imdea materiales

ADVANCED STRUCTURAL MATERIALS FOR TRANSPORTATION AND ENERGY GENERATION

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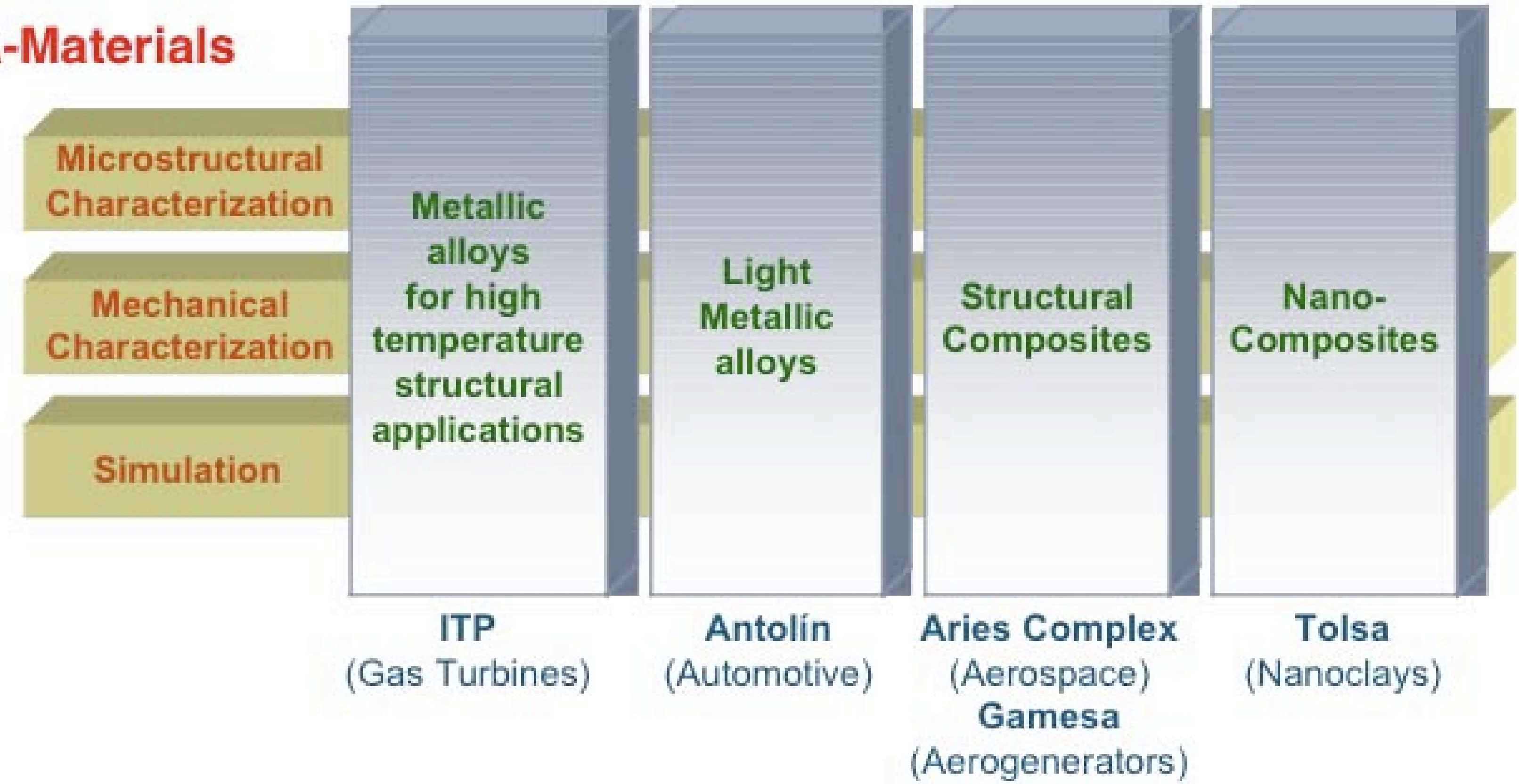
Spain-Japan Joint Workshop on "Nanoscience and New Materials", April 20th, 2009

IMDEA

- IMDEA is a new, efficient and flexible institutional framework promoted by the Comunidad de Madrid to perform research of excellence, carry out technology transfer and attract talented researchers to Madrid in an international environment.

- IMDEA initiative comprises eight research institutes (water, food, social sciences, energy, materials, nanoscience, networks and software). Each research institute is an independent, non-profit private organization.

IMDEA-Materials



IMDEA-MATERIALS

- **Infrastructures:** The research activities of IMDEA-materials began on October 2007 at a provisional site, E. T. S. de Ingenieros de Caminos, UPM. The construction of the final building, located at the Area Tecnológica del Sur (Getafe), will begin in 2009.

- **Researchers:** Over 200 applications for research positions were received from 30 countries in the international calls issued in 2007 and 2008. 18 researchers (from 9 countries) have already joined IMDEA-materials.

- **Facilities:**
  - 2008: Equipment for processing of composites, advanced microstructural characterization and supercomputing (0.6 M€)
  - 2009: Equipment for processing of advanced metallic alloys (0.6 M€)

- **Projects:** (over 2 M€)
  - 4 european projects (Maaximus, Interface, Defcom, Engage)
  - 3 projects funded by industry (Intel, Airbus, FutureFibres)
  - 2 CENIT projects (MAGNO, ICARO)

