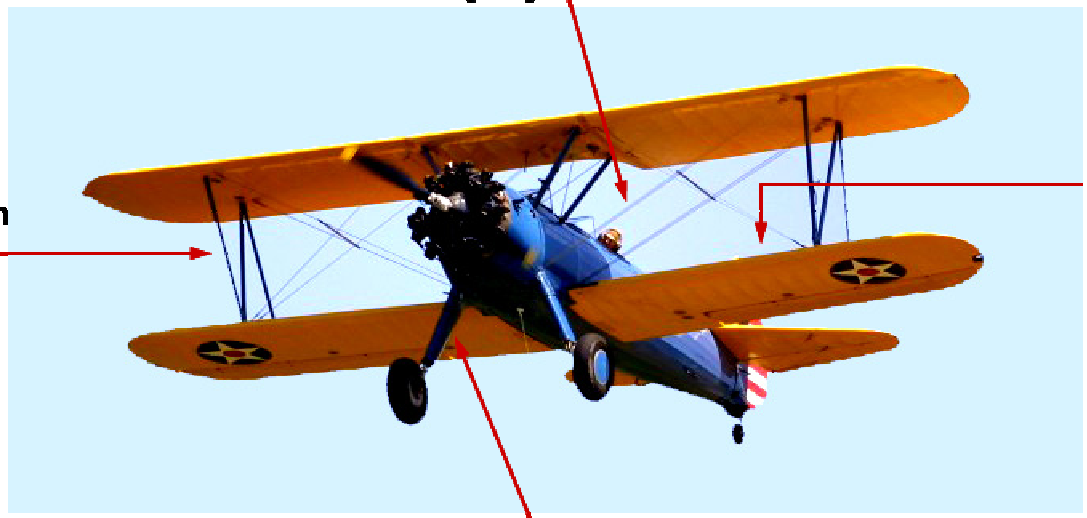
Matériaux Architecturés : Echelles et Passerelles

O. Bouaziz

Aussois
2012 oct 22nd-25th

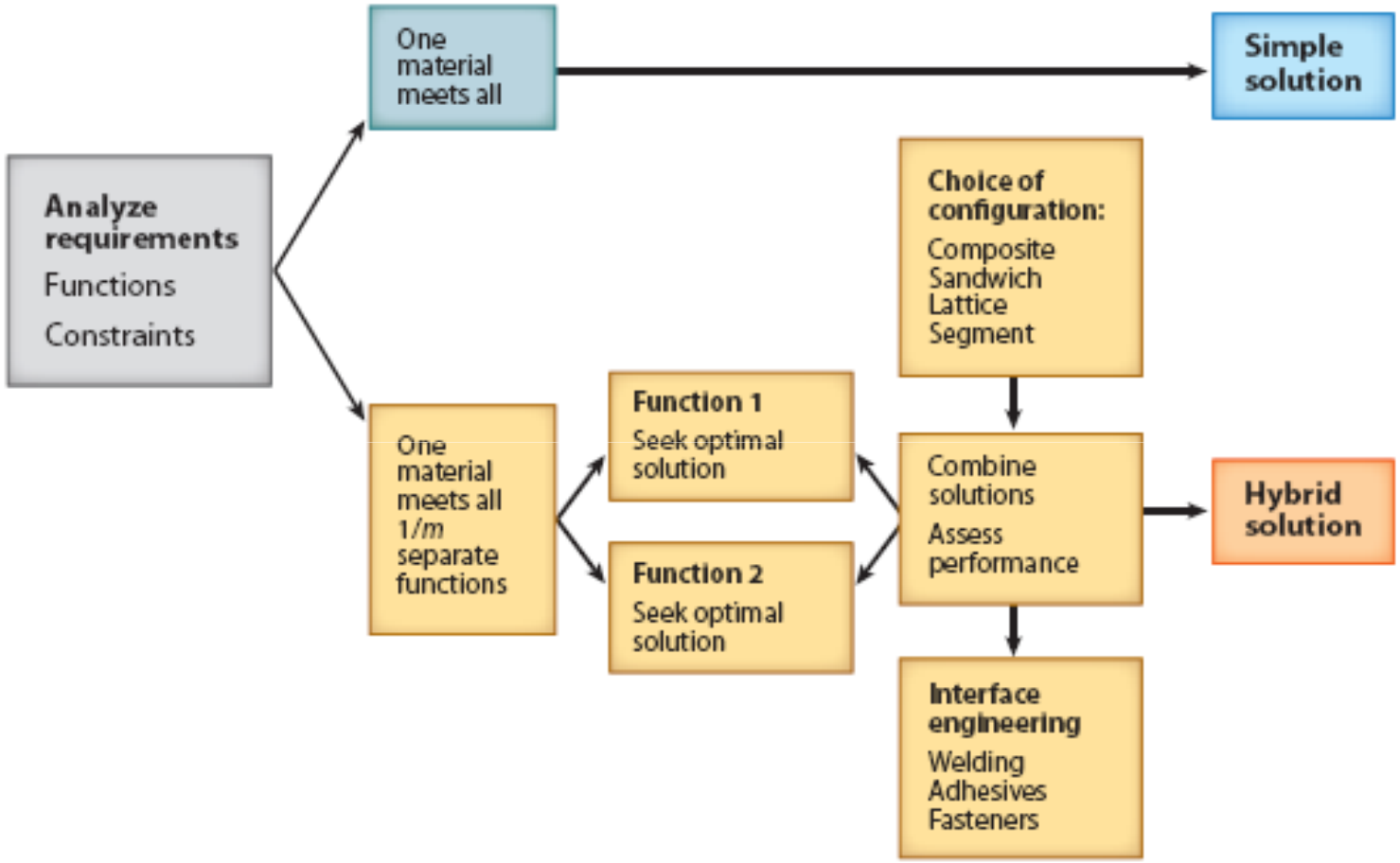
The crucial analysis of requirements : example of minimum weight design



