Structural Sensor & Technologies for TBM (ITER)

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TECNALIA

Barcelona, 19th November 2015

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Who are we?

Tecnalia Spirit & Mission

Inspiring Business

TECNALIA is the first applied research centre in Spain and one of the most important in Europe with around 1.500 people on staff, 122€ millions turnover and more than 4.000 clients.

A unique commitment, an opportunity, a challenge.

To Transform knowledge into GDP.

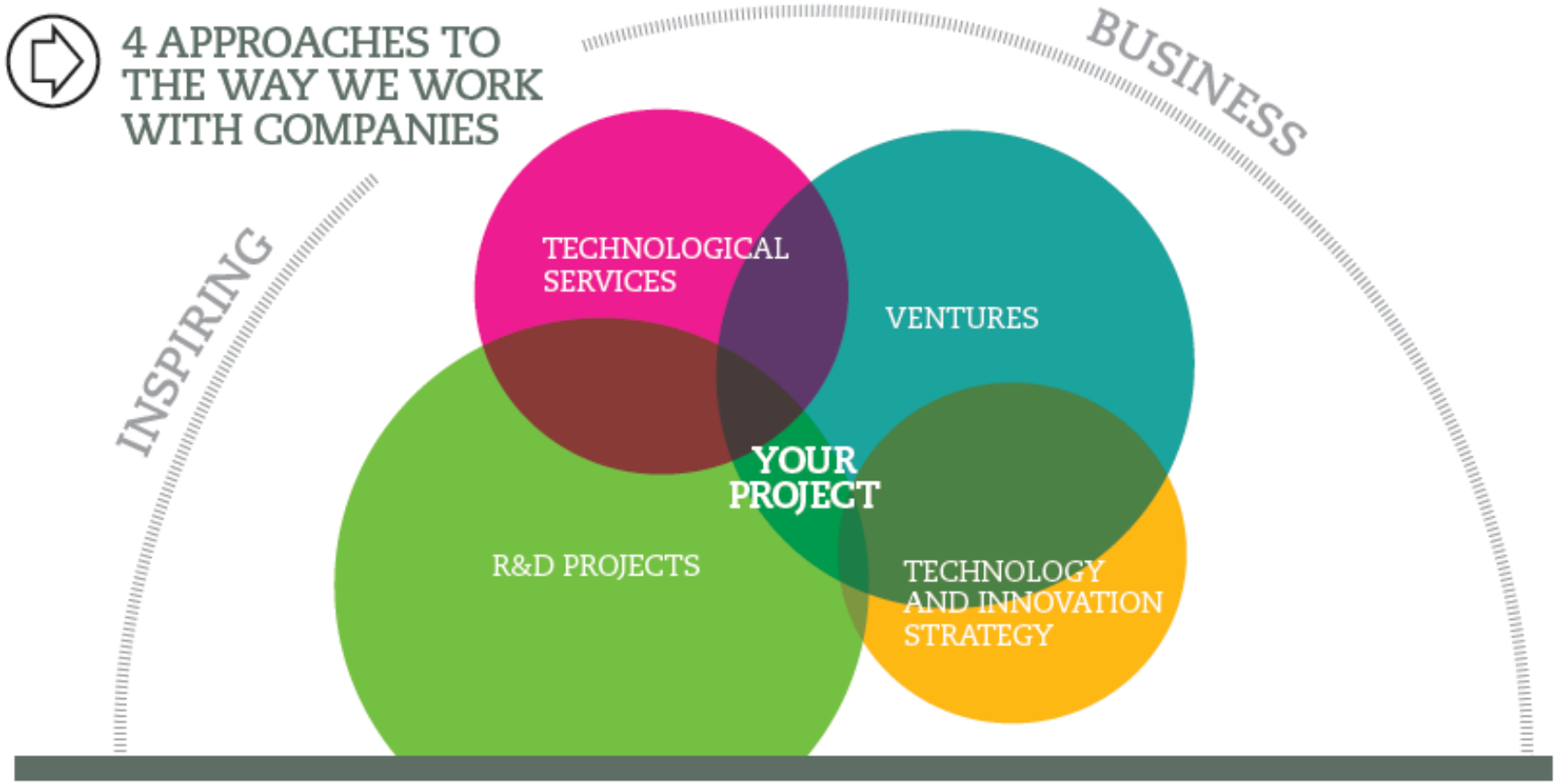
Identifying and Developing Business Opportunities.

Expertise and Specialization in each market.

VALUES

1. COMMITMENT TO THE FUTURE
2. BUSINESS PERSPECTIVE
3. RESEARCH TENACITY
4. EFFICIENT CREATIVITY
5. FLEXIBILITY
6. CONNECTIVITY

TO GENERATE BUSINESS OPPORTUNITIES THROUGH APPLIED RESEARCH



TECNALIA

FIGURES

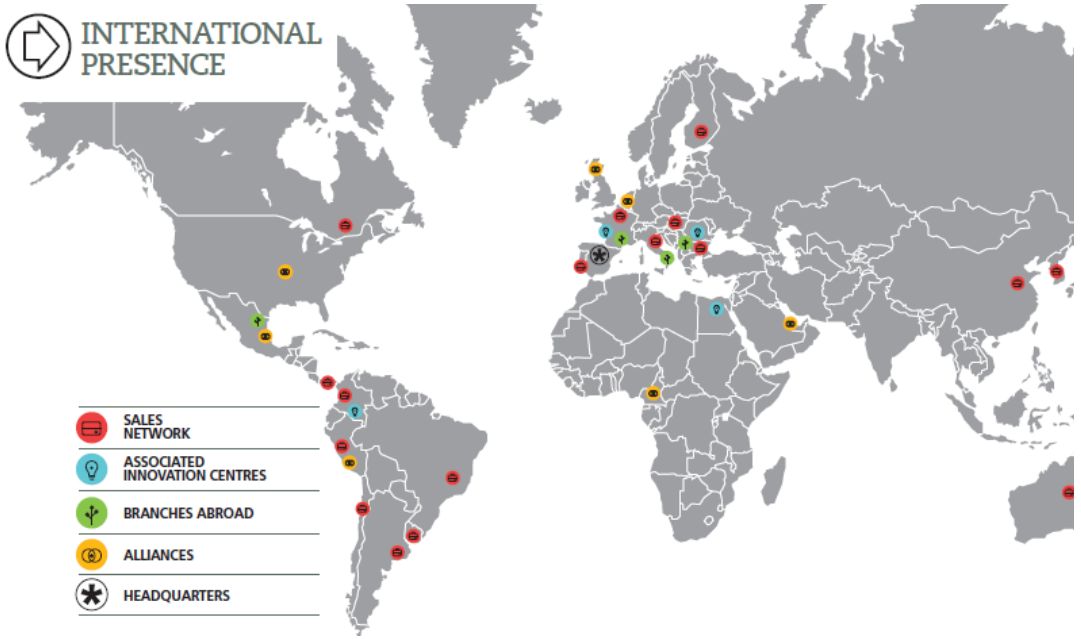
Tecnalia son personas

1.437…… Personas en plantilla

26 …… Sedes

3.796 …… Clientes

164 ….. Doctores



Crear ideas, crear riqueza

53 patentes solicitadas

11 concedidas

3 licenciadas

1M € de ingresos por licencias

Con participación en 31 NEBTs.

VII Programa Marco

169 …… Proyectos aprobados

34 …… Proyectos liderados

58,07 …… millones de Euros

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Organized in 7 Business Divisions

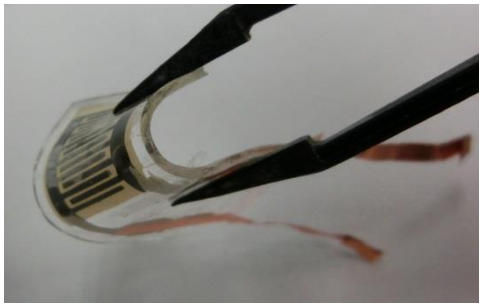
1. SUSTAINABLE CONSTRUCTION
2. ENERGY AND ENVIRONMENT
3. INNOVATION STRATEGIES
4. ICT-EUROPEAN SOFTWARE INSTITUTE
5. INDUSTRY AND TRANSPORT
6. HEALTH
7. TECHNOLOGICAL SERVICES

We work from the experience and the expertise in each of the markets in which we operate, with an efficient and proactive attitude.

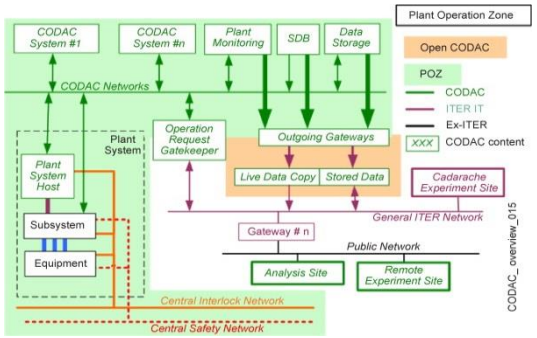
What do we do?

