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UNIVERSITÀ DI ROMA

MIAMI SCIENTIFIC
ITALIAN COMMUNITY

CYBER 4.0
CYBERSECURITY COMPETENCE CENTER

Prof. Teodoro Valente

Department of Chemical Engineering Materials Environment

February 25, 2022
3:00 pm USA time

Topics

- *The Italian National Competence Center on Cyber-Security – Cyber4.0*
- *Materials Technology & Aerospace at Sapienza University of Rome (some cases..)*

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Pandemic-related cybersecurity issues in Italy

- Companies have strengthened their security measures → Attackers focused on endpoint
  - Attacks to personal devices increased from 45k in 2019 to 85k in 2020
- DDoS increased in number and power
  - 7 Tbps in 2020 vs. 1.8 Tbps in 2019
- 220 malware families (+33% vs. 2019)
- Double extortion ransomware – Decryption and recovery
  - Malspam for massive attacks
  - Compromised websites
  - Targeted Attacks
  - Vulnerabilities of targeted organization's network

Clusit – Rapporto 2021 sulla Sicurezza ICT in Italia

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What to do – the three C's

Commitment

Legal framework in line with international standards

- 3 laws have been passed in Italy, for the creation of the National Agency and the definition of the national perimeter

National policies and strategies adopted, **resources allocated**

Cybersecurity **a priority of decision makers**

Capacities

Establishment and maintaining of **core capabilities and competencies**

Continuous **capacity enhancement on cybersecurity and cybercrime**

Education and awareness campaigns

Cooperation

Inter-agency cooperation, defined roles and responsibilities

Strengthening public-private cooperation

Information sharing mechanisms

International cooperation, formal and informal, network of trust

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Cyber 4.0 – Key partners

National Cybersecurity Competence Center

Promoted and funded by the Italian Ministry of Economic Development

SOGGETTI PRIVATI

Acrm Net srl	Fondazione Amaldi	Lazio Connect Associazione	Poste Italiane SpA	Technocenter srl
Agfa SpA	Fondazione Formit	Leonardo SpA	PRISMA srl	Tecnorad srl
Aizoon group Srl	Fondazione ICSA	Mashfrog SpA	Radio6ense srl	Telecom Italia SpA
Arpex Environment Trentino srl	Gruppo Daman srl	Mediaservice.net srl	Rdslab srl	Telespazio SpA
Bioc check up srl	I.S.A.M. srl	Mediavoice srl	SDN SpA	Thales SpA
Bioscience Genomics srl	IAM Scarl	Netcom Group SpA	Selta SpA	
BV Tech Spa	INTECS Solutions SpA	NSR srl	SFC ScpA	
Cy4gate srl	Land srl	Obiectivo Technology srl	Sogei SpA	

SOGGETTI PUBBLICI

Sapienza Università	Università Tor Vergata	Università Roma 3	LUISS	Università Tuscia
Università Cassino	Università L'Aquila	CNR		

ENTI PUBBLICI NON ECONOMICI

INAIL

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Cyber 4.0 in a nutshell

CAPACITY BUILDING	ORIENTATION	RESEARCH & INNOVATION

- Operational since April 2021, HQ in Rome
- **PPP –** 8 Public Research entities, 1 PA, 34 Private Partners
- 4 Domains: **Core Services, Aerospace, Automotive, E-Health**
- Institutional activities to support **Public Administration and SMEs** on cybersecurity capacity building and innovation
- **Roster of 100+ experts**
- **15 Research and Innovation Projects** funded in 2021, started in 2022 – TRL 7/8

150+ Cybersecurity services available to public and private entities on: **Cyber risk management, Threat management, Data Protection, System Protection, Incident Handling, Certification, Training, Consulting**

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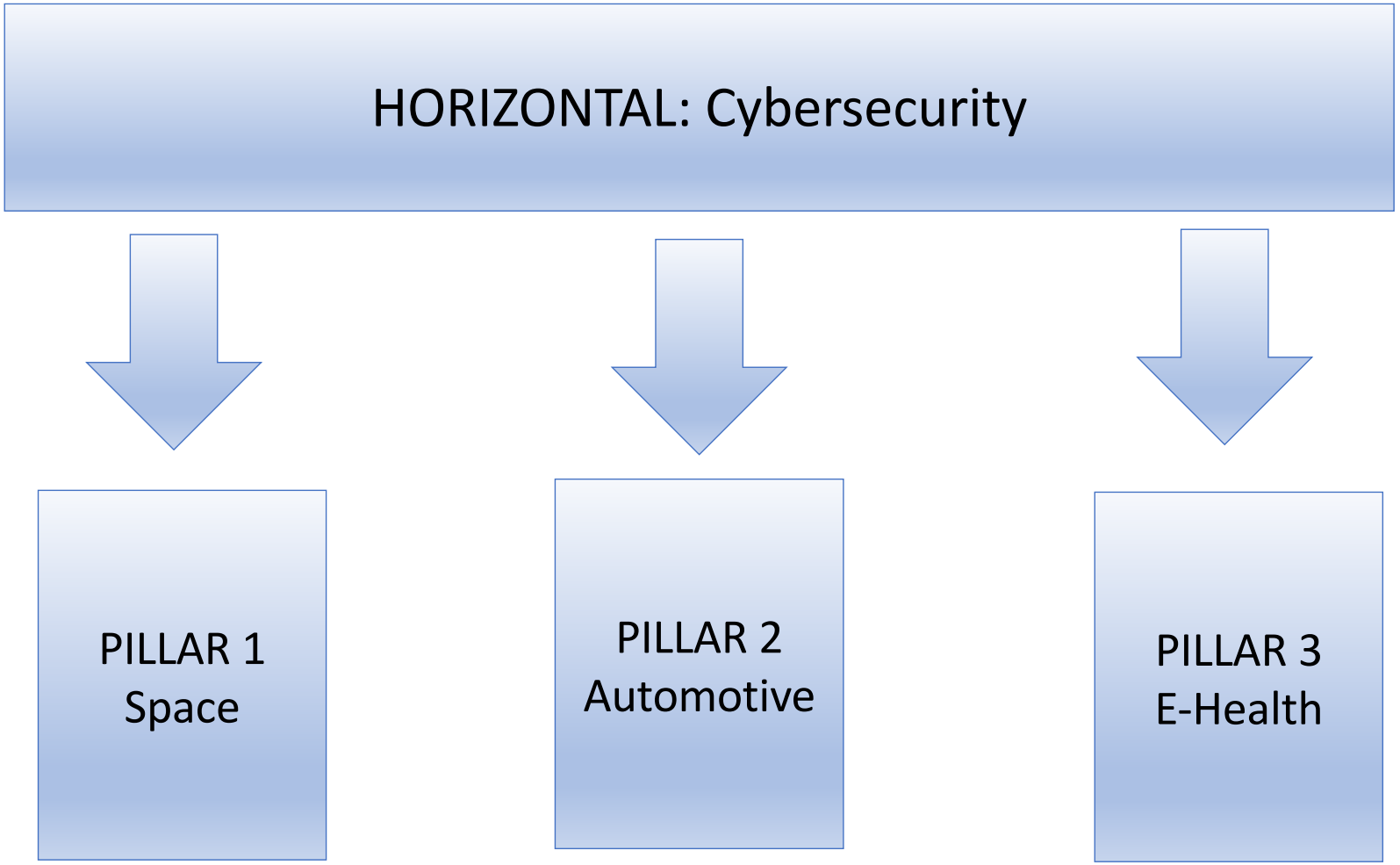
Activities



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Activities

Cybersecurity

Cybersecurity awareness ,Analisi di vulnerabilità, rivelazione e risposta/mitigazione di attacchi Cyber-insurance, Cyber intelligence, Digital Forensic, Distributed Ledger Technology, Incident management, Sistemi di crittografia (tradizionale, quantistica e di strato fisico), Sistemi di riconoscimento biometrici, Cybersecurity by design, Interfacce avanzate di visualizzazione e tecniche di visual analytics, Giuridico (GDPR, contrattualistica, cybercrime, diritto amministrativo), Manageriale (IT governance, Risk Management, Data Management, Data Protection), Politologica (politiche di cyber defence nazionali e internazionali), Economica (fintech)

Space

AI, sviluppo HW, uso COTS HW nei progetti spaziali
Uso sicuro di dati satellitari
Progettazione e manifattura delocalizzata di componenti space

Automotive

Resilienza vs minacce cyber
Crittografia, integrità e autenticazione,
Sensori embedded interconnessi
Machine learning, Meccatronica
Protezione privacy di passeggeri e veicoli
Strumenti di data analytics su architetture Cloud-IoT/Fog computing

E-Health

Infrastrutture di sicurezza, comunicazione e cifratura per la telemedicina, rilevazione e analisi dei dati biometrici, genetici, cerebrali, cardiaci, Meta analisi e integrazione dati sociali, clinici, genetici e epigenetici,
Analisi rischio e medicina personalizzata
Sicurezza nell'uso dei dispositivi medici connessi in rete, privacy,
Certificazione e security assessment di sensori e dispositivi

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Activities

- **CYBER 4.0 Academy** – Management, Legislation and Policy, Tech and Procedures, Immersive simulations
- **Assessment SMEs**
- **Cyber posture Health System**

TRAINING and CAPACITY BUILDING

- 12/18 months, start January 2022
- **Budget 2,2 Mln EUR**
- **Call 1** – 40+ proposals, 7 projects
- **Call 2** – 20 proposals, 8 projects

RESEARCH and INNOVATION PROJECTS

- **Case Studies**
- **Showroom/ demo lab**
- **Cyber Range**
- Malware Lab

TEST BEFORE INVEST

- **Service Catalogue** – 8 categories
- **Roster of 100+ experts on 8 lots of competencies**

SERVICES and RESOURCES

- **EDIH**
- **National Cybersecurity Agency**
- **National CC Network**
- **EU CyberNet Stakeholder Group**
- Cybersecurity Agency of Catalunya
- Other EU funded projects

NETWORKING and COOPERATION

- Website
- Newsletter
- **eLearning Platform**

COMMUNICATION

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CYBER 4.0 support to Public Administration and SMEs

- **Cyber risk assessment**
- **Data Protection**
- **Protection of systems**
- **Threat monitoring and detection**
- **Incident response and incident handling**
- **Certifications**
- **Training**
- **Strategic support**

- **8 categories**
- **100+ qualified services**
- Collaborative effort of Cyber 4.0 Partners in **public-private partnership**

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CYBER 4.0 available training courses

- Cyber Risk Management
- Data Protection
- Sstem Protection
- Cyber threat management
- Incident Handling
- Certifications
- **Training**
- Consulting

CYBER 4.0 Academy

Management and organization

- Custom courses for managers on cyber security and data control
- Master Cybersecurity, Public Policies, Regulations and Management
- Data Driven Enterprise
- Digital marketing and Communication strategy
- Digital Discovery Lab
- Digital Innovation and Governance
- Governance Risk and Compliance

Legislazione e Policy

- GDPR
- Digital systems and smart working
- Legislation, Cybersecurity
- NIS and Cybersecurity Act

Tecnologie e Processi

- Monographic courses: Cybersecurity in IoT and Industry 4.0, Cloud Security, Cryptography, Social Media and Security
- Industrial Security (ICS/SCADA)
- Specialized courses for SOC/ CERT/ CSIRT operators
- OSINT, SOCMINT
- Incident Handling – Case study Analysis
- Malware Analysis
- Secure Coding
- HTTP vulnerabilities and securization

Simulazioni immersive

- Cyber Range
- Simulation of critical processes
- Crisis simulation

Thematic focuses – e-Health, Automotive, Aerospace

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Training opportunities

Tailored training courses

- **Target**:
  - Managerial/ Technical/ Research
- **Training needs**:
  - Basic/ Advanced;
  - Hands-on/ Theoretic
- **Program**:
  - Intensive/ Extensive
  - Full-Time/ Part-Time
- **Delivery**:
  - In Presence/ Online/ Hybrid
  - Live/ Self paced

Example – Blockchain

Short course (1-3 days)

Basics of blockchain technologies and smart contracts + case studies

Targeted course (4-6 days)

Small group, intensive and interactive, Customisable topics

Regular course (8-10 days)

Blockchain technologies rationale and concepts + smart contract design and coding + Dapp design and development + use cases + impact analysis + legal aspects

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Research and Innovation

Call 1

1. Cyber security core

1. Blockchain and Smart contract
2. Threat Intelligence

2. Aerospace

1. Ground segment security gateway and communication protocols enforcement
2. Cyber risk analysis for aerospace systems
3. Test bed for quantum communications

3. Automotive

1. Security assurance for connected vehicles

4. eHealth

1. Secure access to HW e SW medical systems

1 Mln EUR, 40+ Proposals, 7 Projects financed

Call 2

1. Cyber security core

1. Digitalization with trustless infrastructures
2. Machine learning for innovative cybersecurity services

2. Aerospace

1. Protection of space critical assets
2. Satellite constellations for trusted node QKD networks

3. Automotive

1. Security at vehicle level

4. eHealth

1. Cybersecurity for continuity in telemedicine

1.2 Mln EUR, 20 Proposals, 8 Projects financed

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Materials and Surface Engineering Lab

Research partners

AIRBUS DEFENCE & SPACE

GE Oil & Gas
Nuovo Pignone spa

esa

asi
agenzia spaziale italiana

ThalesAlenia Space
A Thales / Finmeccanica Company

CIRA

ANSV

Avio Aero
A GE Aviation Business

aviospace

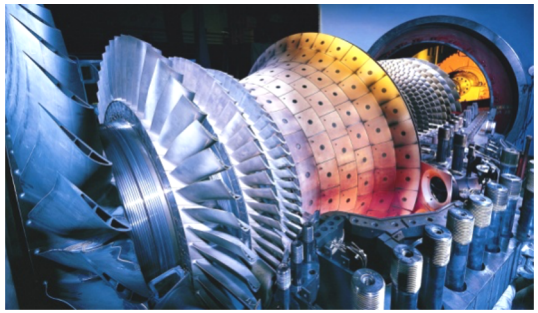
WÄRTSILÄ

MBDA
MISSILE SYSTEMS

AVIO

Topic: materials for severe operating environment

Heavy combination of mechanical stresses and aggressive environment



Temperature

Mechanical stress

Oxidation

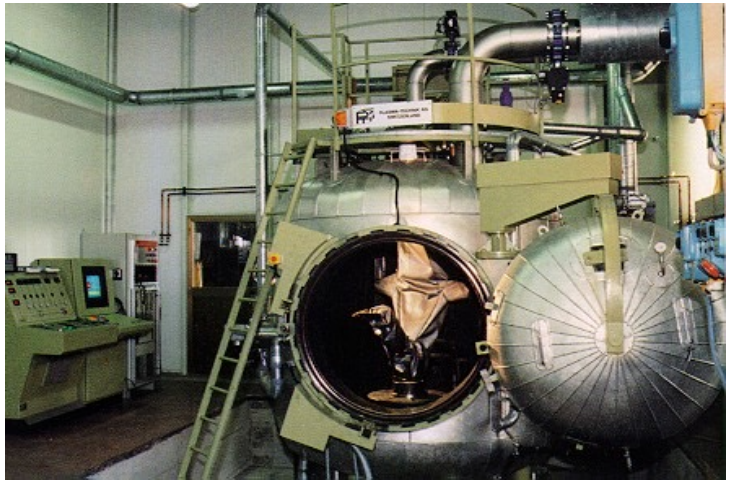
Corrosion

Wear

Thick coating by thermal spray

Plasma spraying deposition technique

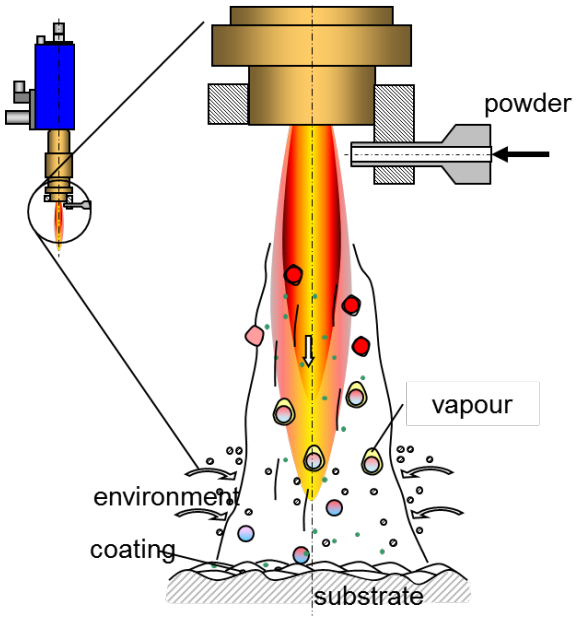
The CAPS facility permits to control the deposition environment



Besides Atmospheric Plasma Spraying (APS), several configurations are possible:

- Vacuum Plasma Spraying (VPS);
- Low Pressure Plasma Spraying (LPPS);
- Inert Plasma Spraying (IPS);
- Reactive Plasma Spraying (RPS).

Coating is built by the layering of splats

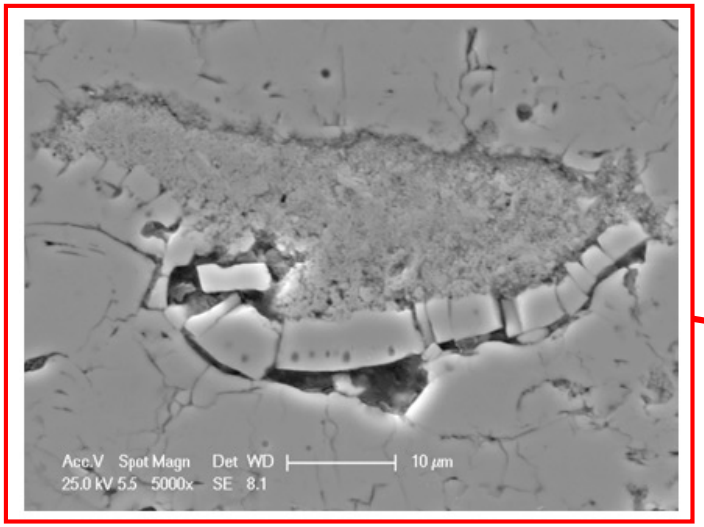


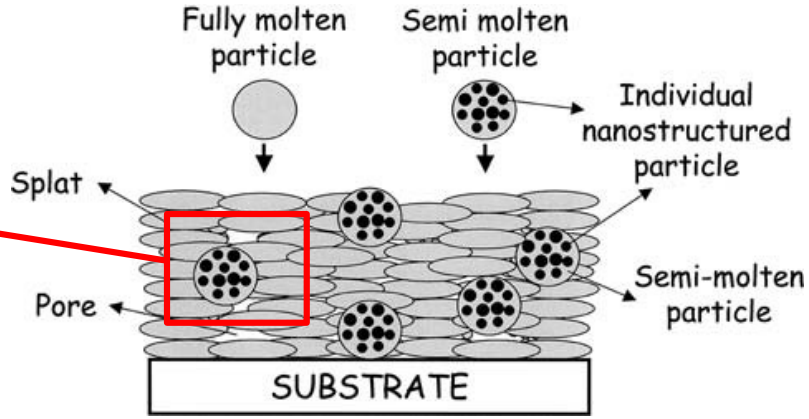
Innovative TBC for gas turbines

Nanostructured YSZ

EU funded project

ip nanoker





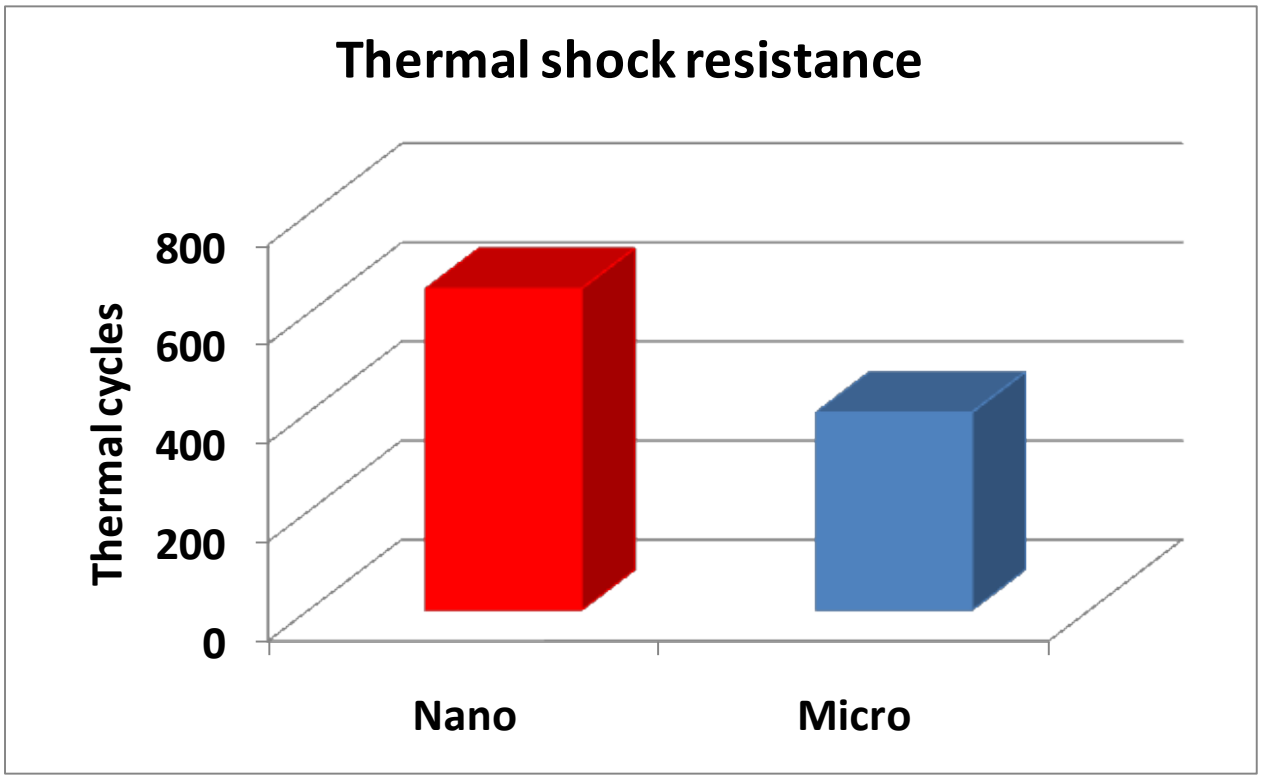
The strategy is to reach a semi-molten state of particles upon impact on the substrate by optimizing the operating parameters.

- **Molten fraction** of particles ensures the cohesion;
- **Semi-molten** fraction: **nanostructure**.

