National Institute for Aerospace Research & Development
"Elie Carafoli"
I.N.C.A.S.

# Nanocomposites and Nanotechnologies in Aerospace Research

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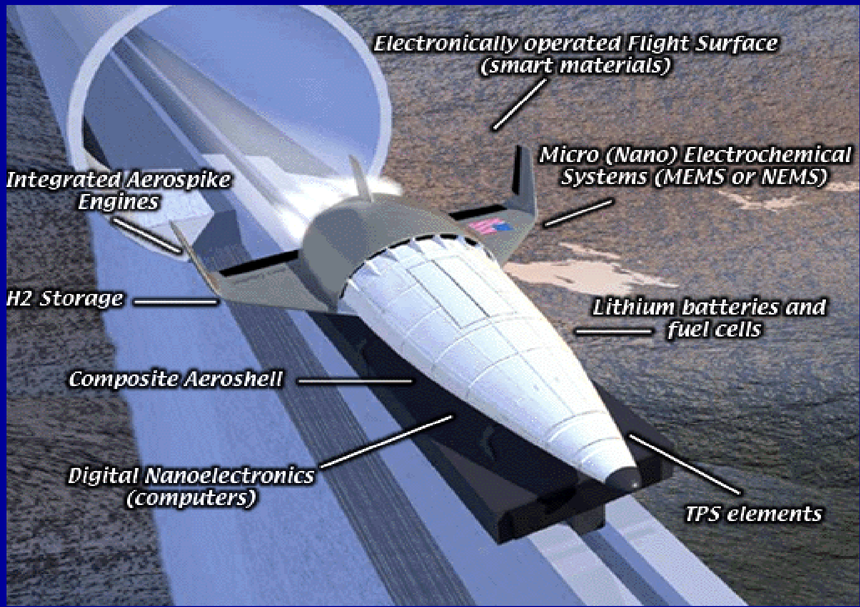
# NANOMATERIALS AND NANOTECHNOLOGIES

- The interest in nanomaterials and nanotechnologies is a direct consequence of the synthesis of fulerens in 1985 (Smoley and Croto), the third existence  form of carbon, a stable and an ordered structure, besides the already existing as diamond and graphite.



## APPLICATIONS OF NANOMATERIALS

- **In aircraft construction the nanocomposites represent an advanced material solution:**

  - **In aircraft construction as strengthening element for the structure (stringers, frames) or as skin for the honeycomb type structures use at wings and fuselage;**
  - **Base materials for high temperatures, the nano carbon-carbon composites were first developed for the aerospace technology (components and missiles, re-entry vehicles, space shuttles and as a brake lining and brake disk material for civil and military aircraft. These materials with nanoadditivated ceramic matrix represents the potential unique solution for the radoms of the hypersonic airplanes;**
  - **Nanocomposites with the form of zirconia based complex nanopowders are used as thermal protection for pieces of turboengines;**
  - **INCAS researches regarding nanomaterials and nanotechnologies has a start stage the projects form the CEEX programme 2005 and they are reffering to two types of nanocomposites:**
    - **Polymeric nanocomposites additivated with carbon nanotubes and nanoclays**
    - **$ZrO_2$ based nanocoatings as thermal barrier coatings**

# RESEARCH DIRECTIONS

- **Nanocomposites**

- Polymer nanocomposites with carbon nanotubes and nanoclays;
- Carbon fibre – nanoadditivated polymer matrix composites;
- Glass fibre – nanoadditivated polymer matrix composites;
- Carbon-carbon composites (nanoceramics matrix);
- Hybrid metal/fiber composites (Graal type) with nanoaddtivated matrix;