Technologies

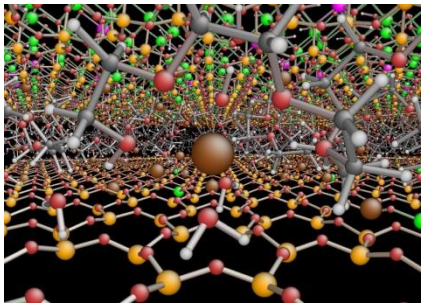
Technologies



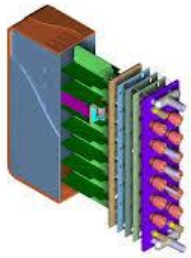
Sensors



CODAC

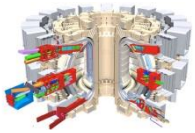


Materials



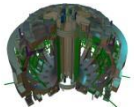
Test Blanket Module

Remote Handling

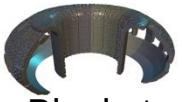


Diagnostics

Ion Cyclotron



Magnets

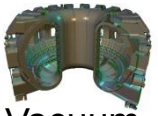


Blankets

Assembly

Engineering Support

Cryoplant



Vacuum Vessel

Divertor

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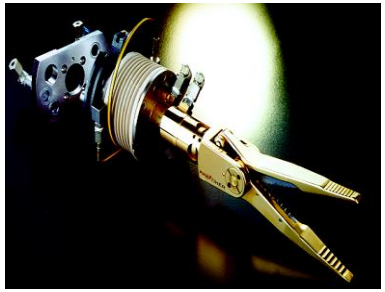
Technologies

Remote Handling

R&D and Technological Solutions

- ✓ Neutral Beam RH
- ✓ Engineering support activities for studies in general areas
- ✓ Design activities:
  - DTP2 extension and upgrades
  - Studies on transfer cask path



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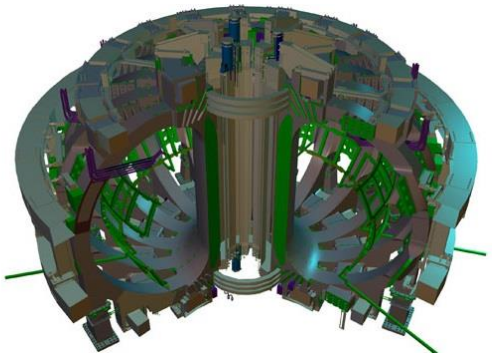
Technologies

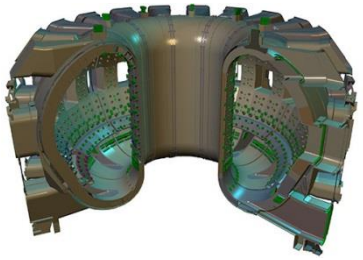
Materials for Magnetic Environment R&D



- ✓ Closure welding
- ✓ DGEBA epoxy resin
- ✓ Cyanate ester
- ✓ Development of welding procedure
- ✓ NDE procedure
- ✓ Irradiation resistant resin

Technologies

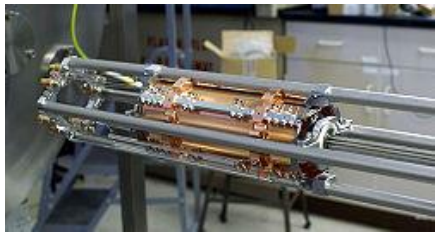
Vacuum Vessel



- ✓ Stainless steel material procurement
- ✓ Local vacuum EB weld system development
- ✓ Weld distortion control of VV segment manufacture.
  - Design & development
  - Corrosion issues
  - Consultancy support to material procurement

Technologies

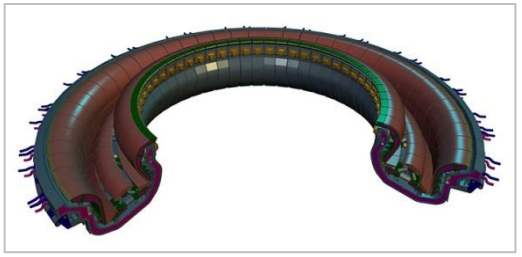
ION CYCLOTRON H&CD antenna



- ✓ RF windows
- ✓ Faraday shield
- ✓ Characterisation of window materials
- ✓ Bonding methods
- ✓ Braze qualification /optimisation
- ✓ H_2 embritlement of Ti alloys
- ✓ Plating Ti
- ✓ Validation of thermal capability of FS protection bars

Technologies

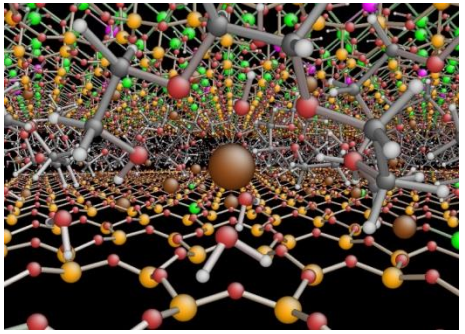
Divertor



- ✓ CFRP for the inner vertical target prototype
- ✓ Characterisation of alternative CFC material
- ✓ Destructive examination of mockups
- ✓ High heat flux (HPPF/HOVF) test and TVC
- ✓ Manufacturing mock-ups
- ✓ Qualification of repair technologies

Technologies

Materials

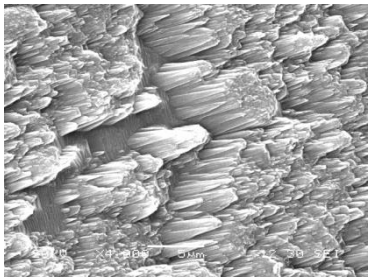


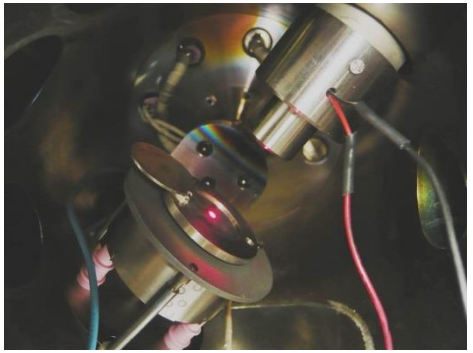
- ✓ EUROFER base materials and welds for TBM
- ✓ Characterisation and validation of both materials and welds
- ✓ Testing design
- ✓ SiC-SiC brazing
- ✓ Heat flux and thermal fatigue test on CuCrZr
- ✓ CuCrZr with different materials joining development (HP/Brazing)
- ✓ Chemical, Morphological and Mechanical testing

Technologies

Engineering support

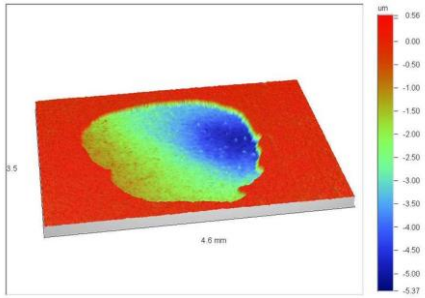
- ✓ Mechanical analysis (Stress analysis and support on components manufacturing
- ✓ Structural design criteria for in-vessel components





Plasma

- ✓ Experimental Plasma-wall interaction
- ✓ Ion sputtering accelerated test (metals & ceramics)



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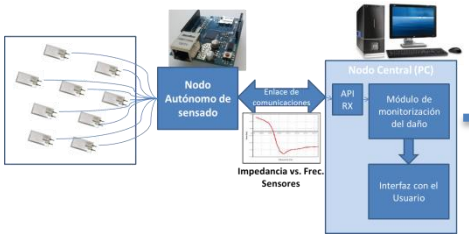
What do we do?

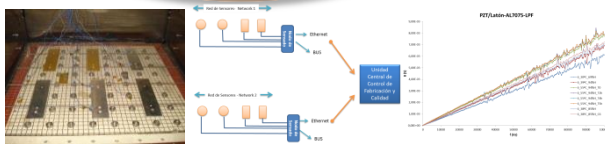
SHM Technologies

Structural Health Monitoring

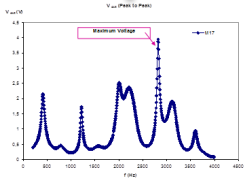
Health Monitoring Strategy



Red de Sensor



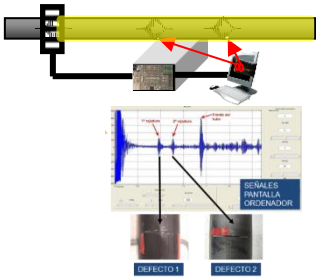
Energy Harvesting



Unidad Electrónica

Método de Impedancia

Ultrasonidos



Gestión inteligente de los datos

Comunicación
(Wireless, Ethernet, …)

Modelo de aprendizaje supervisado

Software para la identificación del daño/fallo

Software de interfaz con el usuario

Unidad Principal de Comunicación

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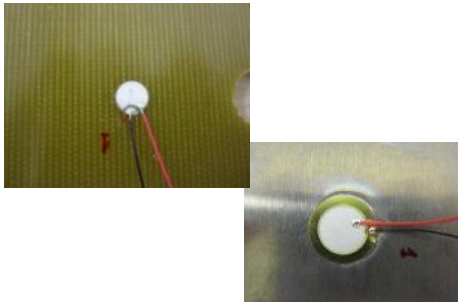
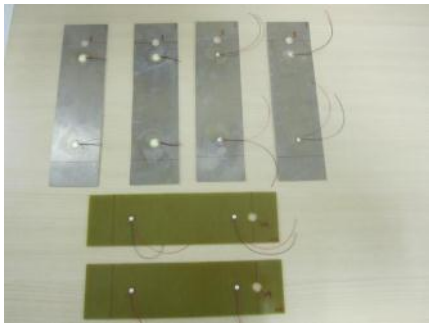
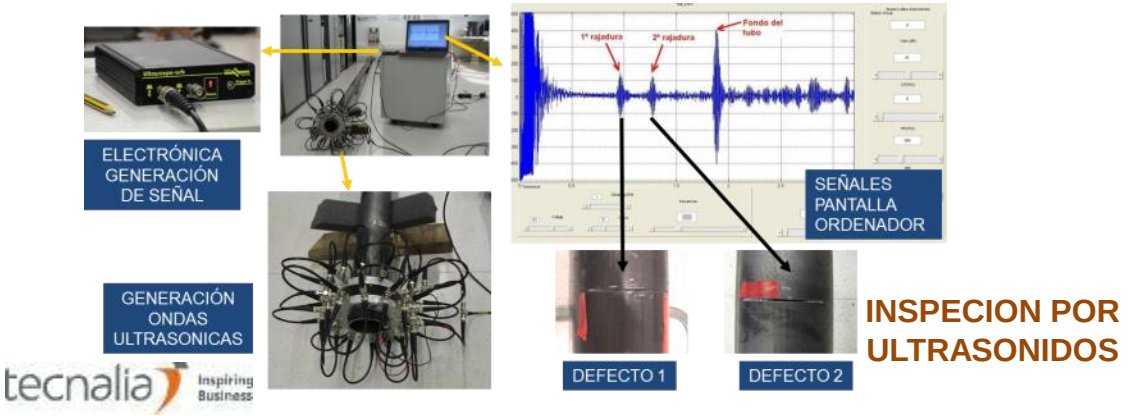
Determinacion de la Salud Estructural - SHM

Determinación de defectos y corrosión en líneas de transmisión y contenedores basados en tecnologías de sensores piezoeléctricos:

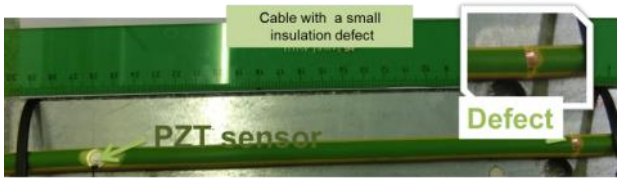
- Monitorización de defectos en materiales metálicos compuestos o plásticos incluyendo cableado.
- Sensores PZT ensayados bajo condiciones de Tª y Humedad controlada.
- Diseño de sensores a medida
- Redes de sensores de bajo consumo con capacidad para la comunicación Wireless.
- Inspección por ultrasonidos de grandes longitudes de tuberías.
- Estrategias a medida en función de las necesidades de monitorización y la frecuencia de seguimiento de los sensores.
- Posibilidad de auto-alimentacion de las redes de sensores mediante estrategias de *energy harvesting*.