Innovative TBC for gas turbines

Nanostructured YSZ

Total number of shock cycles required to achieve 50% damage of coating surface (1020 ºC – RT)



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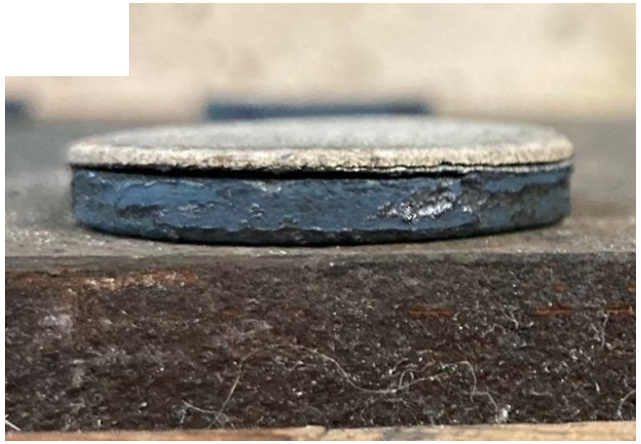
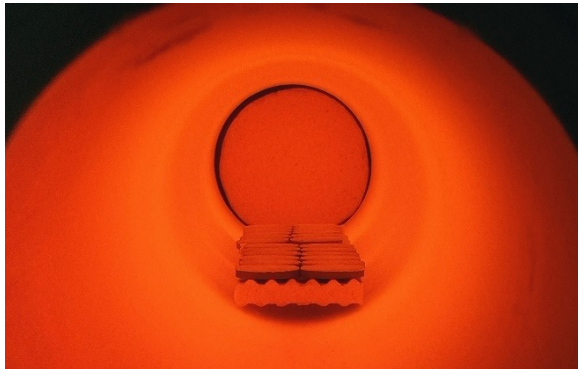
Innovative TBC for gas turbines

Thermal cycling failure evaluation study





⚠ **Delamination**

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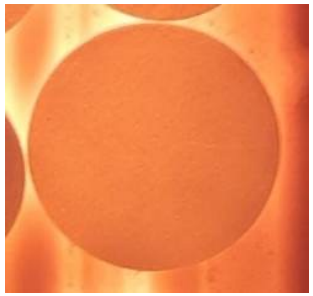
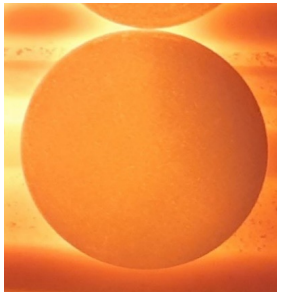
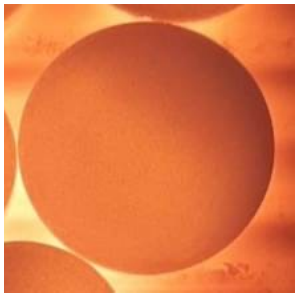
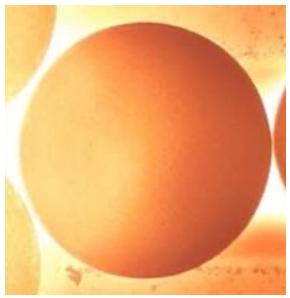
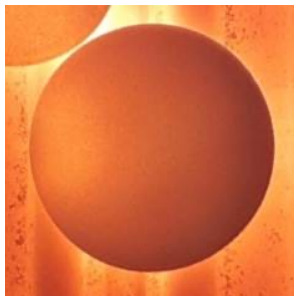
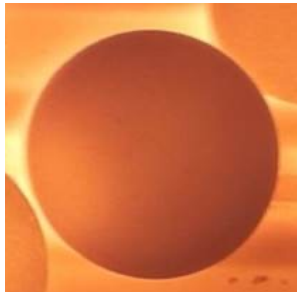
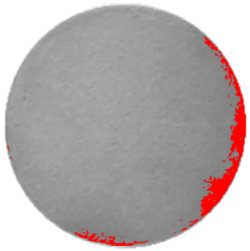
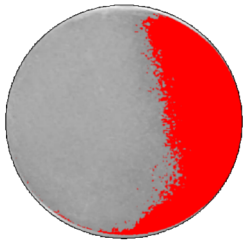
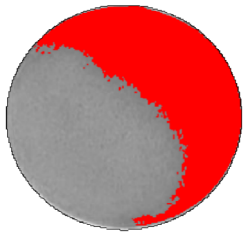
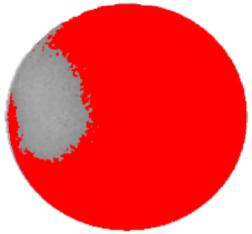
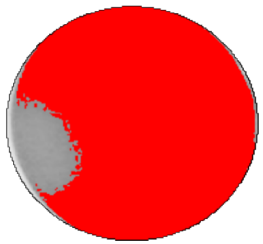
Innovative TBC for gas turbines

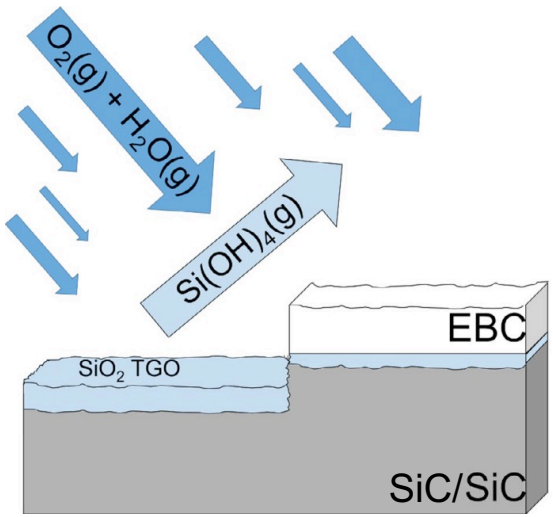
Thermal cycling failure evaluation study

Ciclo 120	Ciclo 130	Ciclo 140	Ciclo 145	Ciclo 150	Ciclo 160
					
Area Sollevata: 4%	Area Sollevata: 31%	Area Sollevata: 43%	Area Sollevata: 54%	Area Sollevata: 82%	Area Sollevata: 88%
					

⚠ Failure al ciclo 169

Environmental barrier coatings (EBC)

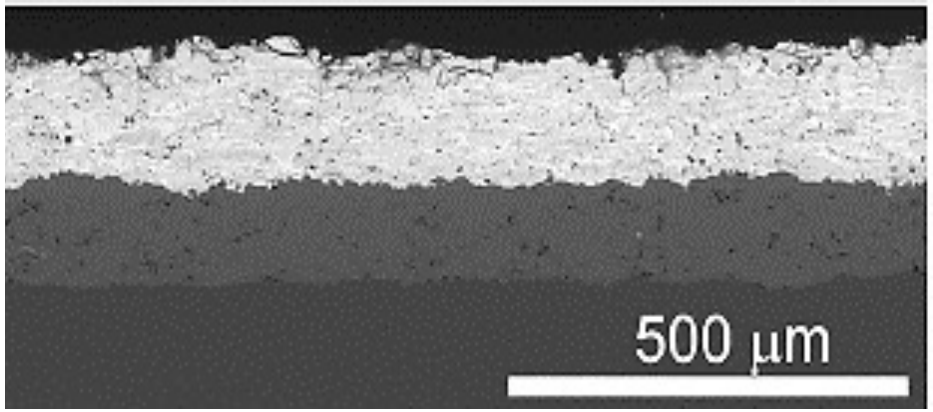
SiC/SiC gas turbine components need to be protected by EBC



Water vapour resistant layer

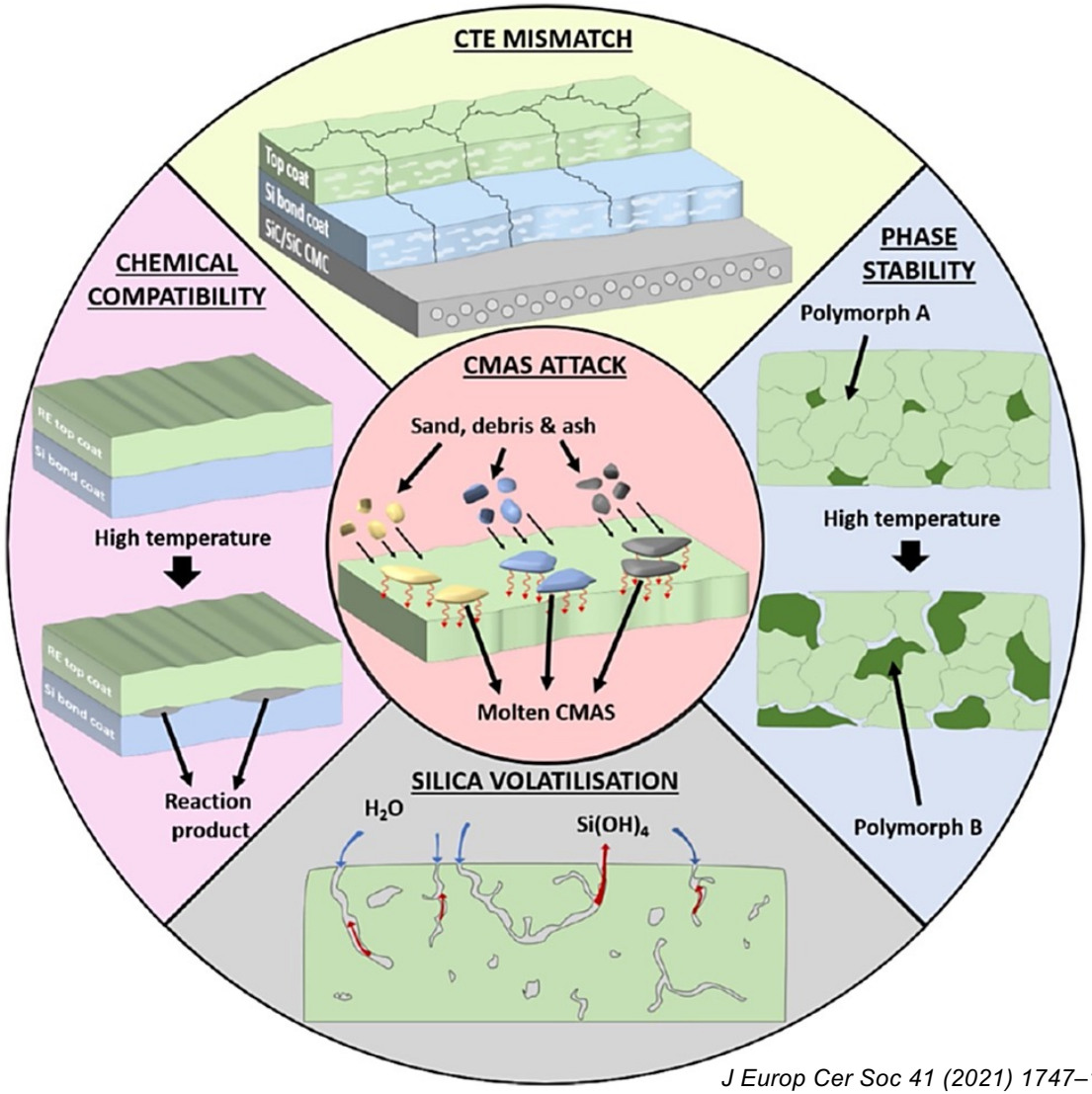
Bond coat
(adhesion, oxidation resistant layer)

CMC substrate



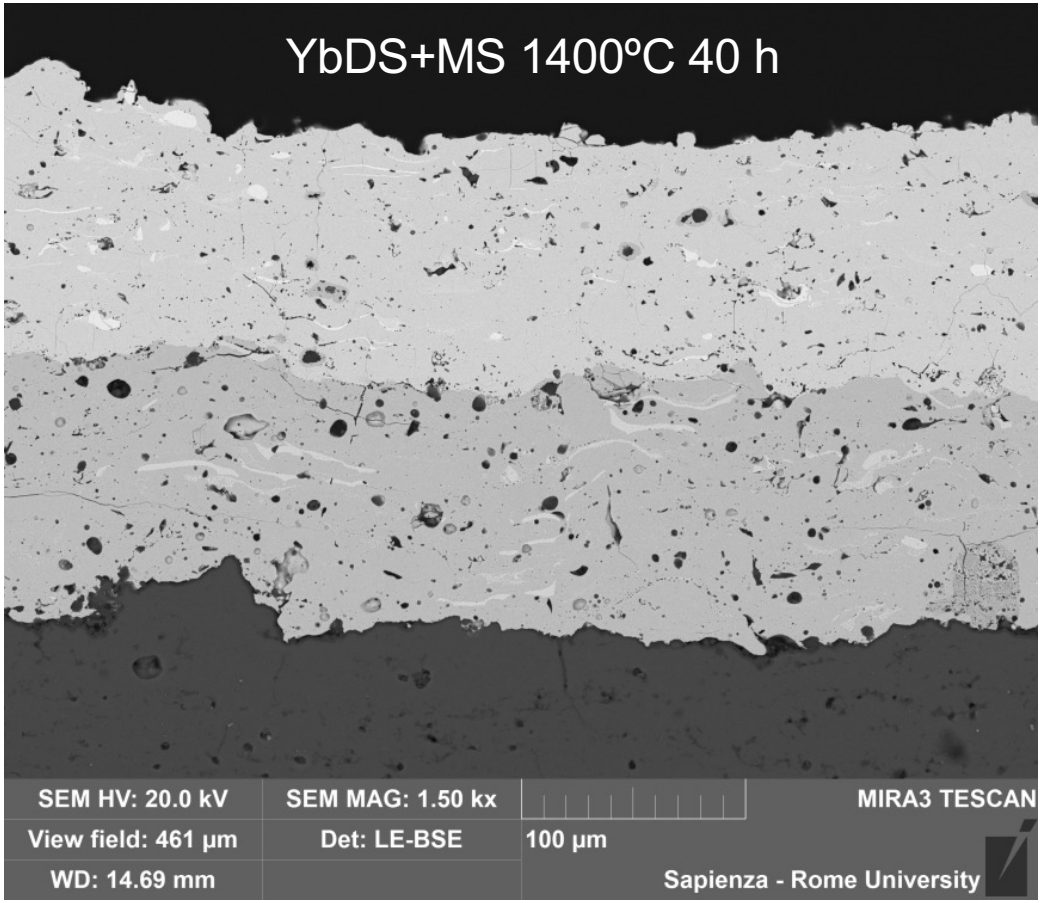
EBC

Requirements



J Europ Cer Soc 41 (2021) 1747–1768

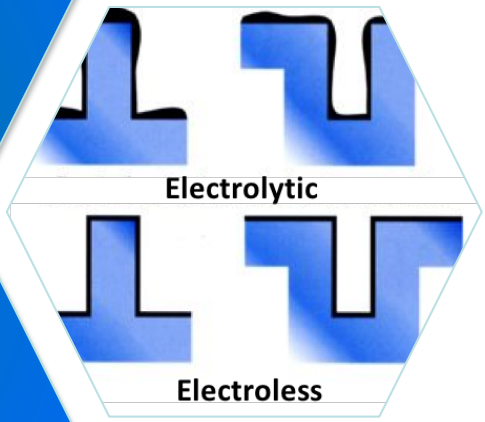
YbDS-YbMS optimized system



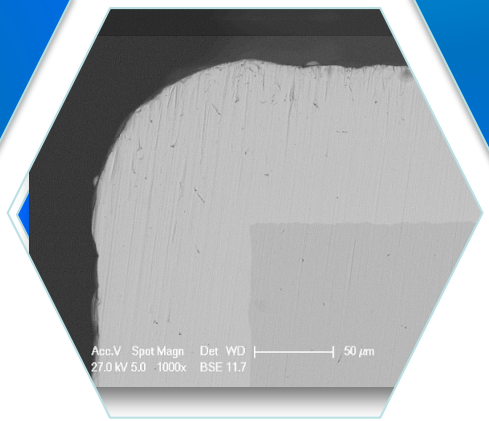
Cracks and porosity can be tailored by optimization of deposition parameters and thermal treatments

No applied electric field

Low cost



Non line-of sight technique



Conformal

Homogeneous thickness

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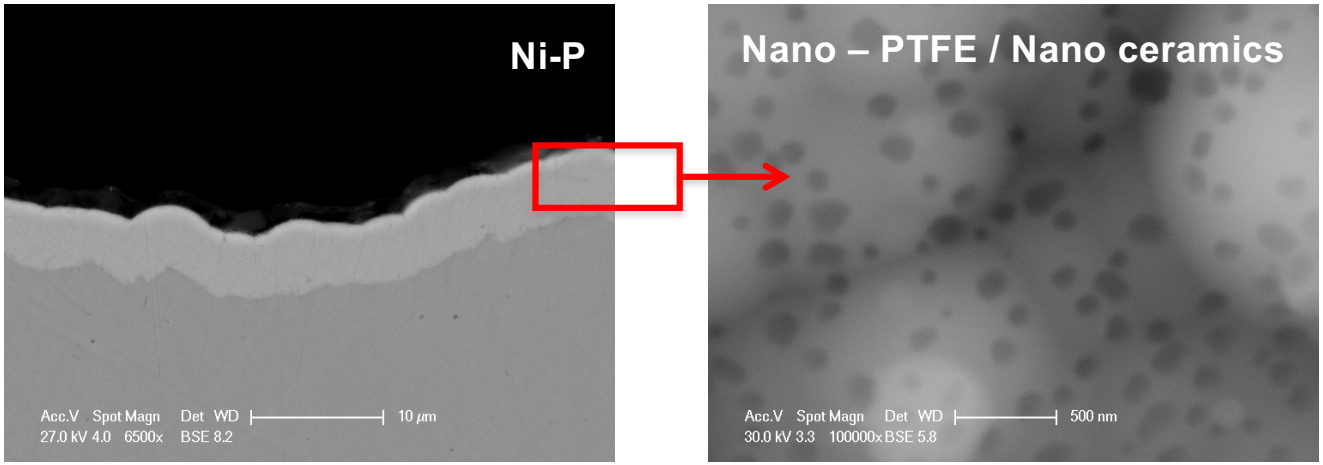
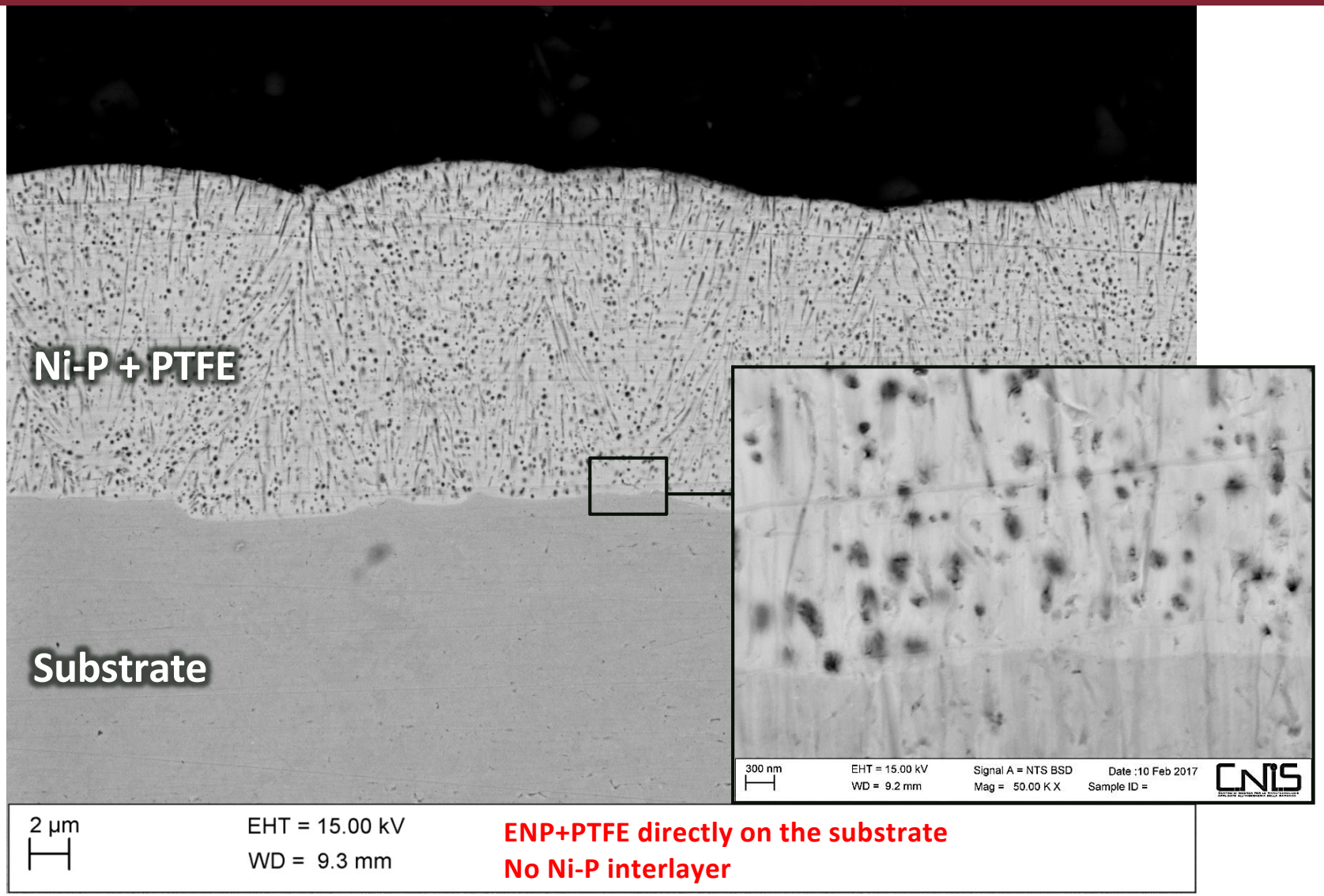
Antifouling and anti-erosion coating for oil&gas

Electroless Ni-P nanocomposite coatings



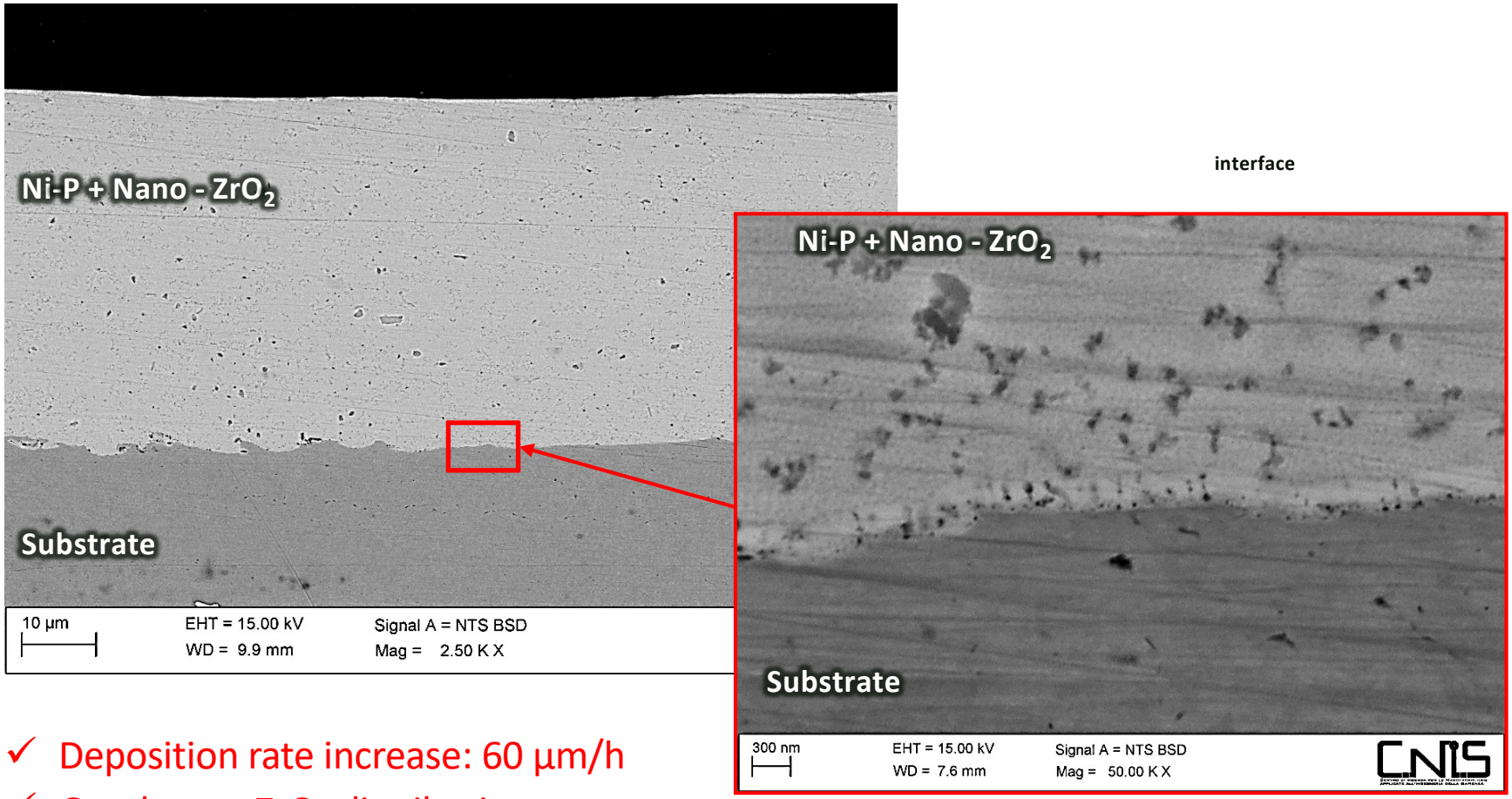
The goal is to develop an anti-fouling and anti-wear coating by means of an electroless-nickel plating process; the coating properties are enhanced by dispersing nano-polytetrafluoroethylene (PTFE) and nano-ceramics particles in the coating.

