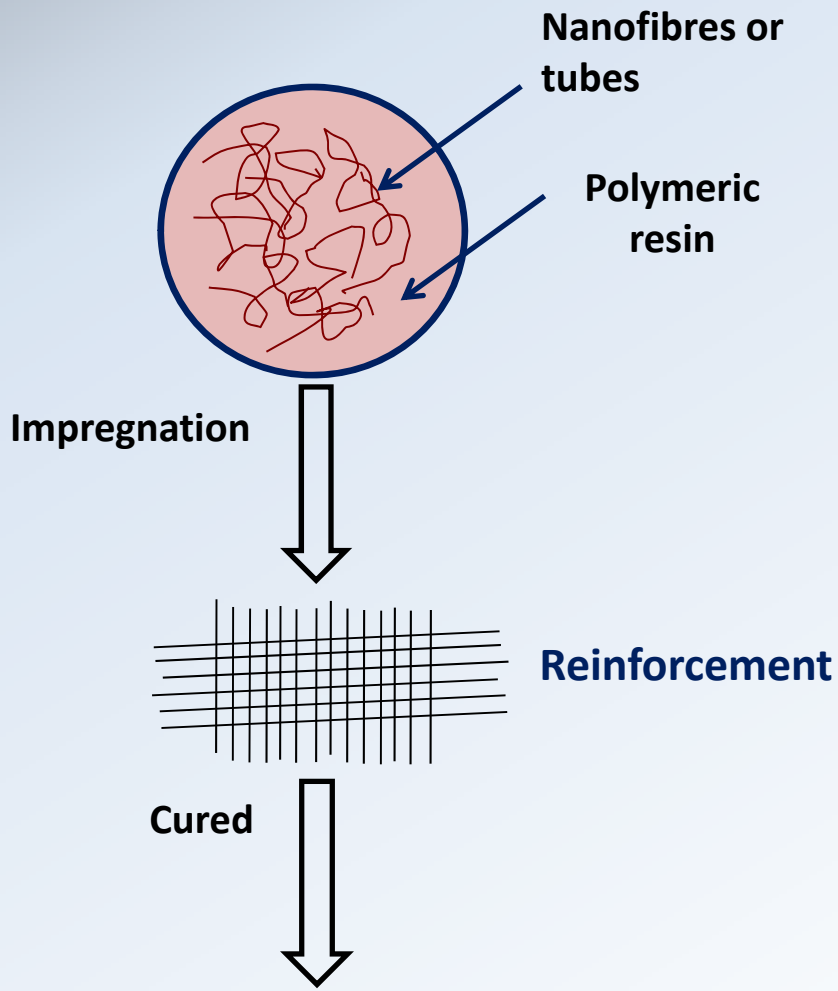


CNT grown, deposited or sprayed

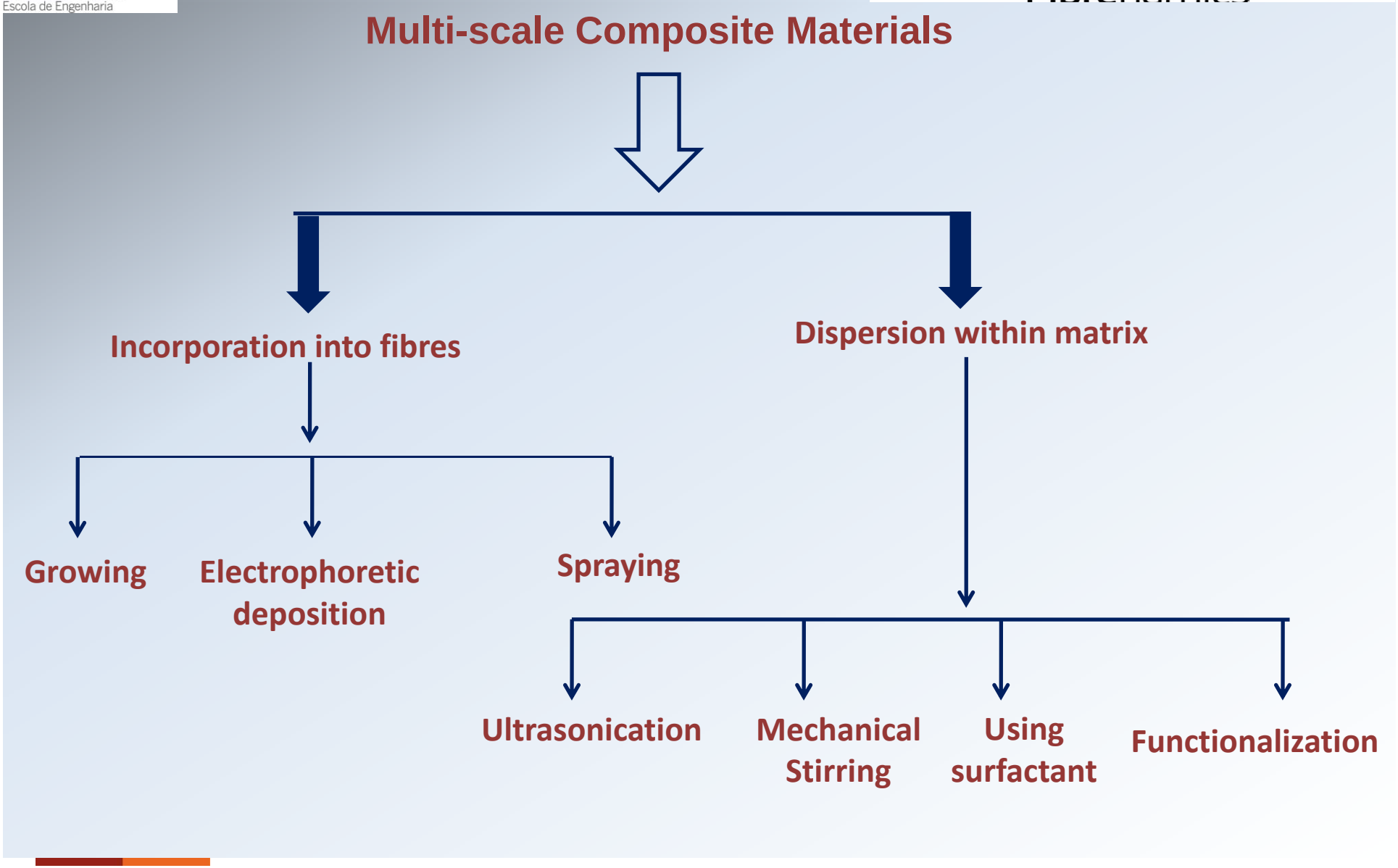
Fibre ⇒ Resin ⇒ Multi-scale Composite

Multi-scale Composites

What are Multi-scale Composites ?