INSPECION POR ULTRASONIDOS



SENSOR PZT ULTRAFLEXIBLE

Piezoelectric sensor & actuator

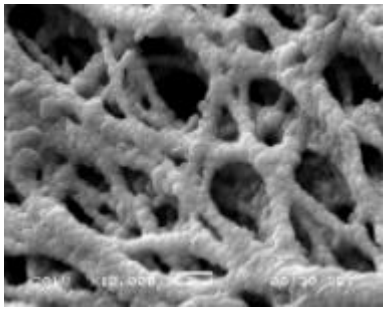
Materials & Technology
CERAMIC & POLYMERIC

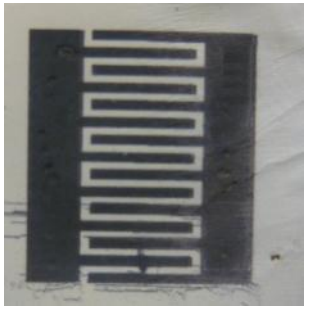
Advantages

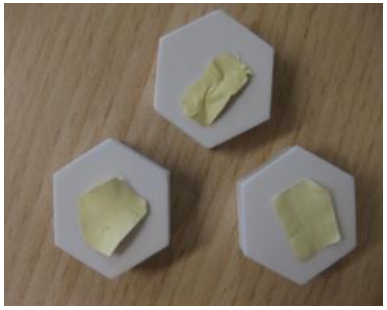
- ✓High sensitivity & fast response
- ✓Frequency: High range of operation
- ✓Low power consumption & cost
- ✓Robustness
- ✓High integration into complex structures
- ✓Wide range of geometries

Capacity for

- ✓Definition of specifications
- ✓Active material design & fabrication
- ✓Sensors/actuator design & fabrication
- ✓Component testing
- ✓Prototype development
- ✓System modeling







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High Temperature Piezoelectric Transducer

MATERIAL		T_c (ºC)	T_o (ºC)
PZT	PZT	350	150-200
	PZT-5a	365	
	Piezocomposite PZT		180
Bismuth Titanate $Bi_4Ti_3O_{12}$	Pz45	500	
	Pz46	650	500-550
	B8613	N.A.	500
	PzS90	670	500
	PzS96	920	700
	Modified Bismuth Titanate (Kezite K15)	600	
$LiNbO_3$	Lithium Niobate	1210	600
	LNN based on $LiNbO_3$		650
Lead Metaniobate	Lead Metaniobate $PbNb_2O_6$	540	300
	Modified Lead Titanate Pz32	400	
	Modified Lead Metaniobate K-81, K-83	570	300
Galium Orthophospate $GaPO_4$			700
Aluminium Nitride AlN			1100
BMT-PT		450	
BS-PT		400	

What do we do?

Energy Harvesting

ENERGY HARVESTING (I)

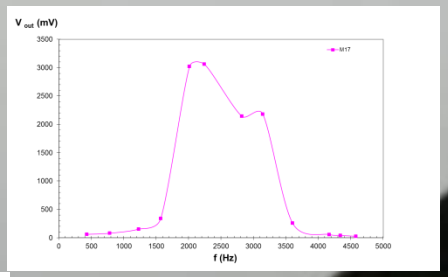
PIEZO ACTIVE MATERIALS

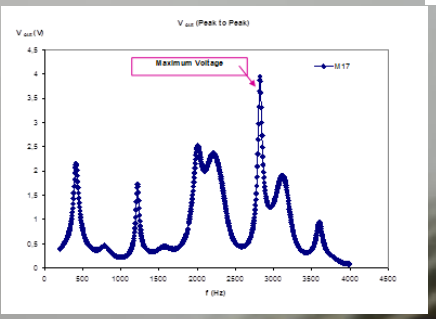
- ✓ Design of Harvest piezoactive strategy.
- ✓ Piezoelectric Material development.
- ✓ Fabrication of piezo-actuator for the power required.
- ✓ Definition of the Harvest unit to collect energy maximizing the efficiency as function of the mechanism (vibration, environment, movement, pressure, …)
- ✓ Power output from few μW to 900 μW as function of frequency, Force and sensor configuration.

Piezoelectric materials and systems for harvest the energy

ENERGY HARVESTING (II)

VOLTAGE GENERATION





Electronic Module

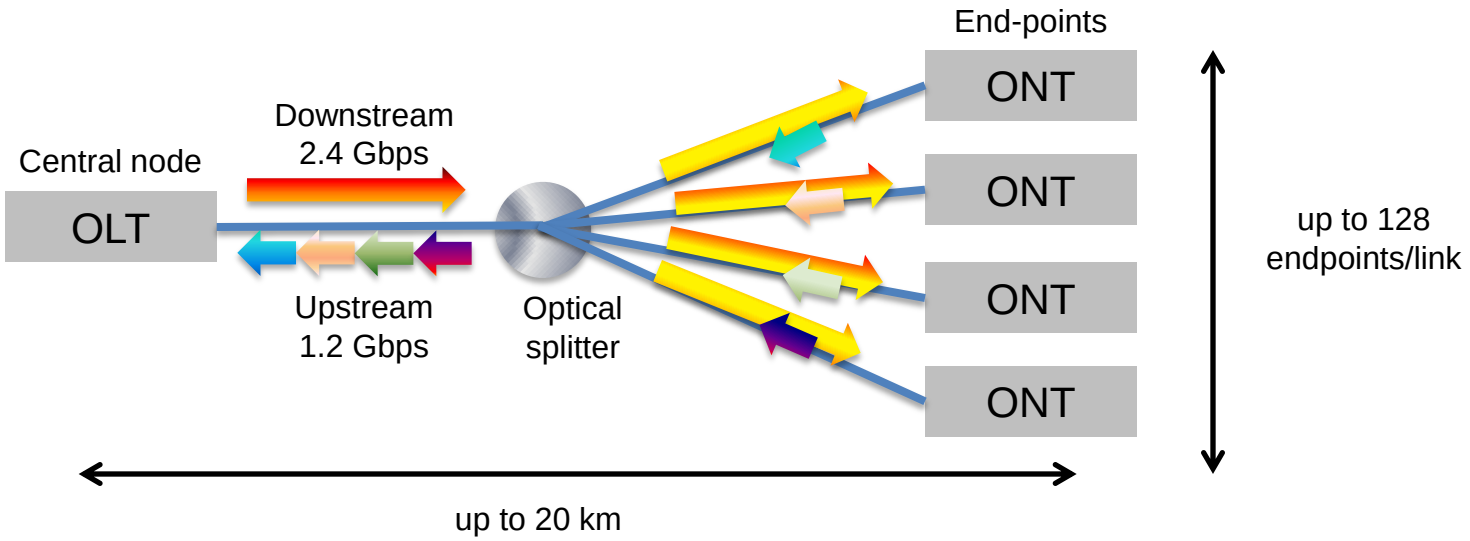
- ✓ Energy harvesting piezo active elements produce electrical energy that is capture, accumulate, and conserve by the electronic module to provide power at output voltage and current levels that are within the limits of a particular electronic system power supply specifications.

What do we do?

CODAC

PON based Monitoring and Control Communication System

Passive Optical Networks (PON)



- ✓ **Point to Multipoint** optical to the end-point network
- ✓ **Passive** (unpowered) distribution network using splitters
- ✓ A **single fiber** serves up to **128 end-points**
- ✓ **Donwstream** signals are **broadcast** @ **2.4Gbps**
- ✓ **Upstream** signals are multiplexed and **combined** (TDMA) @1.2Gbps
- ✓ Extensively used in access networks (FTTH)

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PON based Monitoring and Control Communication System

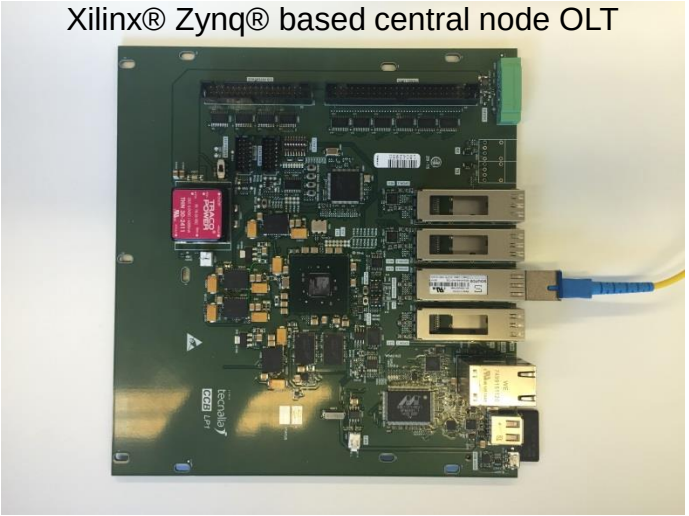
Why PON?