Industrial project funded by: GE Oil & Gas Nuovo Pignone spa



ENP+PTFE directly on the substrate
No Ni-P interlayer

ENP + nano ZrO_2



- ✓ Deposition rate increase: 60 µm/h
- ✓ Good nano-ZrO_2 distribution
- ✓ No porosity – excellent interface adhesion

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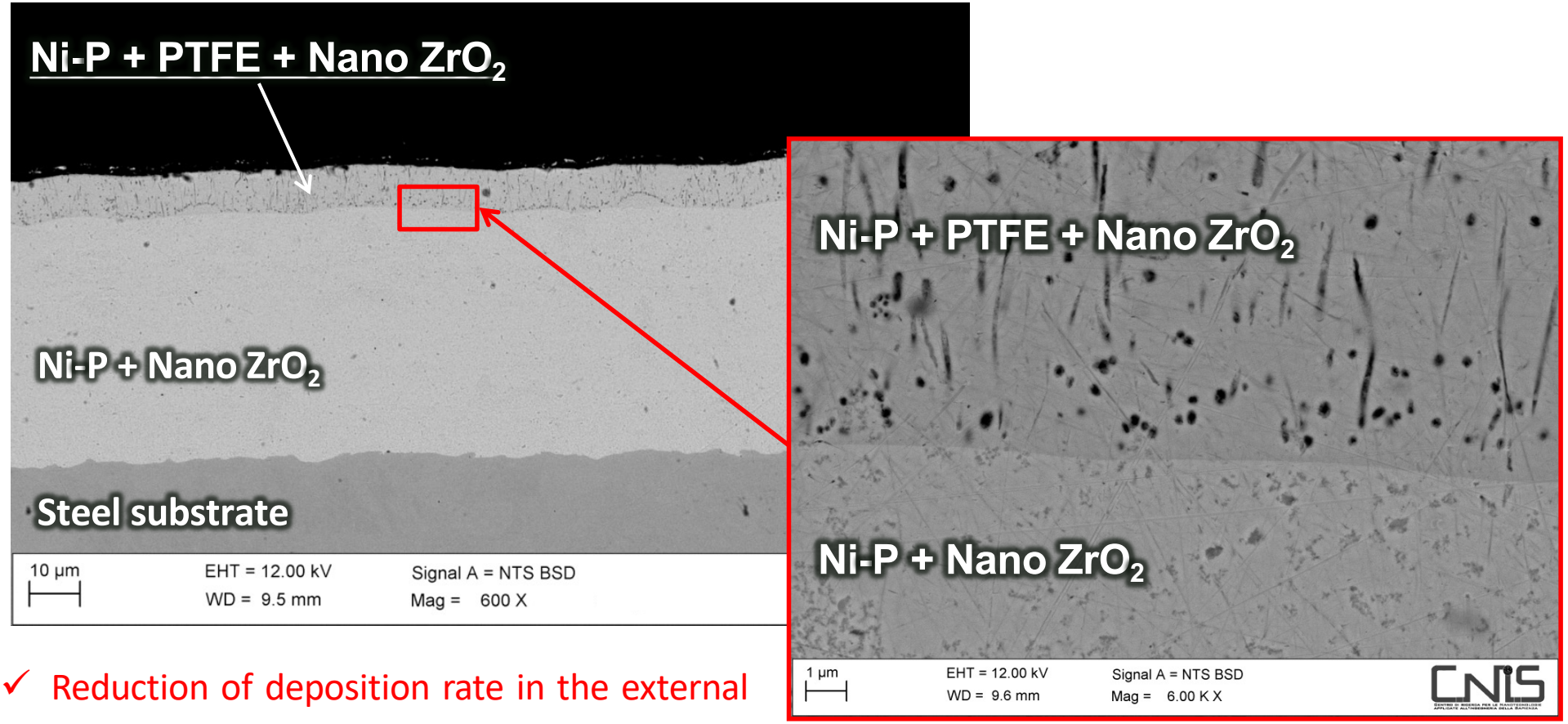
Antifouling coatings with improved erosion resistance



- ✓ Reduction of deposition rate in the external layer (with PTFE)
- ✓ Excellent interface adhesion

Patent IT102019000003463

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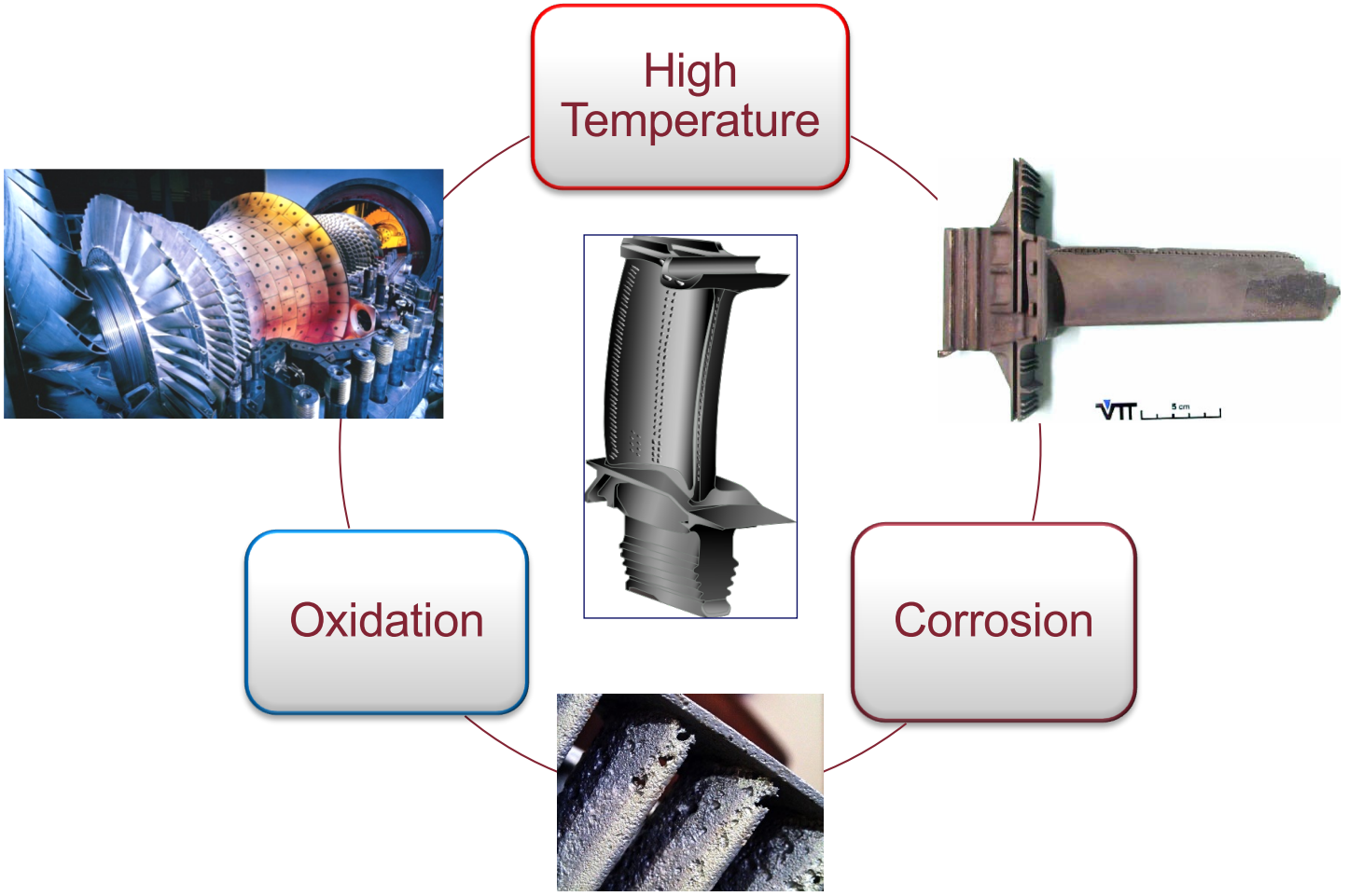
Deposition of
coatings developed on a demonstrator
of complex geometry

Gas turbine harsh environment

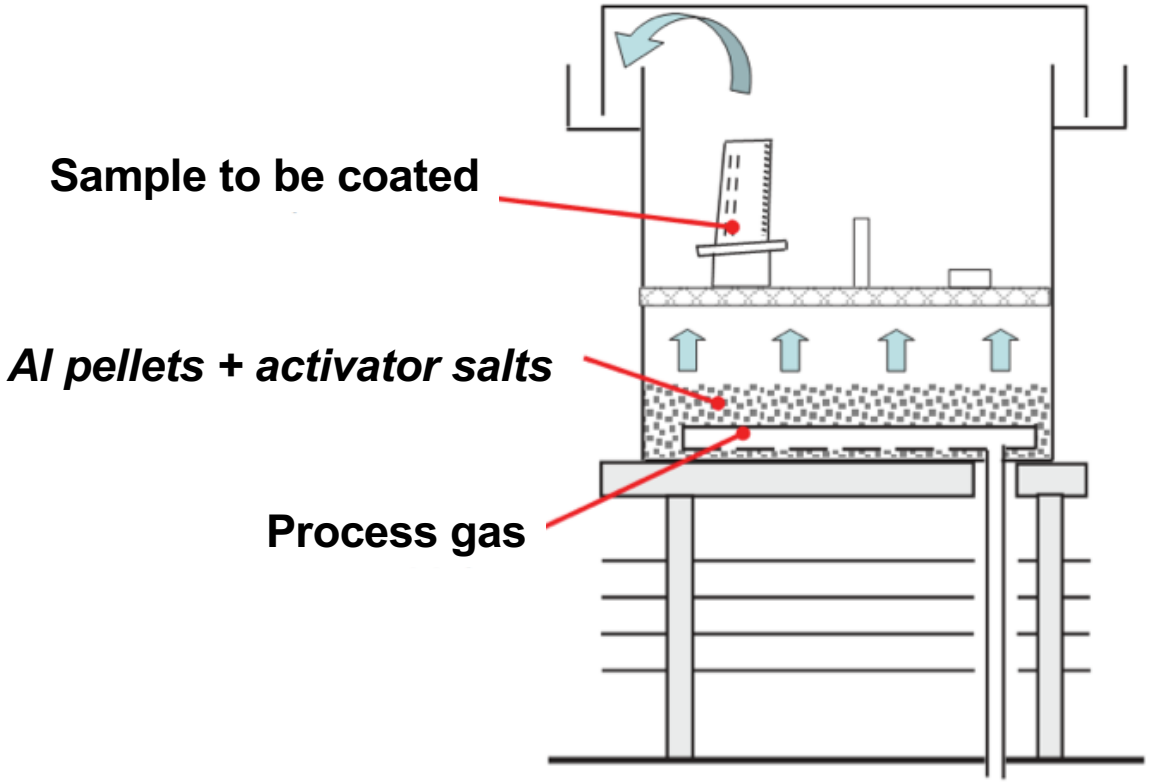
Turbine blades durability issue



Diffusion coating

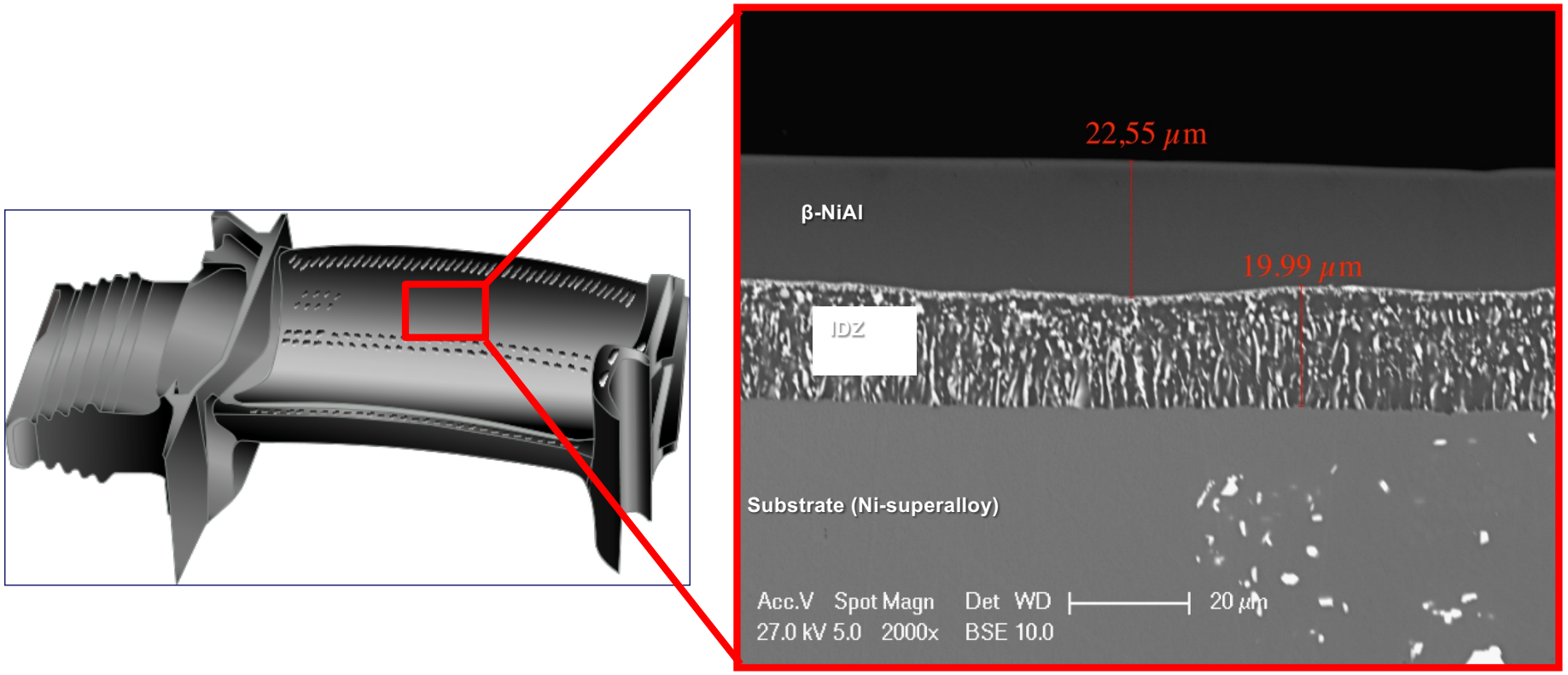
Pack cementation facility

1. **Generation of vapours** containing the metal to be deposited
2. **Transport of vapours** towards the component surface
3. **Reaction with the substrate and diffusion**



Diffusion coatings for turbine blade

Standard coating architecture

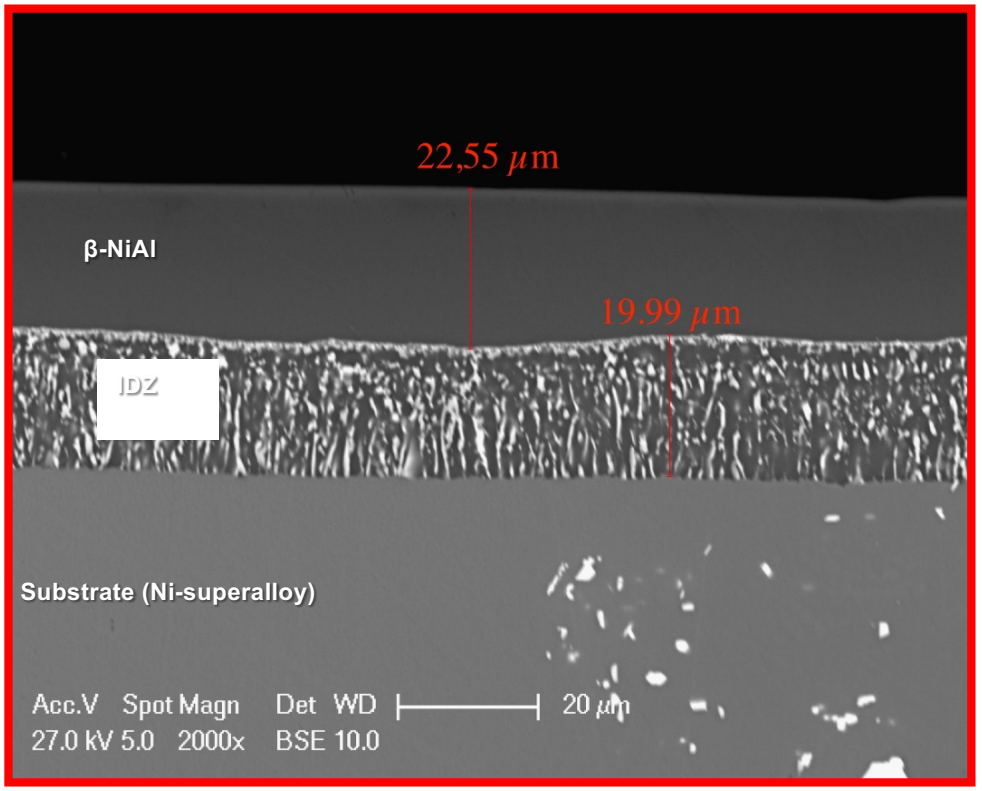


Diffusion coatings for turbine blade

Standard coating architecture

Problems:

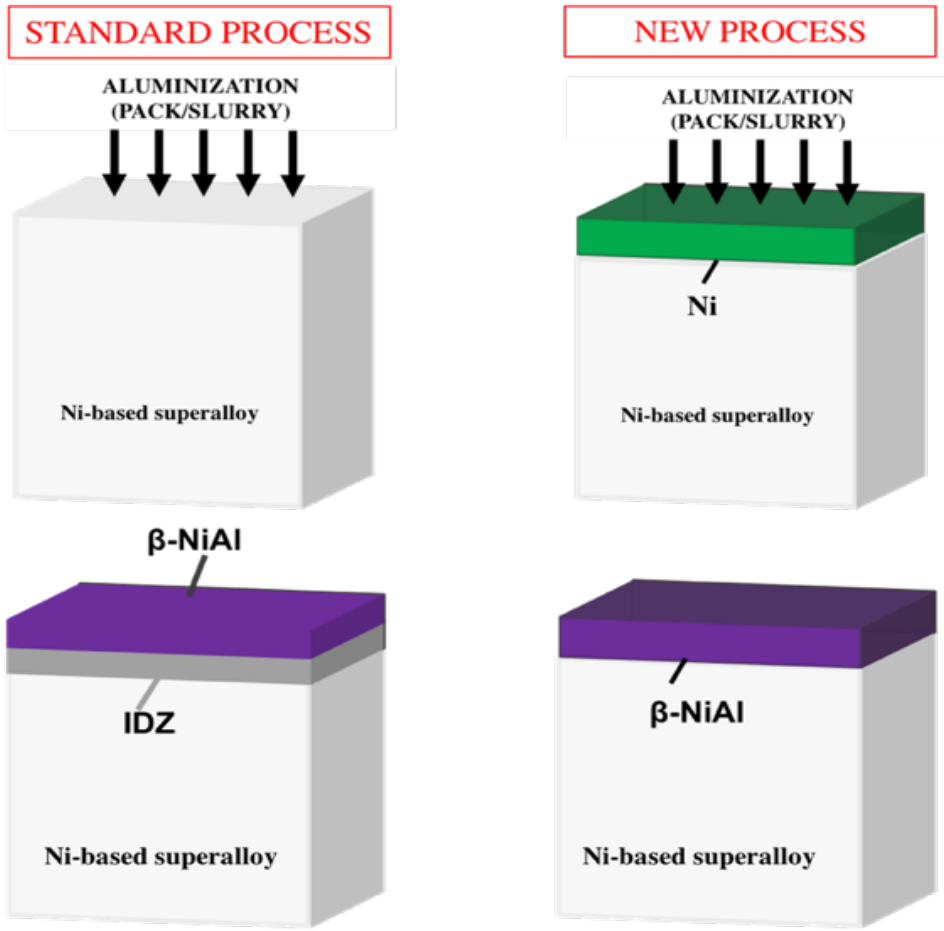
- Limits in max. NiAl thickness
- Brittleness of interdiffusion zone



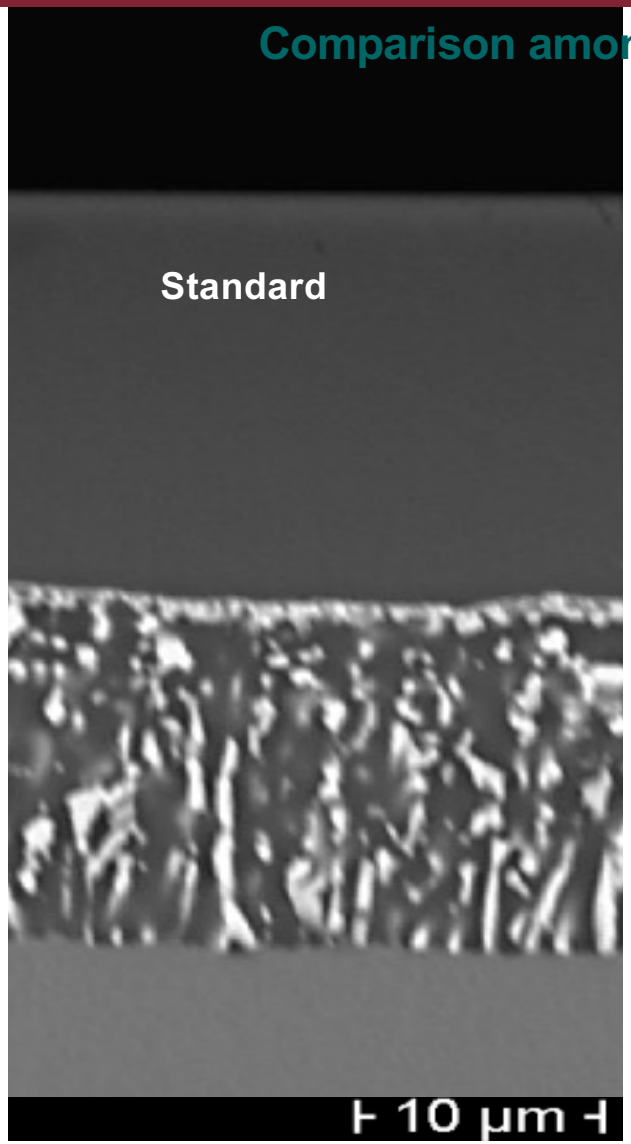
Innovative approach based on the electroless coatings?