More information: http://www.materials.imdea.org imdea materiales

SUMMARY

1. OPPORTUNITIES FOR STRUCTURAL MATERIALS

- Transportation
- Energy generation

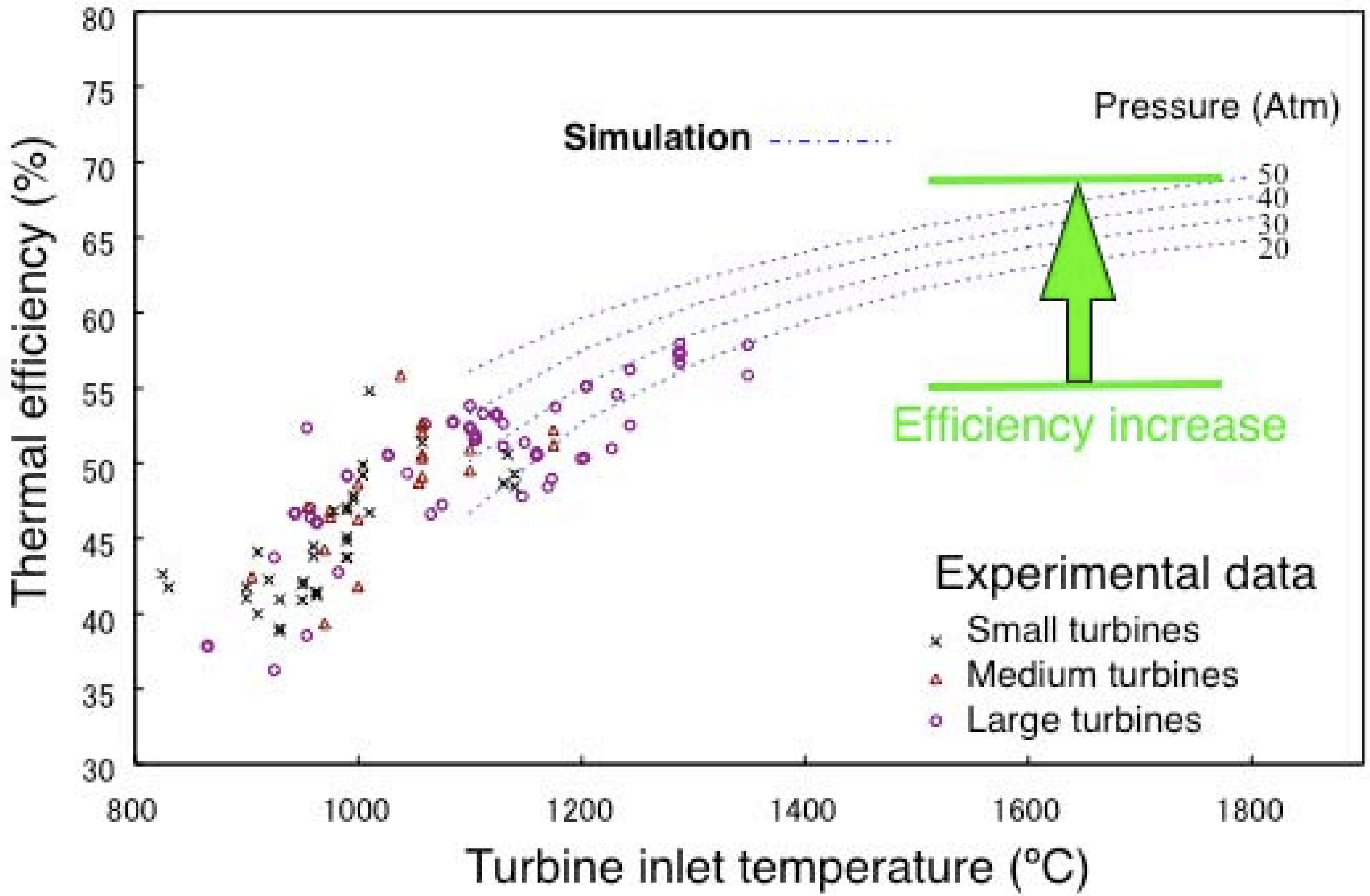
2. RESEARCH LINES

- Polymer nanocomposites: multifunctional capabilities
- Structural composites: supertough and green composites
- Metallic alloys for high temperature: TiAl intermetallics
- Light metallic alloys: Mg
- Multiscale materials modelling: virtual materials

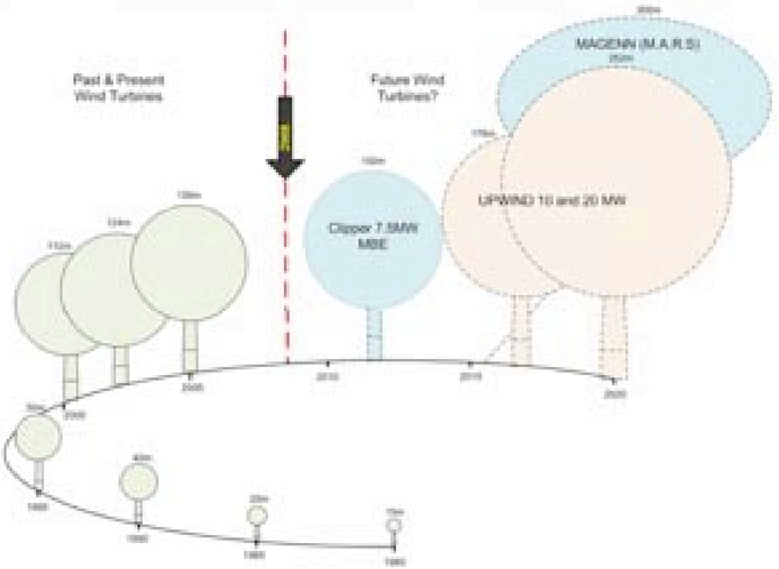
ENERGY CRISIS vs. STRUCTURAL MATERIALS

- High energy prices in the foreseeable future will act as driving force to:
  - Increase the contribution of renewable, clean energy sources.
  - Increase the efficiency of current energy generation systems.
  - Reduce weight in transportation.