- ✓ Point to Multipoint architecture fits with many monitoring and control applications
- ✓ All information sent by central node is received simultaneously by all end-points
- ✓ If and end-point crashes the network is not affected
- ✓ Simple distribution network with passive components
- ✓ Only one fiber from central node to splitter to serve up to 128 end-points (Tx and Rx)
- ✓ Up to 20 km reach
- ✓ Few nanoseconds Synchronization accuracy
- ✓ High-speed: 2.4 Gbps downstream / 1.2 Gbps upstream

PON based Monitoring and Control Communication System

TECNALIA's PON based Monitoring and Control Communication System

Xilinx® Zynq® based central node OLT



Xilinx® Artix-7® based end-point ONT

- ✓ Existing PON devices and protocols have been designed to replace copper (ADSL) in access networks for triple play services (voice, internet data and video)
- ✓ Monitoring and Control systems have different **requirements**: **synchronization**, **reliability**, **determinism**, etc. => **NEW HARDWARE AND PROTOCOLS NEED TO BE DEVELOPED**
- ✓ **Tecnalia** has developed **FPGA based hardware and protocols** for both OLT (central node) and ONTs (end-points)

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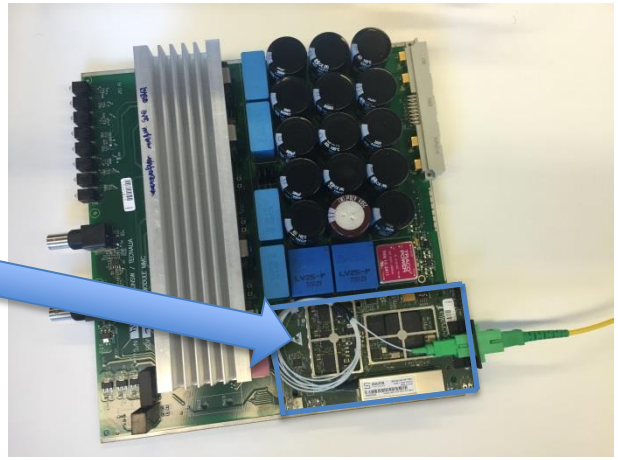
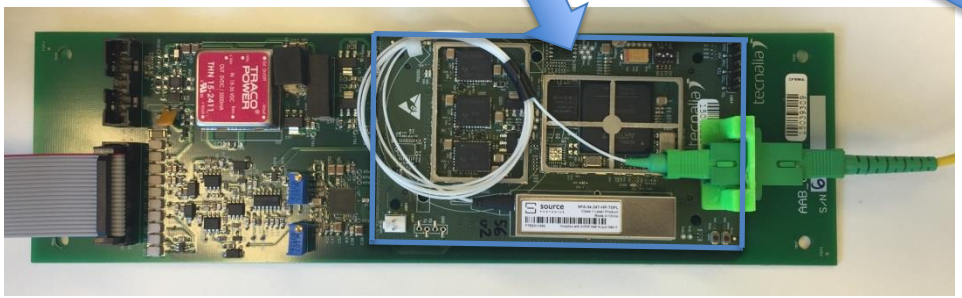
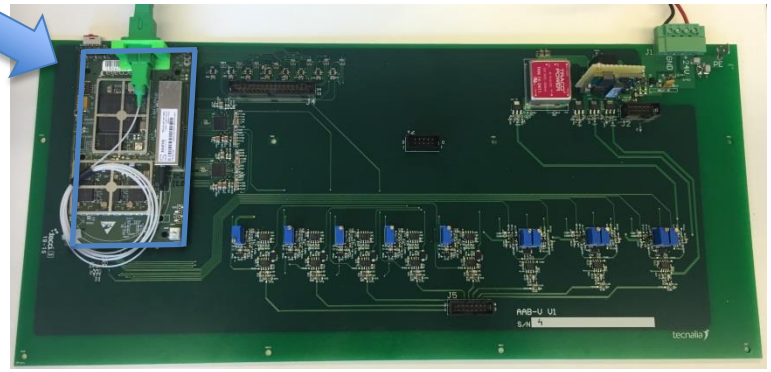
PON based Monitoring and Control Communication System

TECNALIA's PON based Monitoring and Control Communication System

Plugable end-point ONT







These ONTs developed by Tecnalia have been designed to provide PON based communication to different application specific hardware

PON based Monitoring and Control Communication System

First success story

Modular Multilevel Converter

- ✓ Main cabinet includes Central Communications node (OLT) and optical splitter
- ✓ 3 different types of hardware devices for monitoring and control are equiped with communications end-points (ONTs):
  - 48 Submodules with voltage and temperature sensors and 6 MOSFETs synchronously switching as commanded by the Central Node.
  - 6 System Current Supervisor units
  - 1 System Voltage Supervisor unit

What do we do?

Fibre Optic Operational Testing

FIBRE OPTICS HIGH TEMPERATURE MONITORING SYSTEM

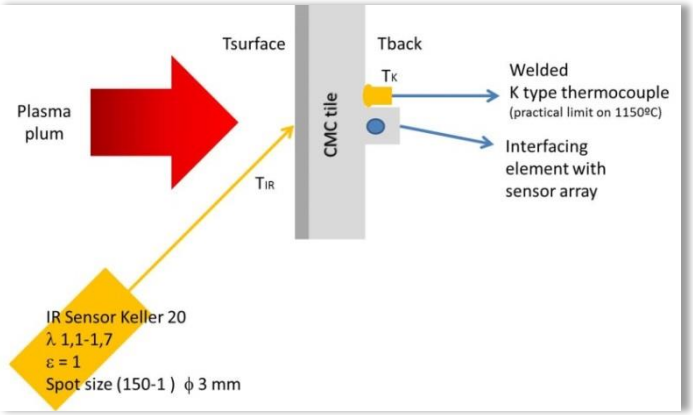
ESA CONTRACT No. 4000114501/15/NL/RA/zk

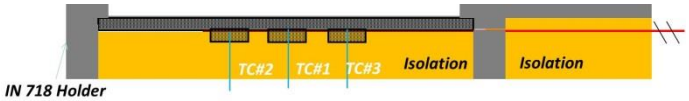
Prime contractor*: EMBEDDED INSTRUMENTS AND SYSTEMS, S.L.*

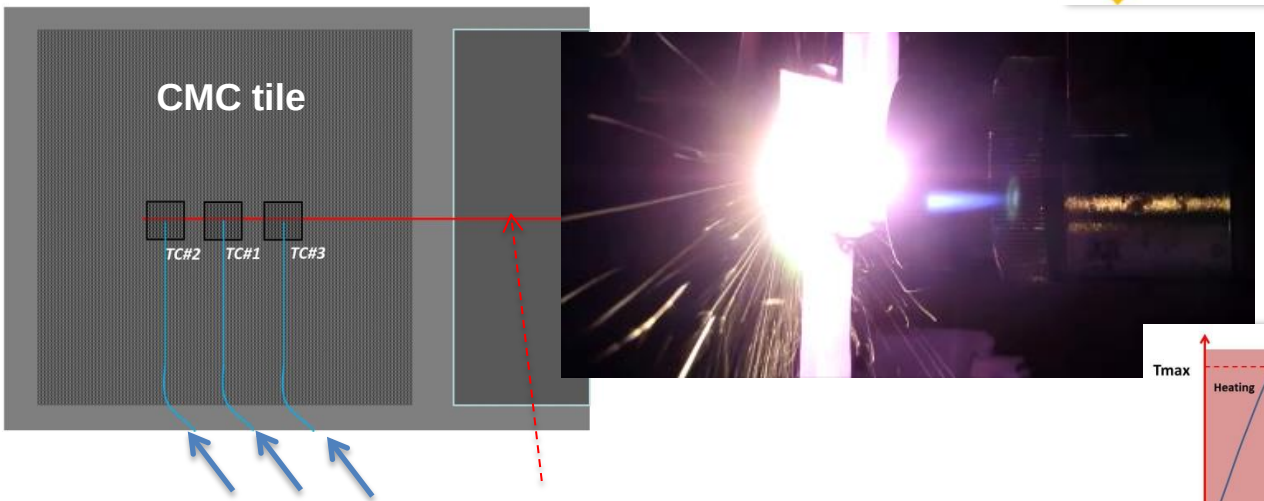
HiTOS
High Temperature Optical Sensors

Role of TECNALIA (Subcontractor):

- ✓ Assembly to interfacing elements (CMC tile).
- ✓ Functional testing under relevant service conditions for TPS applications (max. service temperature ~1100°C)

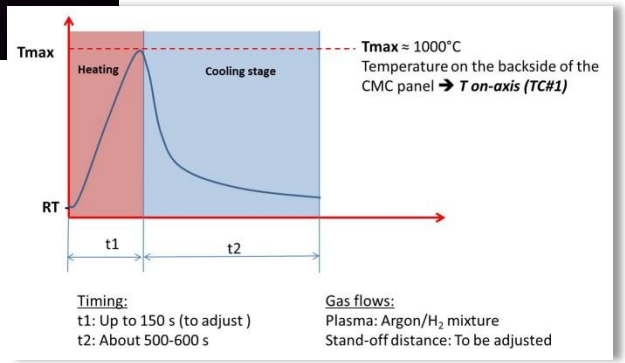






Correlation with:

- ✓ Non-contact Temperature measurements
- ✓ Contact measurement (thermocouples)



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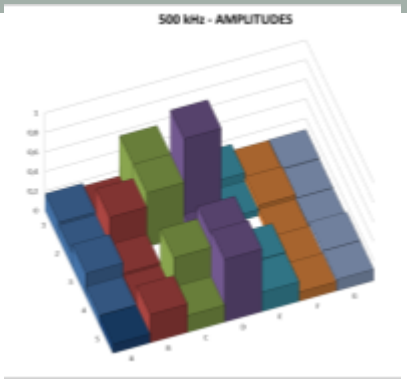
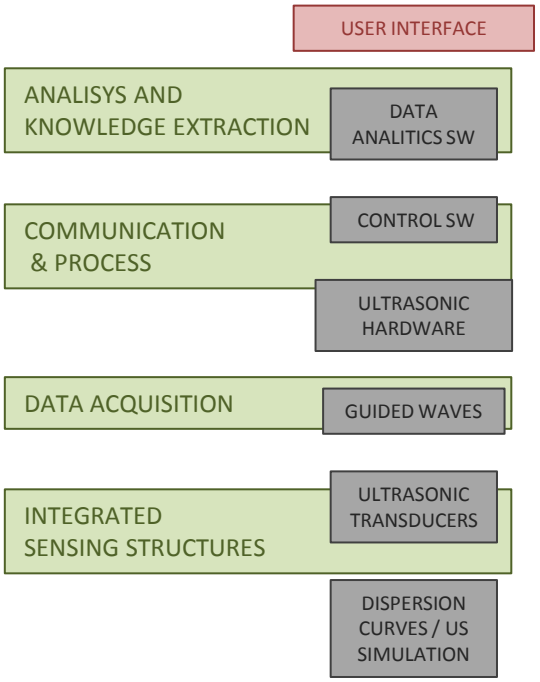
What do we do?