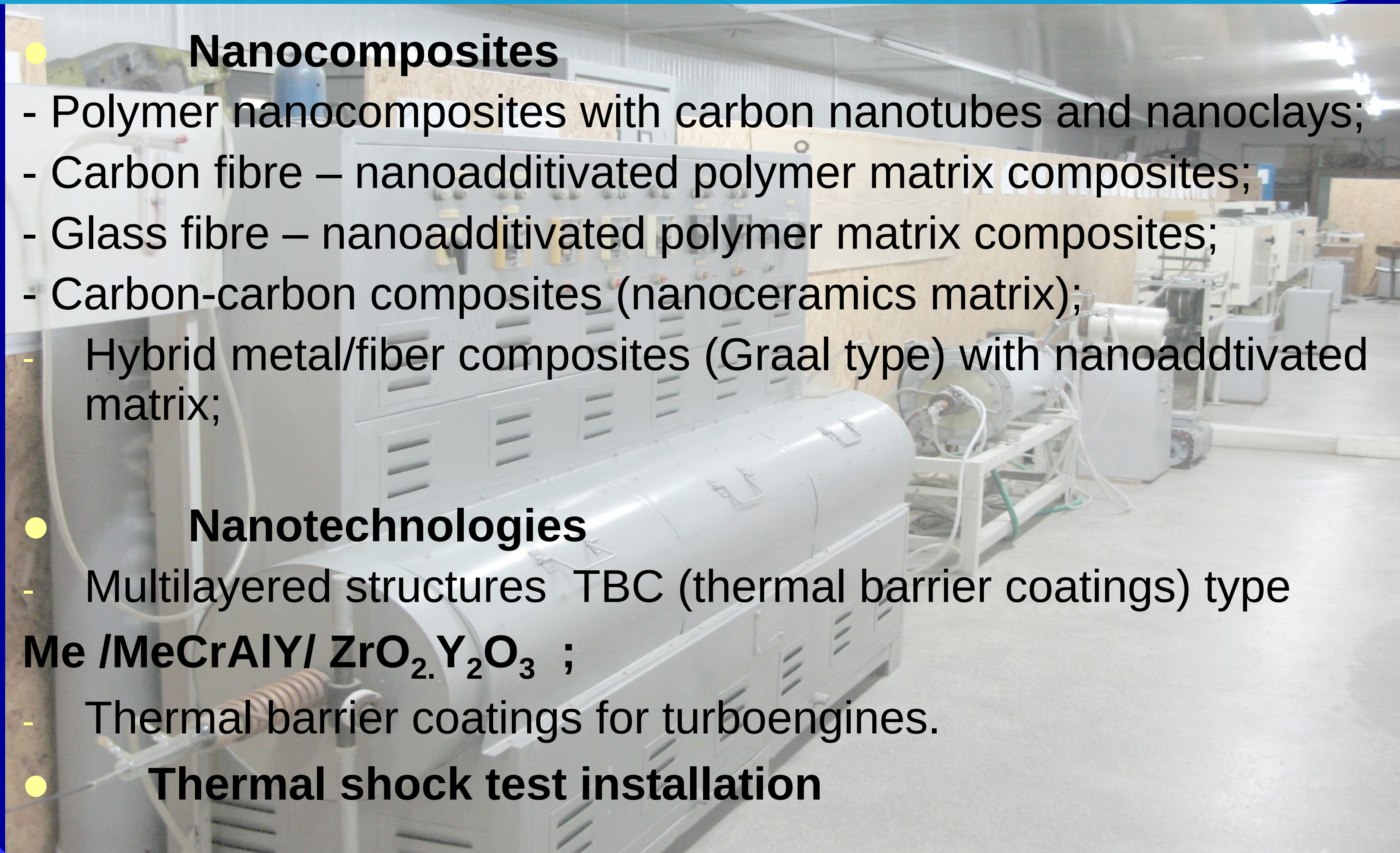
- **Nanotechnologies**

- Multilayered structures TBC (thermal barrier coatings) type

**Me /MeCrAlY/ $ZrO_{2.}Y_2O_3$ ;**

- Thermal barrier coatings for turboengines.