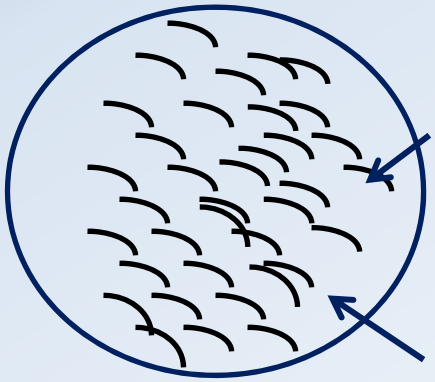


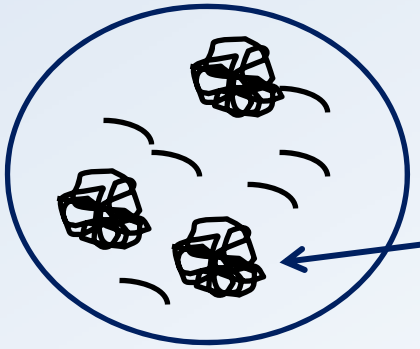
Multi-scale Composites



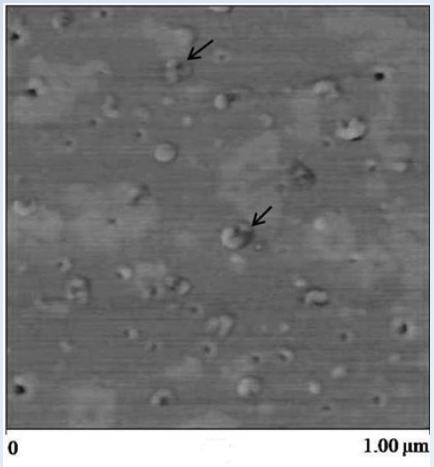
Dispersion

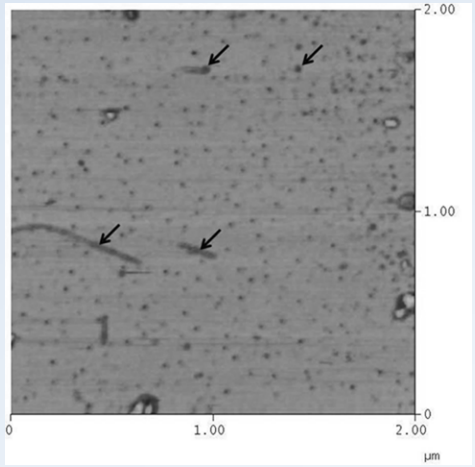
Dispersion is the most critical issue in case of nano material reinforced composites





AFM Phase Image





Homogeneous CNF and CNT dispersion within Epoxy Matrix

Excellent dispersion of CNF/CNT within epoxy matrix has been achieved through ***use of ultrasonication in combination with high speed mechanical stirring (2000 rpm)***

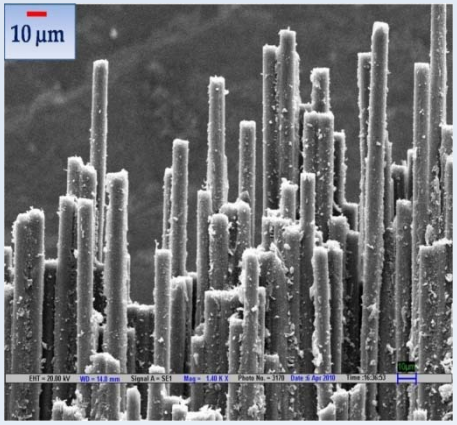
Fangueiro, et al, J Appl Polym Sci 125, 3,1951–1958, 2012

Coordinator| **Raul Fangueiro** | rfangueiro@civil.uminho.pt

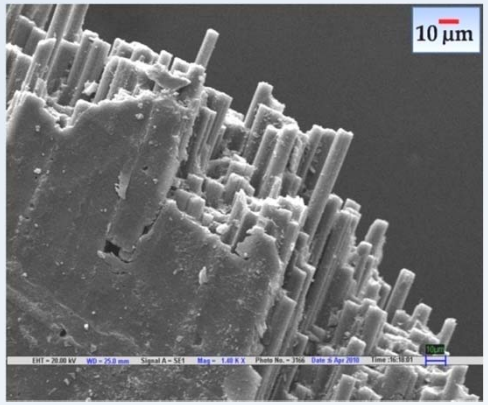
Properties of Multi-scale Composites

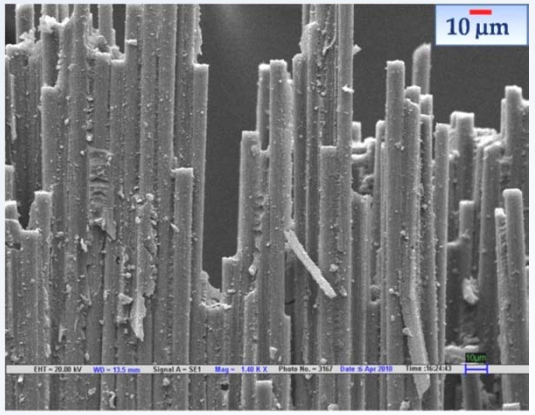
Multi-scale composites with	Improvement in Elastic Modulus (%)	Improvement in Tensile Strength (%)	Improvement in Compressive Modulus (%)	Improvement in Compressive Strength (%)
0.1% CNF	35	11	15	12
0.5% CNF	37	18	50	18
1.0% CNF	23	-14	42	4
0.05% CNT	47	21	42	16
0.1% CNT	95	31	76	41

The main reason for such strong improvement of in-plane mechanical properties in case of multi-scale composites is the formation of a very strong interface