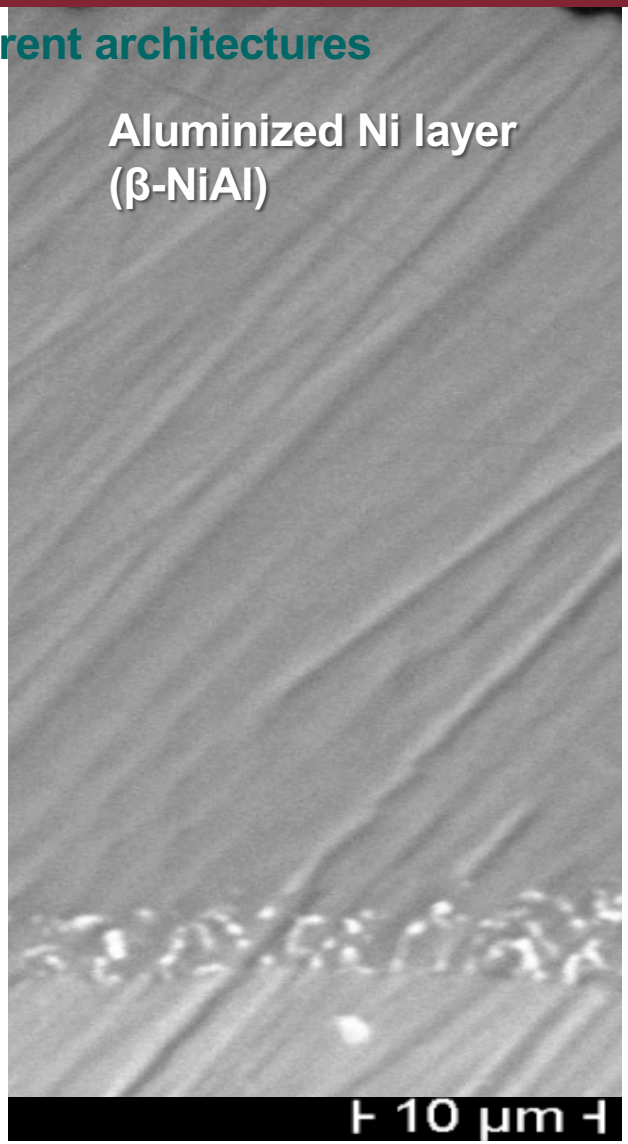
Modified aluminide coatings

Addition of electroless Ni layer

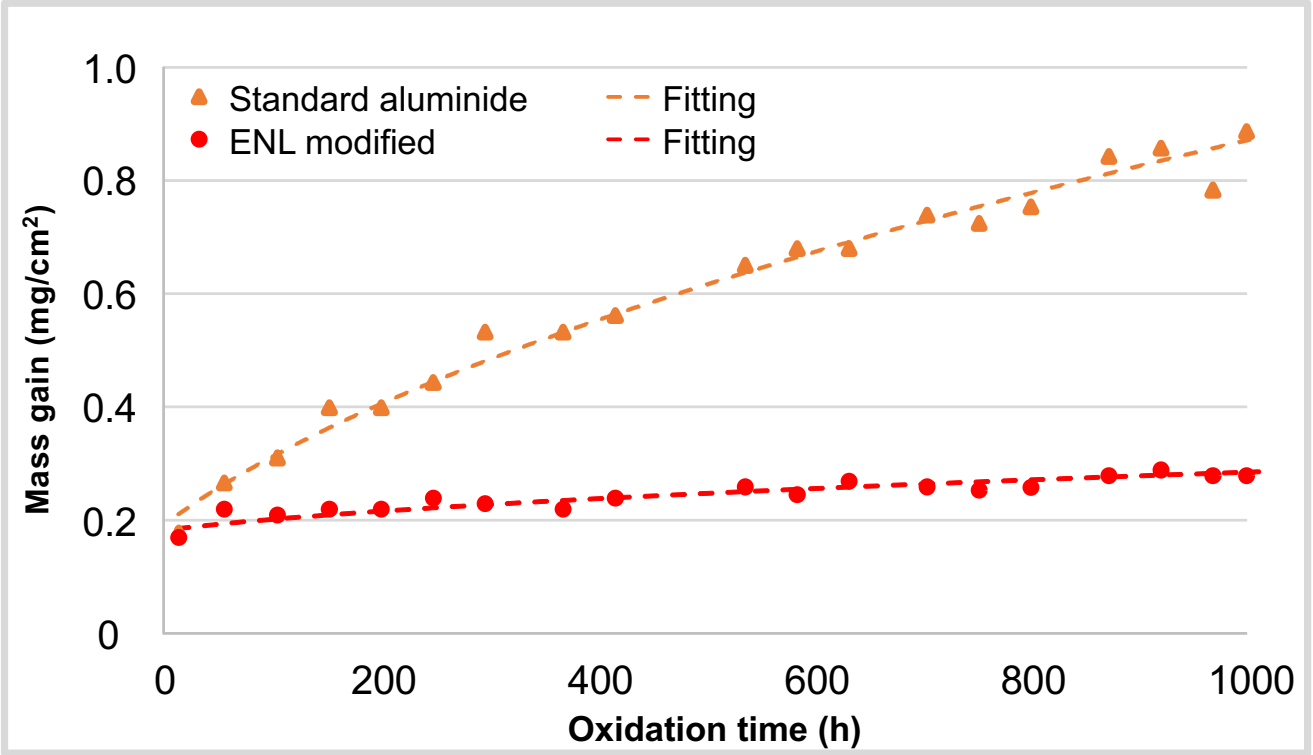


Comparison among different architectures





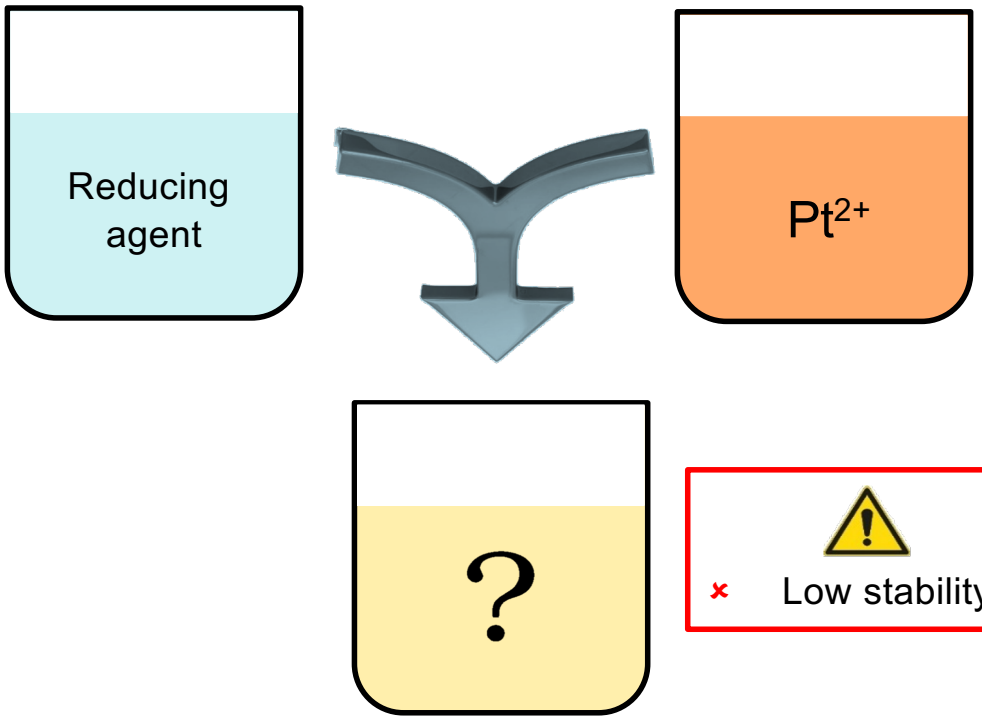
High temperature oxidation tests



Electroless platinum plating

Very strong reducing power

High nobility of platinum



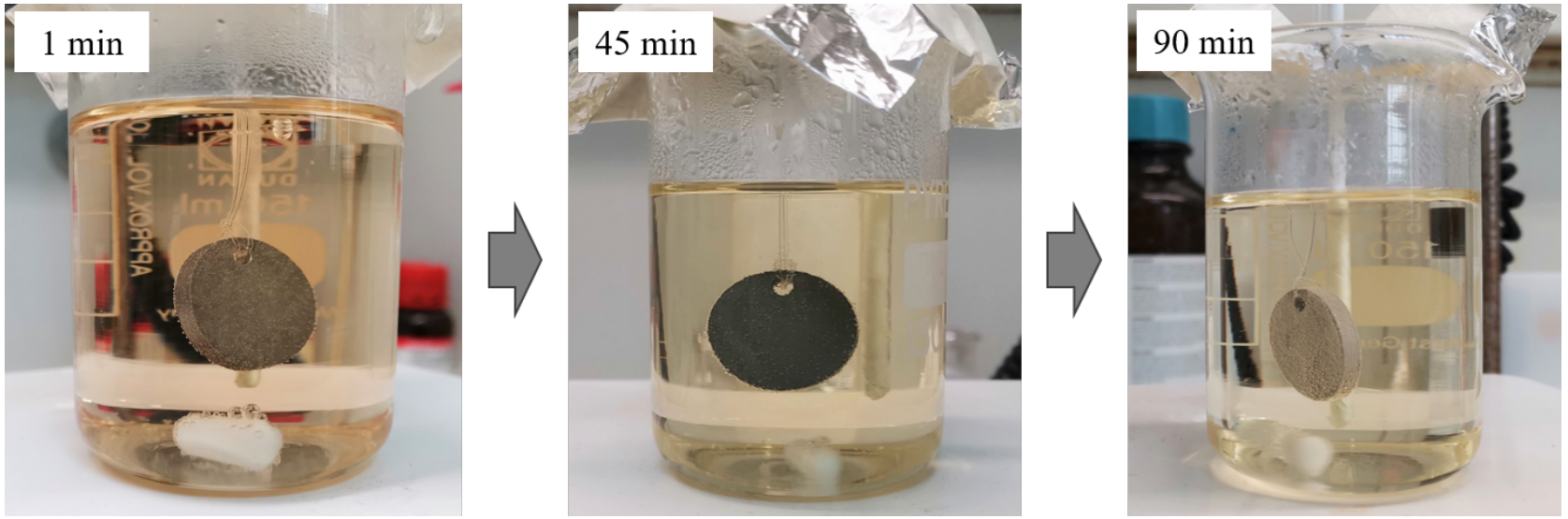
$$Pt^{2+} + 2e^- \rightarrow Pt$$

$$E_0 = +1.2\ V$$

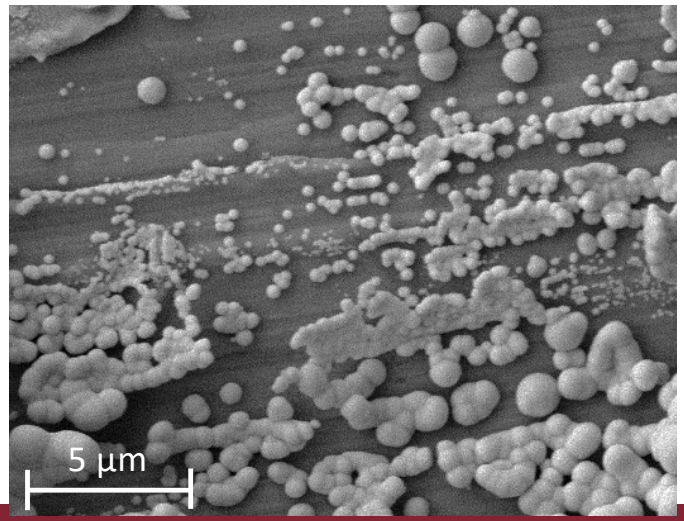
× Low stability!

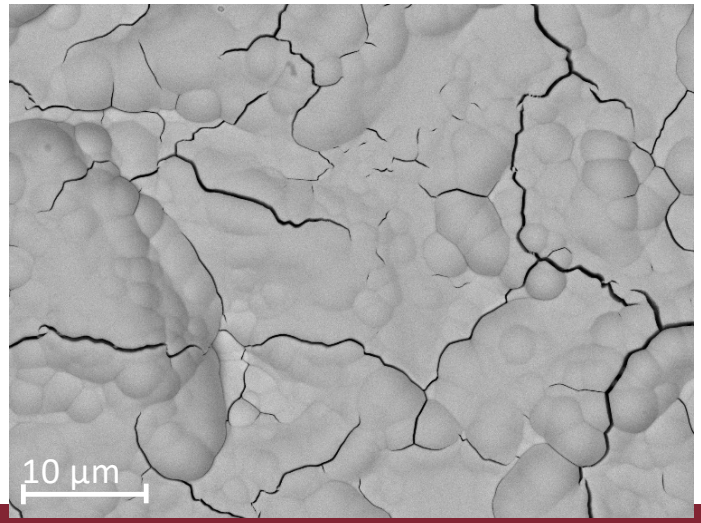
Pressing demand to the development of a stable electroless plating solution for deposition of sufficiently thick platinum films for high temperature applications.

Experimental Activity – Platinum plating solution



Growth mechanism

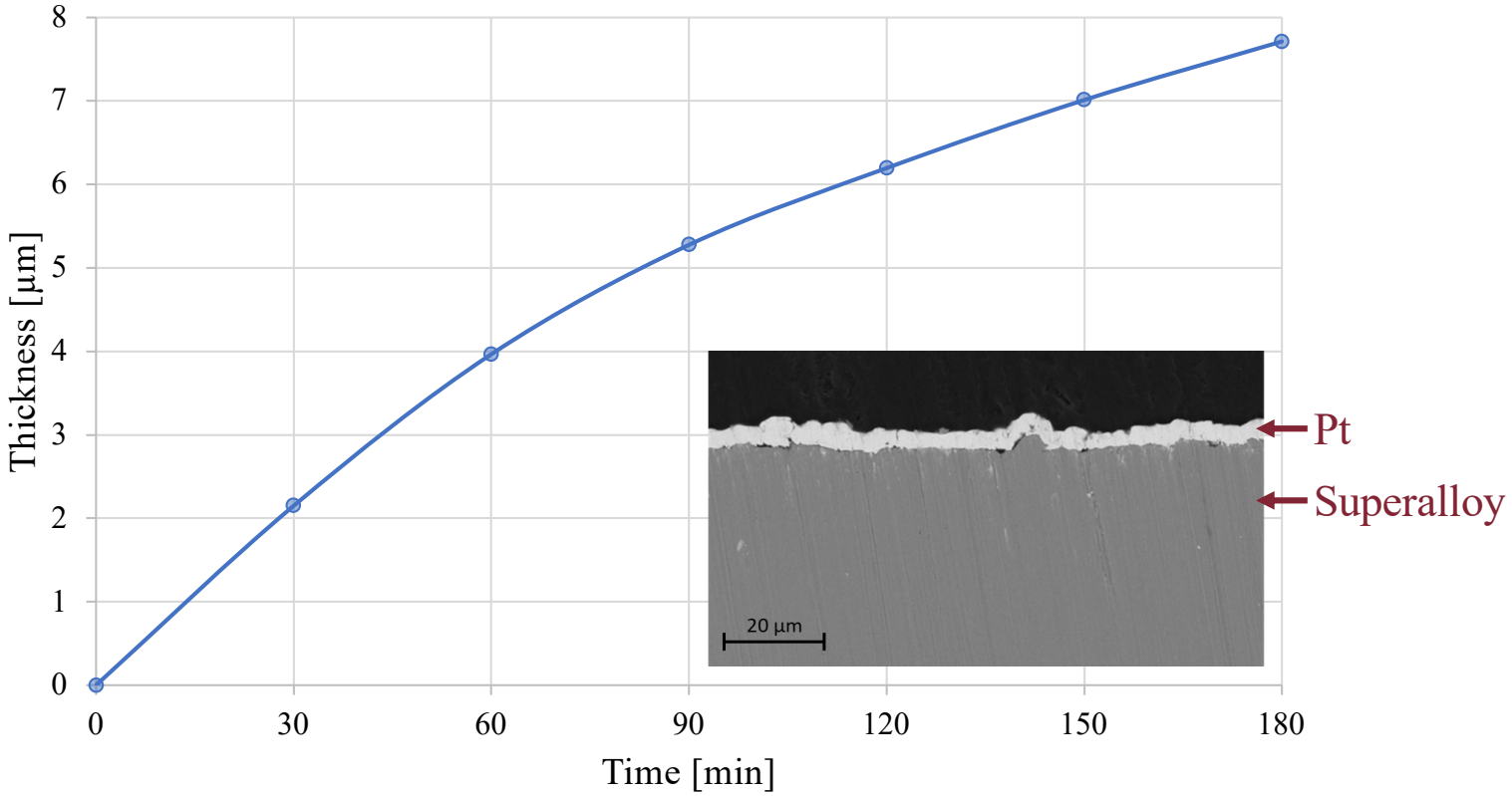




Experimental Activity

Bath tuning in terms of:

- **Temperature**
- **Composition**



Sufficient thickness for Pt modification of aluminide coatings.

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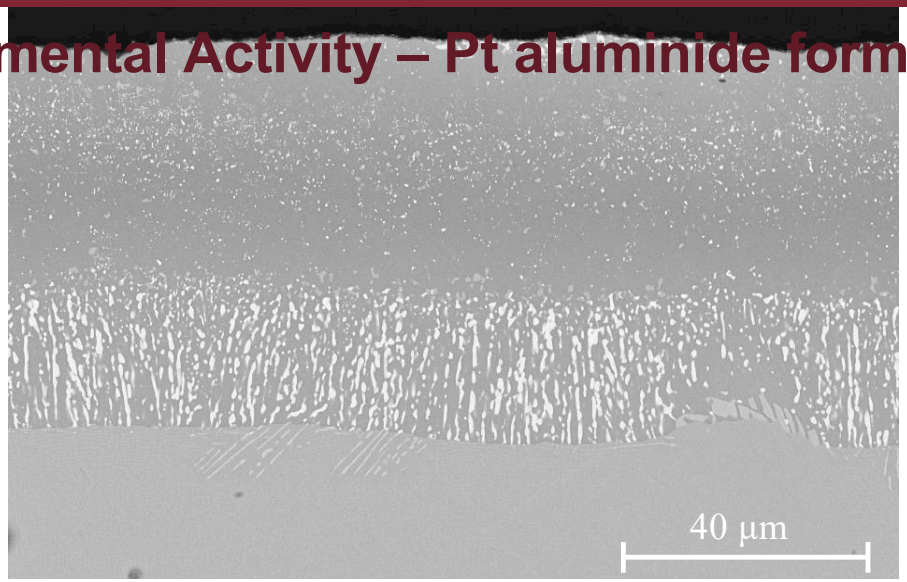
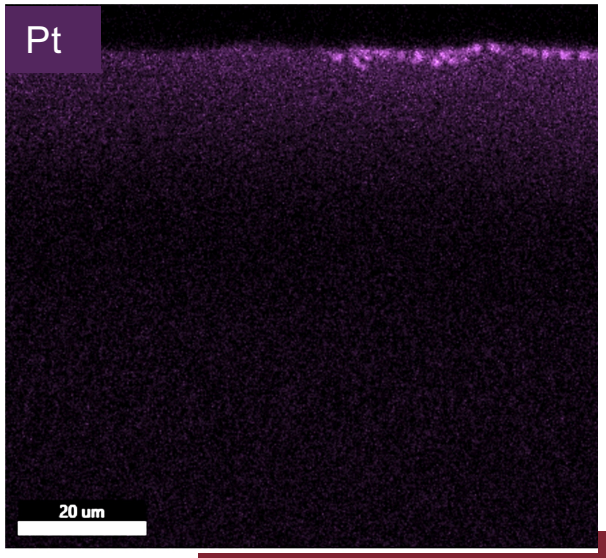
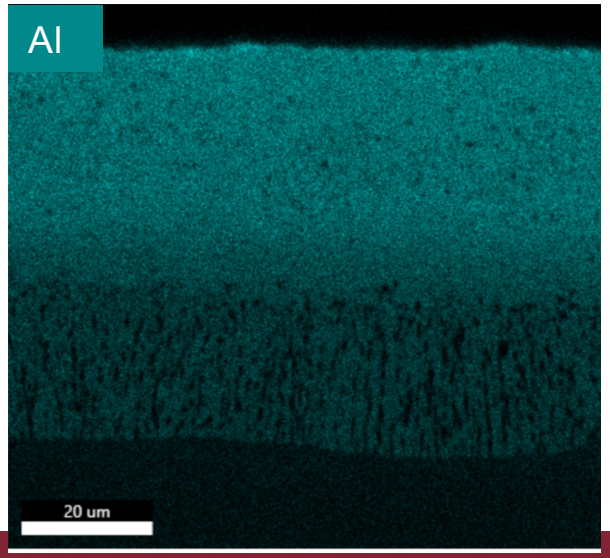
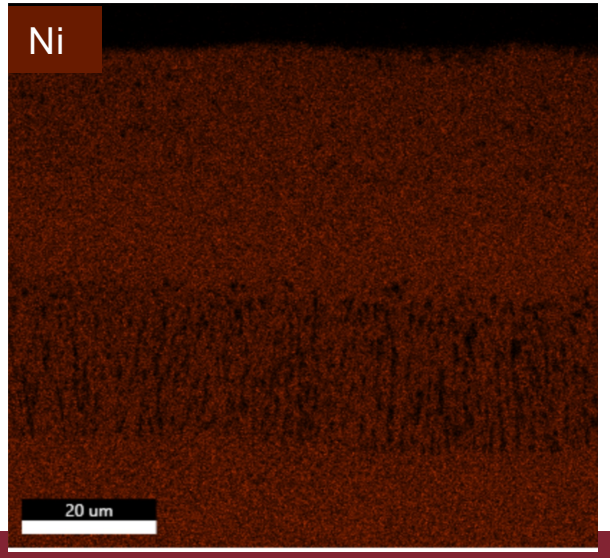
Experimental Activity – Pt aluminide formation