REFERENCES

Structural Health Monitoring: success stories

ULTRASONIC GUIDED WAVES BASED SHM SYSTEM



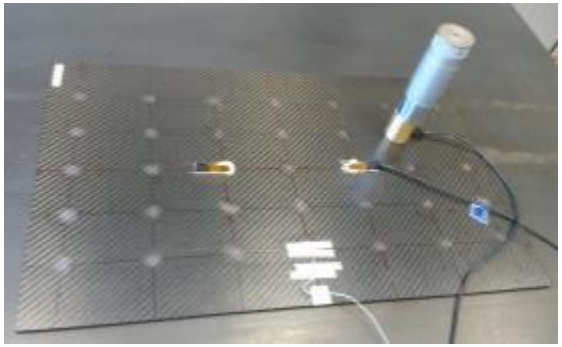


Tecnalia has developed a n SHM system for aeronautic structures based on guided waves able to:

- Detect damages produced by impact and fatigue
- Detect bending
- Calculate Damage Index or Bending Index by using SDC technique

Characteristics:

- The damages have been evaluated in plate composite structures by using Accelent single sensor and piezoelectric materials.
- The system is composed by a HW that controls the emission and reception parameters and a SW that calculates de Damage Index (DI) or bending Index comparing the signal before and after the damages.
- Dynamic pattern generation SW has been developed to compensate temperature effect in measures.
- Data analytics and IA techniques are applied to calculate Damage index



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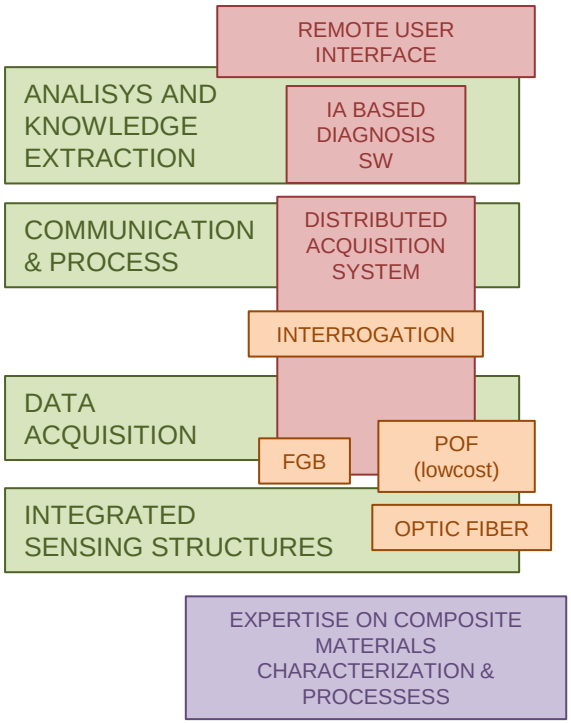
Structural Health Monitoring: success stories

OPTIC FIBER BASED SHM



Applications:

- Ice detection system using non-intrusive sensors
- Vibration measurement, strain monitoring.
- Instrumentation for temperature gradient in gearboxes
- Prediction system for torque determination, etc…

Characteristics:

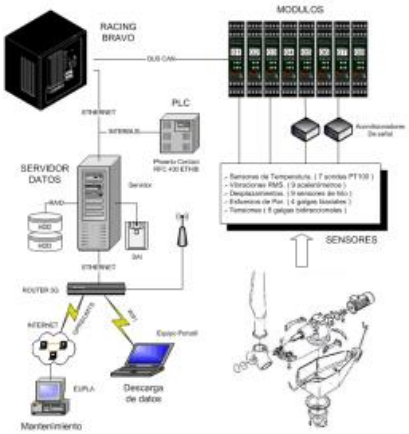
▪ Integration of wired and wireless sensors in extreme conditions: FBG or POF networks,

▪Integration of the system in composite material structure with adhoc conectors

▪ Control-communication-signal processing-filtering-monitoring

▪ Local data pre-processing through embedded computing

▪ Monitoring system can be implemented on the composite structure during the manufacturing procedure and will monitor de assemblies status through its entire life.



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Structural Health Monitoring: success stories

MIPMADE – Increasing European Resilience Electrical Tower SHM

Company

ISDEFE

Description

Piezoelectric sensor network for electrical tower structural integrity monitoring.

Technologies

Impedance based SHM network based on PZT sensor.

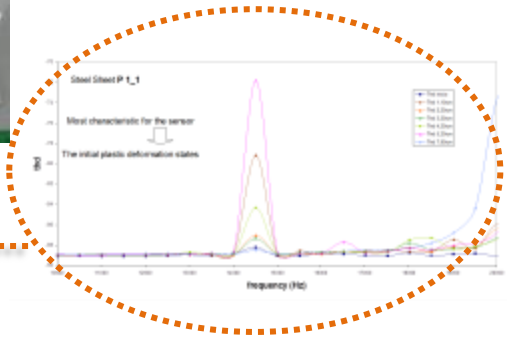
Our main role

Sensor design , integration and testing under field conditions.

Benefits obtained in facts

Low cost solution

Easy to integrated in long areas to guarantee the structural integrity of electrical tower .



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Structural Health Monitoring: success stories

Low cost Piezoelectric sensor network for UAVs

Company

INDRA

Description

PZT sensors network for damage identification and the health monitoring. of components.

Technologies

Impedance method based SHM network based on PZT sensor.

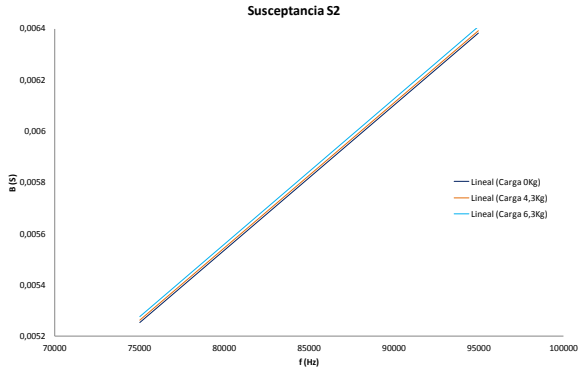
Our main role

Sensor design , integration and testing under field conditions.

Benefits obtained in facts

Low cost solution .

Low power consumption sensor network.



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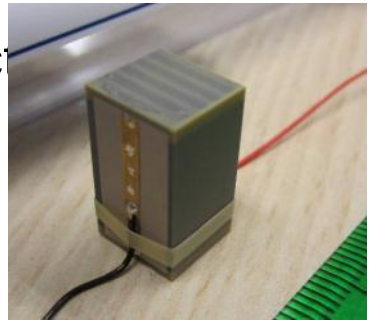
What do we do?

Smart Actuators

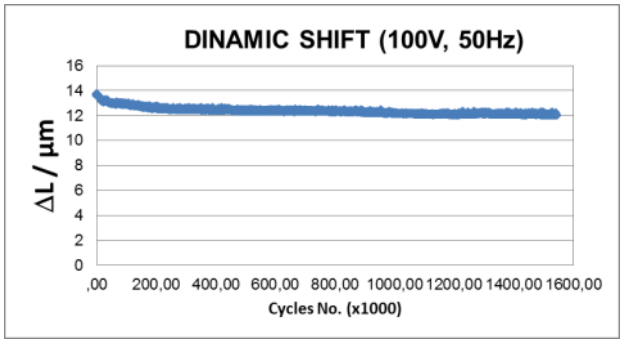
Piezoelectric Actuators

✓Positioning and actuation systems of mechanical struct



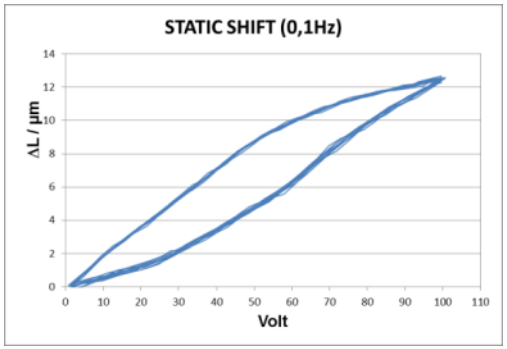
Multilayer piezo stack actuators for:

- ✓ Static operation.
- ✓ Dynamic operation.



Benefits

- ✓Superior lifetime even under extreme conditions.
- ✓Very large operating temperature.
- ✓High humidity resistance.
- ✓Temperature stability.
- ✓High stiffness
- ✓High repeatibility



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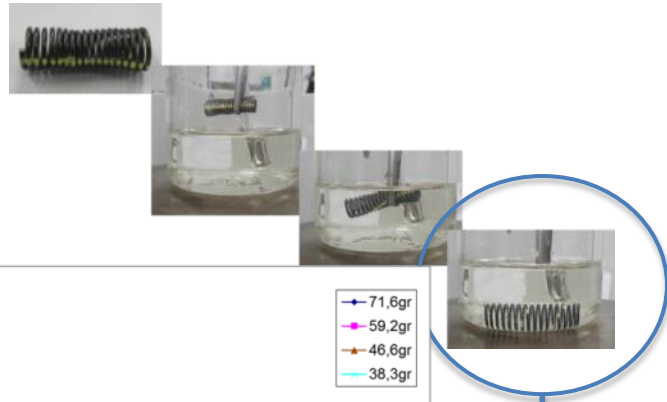
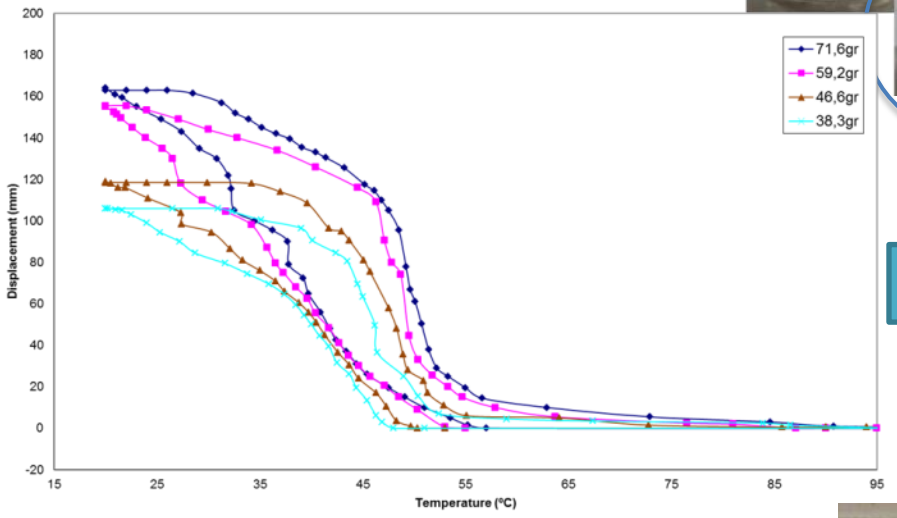
SMA Actuators

✓Actuation applications by temperature control.



Multishape SMA actuators based on:

- ✓ Wires
- ✓ Springs



425 gr.

Benefits

- ✓Superior lifetime even under extreme conditions.
- ✓Very large operating smart structures.
- ✓High resistance.
- ✓Temperature stability and cycles operation.