Neat carbon/epoxy composite





Multi-scale composite

Fangueiro, et al, J Appl Polym Sci 125, 3,1951–1958, 2012

Properties of Multi-scale Composites
Thermal and Electrical Conductivity

Composites	Thermal conductivity ($Wm^{-1}K^{-1} \times 10^{-3}$)	Thermal resistance ($W^{-1}\ K\ m^2 \times 10^{-3}$)
Carbon Fabric	71±0.5	39.0±0.5
Carbon/epoxy	193±5	7.9±0.2
Carbon/epoxy/0.1% CNF	224±8	6.9±0.3
Carbon/epoxy/1% CNF	249±15	5.9±0.4
Carbon/epoxy/0.01% CNT	278 ± 14	6.95 ± 0.4
Carbon/epoxy/0.1% CNT	343 ± 20	4.3 ± 0.3

Dispersion of 0.1% SWCNT improved thermal conductivity of carbon/epoxy composites by 78%

Samples	Electrical conductivity (S/cm)
Carbon/epoxy	1.4×10^{-4}
Carbon/epoxy/0.5% CNF	2.6×10^{-3}
Carbon/epoxy/0.1% CNT	8.9×10^{-4}

Dispersion of 0.5% CNF improved electrical conductivity of carbon/epoxy composites by 20 times

Rana et al. Composites Part A, 42, 439-445, 2011

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RESEARCH PROJECTS

> BRAIDED COMPOSITE ROD FOR CONCRETE REINFORCEMENT AND MONITORING <

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> BRAIDED COMPOSITE ROD FOR CONCRETE REINFORCEMENT AND MONITORING

To develop a hybrid braided composite rods (glass/carbon fiber) that works as concrete reinforcement and as a structural monitoring system at the same time.

- ✓ Corrosion of steel is mainly due to reaction of lime present in hydrated cement with carbon dioxide or to the action of chlorides.
- ✓ High costs of renewal and rehabilitation

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Braided composite rods - BCR

Composition

Outer layer

Inner layer

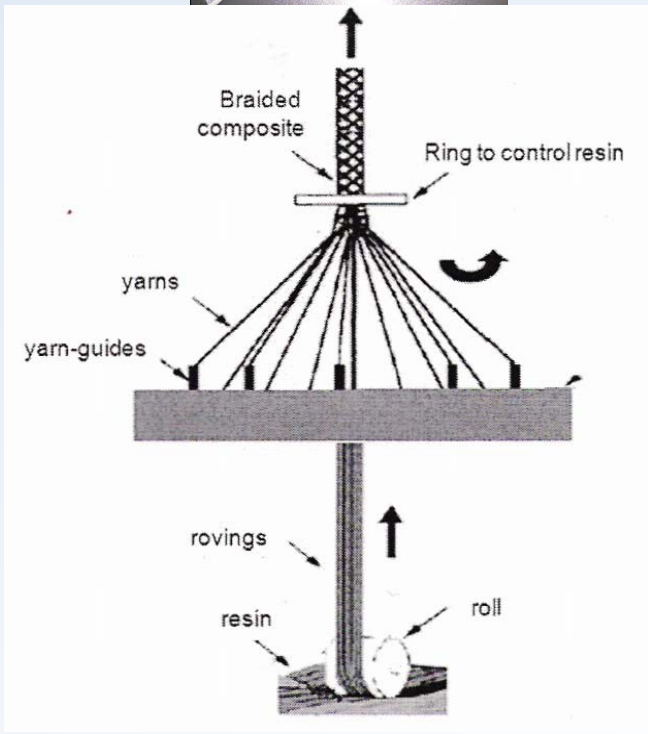
Rib braided structure

Reinforcing fibres

Conductive fibres

Axially introduced for reinforcing capabilities

Axially introduced for sensing capabilities



Impregnated with a resin in a single step process, by vertical braiding.