Initial Pt layer thickness:
~ 8 µm





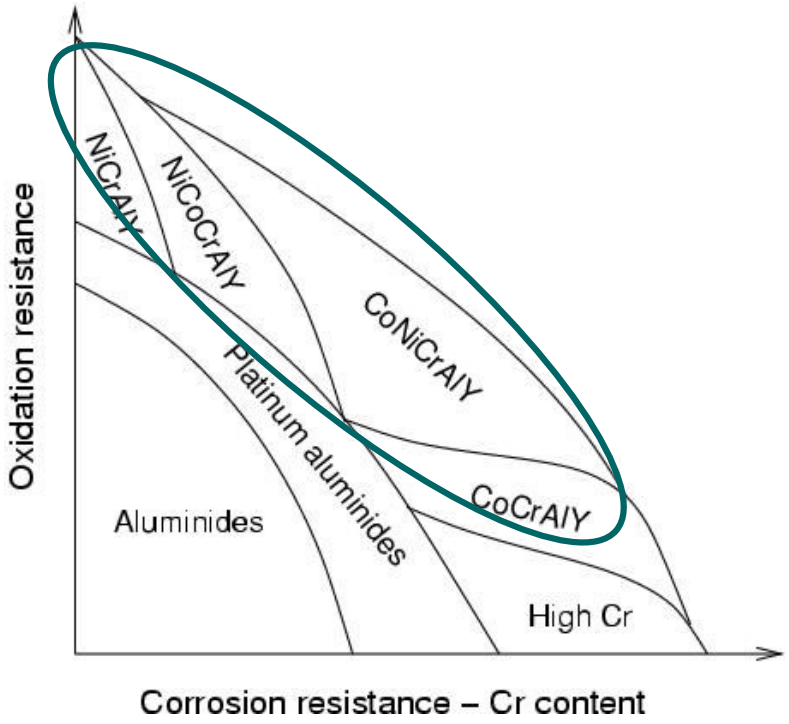


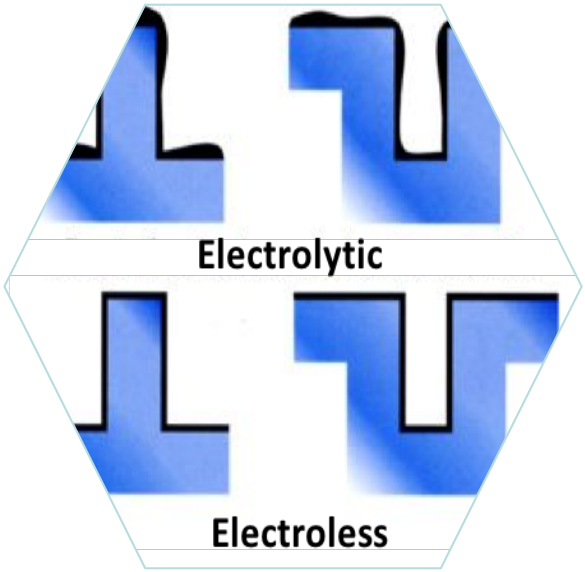


MCrAlY electroless for TBCs

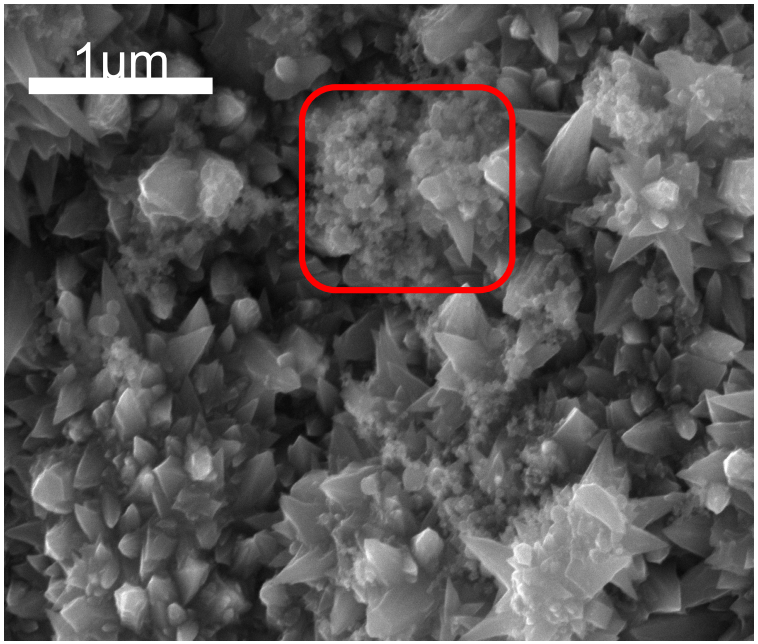
High temperature

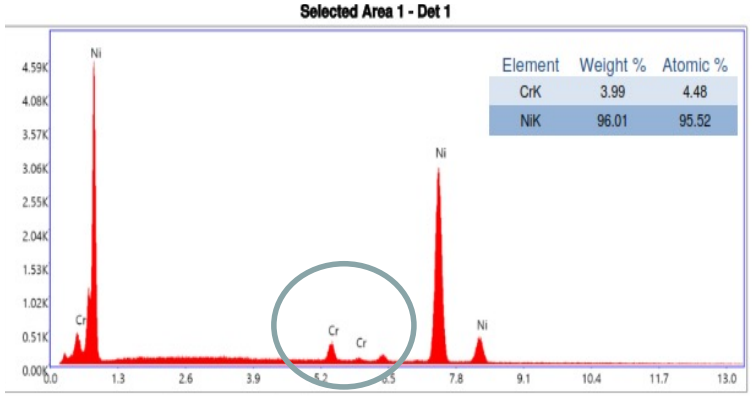
Electroless Plating

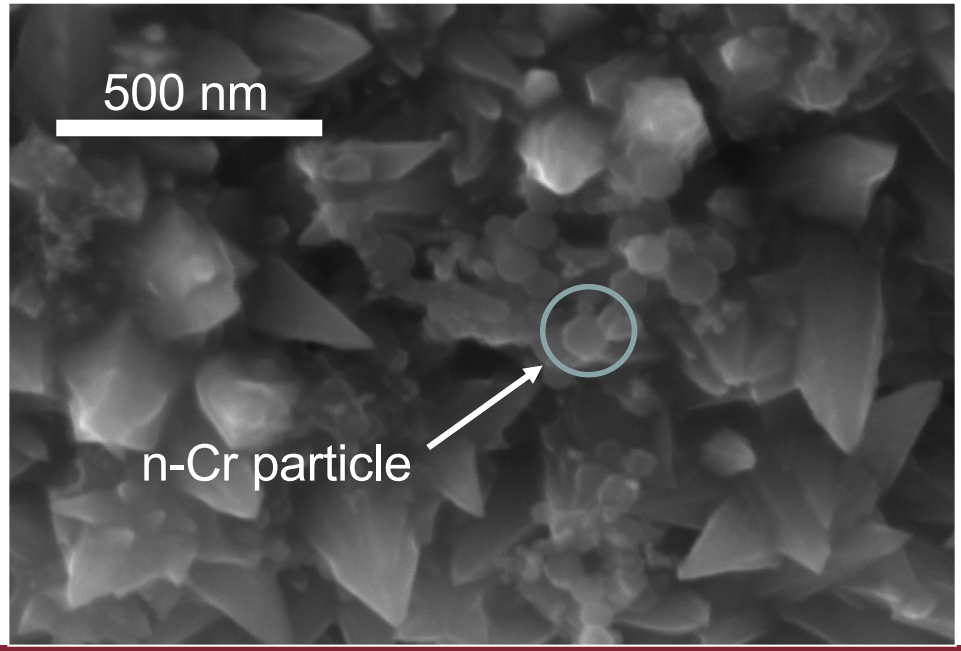




MCrAlY electroless for TBCs





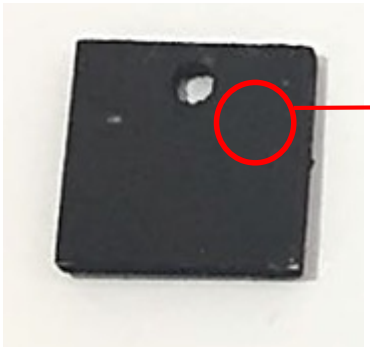


SEM micrograph of the surface of the coating:

- Pure Ni + nano Cr particles

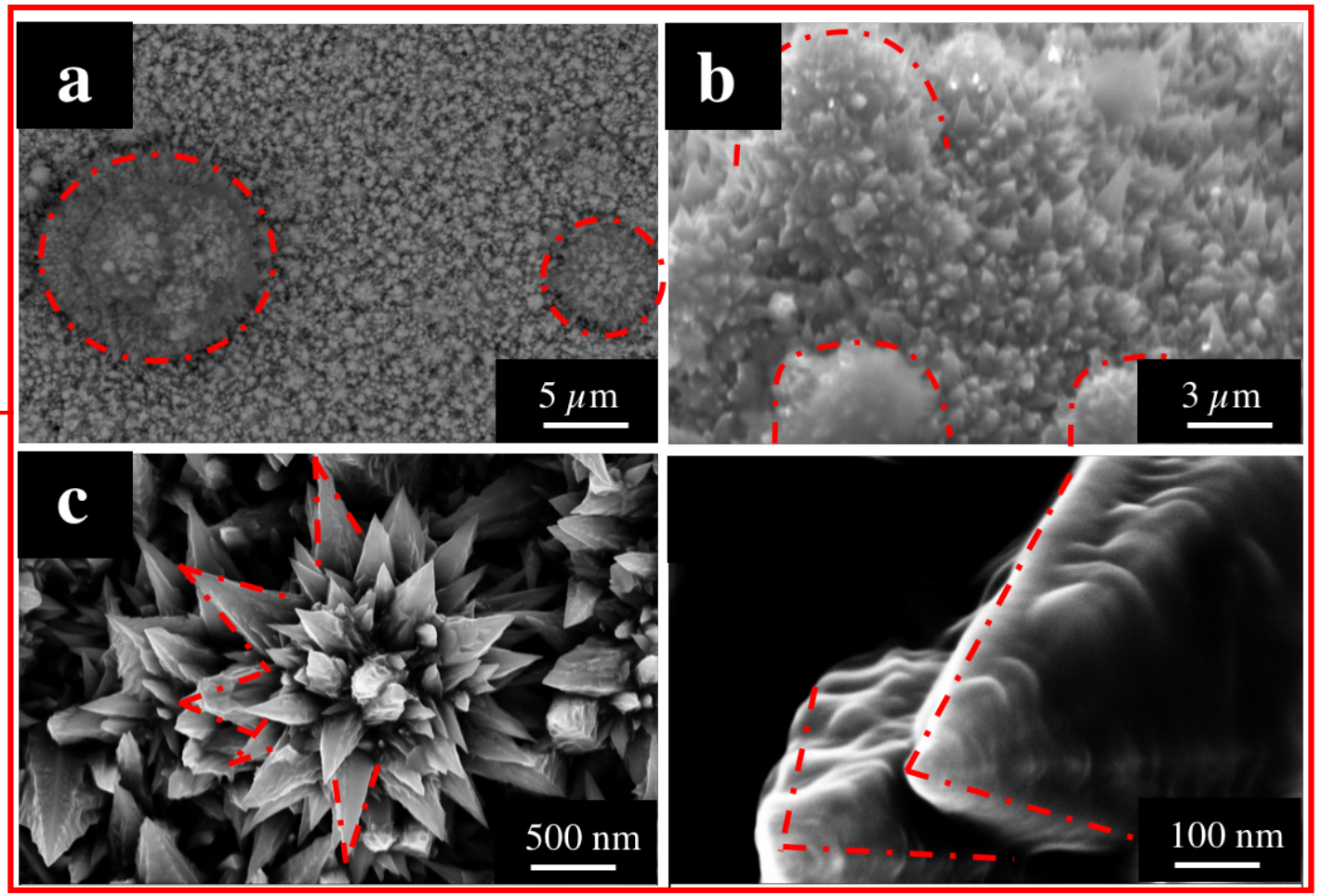
Ni pure electroless coatings

Bare sample



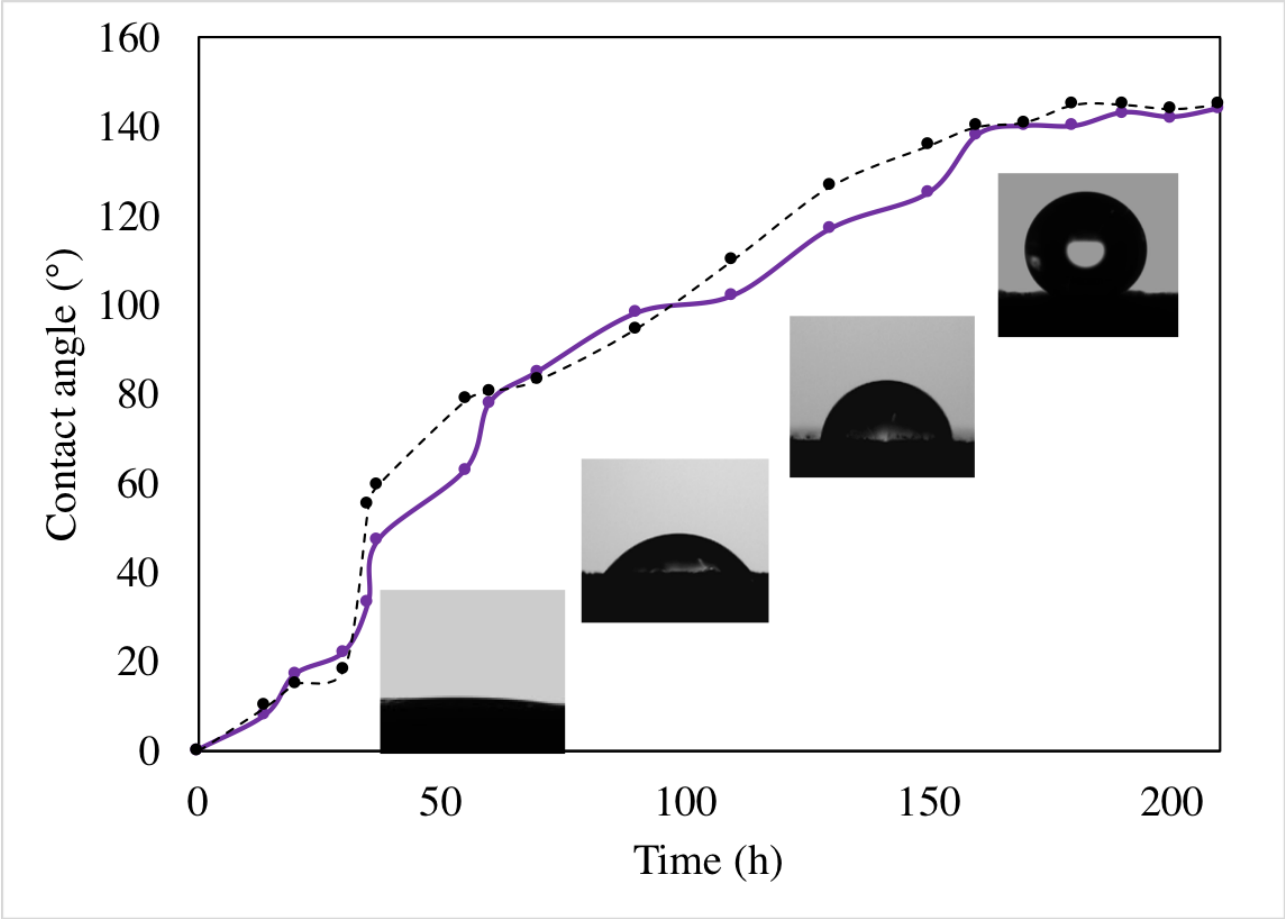
Ni electroless coating

Tailorable wetting properties – preliminary results



Ni pure electroless coatings

Tailorable wetting properties – preliminary results



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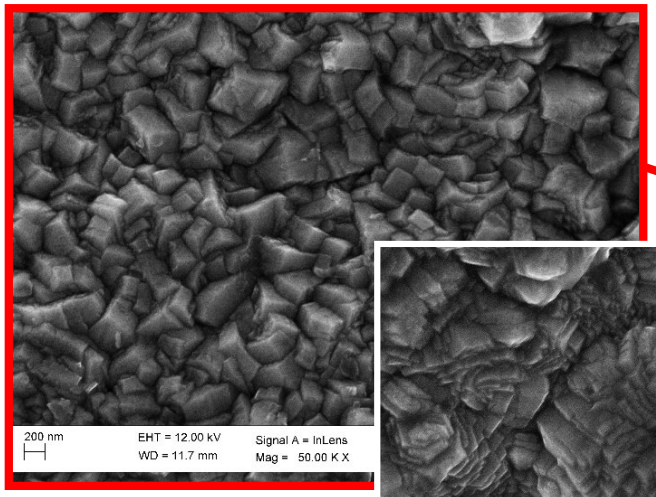
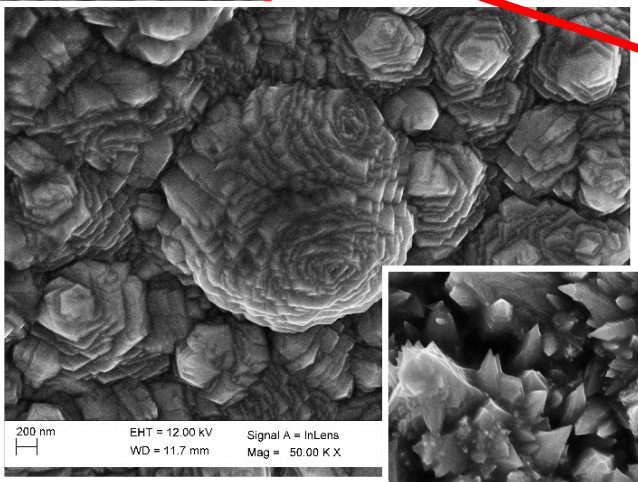
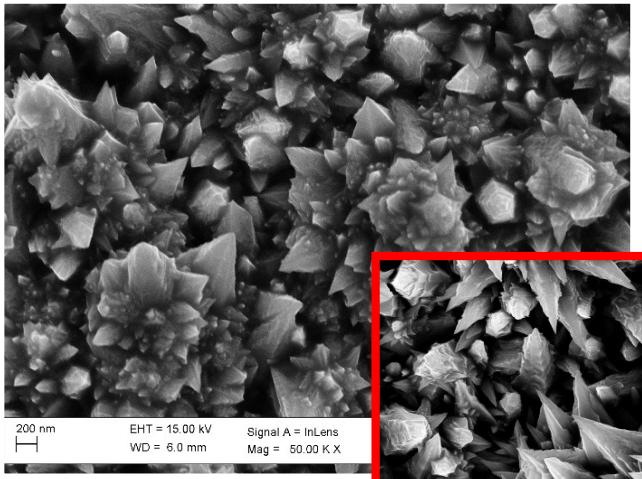
Ni + Co electroless coatings

Anti-icing behaviour?





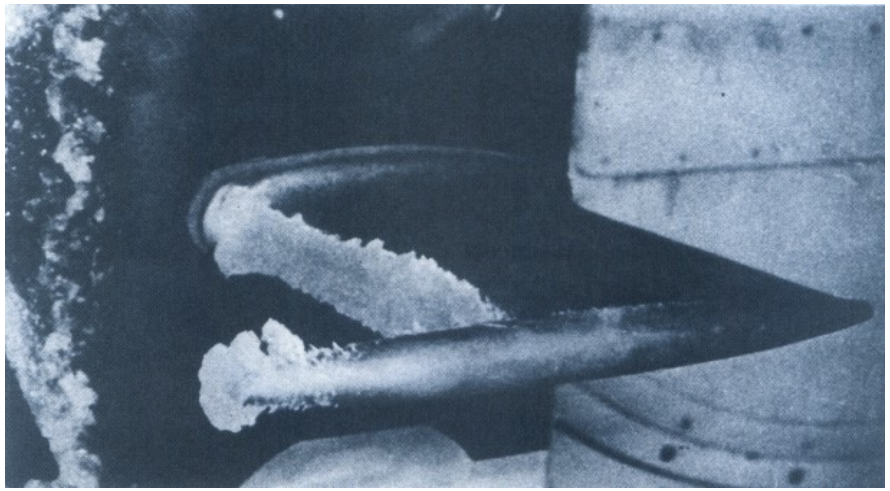


AIRBUS

Increasing Ni content

Nickel coating

Anti-icing coatings



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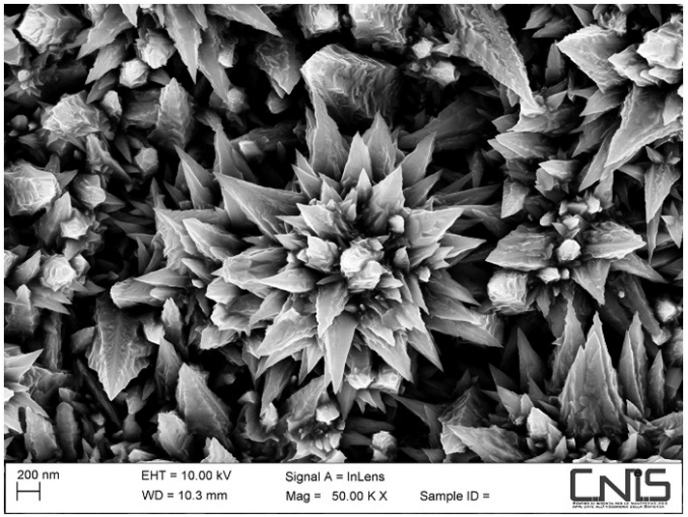
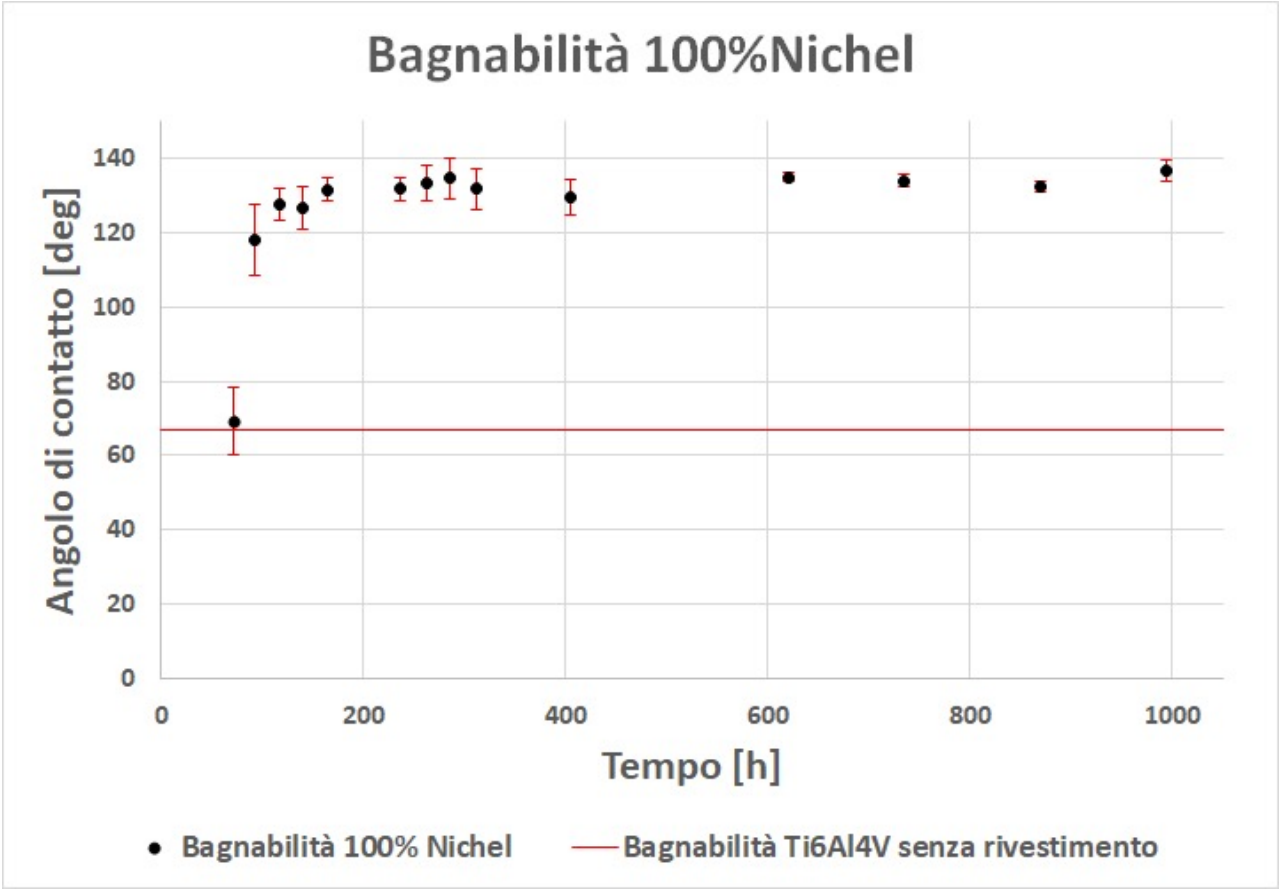
AIRBUS DEFENCE & SPACE