- **Thermal shock test installation**



# EXPERIENCE

- Advanced materials for aerospace industry: carbon-carbon composites mesophasic matrix with nanotubes fillers and hybrid fibre/metal composites –X1C05 –Compas

- Nanocomposites polymer-nanocarbon and polymer-nanoclays – NANOCHRASN

- **Advanced composite structures for aerospace and transportation** –SUPERSOLID

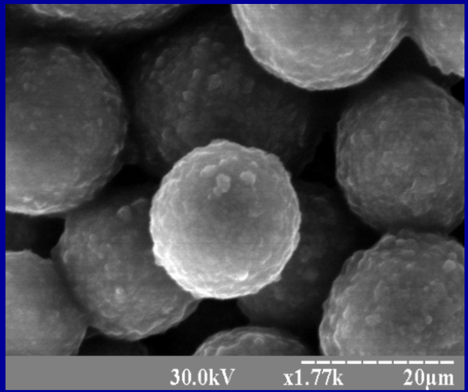
- **Advanced materials for aerospace industry and transport: polymer nanocomposites-carbon/ glass fiber reinforced structure additivated with carbon or silicon carbide –** MAVIAT

- **Multilayered materials for extreme heat conditions in aeronautics. Installations and test method**- MMCTE

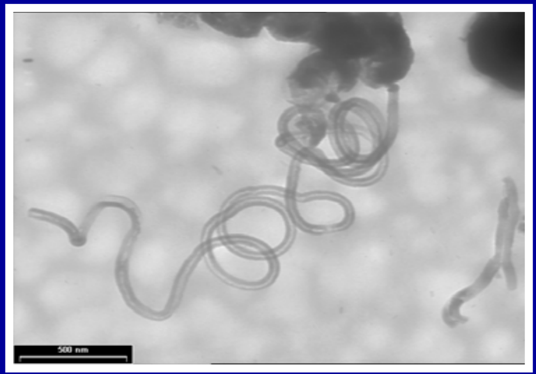
- Compositional gradient materials based on micro-and nanostructured zirconia for thermal-resistant structures with applications in energy and aerospace industry - GRAZIR

# NANOMATERIALS

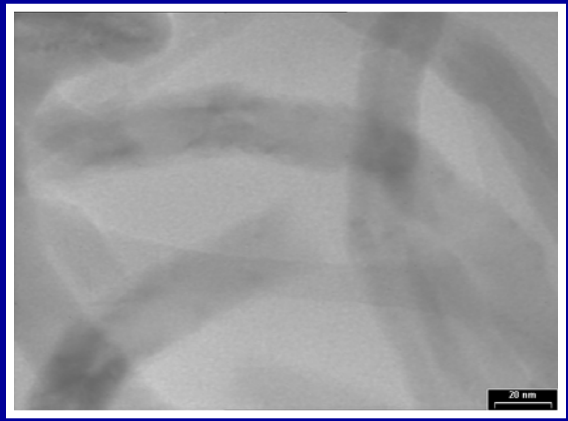
- Carbon-carbon composites consisting of a carbon fiber reinforced structure embedded in a polymer matrix or mesophases that through a proper heat treatment transforms all in carbon;