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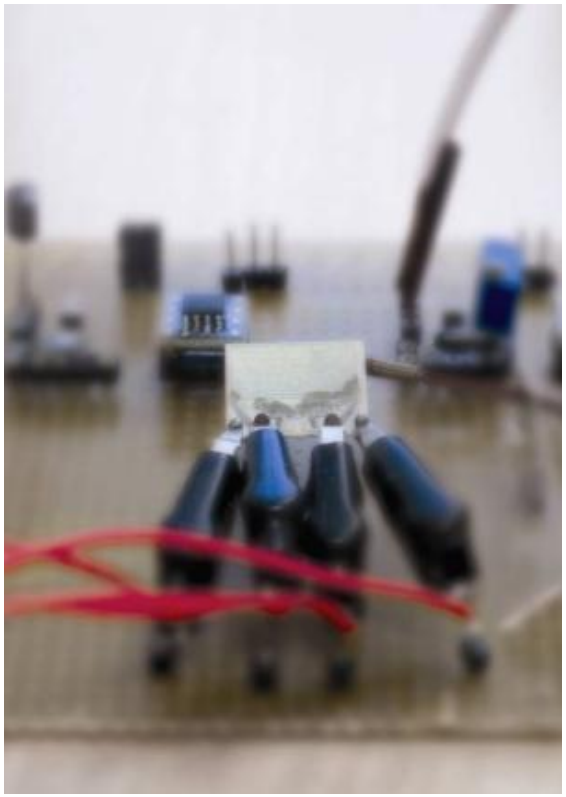
What do we do?

Other Sensors Technologies

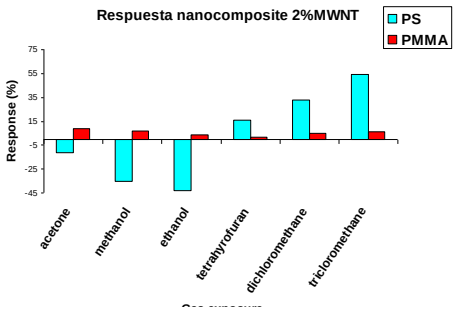
Gas Sensors

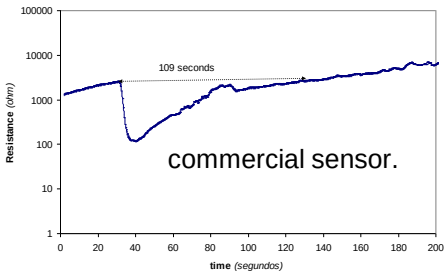
- ✓ Lower detection limits
- ✓ Faster response time
- ✓ Faster recovery time
- ✓ Low cost
- ✓ Extreme T operation (market niche for monitoring combustion systems – no commercial solutions available)

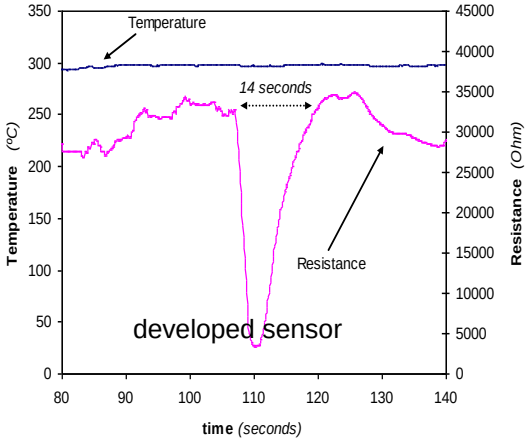


Resistive sensors

- Ceramic sensors: SnO_2, ZnO, WO_3, Nb_2O_3, MoO_3, CeO_2 and Ga_2O_3.
- Mixed oxides:Cr_2O_3–TiO_2 and WO_3–TiO_2.
- Polymeric sensor with CNTs, Graphene, …







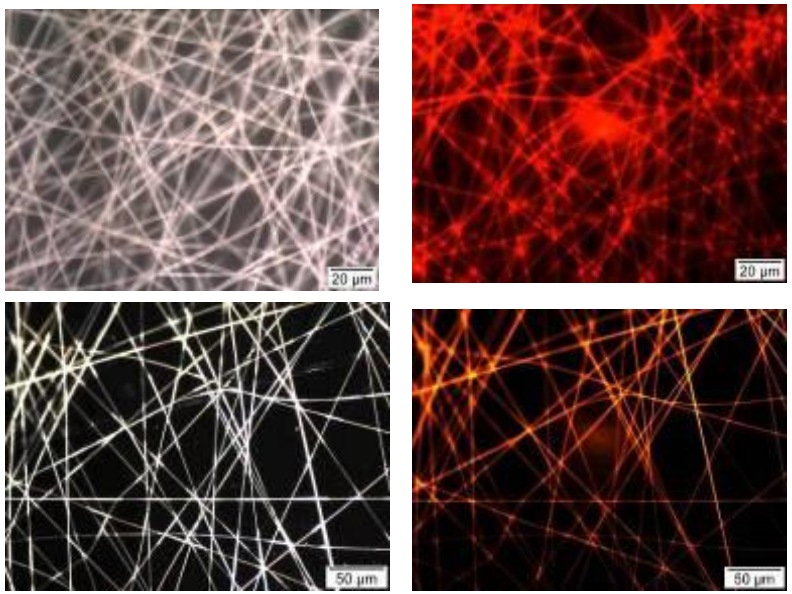
Commercial sensor vs WO_3 nanofiber developed one (Top = 300ºC).

Luminescent optosensor

- ✓ Detection of Chemical

✓ Advantages

- High sensibility
- Low limit of detection
- Multidetection capability combining different materials
- Robust
- Low cost and simple to use



- ✓ Luminescent nanofibers based on Ru-probe.
  - Blue led interrogation with red answer
  - Higher sensitivity than thin films or coatings.

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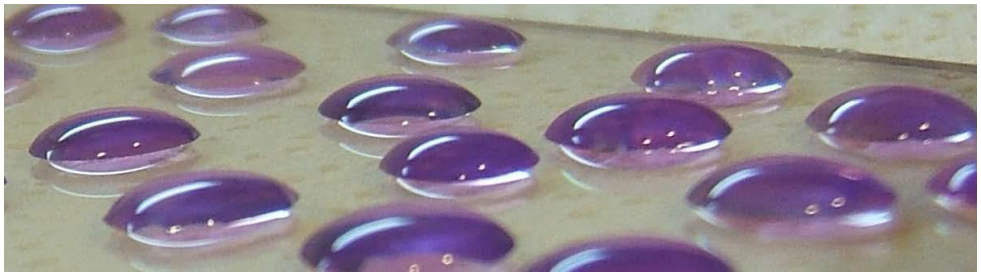
DESARROLLOS EN TINTAS FUNCIONALES

TINTAS



- ✓Tintas conductoras: Ag y Cu
- ✓Tintas funcionales:
  - Fluorescentes/Fosforescentes/Luminiscentes
  - Sensibles a distintos estímulos: pH, temperatura
  - Superhidrófobas/superhidrófilas
  - Capacidad autoreparante
- ✓Fluidos térmicos:
  - Introducción de Phase Change Materials (PCMs) en diversos fluidos
- ✓Base tintas:
  - Agua
  - Ethylene- or tri-ethylene-glycols, MEK, etanol y otros alcoholes
  - Aceites y otros lubricantes
  - Soluciones poliméricas

SUSTRATOS

- ✓ Métodos de deposición:
  - ink-jet printing
  - screen-printing
  - spinner-sprayer
  - microcontact printing

APLICACIONES

- Circuitos flexibles
- Electrodos
- Textiles
- Hologramas seguridad

- ✓ Superficies sobre las que trabajar:
  - Poliméricos
  - Vidrios
  - Cerámicas
  - Textiles
  - Papel
- ✓ Preparación de superficies para mejora de la mojabilidad y de adhesión mediante plasma o procesos químicos

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Recubrimientos-Films conductores transparentes base Grafeno

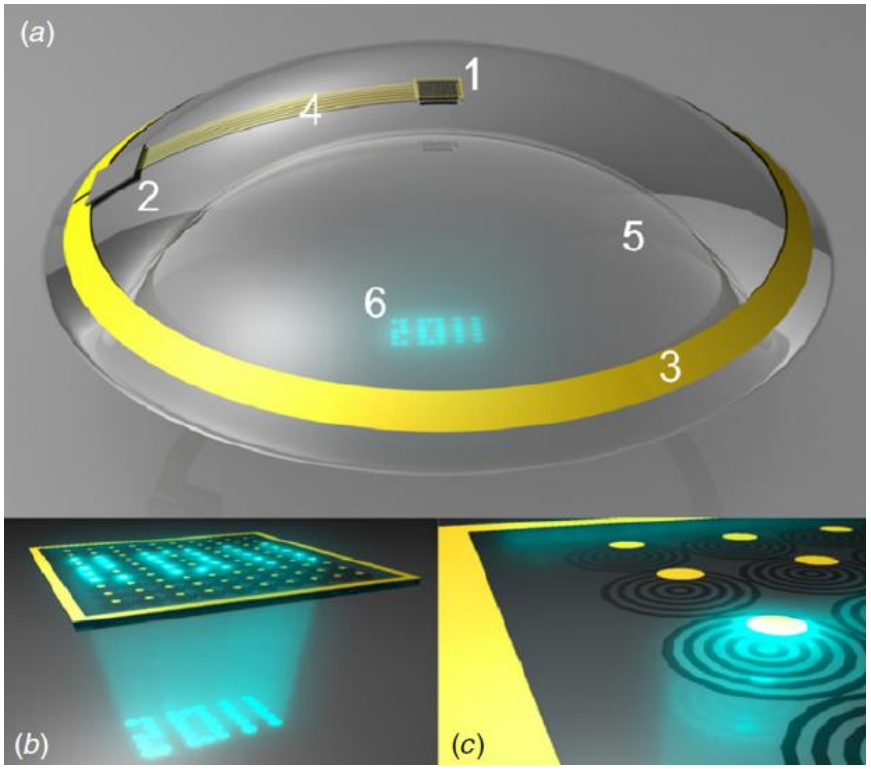
- ✓Dispersiones nanoestructuras carbonosas, especialmente grafeno
- ✓Recubrimientos mediante spin-coating, dip-coating, spray-coating
- ✓Ink-jet printing