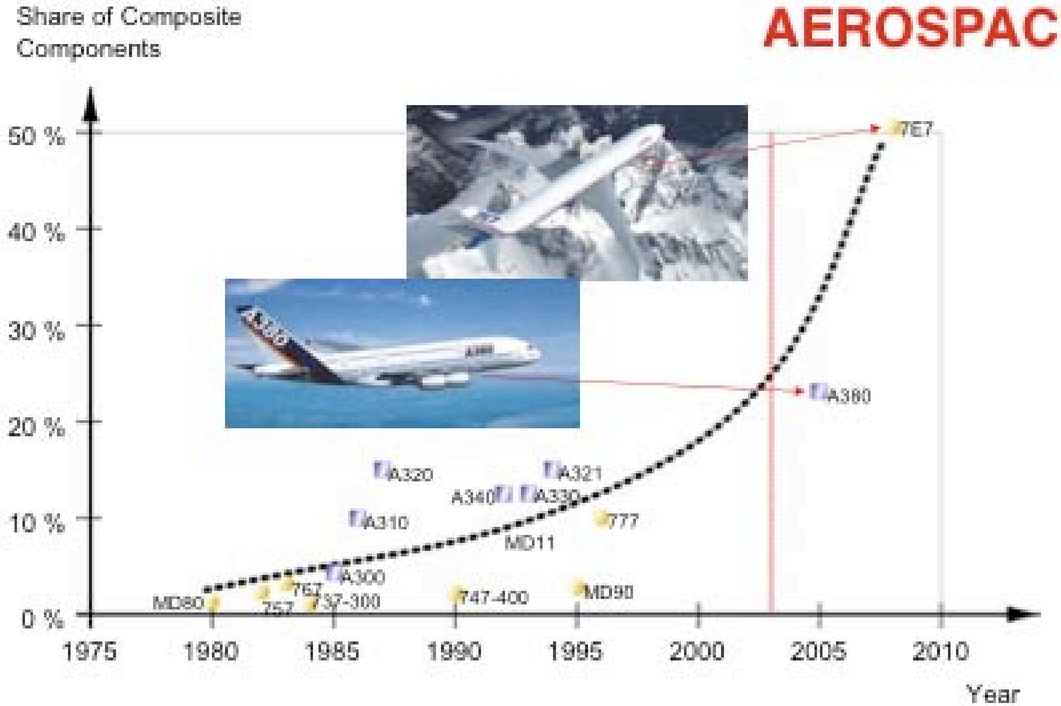
GAS TURBINES



EOLIC ENERGY



AEROSPACE



STRUCTURAL MATERIALS: CHALLENGES

- Higher stiffness and strength, low density.
- Higher temperature operation capabilities.
- Incorporation of multifunctional features (on top of structural ones)
- and last (but not least), structural materials should be damage tolerant ...

Montreal, June 10th, 2007. Robert Kubica is driving his BMW at 280 km/h during the Formula 1 Grand Prix and ...

The “brittle” composite structure was able to absorb the 1.8 MJ of energy. Robert Kubica was out of the hospital in 24 hours.

This was possible through the use of sophisticated materials engineering ...

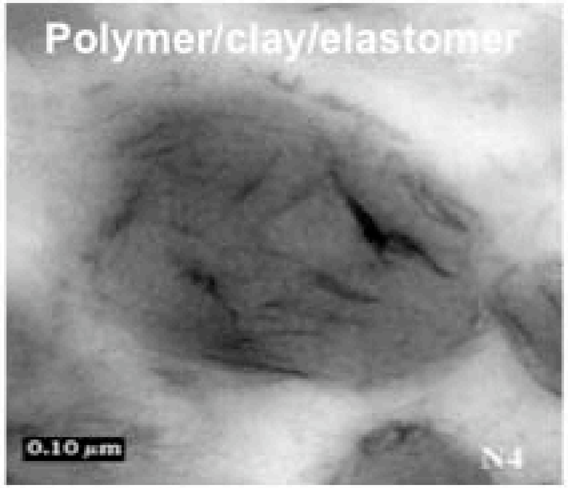
MULTIFUNCTIONAL NANOCOMPOSITES

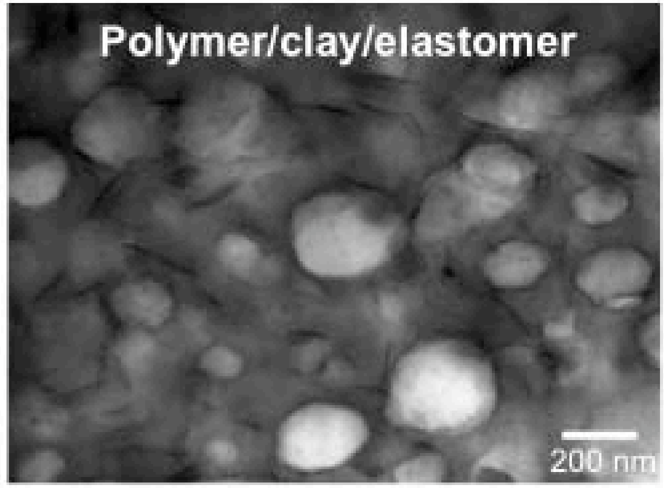
- Exploit and fine tune the characteristics of nanofillers to obtain structural nanocomposites with multifunctional properties:

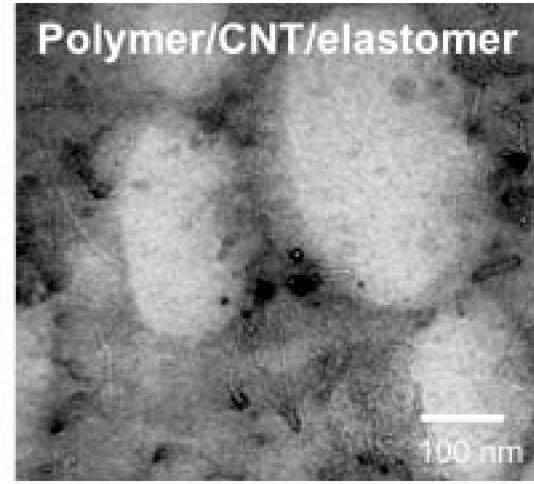
  - Optimum fracture toughness and tribological resistance
  - Thermal stability and fire retardancy
  - Electrical conductivity
  - UV shielding and self-cleaning

- Incorporation of multifunctional nanocomposites as matrices in structural carbon fiber composites to provide enhanced multifunctional capabilities.

MECHANICAL + ELECTRICAL PROPERTIES





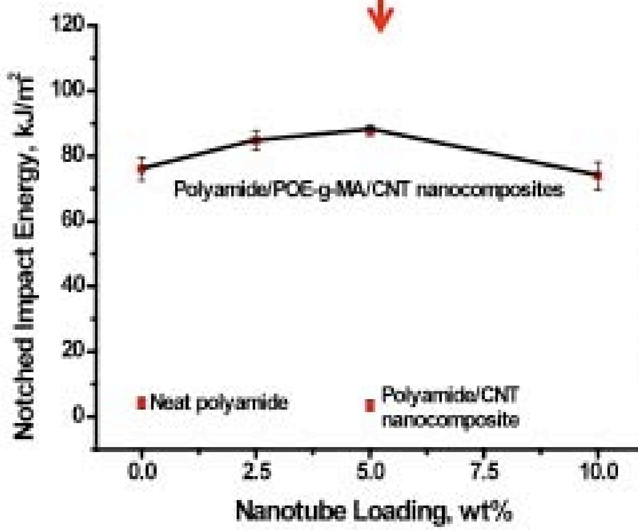


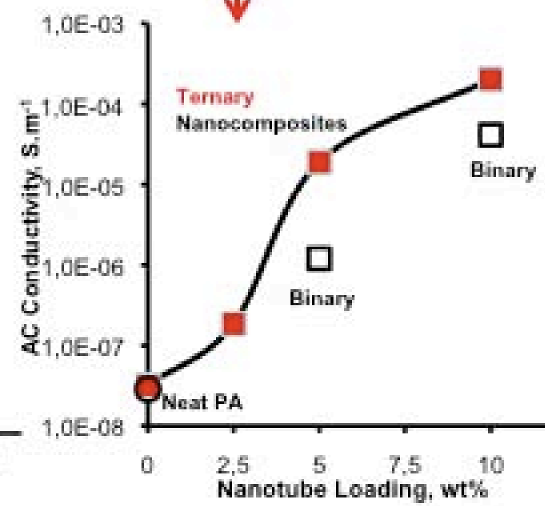
No good for toughness: rigid particles in rubber makes the latter rigid and reduces their ability to cavitate.