Oil mesophase additived with carbon nanotubes



**Carbon nanofibres**

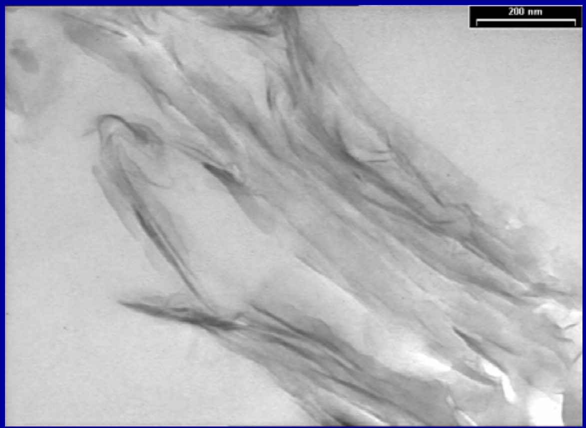


Tubular structure of MWCNTs

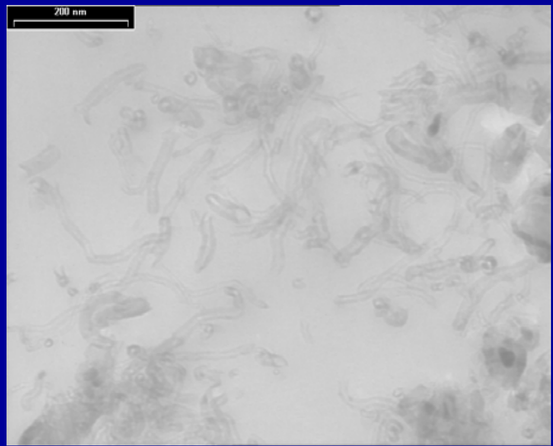
# NANOMATERIALS

- Nanocomposites with epoxy or polyamide matrix additivated with two types of nanofillers: laser-synthesized nanocarbon and layered silicate

- Structural carbon fiber reinforced composites with a matrix made from the two types of nanocomposites.




Nanocomposite Epoxy/ montmorilonite




Nanocomposite Epoxy/carbon nanotubes

# Thermo-mechanical results for the system matrix + 2% nanoadditive

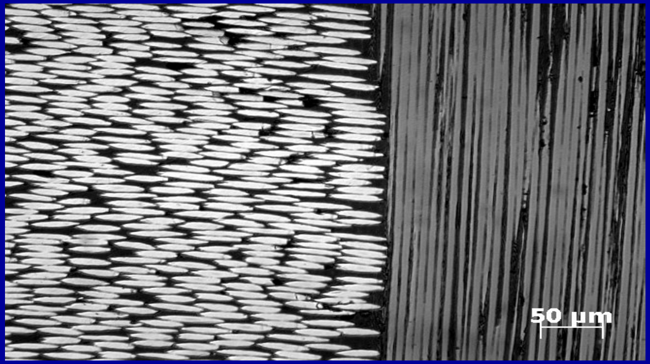
| No | The material | Tensile strength MPa | Shore Hardness | Thermal stability °C |
|---|---|---|---|---|
| 1 | P 401 | 95 | 75 | 50 |
| 2 | P401 + 2% Montmorillonite 30B | 102.5 | 83 | 56 |
| 3 | P 401 + 2% Montmorillonite 93A | 92.2 | 83 | 56 |
| 4 | P 401 + 2% $C_2H_2/C_2H_4$ | 115 | 81 | 59 |
| 5 | P 401 + 2% $C_2H_2/SF_6$ | 85 – 90 | 79 | 56 |
| 6 | P 401 + 2% $C_6H_6/C_2H_2$ | 86 | 79 | 56 |
| 7 | P 401 + 2% MWNTs –China | 121.8 | 85 | 59 |
| 8 | P 401 + 2% SWNTs– China | 96 | 77 | 55 |
| 9 | P 401 + 2% MWNTs -Greece | 98 | 77 | 55 |
| 11 | P401+2% $C_2H_4/C_6H_6/N_2O$ | 120 | 83 | 57 |

| No | The material | Modulus of elasticity x $10^4$ |
|---|---|---|
| 1 | P401 | 2.8 |
| 2 | P 401 + 2% MWNTs | 3.42 |
| 3 | P 401 + 2% $C_2H_2/C_2H_4$ | 3.60 |
| 4 | P401 + 2% Montmorillonite 30B | 3.1 |
| 5 | P 401 + 2% $C_2H_4/C_6H_6/N_2O$ | 3.6 |

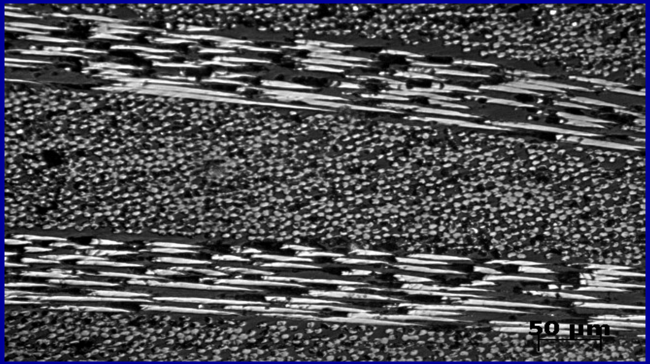
- P 401 – the epoxy resin
- C2H2/C2H4 – laser synthesized nanocarbon particles (INFLPR)
- C2H2/SF6 – laser synthesized nanocarbon particles (INFLPR)
- C6H6/C2H2 – laser synthesized nanocarbon particles (INFLPR)
- C2H4/C6H6/N2O – laser synthesized nanocarbon particles (INFLPR)