Nickel coating

Anti-icing coatings

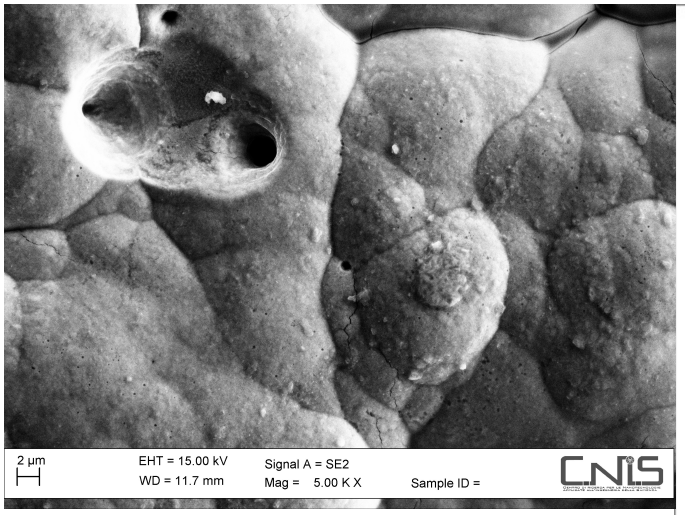


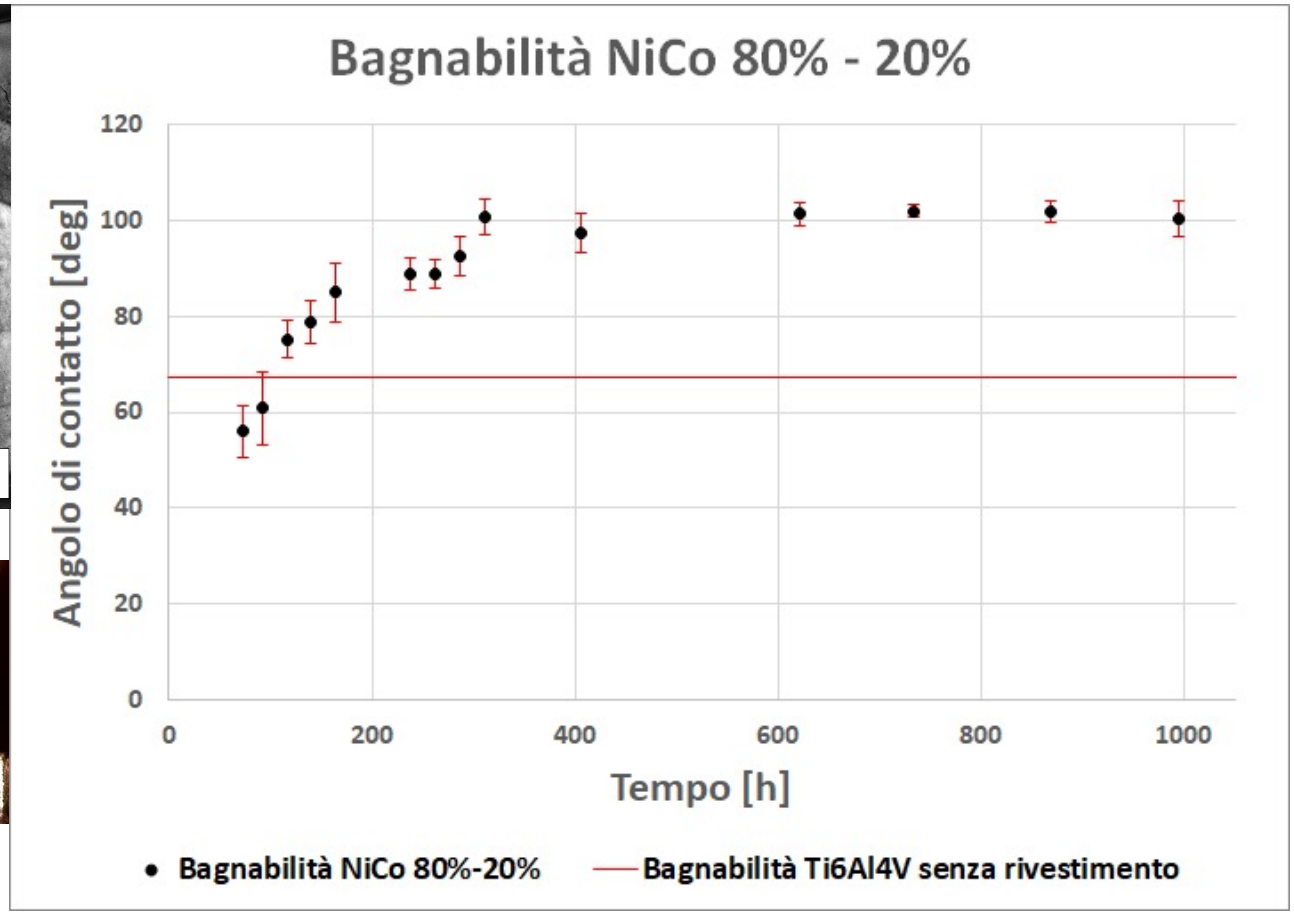


AIRBUS DEFENCE & SPACE

Nickel coating

Anti-icing coatings





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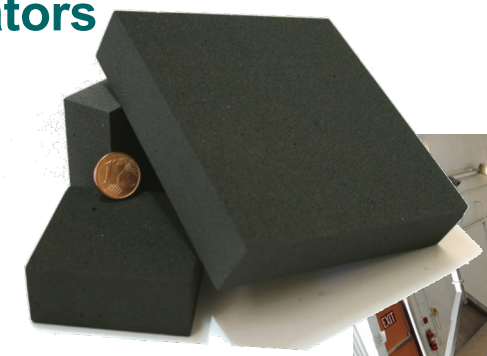
Development of ablative materials for reentry vehicles

Carbon/Phenolic composite ablators



Lightweight Carbon Phenolic (C\P)

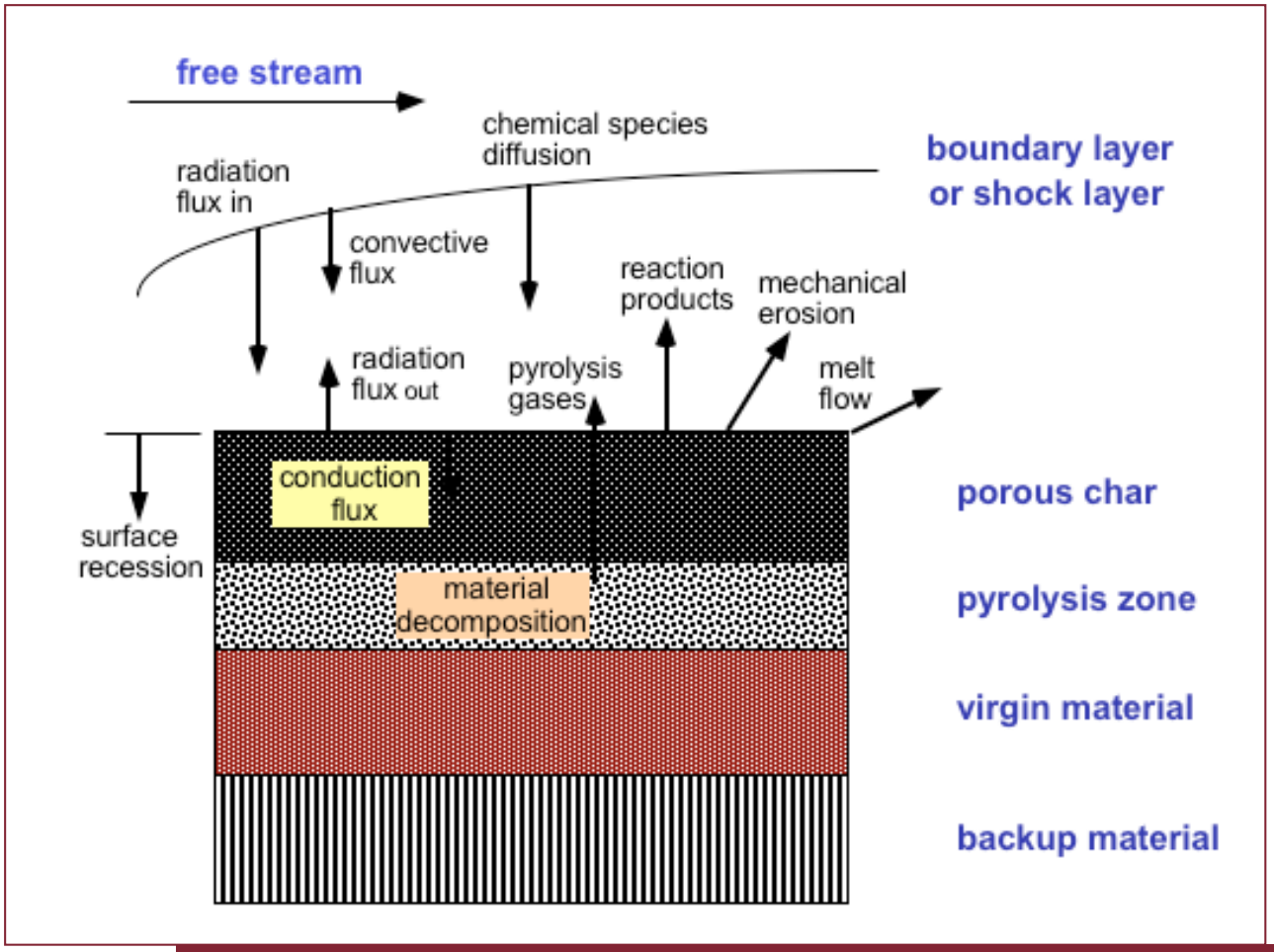
Ablators features:

- The reinforcement is a low-density (< 200 kg/m^3) carbon tile substrate with low thermal conductivity (< 0,2 W/mK at RT);

- The substrate is partially impregnated with a resole phenolic resin (matrix);

- Final density could be lower than 300 kg/m^3 (it depends on impregnation degree: changing the resin amount, thermal and charring behaviour changes).

Ablative TPS materials are usually (but not always) reinforced composites employing organic thermosetting or thermoplastic polymers as binders



e.g. charring ablative material

-Thermal transient;

- Pyrolysis;

- Pyrolysis gases evolution;

- Char formation (porous, high emissivity);

- Chemical ablation;

- Mechanical ablation;

- Surface recession.

Why nanocomposite ablative materials?

- To reduce the recession rate of exposed surface

  (mechanical stabilization of char)

- To limit sublimation of exposed surface in case of very high heat flux levels

  (physical stabilization of char)

- To reduce chemical ablation in oxidizing atmospheres

  (chemical stabilization of char)

Nanostructures:

- Ceramic nanoparticles
- **ZrO_2 nanofilms by ALD (<100 nm)**
- Carbon nanotubes
- Nanoclays

Modified carbon felts

Carbon fibers coated by ALD ceramic nanofilms

The idea is to fully cover the carbon fibers of felt by a ZrO_2 nanometric film before the resin impregnation step

Aim: protection of carbon fibers – reducing the recession rate

ALD depositions on carbon felts performed at Brescia University

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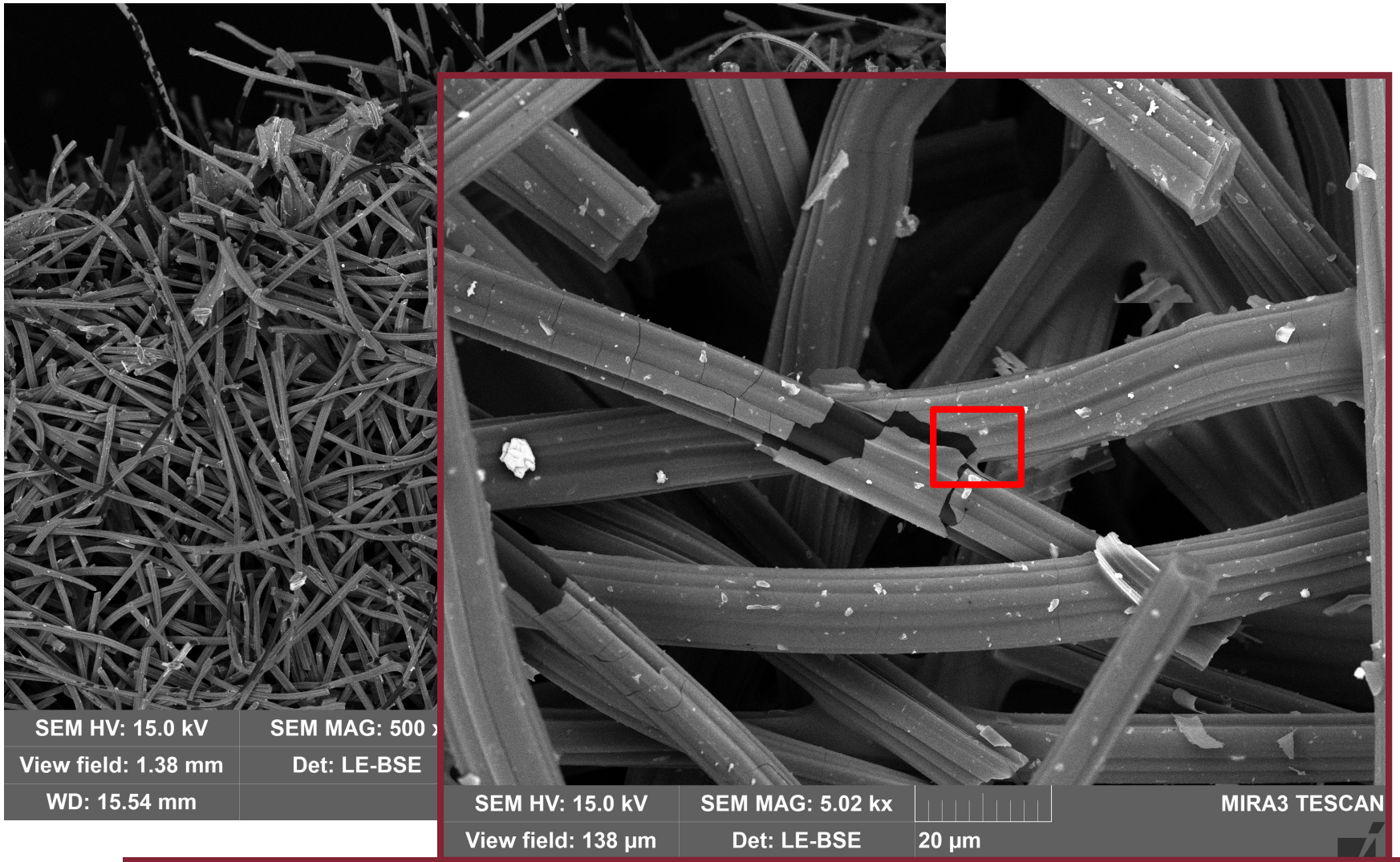
Carbon fibers coated by ALD ceramic nanofilms



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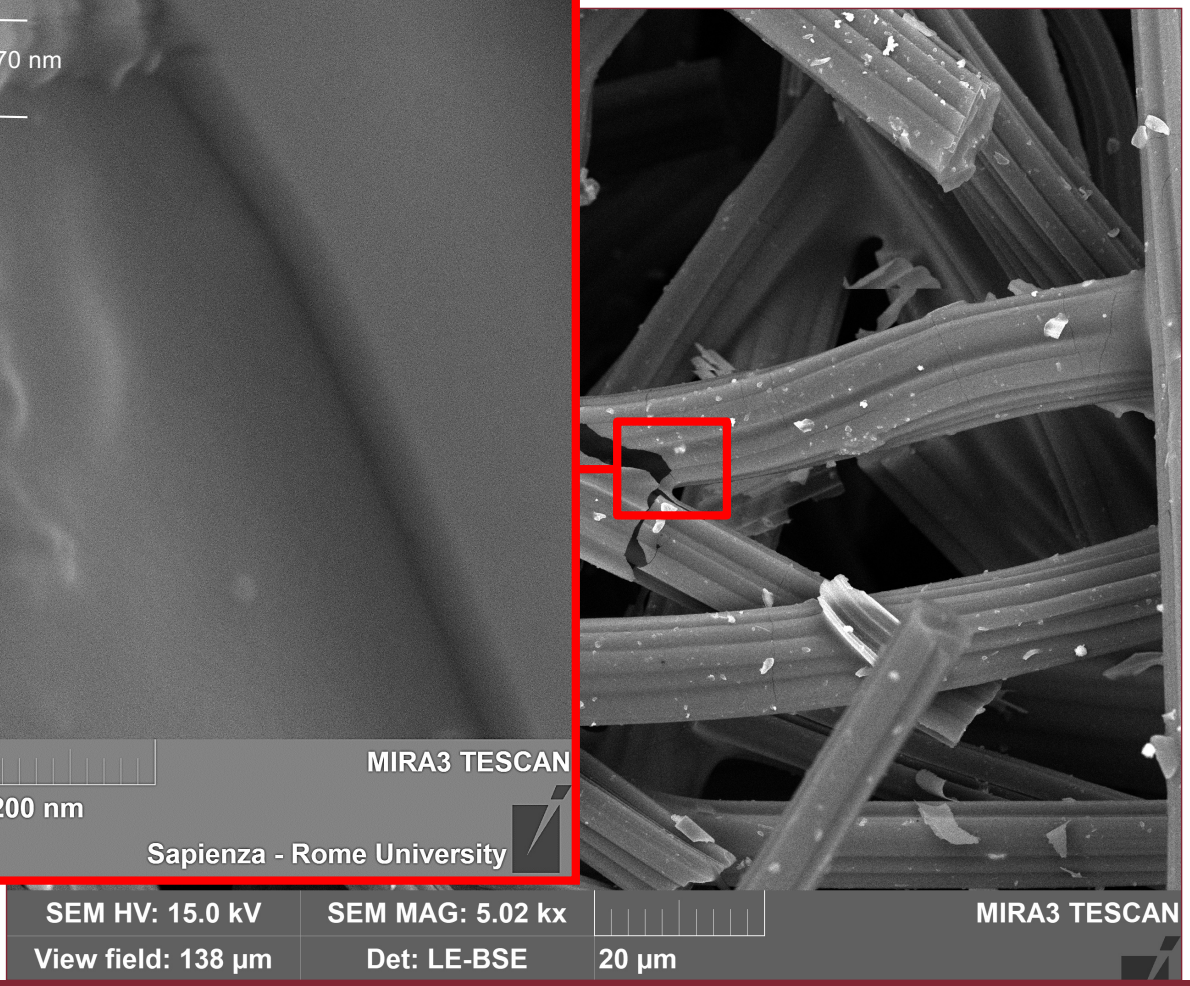
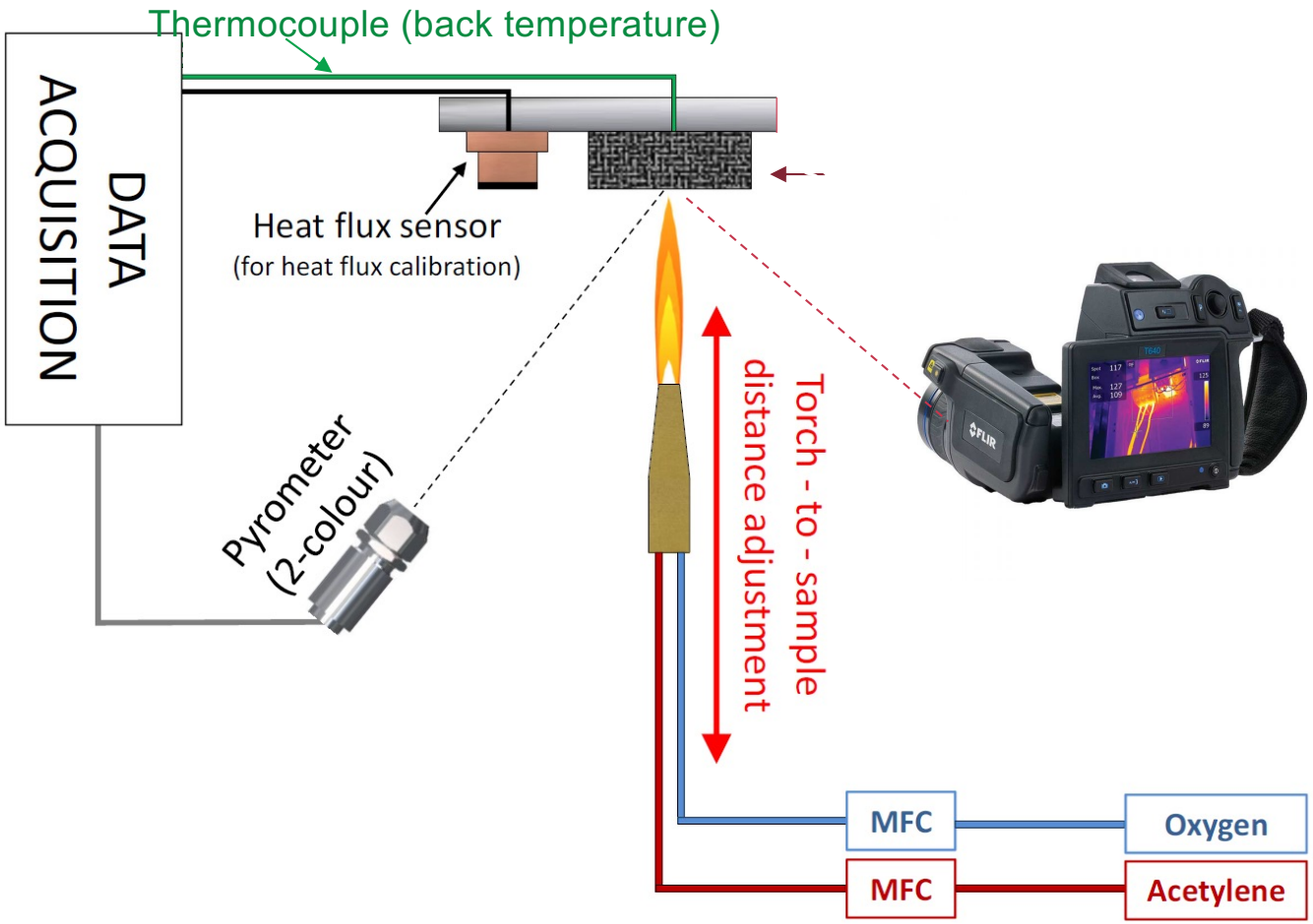
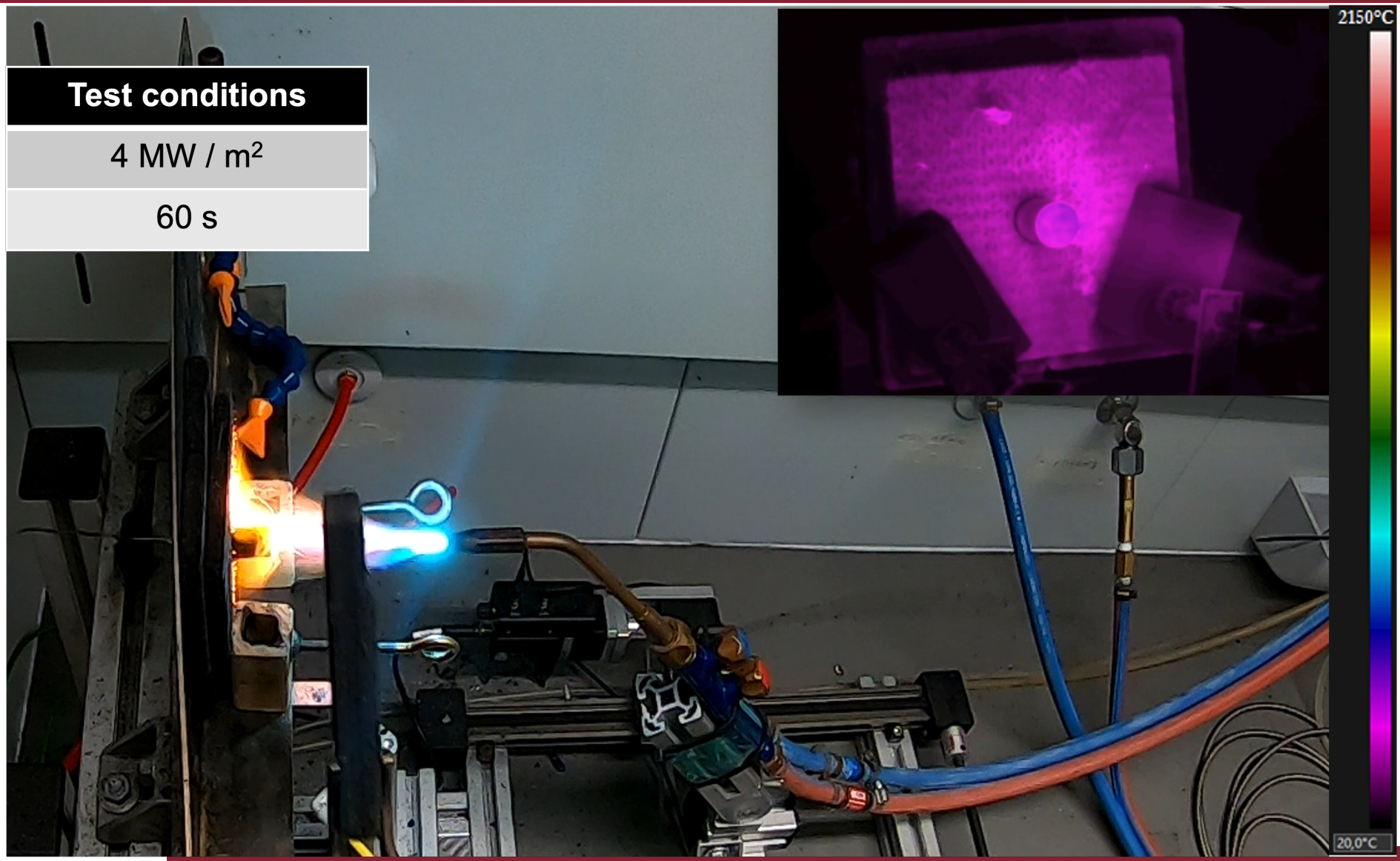