E = Young's modulus ρ = Density σ_y = Yield strength

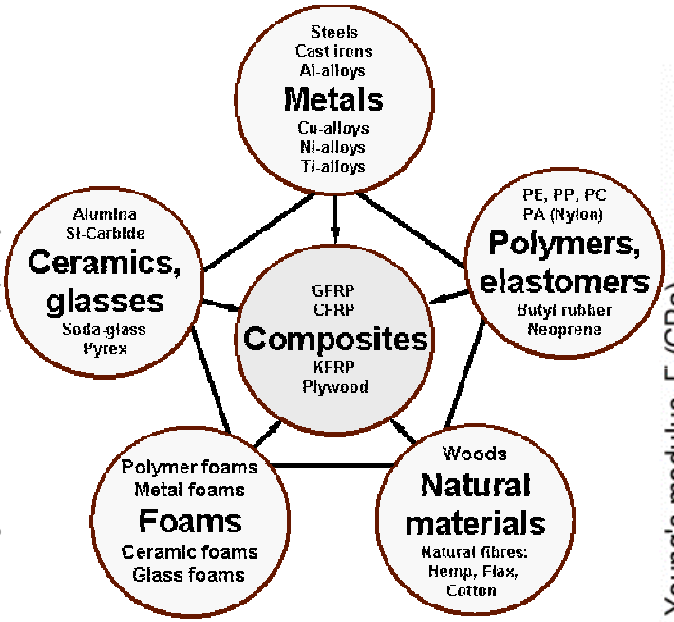
Ashby's performance indexes are the best way to translate a problem of superstructure to a problem of material