# Nanocomposites carbon / glass fibre- nanoadditivated epoxy resin Microstructural analysis


Sample carbon fibre/ non-additivated matrix (200x)




Sample carbon fibre/ nanoadditivated matrix (200x)




Sample carbon fibre/ non-additivated matrix (200x) –cross section

Fairing of the landing gear (hybrid FC/Al epoxy matrix composites)

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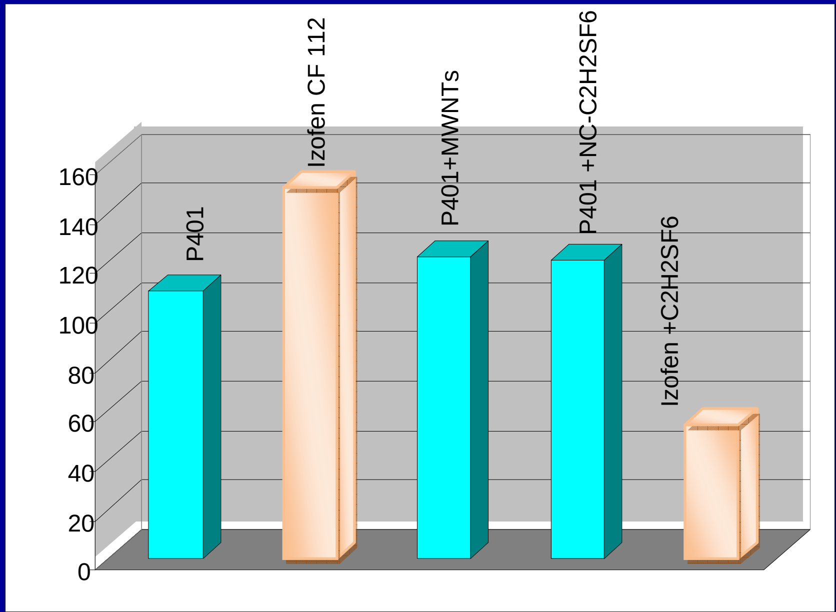
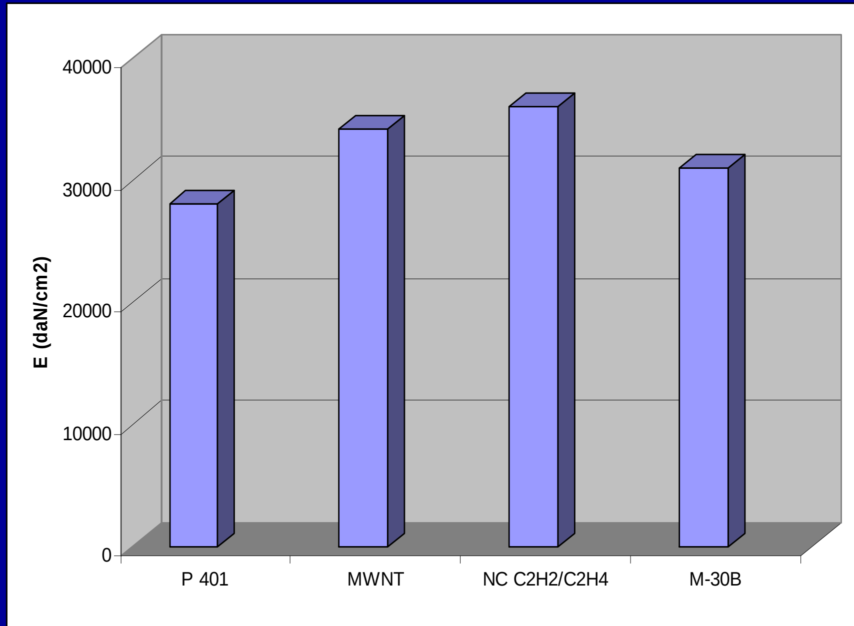
# Thermo-mechanical and tribological properties of nanocomposites carbon / glass fiber – nanoadditivated epoxy resin