Carbon-phenolic ablators modified by n-ZrO_2

Torch test of ablators modified by n-ZrO_2




Test conditions
4 MW / m²
60 s
2150°C
20,0°C

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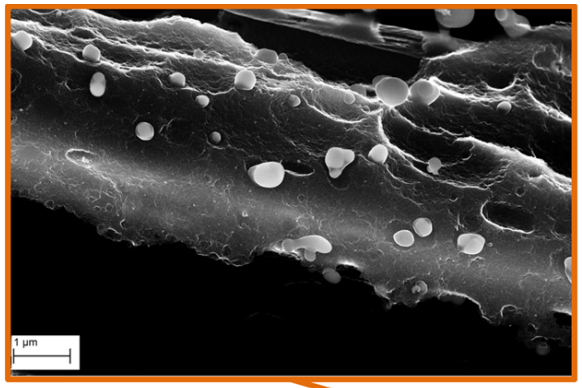
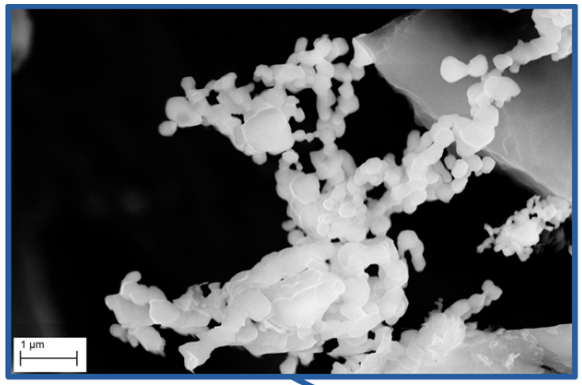
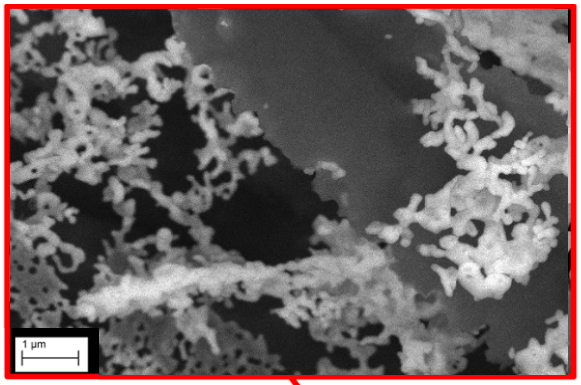
Carbon-phenolic ablators modified by n-ZrO_2

Torch test of ablators modified by n-ZrO_2







0% n-ZrO2

2% n-ZrO2

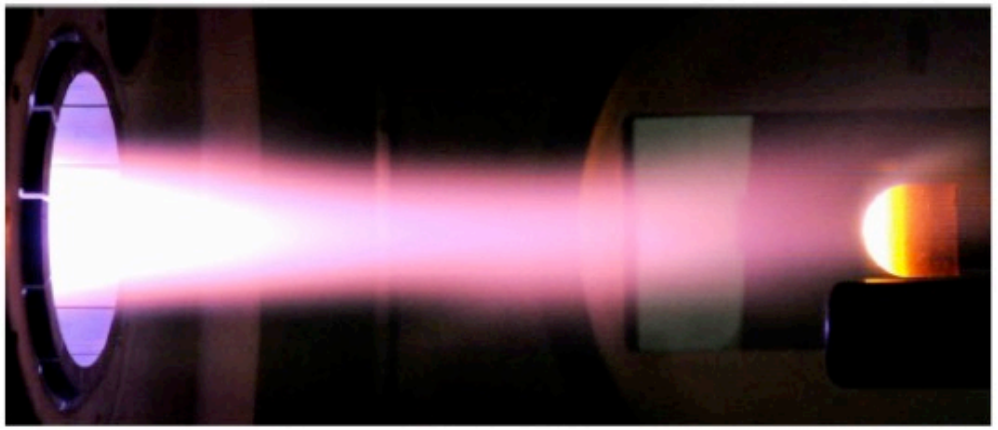
5% n-ZrO2

ALD ZrO2

Carbon-phenolic ablators modified by n-ZrO_2

Plasma wind tunnel test (*Von Karman Institute*)

Test objectives:



Material response **investigation and characterization** of carbon-based materials in **high-enthalpy plasma flow** representative of the environment during atmospheric reentry.

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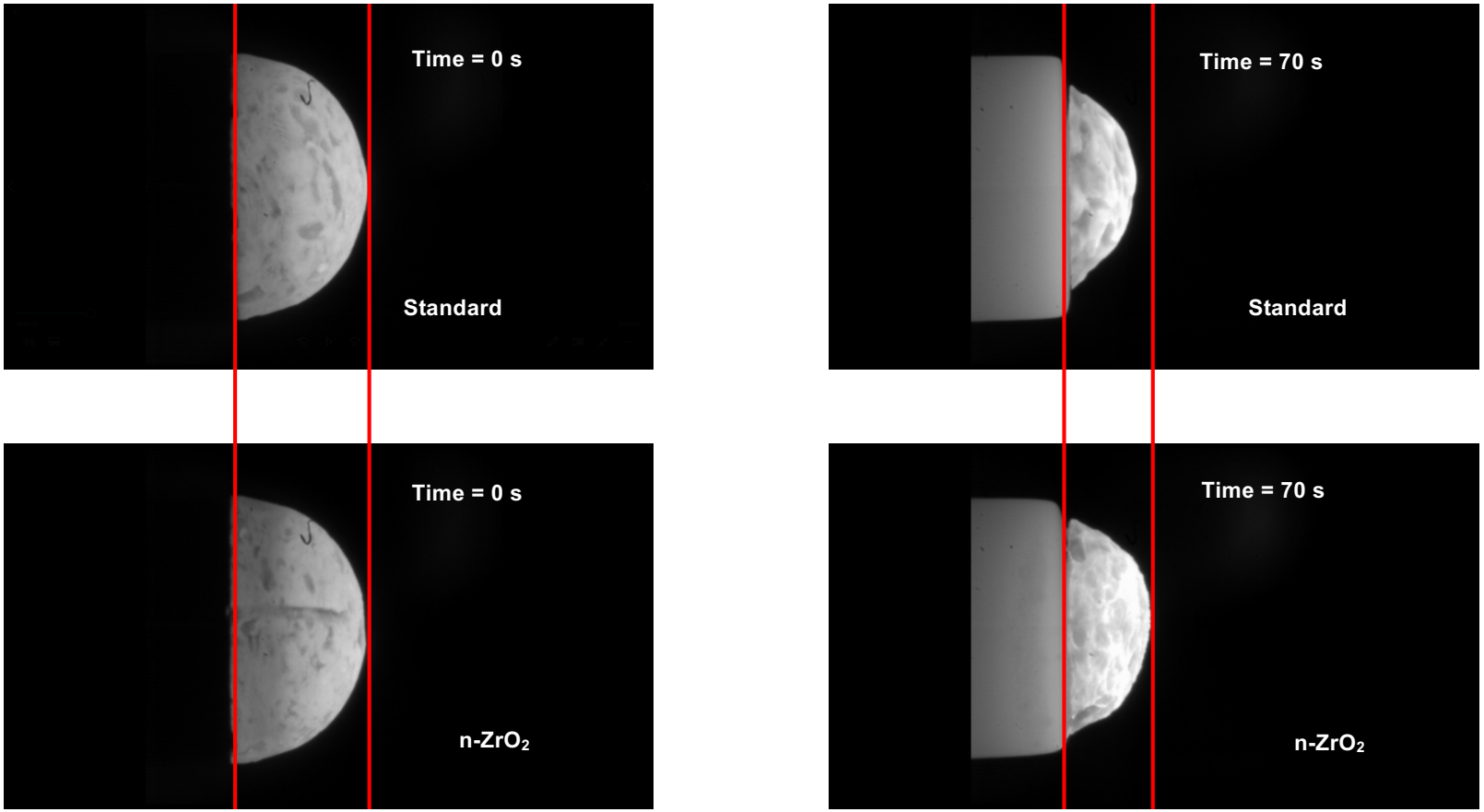
Carbon-phenolic ablators modified by n-ZrO_2

Plasma wind tunnel test (Von Karman Institute)

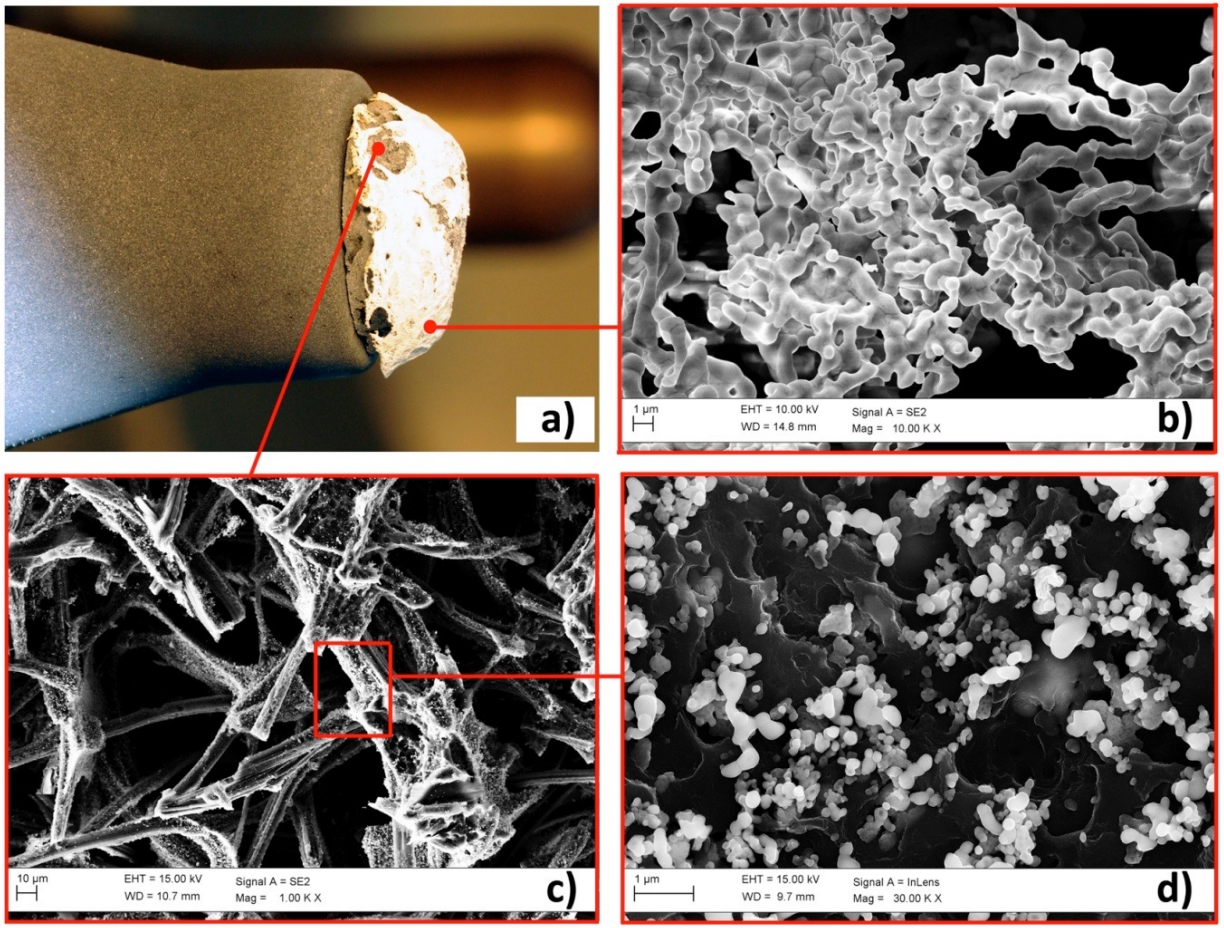
Heat flux: 4 MW/m^2 **Test time: 70 s**



Carbon-phenolic ablators modified by n-ZrO_2

Plasma wind tunnel test (Von Karman Institute)

Heat flux: 4 MW/m^2 Test time: 70 s



Sample modified by n-ZrO_2

Post test analysis

Carbon-phenolic ablators modified by n-ZrO_2

Plasma wind tunnel test (Von Karman Institute)

Heat flux: 3,2 MW/m^2 **Pressure: 200 mbar (air)**

Comparison with ASTERM: recession rate (mm/min)

Sample	Recession rate (mm / min)
ASTERM	**4,26***
Standard Sapienza	**4,16**
n-ZrO_2 Sapienza	**2,95**

* *B. Helber et al. ; International Journal of Heat and Mass Transfer 100 (2016) pp 810–824*

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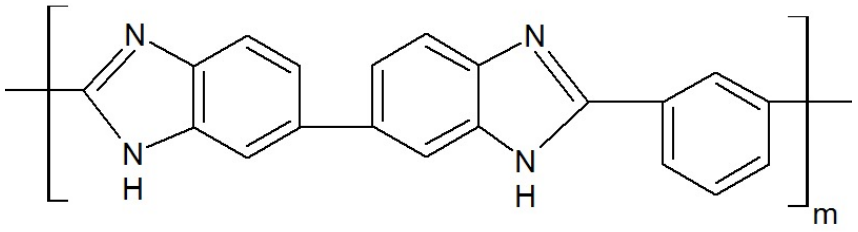
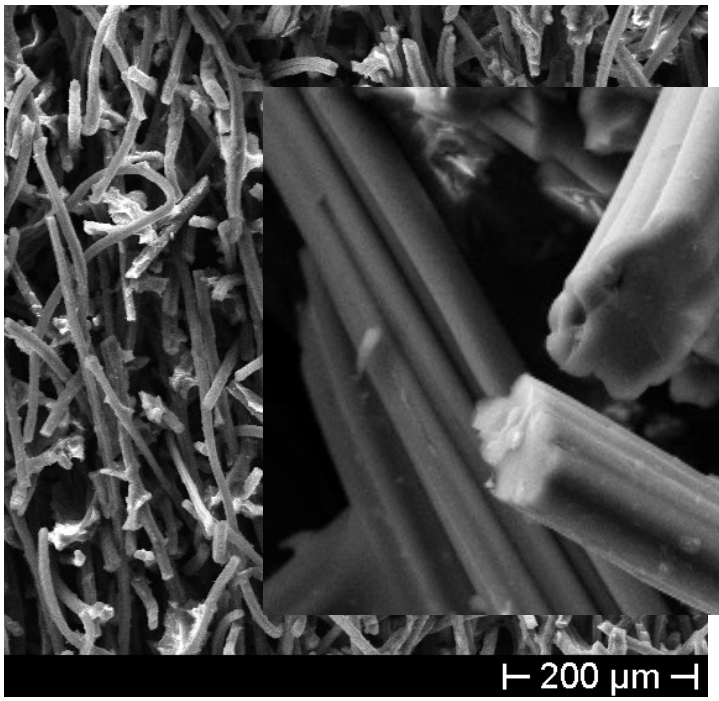
Carbon-thermoplastic ablators modified by n-ZrO_2

Polymeric matrix + **Carbon fibers reinforcing phase**



Polybenzimidazole



Carbon felt

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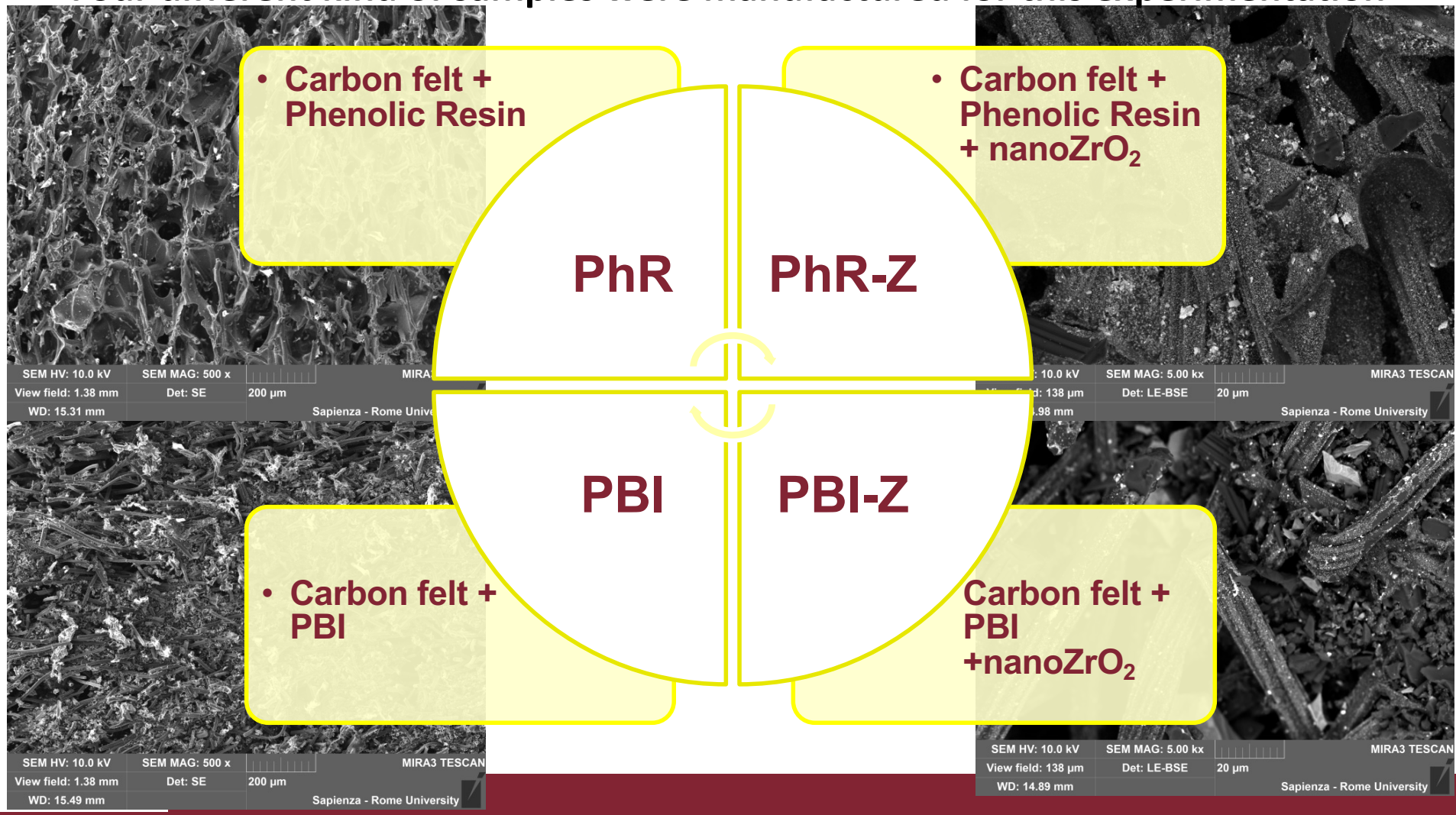
Carbon-thermoplastic ablators modified by n-ZrO_2

Four different kind of samples were manufactured for this experimentation



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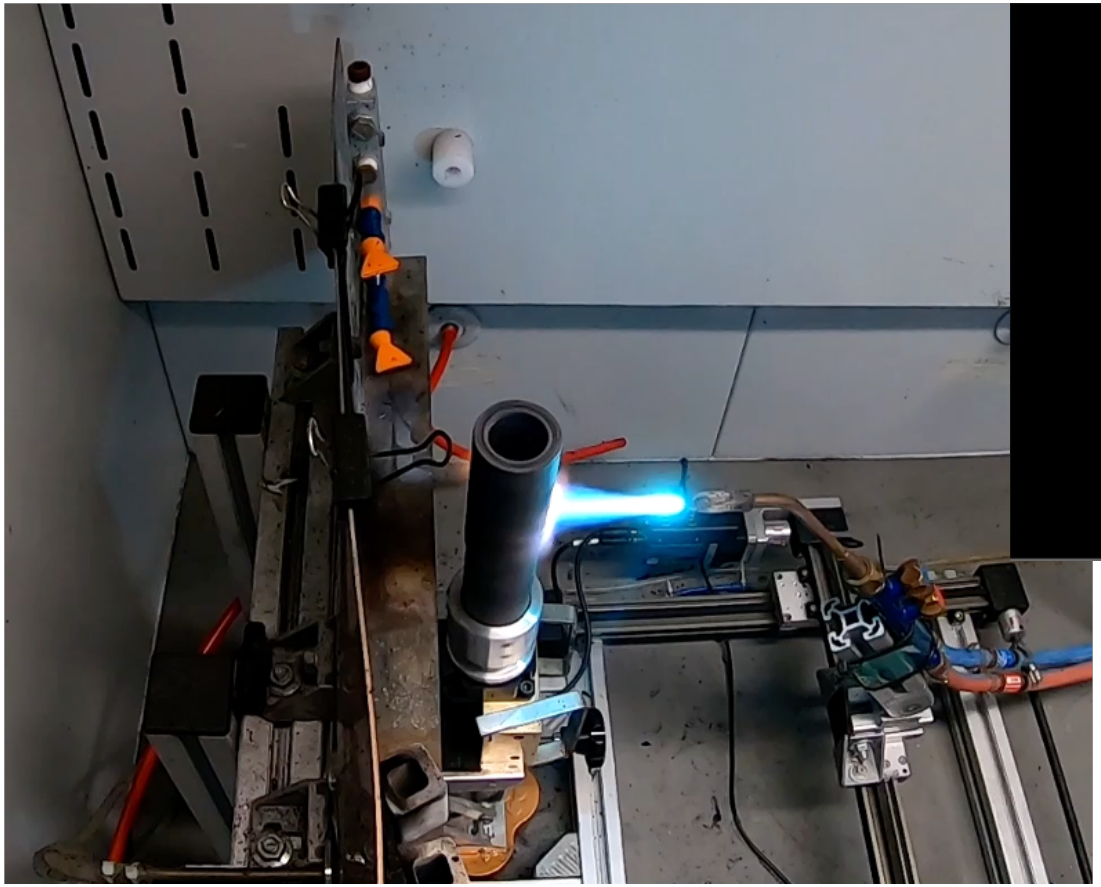
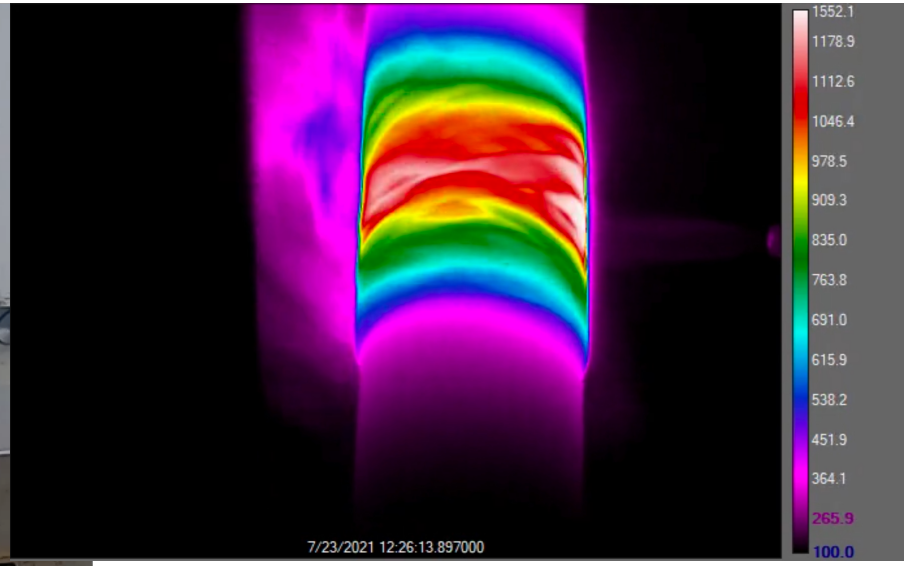
Sapienza ablative materials