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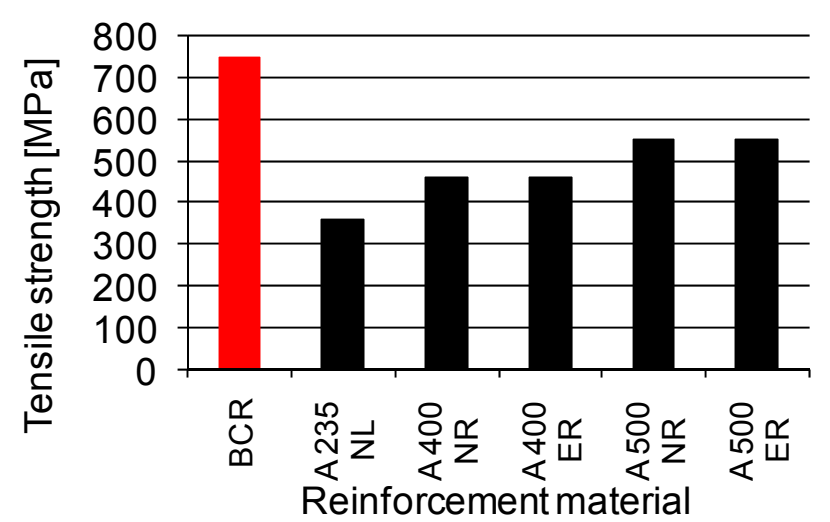
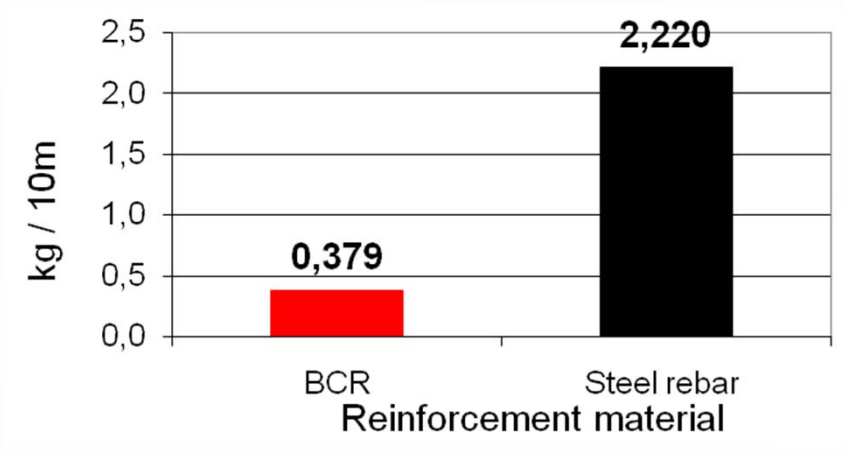