| No. | The material | Tensile strength MPa | Modulus of Elasticity MPa | Shore Hardness | Thermal Stability $^{0}$ C | Friction coefficient |
|---|---|---|---|---|---|---|
| 1 | Rasina epoxi P401 | 95 | 2.8 x$10^{4}$ | 75 | 55 | 0.2 |
| 2 | CF/P401 | 638 | 1.1 x$10^{4}$ | 86 | 130 | 0.132 |
| 3 | GF/P401 | 416 | 2.3 x$10^{3}$ | 83 | 129 | 0.25 |
| 4 | CF/P401+MWNTs-functionalized(2%) | 490.7 | 1.38 x$10^{4}$ | 87 | 131 | 0.134 |
| 5 | CF/P401+MWNTs | 490 | 1.38 x$10^{4}$ | 87 | 136 | 0.134 |
| 6 | CF/P401+SWNTs | 480 | 1.38 x$10^{4}$ | 86 | 128 | 0.130 |
| 7 | CF/P401+carbon nanofibres | 430 | 1.28 x$10^{4}$ | 85 | 135 | 0.130 |
| 8 | CF/P401+nanocarbon ($C_2^-H_2^{3-/}C_2H_4$) | 650.6 | 1.36 x$10^{4}$ | 88 | 138 | 0.130 |
| 9 | CF/ P401+Montmorilonit | 440 | | 87 | 130 | 0.143 |
| 10 | GF/ P401+Montmorilonit | 366 | | 86 | 120 | 0.22 |
| 11 | GF/ P401+ MWNTs-functionalized | 391.4 | | 85 | 120 | 0.19 |

# Beneficial effects of nanoaddtitives




**The tensile strength of epoxy resin P401 + nanostructured additives increases with 1015 % . For the phenolic resin the nanoadditivation had a detrimental effect.**




**The modulus of elasticity epoxy resin P401 + nanostructured additives increases with 20-25%**

# Nanotechnologies (II)

## Nanocoatings

- Multilayer structure, ceramics, temperatures resistant, thermal shock, corrosive and erosive wear, fritting, etc. applied at turbo engines and modern co-generative systems;

- **$ZrO_2$** based **t**hermal barrier coatings;

- Monolayer protections, vitro ceramics, related to functional conditions of turbo engines for "hot parts" protections;

- Mono and multilayers protection, for complex alloys, temperature resistant, corrosive and erosive wear, liquid metal contact resistant, related to vital component from siderurgy- tuyeres, lance tips, etc.;

## Nanotechnologies (II)

The properties of thermal barrier coatings (TBC) achieved using nanoparticles:

- The adherence is rising with 10%;
- Decrease the oxygen permeability;
- Increase the resistance at quick thermal shock with $100^0$C/ sec.