Industrial partnership and collaborations





AVIO

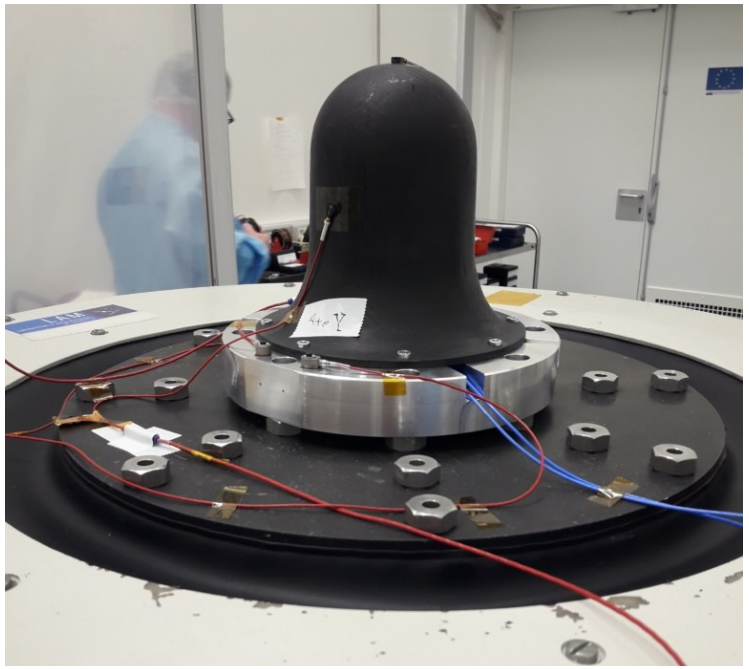
Sapienza ablative materials

Industrial partnership and collaborations

Aviosonic Space Tech

Aviosonic Space Tech is developing the DeCAS (Debris Collision Alert System)

Sapienza University started a partnership with Aviosonic for the development of DeCAS thermal shield



Composite sandwich structures

- ✓ Sandwich composites are increasingly used in aerospace, marine, automotive, construction, transportation and other high technology industries
- ✓ Composite sandwich structures offer many advantages such as high flexural stiffness, low weight, and flexibility in selection from a broad range of materials
- ✓ Other benefits of sandwich constructions include excellent thermal insulation, acoustic damping, fire retardation, ease of machining, ease of forming, etc.
- ✓ A major concern that limits the usage of sandwich composites is their susceptibility to damage due to impact loading (e.g., tool drops, runway debris, bird strikes, hailstorms and ballistic loading)

Composite sandwich structures

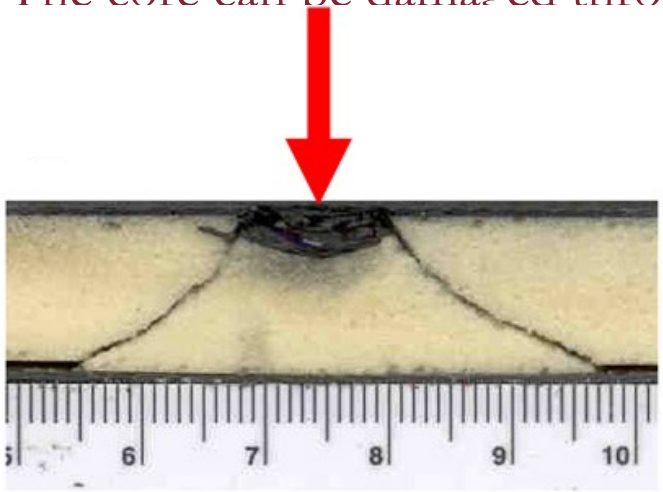
Much more complex scenario compared to conventional laminates……

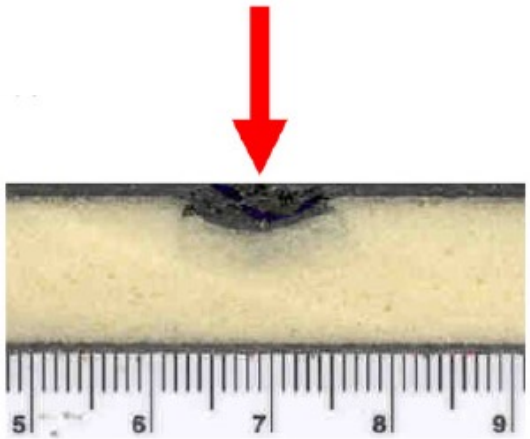
Impact can induce various types of damage in the structure:

✓The facesheets can be damaged through delamination and fibre breakage

✓The facesheet/core interface region can be compromised with debonding

✓The core can be damaged through crushing and shear failure mechanisms





Hosur et al., Materials Science and Engineering A 498 (2008) 100–109

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Green" sandwich structures

DIEHL Aerosystems

DLR

Natural Fiber Reinforced Plastics for Aircraft Cabins

LINEO

AIMPLAS
INSTITUTO TECNOLÓGICO DEL PLÁSTICO

CAYLEY

INVENT

BOEING

A project dedicated to industrial implementation for new flat panels from renewable polymers and natural fiber reinforcements (flax) for the aeronautical industry

Demonstrator sandwich panel made of flax fiber reinforced top layers and flame retardants (A380 hat rack, scale 1:2)

➢ **Numbers of panels can be found in all means of public transport**

- Ceilings
- Fairings
- Compartments
- Overhead lockers
- etc.

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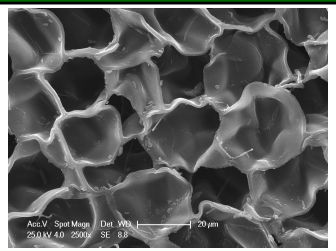
"Green" sandwich structures

- ✓ Cork, obtained from the bark of *Quercus suber L* tree, is an excellent example of renewable and recyclable cellular material
- ✓ Cork is characterized by high dimensional recovery, good thermal and acoustic insulation properties, limited permeability to liquids and gases, chemical stability and durability
- ✓ Another advantage of agglomerated cork is the possibility to tailor its mechanical response by varying those production parameters that have been reported to markedly affect its quasi-static and dynamic response, such as binder type and amount, grain size and agglomerate density

"Green" sandwich structures

✓ ***Sandwich bonding***
Redux 609 by Hexcel
Epoxy film adhesive containing a cotton scrim

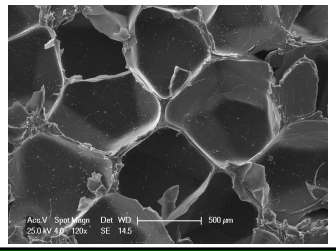
Agglomerated Cork (ELD)
ρ = 145 kg/m³



t = 30 mm

Skins_Flax/Epoxy laminates (t=1.4 mm)
180 g/m² for flax (UD), supplied by Lineo
Quasi-isotropic configuration: $[+60/0/-60]_s$
Panels were vacuum-bagged and fully cured under pressure in an autoclave

Rohacell
ρ = 110 kg/m³



t = 30 mm

Rohacell WF110 is a closed-cell rigid foam based on polymethacrylimide (PMI) highly suited for autoclave prepreg processing and all typical resin infusion processes

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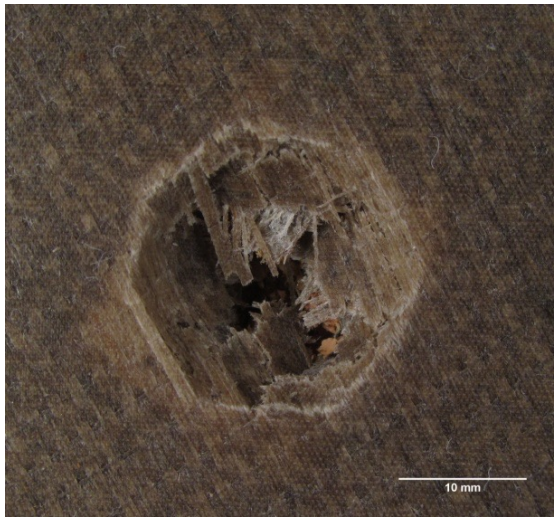
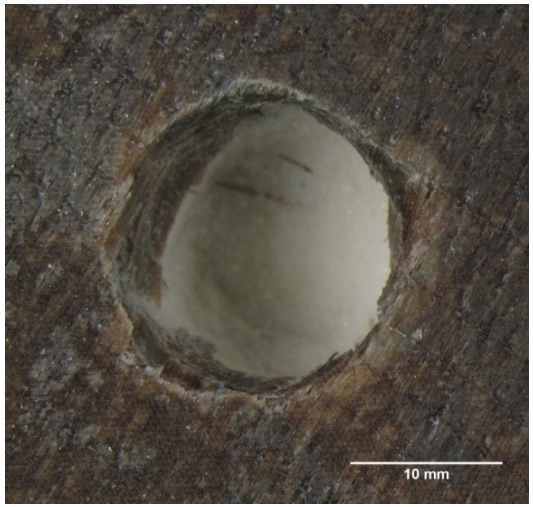
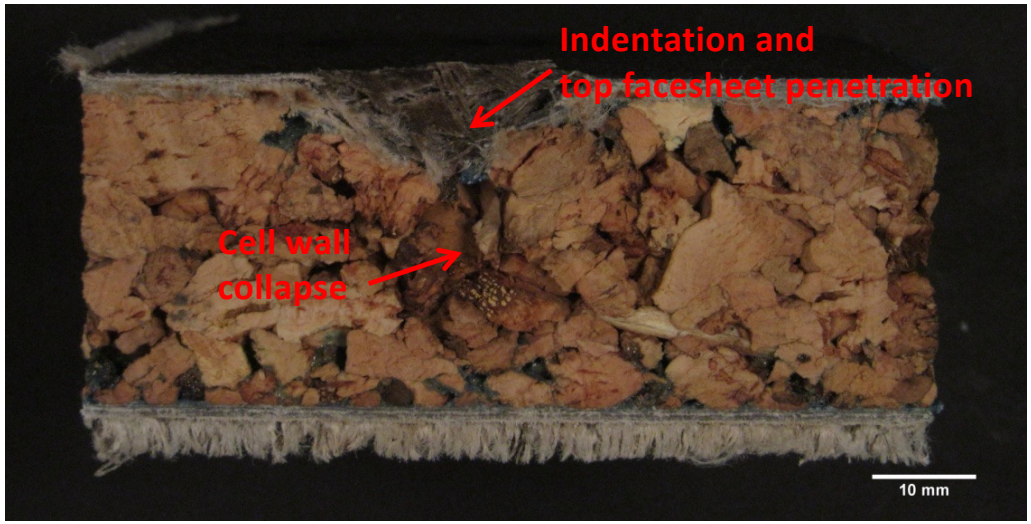
Results-Low velocity impact tests



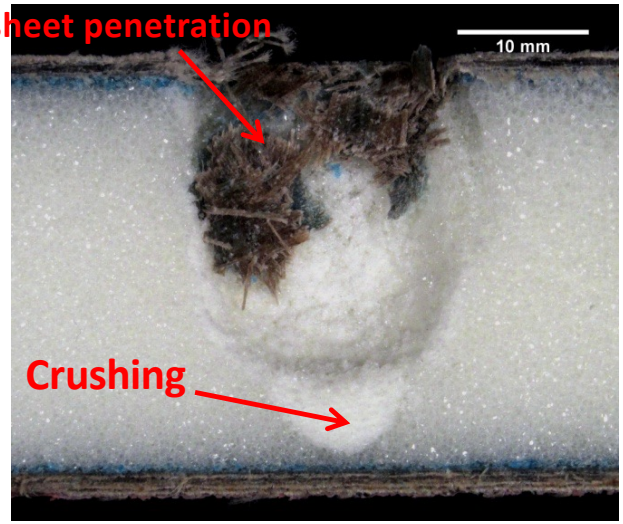
75% of E_p

- ✓ No core shear and cracking up to impact energies ≤ 75% E_p
- ✓ No bottom facesheet damage up to impact energies ≤ 75% E_p
- ✓ Lower damage degree for neat cork and resulting sandwich compared to Rohacell





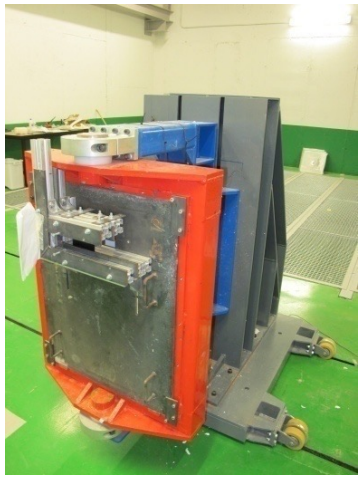
Indentation and
top facesheet penetration



High velocity impact tests

Tests performed at the Universidad Carlos III de Madrid
Mecánica de Medios Continuos y Teoría de Estructuras
Prof. E. Barbero and S. Sánchez Sáez
PhD Student Claudia Sergi – Co-Tutela

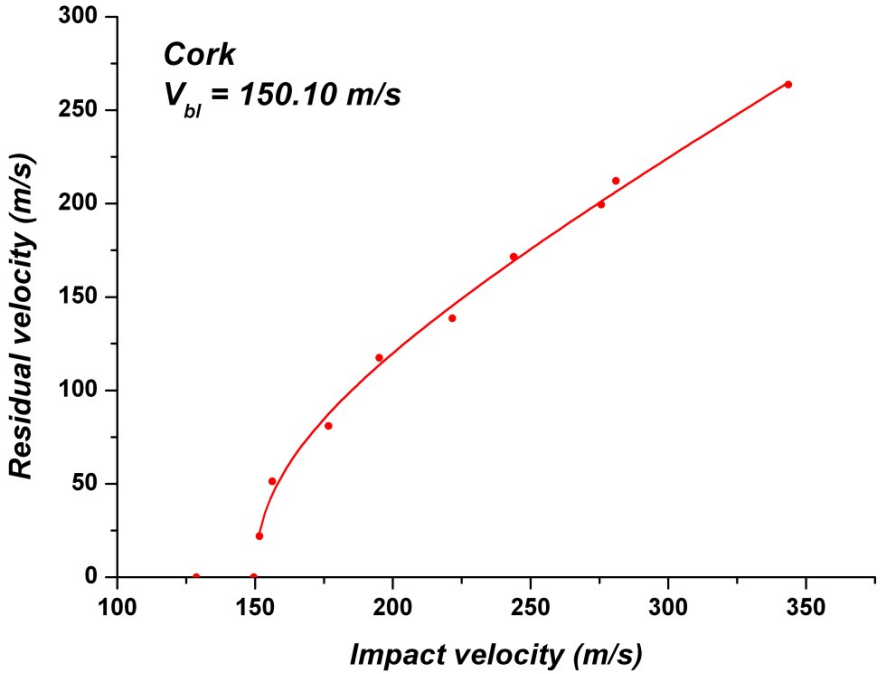
The high velocity impact tests have been performed on 12-15 specimens for each configuration using a helium (stargon) gas-gun test set up with a spherical tempered steel projectile (mass = 1.725 g, diameter = 7.5 mm) over a range of impact energies until complete perforation of the target is achieved



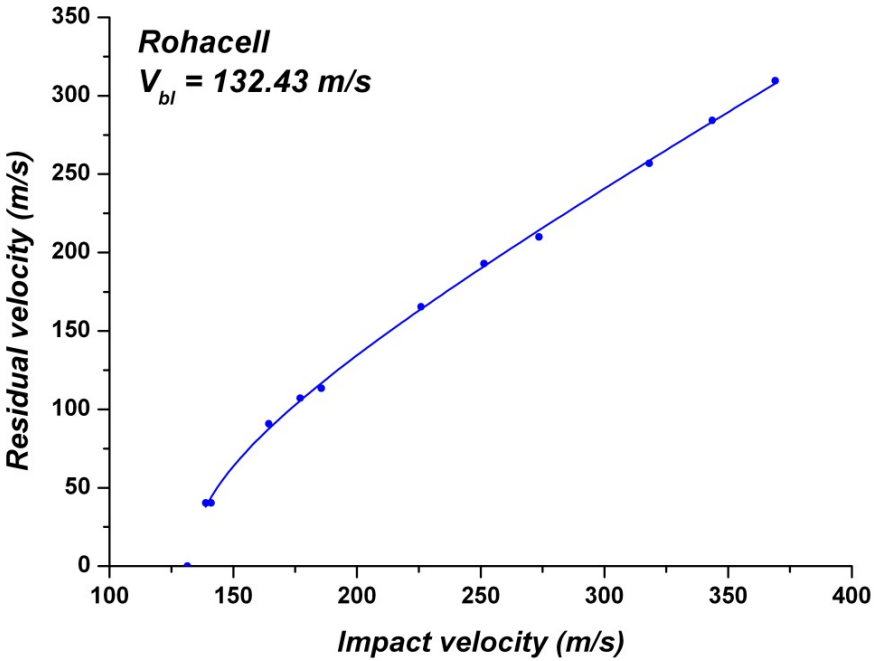
SABRE BALLISTICS A1G

To measure impact and residual velocity, a high speed digital camera ULTIMA FASTCAM APX RS), with a data acquisition system capable of taking 36000 frames per second, is placed beside the impact chamber

Results-High velocity impact tests



V_i ~ 177 m/s



V_i ~ 177 m/s

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Problem Statement and Motivation

- ✓ In an attempt to reduce the environmental impact of synthetic polymers and reinforcements, there has been a resurgent interest in the use of natural fibres in polymer matrices

- ✓ Many types of natural fibres like sisal, kenaf, hemp, flax, jute have been studied and applied but vegetal fibres are very sensitive to thermal and hygroscopic loads and show limited and variable mechanical properties due to the plant growing and harvesting conditions, the fibre extraction system, the variable fibre shape and geometry

- ✓ Another drawback is the chemical incompatibility with many hydrophobic polymer matrices which results in a low fibre/matrix interface strength and limited stress transfer efficiency

- ✓ *A possible solution that takes into account the environmental issues is represented by the use of natural fibres but of mineral origin, such as* ***basalt***

Problem Statement and Motivation

Closed loop recycling process

Pyrolysis – thermal recycling process

Fibres strength decrease

Chemical regeneration treatment

Fibres strength recovery

CO_2

J.L. Thomason et al., Composites: Part A 87 (2016) 220–227
S.T. Bashir et al., Composites: Part A 102 (2017) 76-87

Engineered interfacial adhesion

Two main research areas:

1) Surface modification of basalt and flax fibers by environmentally friendly processes

- Plasma enhanced CVD – In collaboration with Prof. Vladimir Cech (Brno University of Technology, Czech Republic)

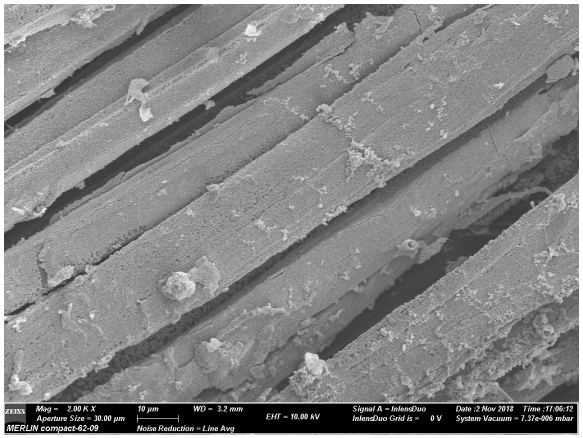
- Supercritical CO_2 treatment - In collaboration with Dr V. Placet (Université de Franche-Comté, France)

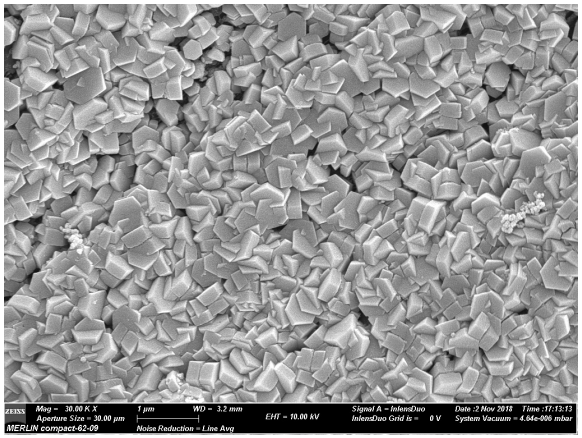
Engineered interfacial adhesion

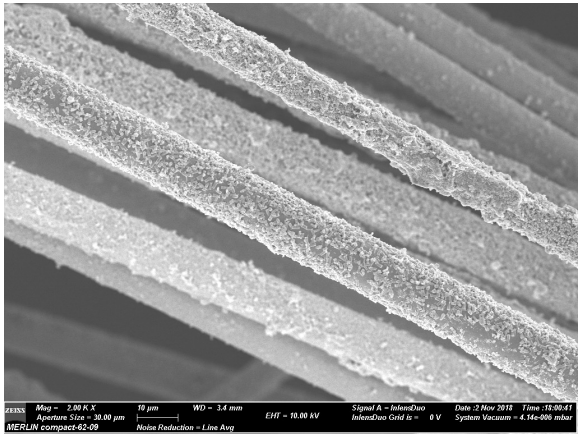
2) Hierarchical structures

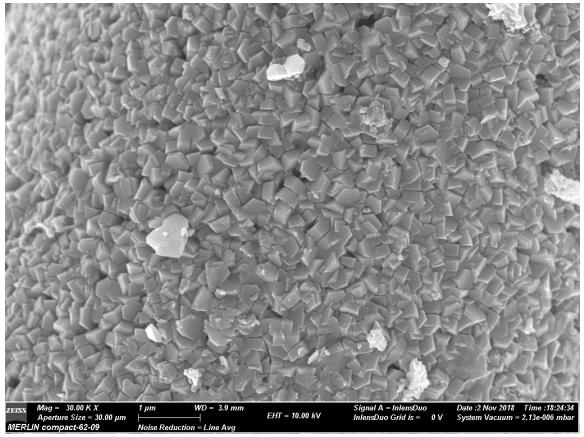
- Decoration of Flax fibers with ZnO nanostructures

- Decoration of Basalt fibers with ZnO nanostructures





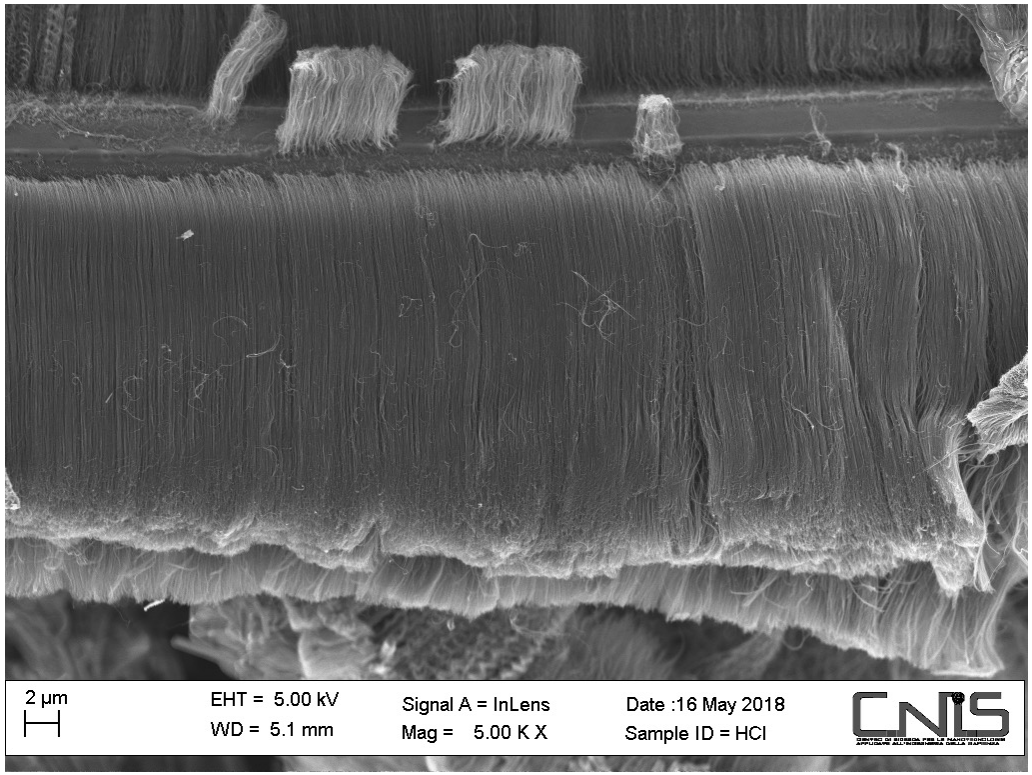




Engineered interfacial adhesion

2) Hierarchical structures

- Growth of MWCNTs on Basalt fibers (by CVD)



Prof. Brian L. Wardle

nano-engineered composite aerospace structures consortium

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