6 mm **BCR** has higher tensile strength than a 6 mm steel rebar



BCR is 83% lighter than steel

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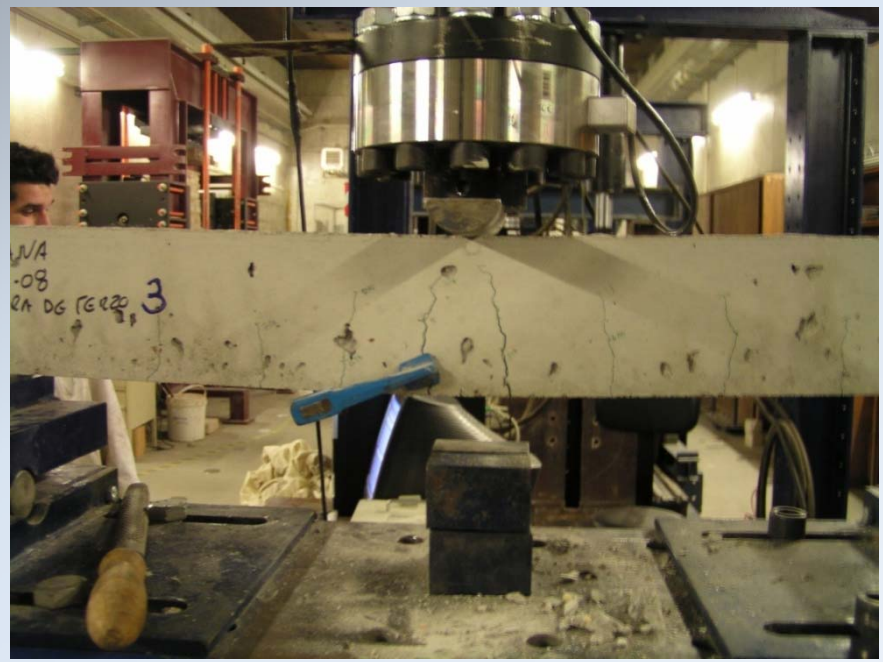
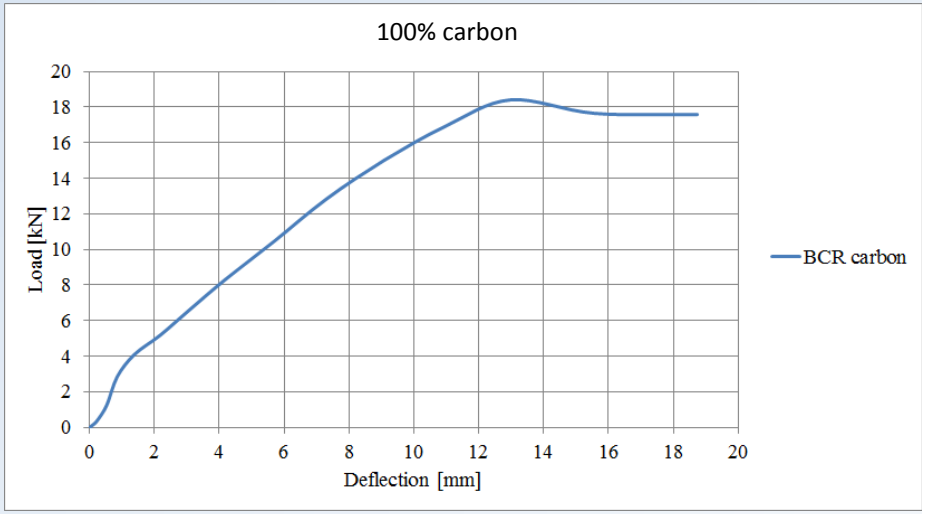
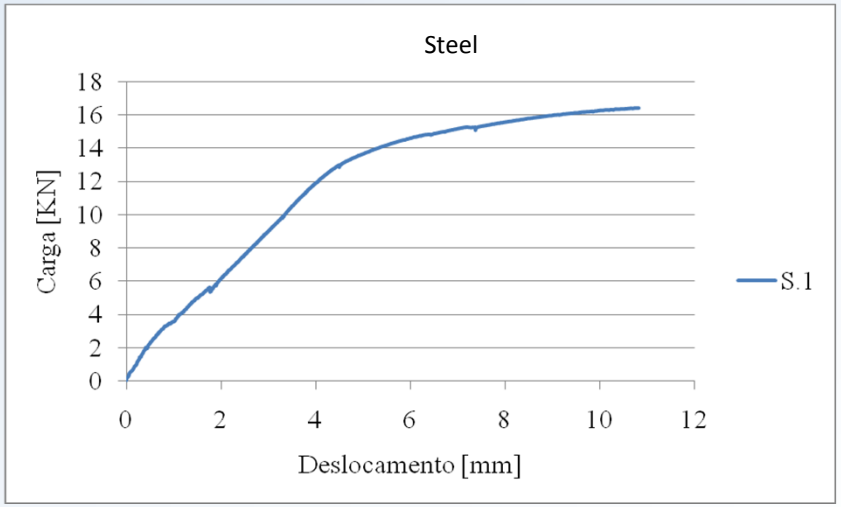
✓ BCR reinforced concrete – bending test







BCRs with improved elastic modulus are presently being developed through reinforcement of steel fibres

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Codes	Fibre weight fraction	Diameter (mm)	Core fibre type	Core composition (wt%)
BCR 1	0.35	5.27	E-glass/carbon	77/23
BCR 2	0.32	5.75	E-glass/carbon	53/47
BCR 3	0.33	6.40	carbon	100

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Gauge Factor of BCR

Cycles	1		2		3		4		Average GF
BCR type	ε (* 10^{-2})	ΔR/ R	ε (* 10^{-2})	ΔR/ R	ε (* 10^{-2})	ΔR/ R	ε (* 10^{-2})	ΔR/ R	
23% C	0,48	0,10	0,48	0,11	0,48	0,12	0,48	0,12	23.4
47% C	0,48	0,04	0,48	0,02	0,48	0,01	0,48	0,01	4.2
100% C	0,55	0,02	0,55	0,01	0,55	0,01	0,55	0,01	2.3

- ✓ *More sensitivity was achieved in case of BCR with lowest carbon fibre content. A gauge factor as high as 23.4 was achieved with BCR.*

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Call for abstracts: deadline 30th October 2014

Natural FIBRENAMICS Award

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Gracias
Obrigada!

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