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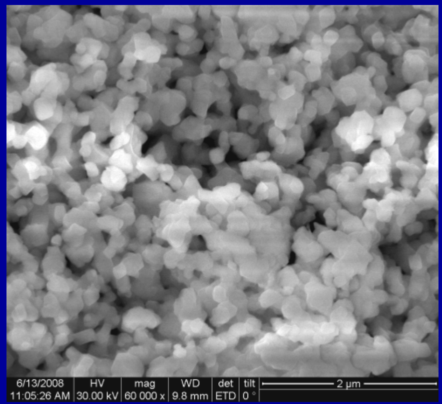
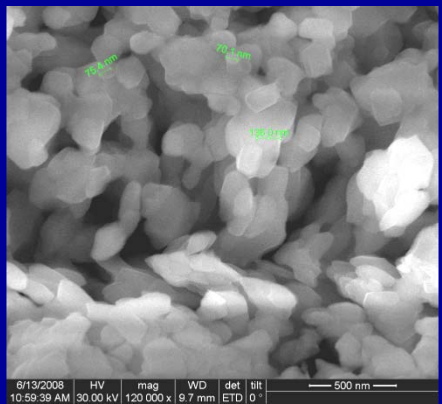
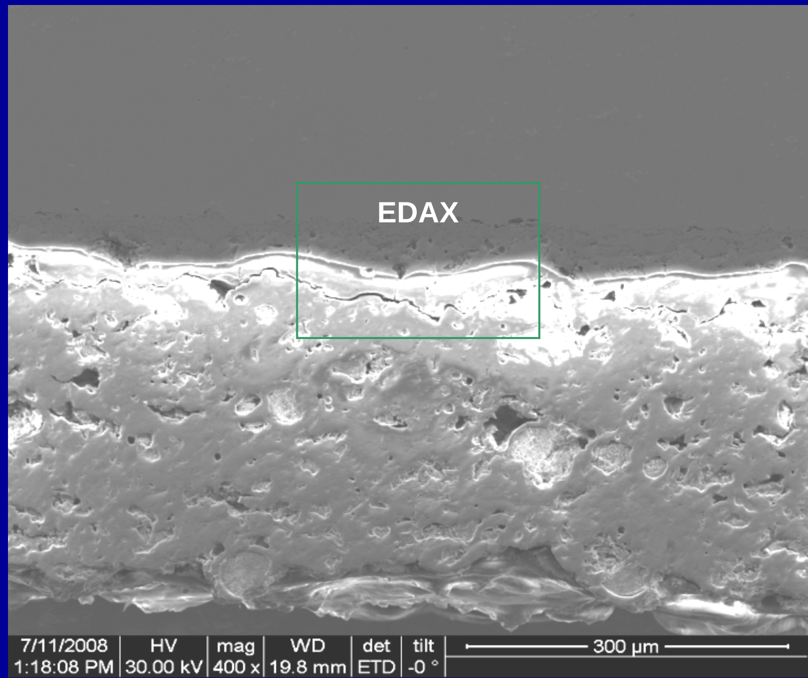
# SEM images of thermal barrier coatings with nanoparticles



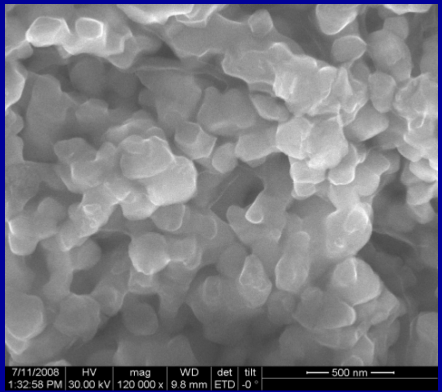




Zirconia nanoparticles observed
at high resolutions (x60 000; x120 000)