Controlled micro/nano-structures

Absence of rigid fillers within elastomer particles

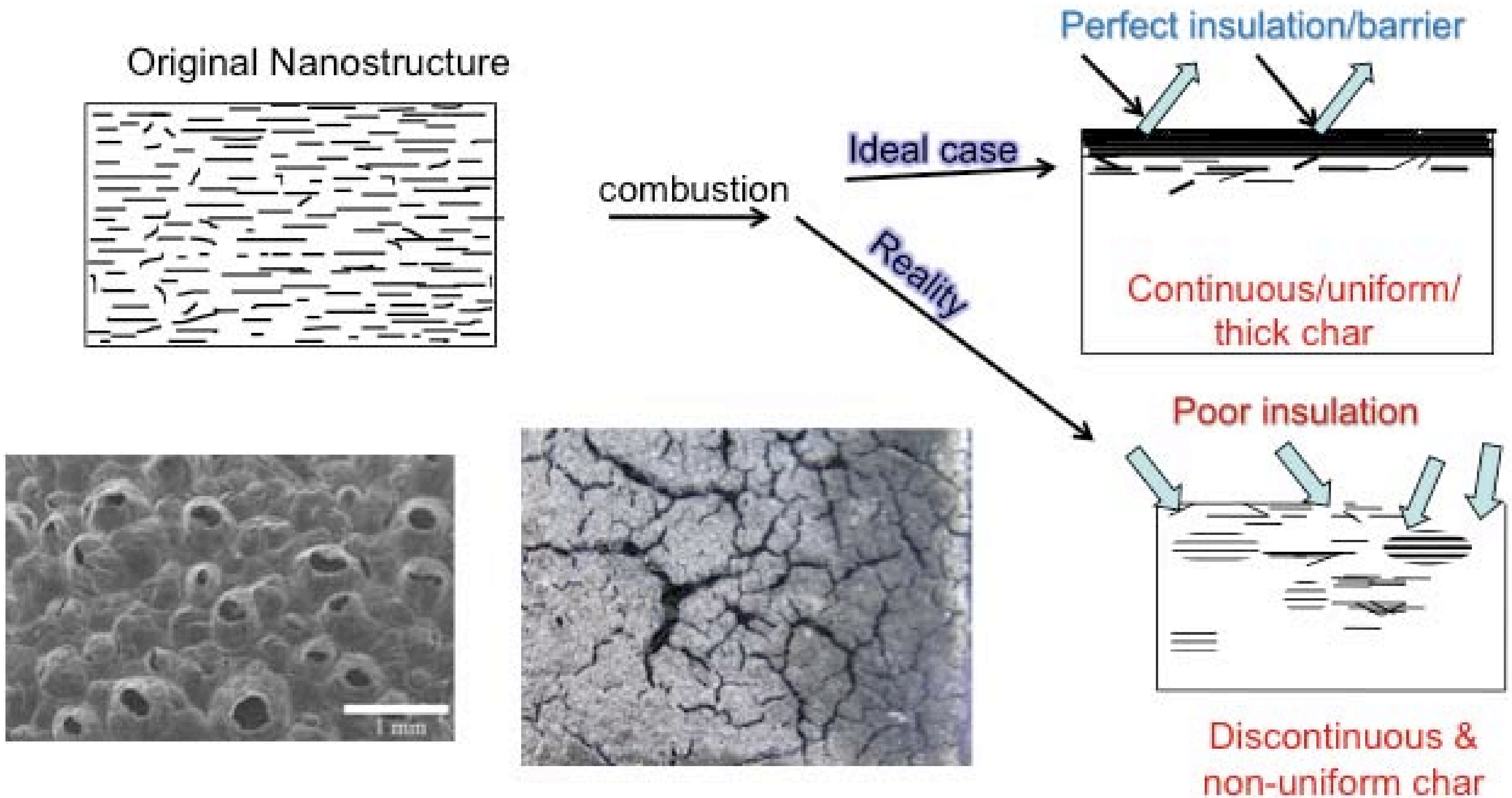
Superior toughness & electrical conductivity





FIRE RETARDANCY

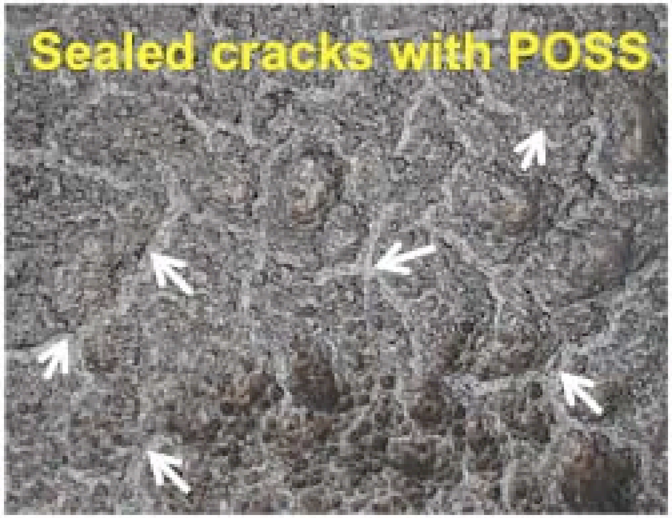
- Every year, more than 300,000 deaths and €15 billion in direct property losses are reported world-wide due to fire hazards (i. e. 20000 TV fires per year in Europe).
- Majority of fires are attributed to polymeric materials in many consumer products including electronics, toys, food packaging, furniture, wall coverings, roof tops, textiles, wires, cables….



FIRE RETARDANCY

OBJECTIVES: use of various approaches with different nanoparticles (clay, CNT, POSS, CNF, graphite oxide, etc) to achieve V-0 rating (in UL94 test), reduced heat release rate and mass loss rate and delayed burning.