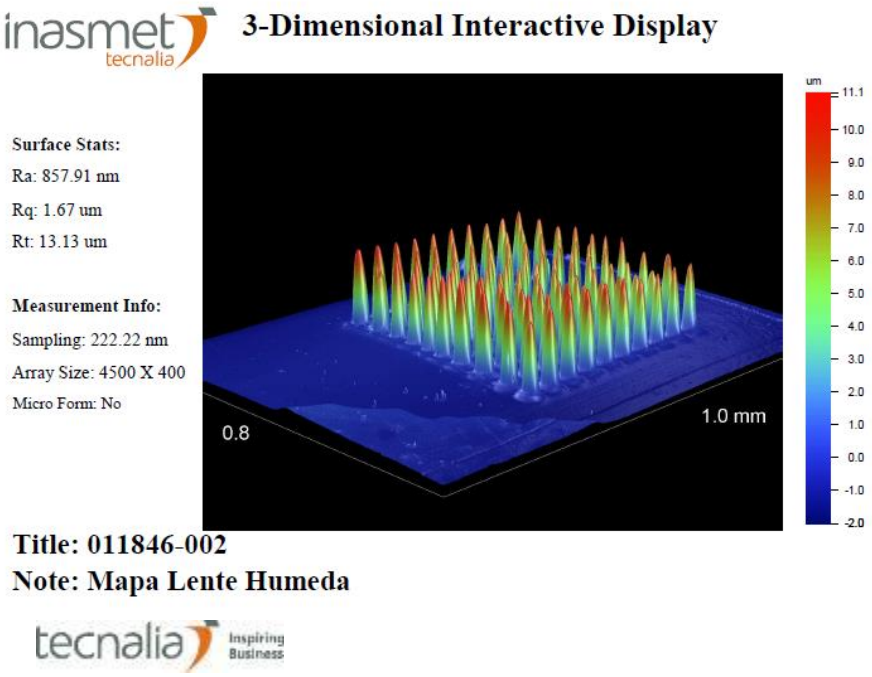
- ✓Colaboración con la Univ. Barcelona, grupo de Electrónica
- ✓Aplicaciones:
  - Films conductores transparentes
  - Electrodos : eHUD (Head-Up Display), Sensores, diodos orgánicos emisores de luz (OLEDs)

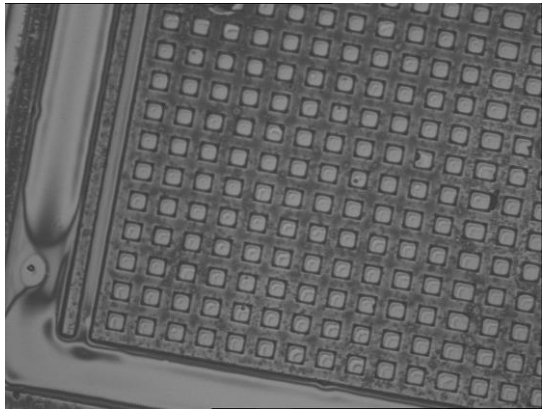
Lentes Reconfigurables basadas en microfabricación

Materiales Inteligentes

- ✓Swelling and de-swelling under several stimuli: pH, temperature, humidity, etc..
- ✓Changes in the refractive index or in the curvature of the lenses







What do we do?

Physical surface treatment

Surface technologies:

- ✓ DRY SURFACE TREATMENTS & COATINGS TECHNOLOGY
- ✓ WET SURFACE TREATMENTS & COATINGS TECHNOLOGY

MW-Plasma Surface tratment

Ion Gun Surface treatment

Plasma spraying (APS, HFPD)

PVD-Magnetron Sputtering

Plasma thermochemical treatment

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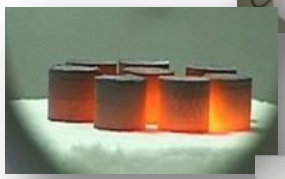
What do we do?

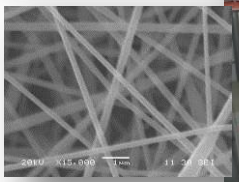
Materials

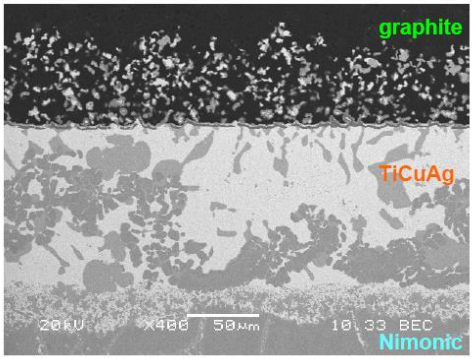
Materials for advanced systems

- Uniaxial Hot-pressing
  - Manufacturing of high-performance ceramics and ceramic composites (SiC, B_4C, AlN, Si_3N_4, BN & Al_2O_3, based composites)
- Advanced ceramics processing
  - Ceramic and metallic foams
  - Pressureless sintering of B_4C for ballistic applications
  - Multilayer Ultra High Temperature Ceramics (UHTCs) based on ZrB_2
- SHS (Self-propagated High-temperature Synthesis)
  - Synthesis of ceramics (carbides, borides, oxides, nitrides, hydrides) and intermetallic (Ti, Al, Ni, Si and/or Fe based) in form of powder, porous structures and/or fully dense components.
- PIM (Powder Injection Molding) and micro-PIM
  - Al_2O_3 based ceramics, porcelains, ferrites, carbon steels and stainless steels and Ni based intermetallics.
- Dielectric processing of materials (microwave, RF, Induction)
  - Reactive synthesis, drying, firing/sintering.
  - Firing / melting of glass
  - Out of autoclave composite curing
- Micro/Nano material processing
  - Nano-reinforced ceramics (CNF-ZrO_2)
  - Structural functionalization carboneous structure (CNT, graphene)
  - UV of thermal NIL for Nanotexturing of functional surface
  - Micro & nanofibers by electrospinning for sensors and filters
- Coatings
  - Thermal barriers / protective coatings (impact/environment/…)
  - Development of thermal spraying techniques (APS, HVOF, OFI…)
  - Electroless coating of Nano-particles



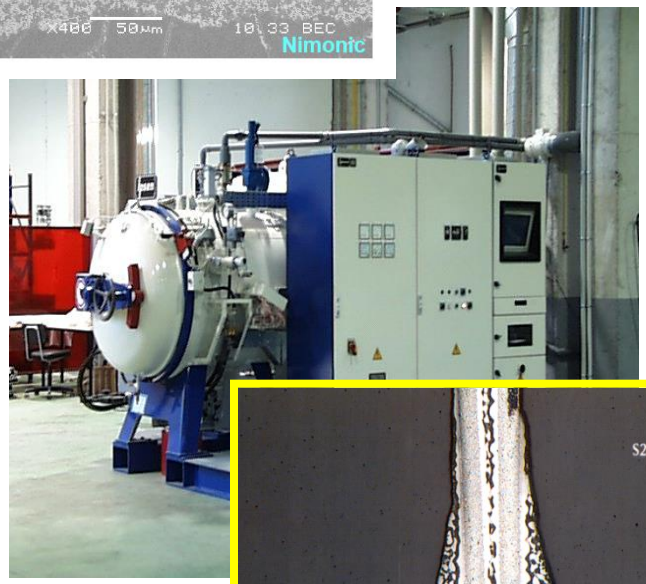



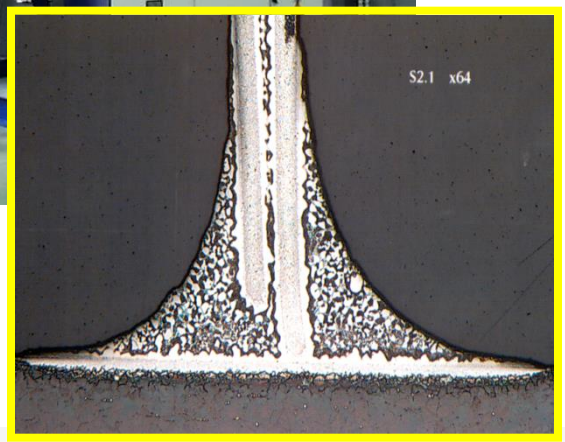


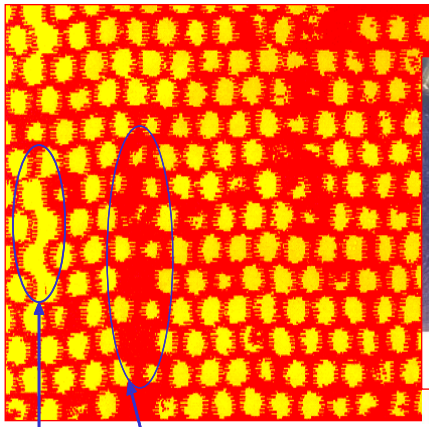



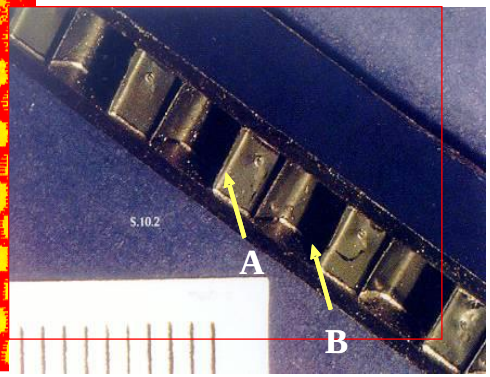
Technology and knowledge

- ✓ Sandwich structure for different metallic alloys: Base Nickel alloys, Base Titanium alloys Dissimilar sandwich structures (core and skin)
- ✓ Development of joints for High temperature applications.
- ✓ Metal-ceramic & ceramic-ceramic
- ✓ Development of materials as filler metals for high temperature applications.