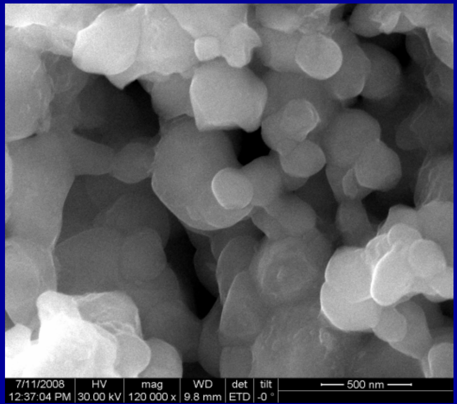



SEM image – TBC coatings **Me /MeCrAlY/ $ZrO_2$.$Y_2O_3$**

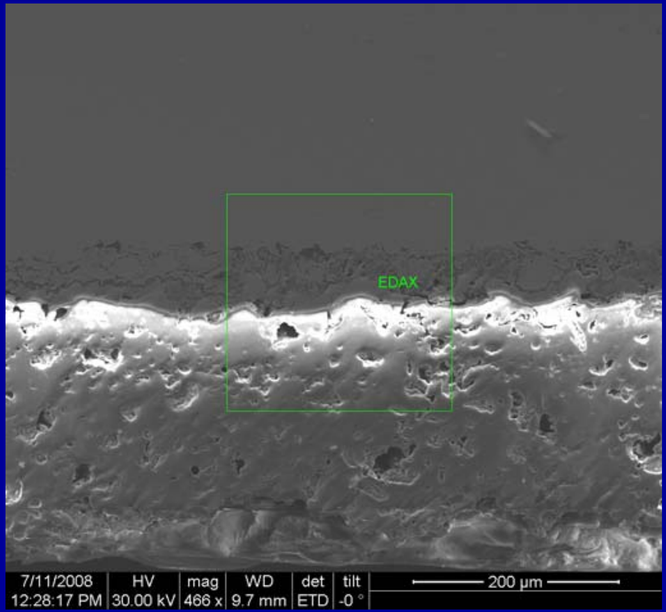
# SEM images of thermal barrier coatings with nanoparticles




Zirconia powder partially compacted (x120.000)




Zirconia powder partially compacted – after quick thermal shock test (x120.000)




SEM image of sample **Me /MeCrAlY/ $ZrO_2Y_2O_3$** submitted at quick thermal shock test

**After the thermal cycling there is formed a TGO (thermal grow oxyde) sublayer associated with the delamination process**

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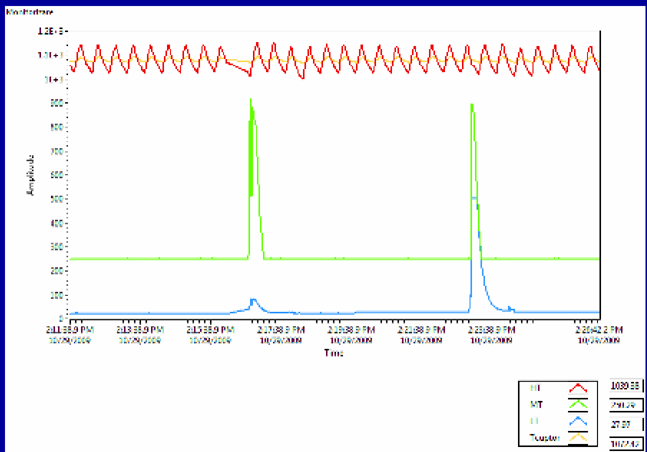
# Thermal shock test installation- QTS2

•Quick thermal shock test installation conceived and achieved by INCAS is going to be patented;
•The installation and the method allows the comparative evaluation of materials reported to the wear resistance;
•The thermal shock test corresponds to heating/cooling speeds of 100$^0$C/sec witch appears in the operation of turbo engines (take-off , landing);
•The thermal shock test equipped with acquisition data system (LabView), it is a real technical solution



LabView data acquisition diagram


Testing temperature: 1700$^0$C,
Specimen heating speed – max 100$^0$C/sec,
Specimen cooling speed – max 100$^0$C/sec,
Operate in manual and automatic cycle;

# INTERNATIONAL PROPOSALS

- The FP7 project proposal HyLam will perform an in-depth technology study of hybrid composite laminates for their use in primary loaded joints of civil aircraft applications; the project comprise a study regarding the nanoadditivated hybrid laminates;

  Partners: DLR-Germany, ARNVA- Spain,
  ARTTIC –France, ASCO INDUSTRIES N.V. –Belgium, CoExPair- Belgium,
  HENKEL KGaA- Germany, INEGI- Portugal, NLR- Netherlands,
  SHORT BROTHERS PLC- United Kindom,
  STORK SP AEROSPACE B.V.- Netherlands, UGNA- Spain.

- The FP7 project proposal, Comp-air aims to explore the existing metal-composite technologies in the small aircraft industry and to make an important step towards the reduction of aircraft development costs;

  Partners: Corvus Aircraft Ltd.- Hungary, Slot Consulting Ltd.- Hungary,
  CENAERO-Belgium, Fraunhofer- Germany, REA – Tech Ltd.- Hungary, KhAI- Ukraine,
  ATARD-Turkey