- Modification of the clay layers
- Stability and continuity of char
- Migration of clay layers to the burning surface
- Second layer of defense



- These approaches can be further exploited by adding another inorganic additive apart from silicate layers to enhance the packing density and improve the flame retardancy (CNTs or TiO_2).
- Multifunctional polymer nanocomposites:
  - CNT: electrical conductivity, EMI shielding and electrostatic dissipation.
  - TiO_2: UV radiation shielding and combination of photocatalysis/hydrophilicity leads to self-cleaning and self-sterilized properties.

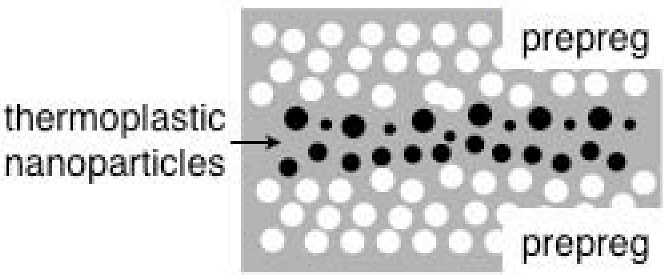
SUPERTOUGH STRUCTURAL COMPOSITES

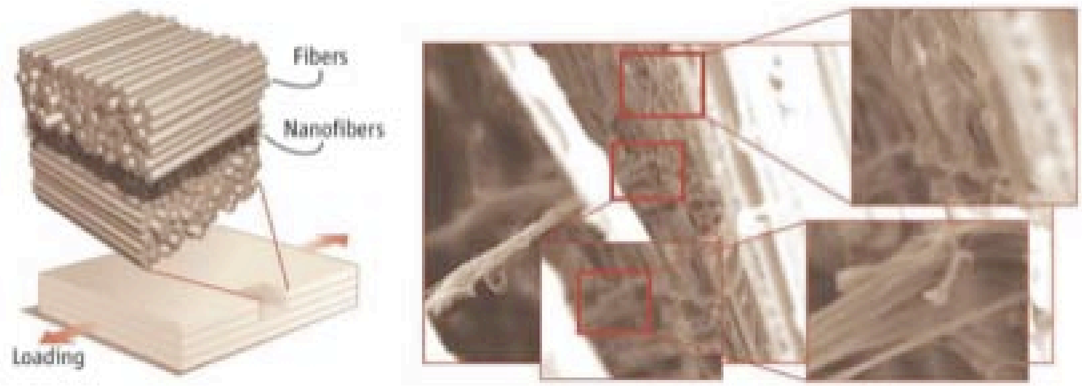
Structural composites are made up by stacking fiber-reinforced polymer laminae. Interlayer strength and toughness is one of performance limiting factors.

OBJECTIVE: Improving interlayer mechanical properties through nanostructured materials

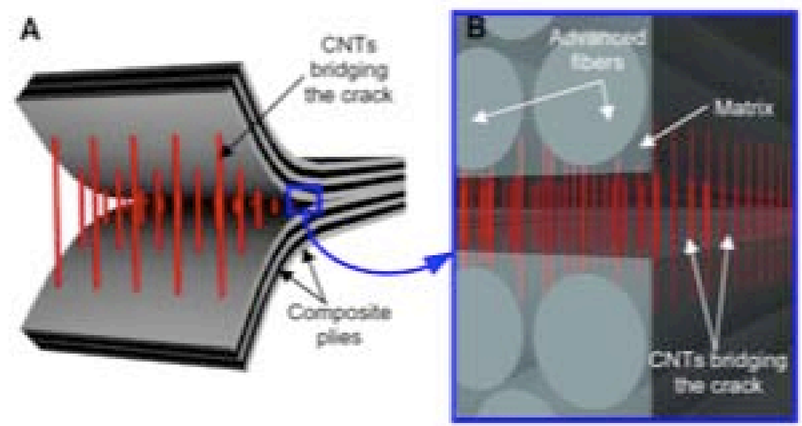
Strategies

dispersion of thermoplastic nanoparticles in the epoxy matrix at the interlayer





Interleaf of electrospun nanofibers (epoxy-compatible polymer + CNT)



Growth of aligned CNT perpendicular to the prepreg plies to bridge the crack

"GREEN" STRUCTURAL COMPOSITES

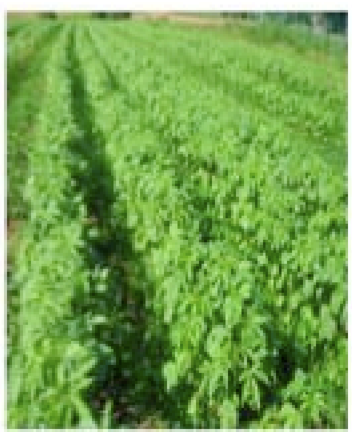
CHALLENGE: Combine traditional and green composites to increase energy efficiency and promote recycling.

Advantages of green composites:

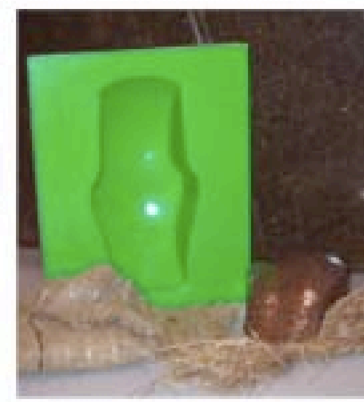
- Lower density (density natural fibers << glass fibers)
- Large and cheap supply of natural fibers (hemp, oilseed flax, kenaf, sisal, etc).
- Fully recyclable when combined with thermoplastic or biodegradable resins.