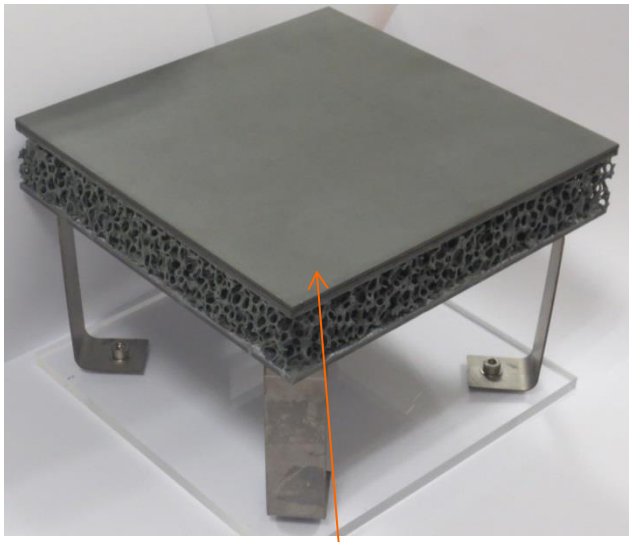


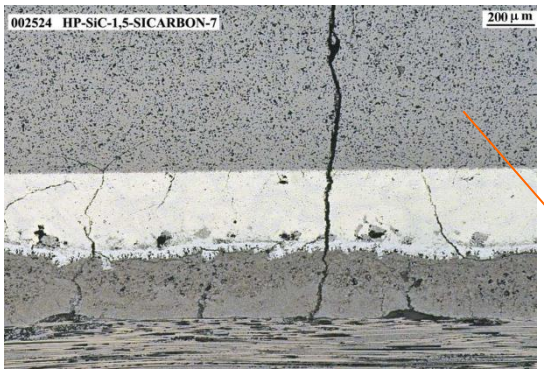
Zone 1 Zone 2

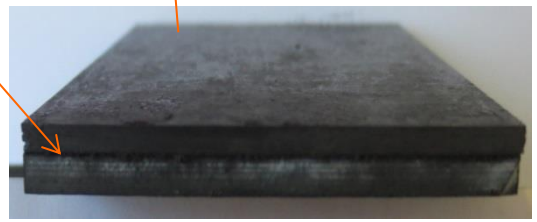
TPS technology sample assembly

Ceramic –Ceramic joints for ultra high temperature applications

- Development of joining routes for **C/SiC ,SiC multilayers, ZrB2** for ultra high temperatures
- Development of new filler materials for ultra high temperatures
- Definition of joining processes conditions for the best performance and avoiding damaging ceramic materials
- Joinings for creating a TPS material





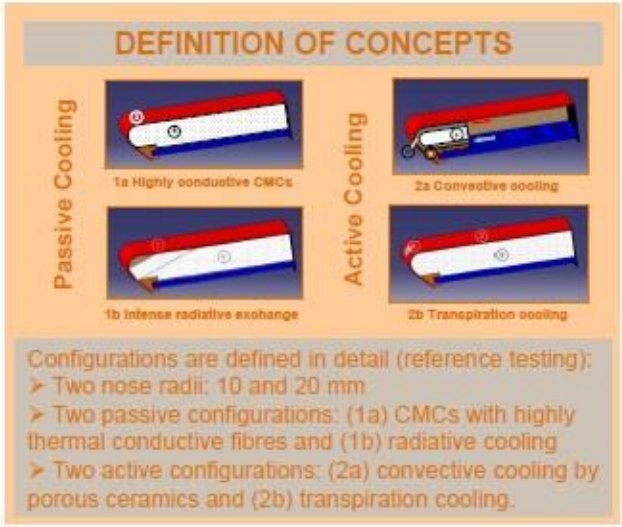


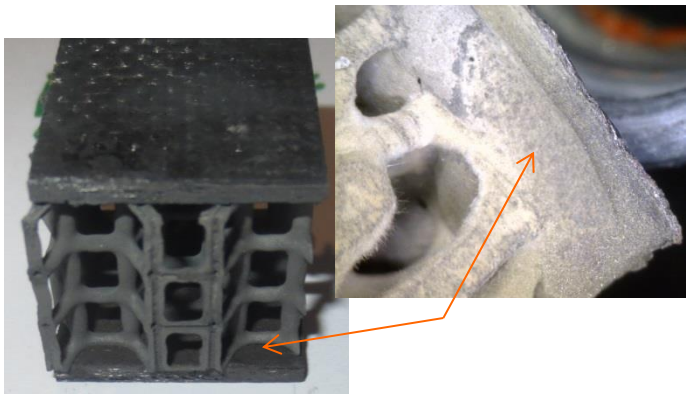
Joining of CCM to ceramic foam and lattice structures by different joining processes for high temperature applications

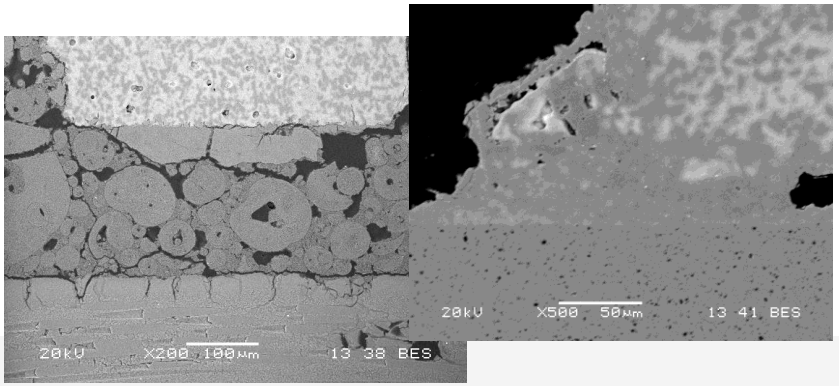
- Development of joining routes for **Monolithic SiC** and **SiC/SiC to SiC foam**

- Different type of filler materials developed for this kind of joinings, as **modificated adhesives, resins or filler alloys.**

- Proccess adecuated to different kind of foam structures with different geometry and properties





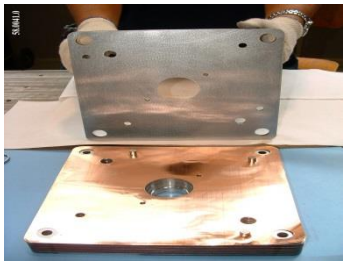


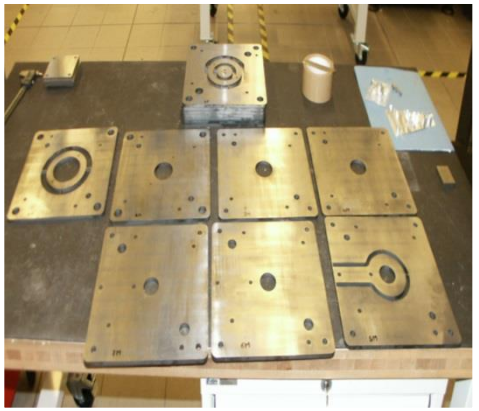
Development of moulds by brazing process.

Moulds by stratoconception

Objective:

Moulds for High Pressure casting





- ✓ Selection of the base materials and filler metals.
- ✓ Definition of the process and parameters for joining
- ✓ Validation of the process by melting 1000 pieces.
- ✓ Quality control after tests: planarity and non

Development of moulds by brazing process.

Moulds by stratoconception

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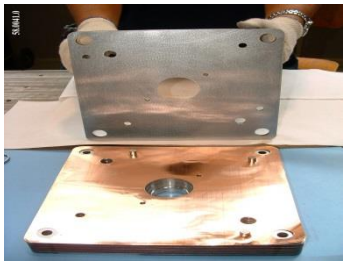
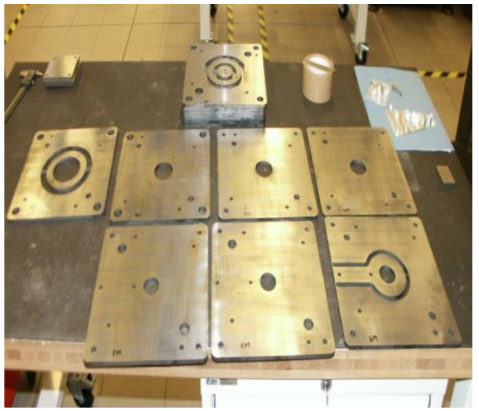


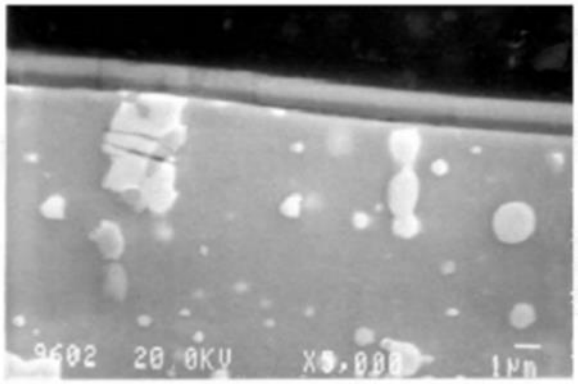


- ✓ Selection of the base materials and filler metals.
- ✓ Definition of the process and parameters for joining
- ✓ Validation of the process by melting 1000 pieces.
- ✓ Quality control after tests: planarity and non

EXTREMAT: new materials for extreme enviroments

Objective:

- ✓ New materials for heat sink, radiation resistance, chemical and technologies application, for manufacturing.
- ✓ Developmento of MMC's with nannoperformance



SEM micrograph of MoS_2 film on steel

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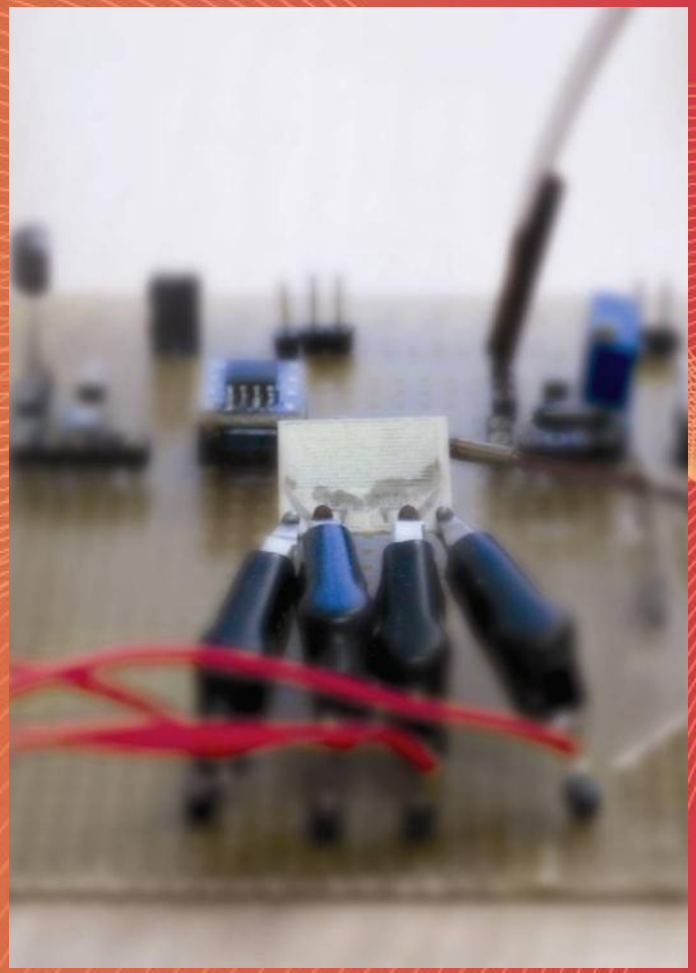
Thanks



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