Liquid Moulding (RTM, Infusion)

Plant natural fibers



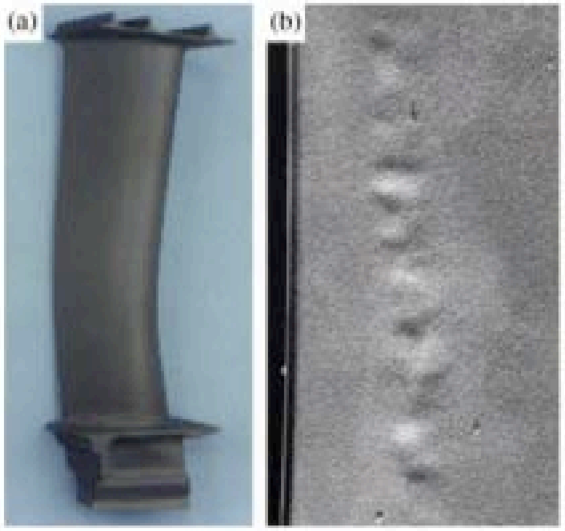
Fiber-Mat Processing



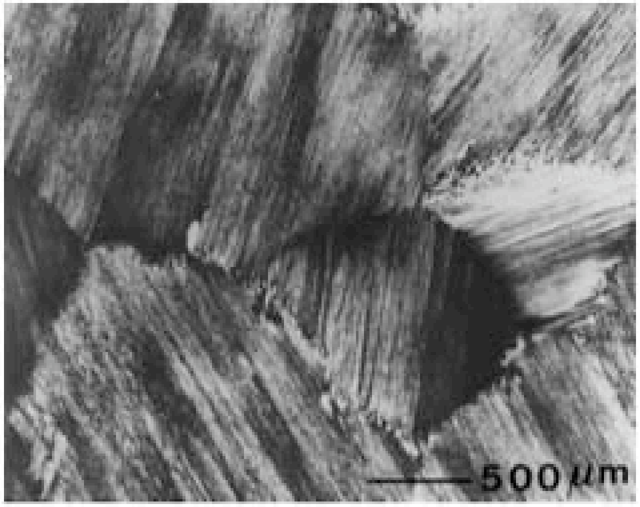
Composite Part

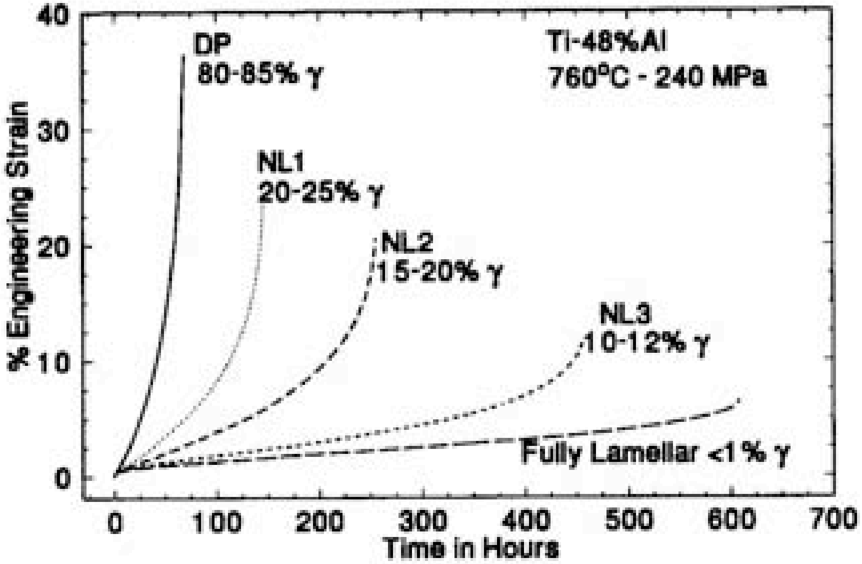
TITANIUM ALUMINIDE INTERMETALLICS

- TiAl offer low density, high specific strength, creep and corrosion resistance up to 800°C.
- They can replace Ni-based superalloys in engine components, but their application is limited by casting defects and poor microstructures, which lead to low ductility and toughness.



- Titanium aluminides present four different phases TiAl, Ti_3Al, alpha-Ti, and beta-Ti, which lead to many different microstructures (DP, NL, FL)
- Optimum microstructures with good ductility and toughness can be obtained by its extremely difficult to control the casting conditions to obtain homogeneous properties throughout the sample.

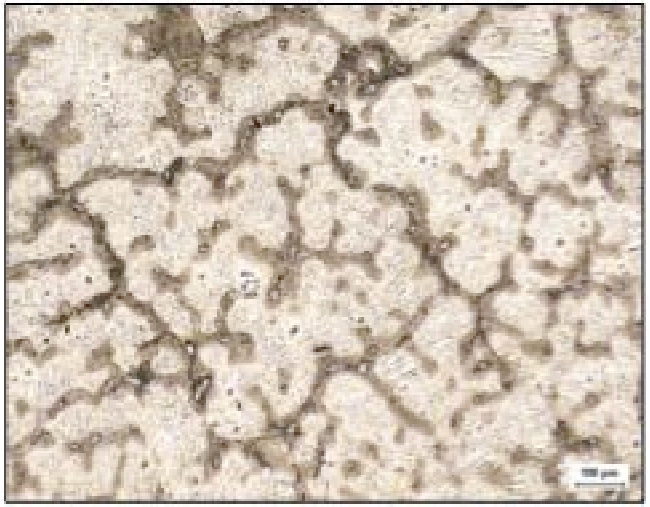




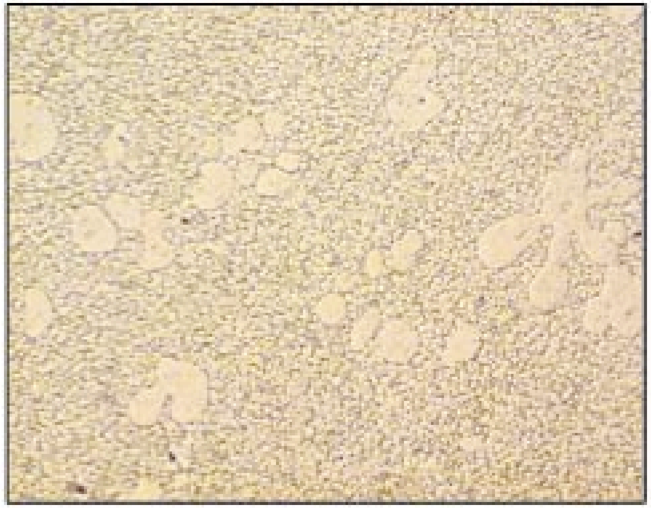
LIGHT ALLOYS

- Mg alloys are castable materials which present outstanding potential as structural materials due to their low density (1.7 g/cm³) and good mechanical properties.
- Their incorporation into the market has been hindered by the limitations in understanding and controlling casting conditions to optimize the microstucture and properties.

AM60
Ingot- Die casting

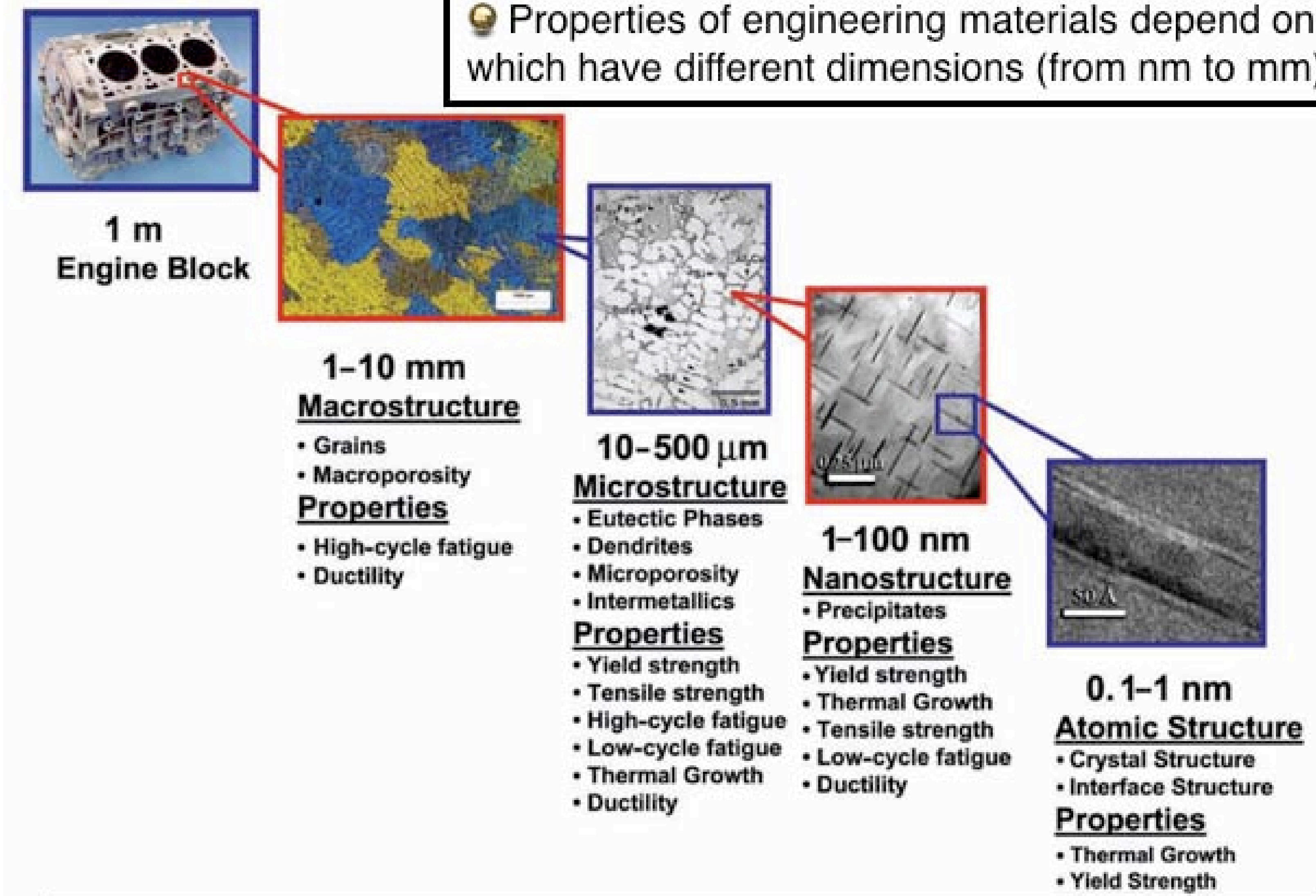


AZ91
Injection moulding

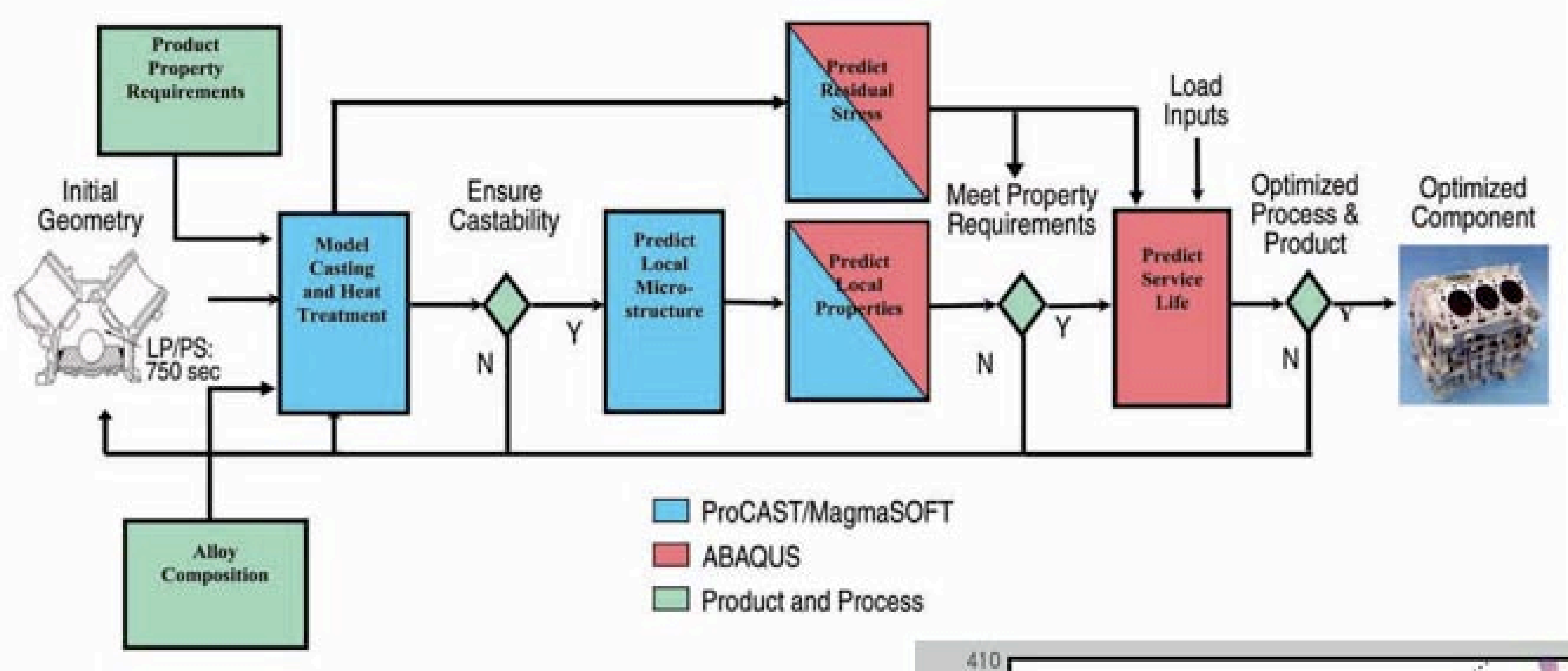


OBJECTIVES: Optimization of processing (casting) through multiscale modeling techniques to develop novel microstructures with superior mechanical properties.

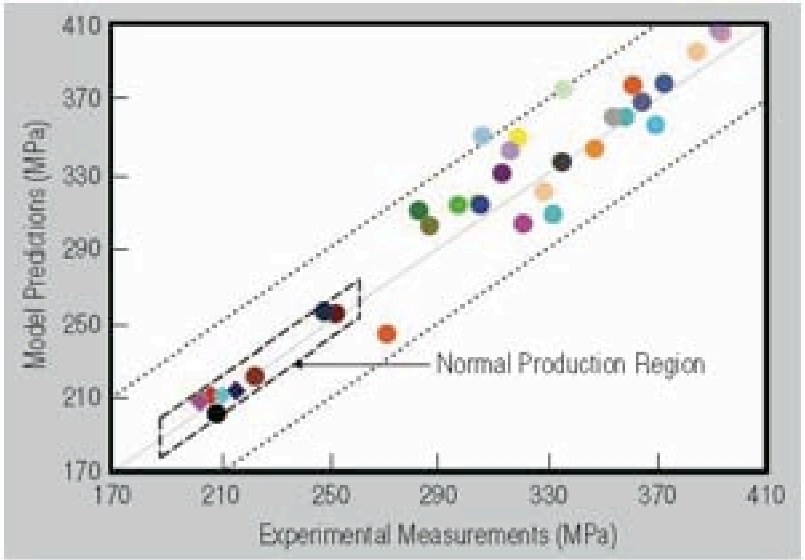
- Properties of engineering materials depend on features which have different dimensions (from nm to mm).



- so far, engineering materials have been developed using a "trial and error" strategy, which is very time consuming and hinders progress.

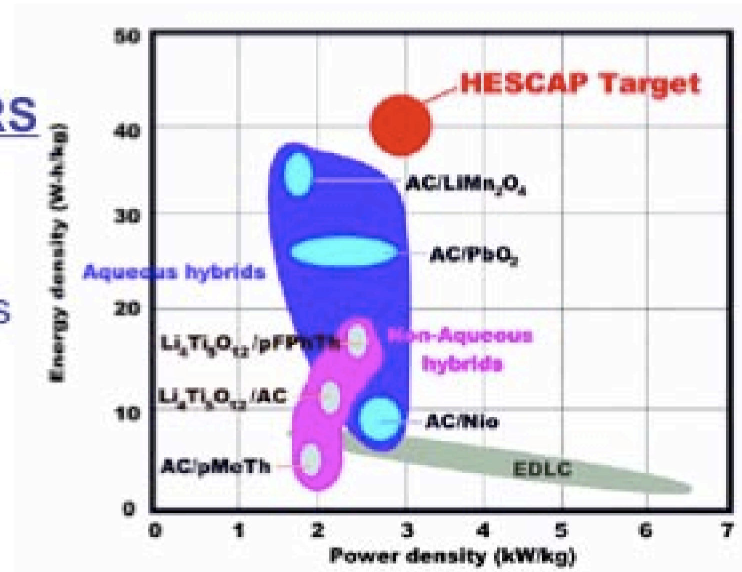


Predictions and experimental data of the yield strength at different points in a wide range of components, casting conditions and heat treatments.



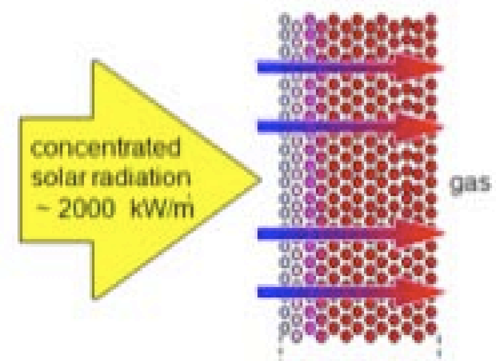
ELECTROCHEMICAL STORAGE FOR RENEWABLE ENERGY AND GREEN CARS

- Nanoporous metal oxides as electrodes for electrochemical capacitors (HESCAP project).
- Nanostructured anodes for lithium-ion batteries
- Redox flow batteries for solar dish/Stirling systems.
- Carbon electrodes coated with nanoparticles for capacitive water deionization.



SOLAR FUELS AND CHEMICALS VIA THERMOCHEMICAL CYCLES

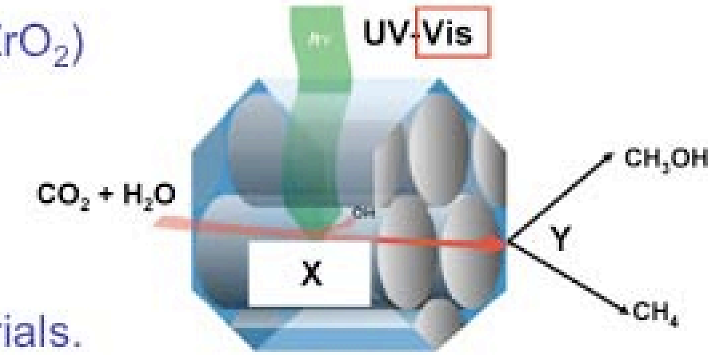
- Porous materials (foams, wire mesh, ceramic monoliths) for high flux/temperature solar absorbers (above 2 MW/m^2 and 1000ºC).
- Hydrogen production from thermochemical cycles (metal/oxide, mixed ferrites, doped Ce oxide)
- CO_2 capture and valorisation via solarized thermo-chemical cycles.



CO_X-FREE HYDROGEN PRODUCTION BY CH_4 DECOMPOSITION

- Transition Metal based catalysts:

Bulk (Spinel, Perovskite); Supported (Carbon, ZrO_2)



PHOTOCATALYTIC PROCESSES

- H_2 production by water splitting
- CO_2 removal and valorisation

Catalytic systems based in semiconductor materials.

BIOLOGICAL HYDROGEN PRODUCTION

- Development of a biological sensor for hydrogen
- Enzymatic H_2 production by nitrogenase