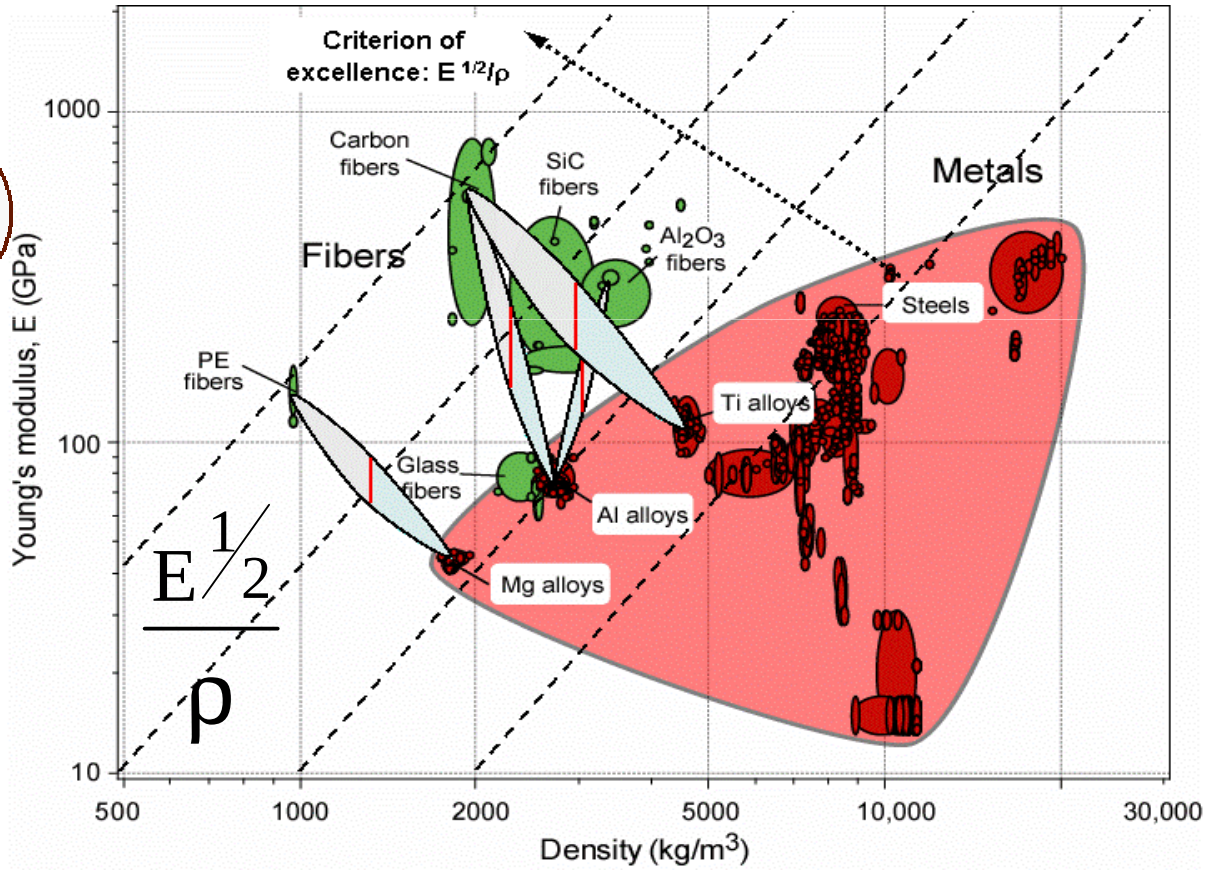
Functions and materials



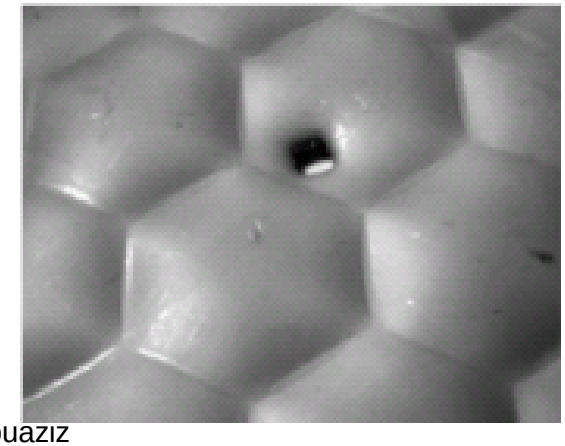
[From M. Ashby]

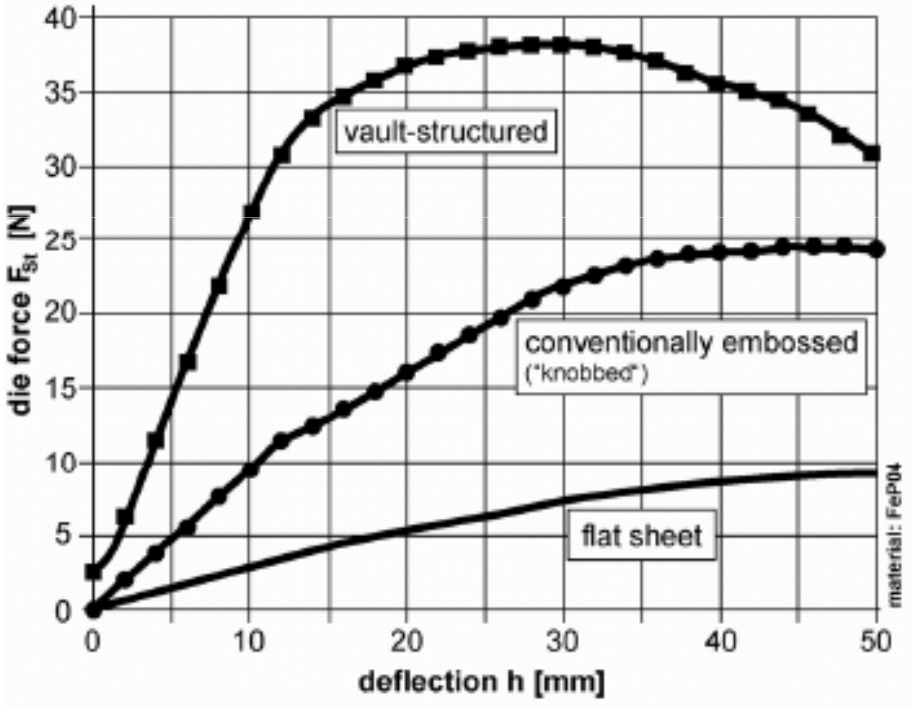
The pure metallurgical response to improve specific stiffness



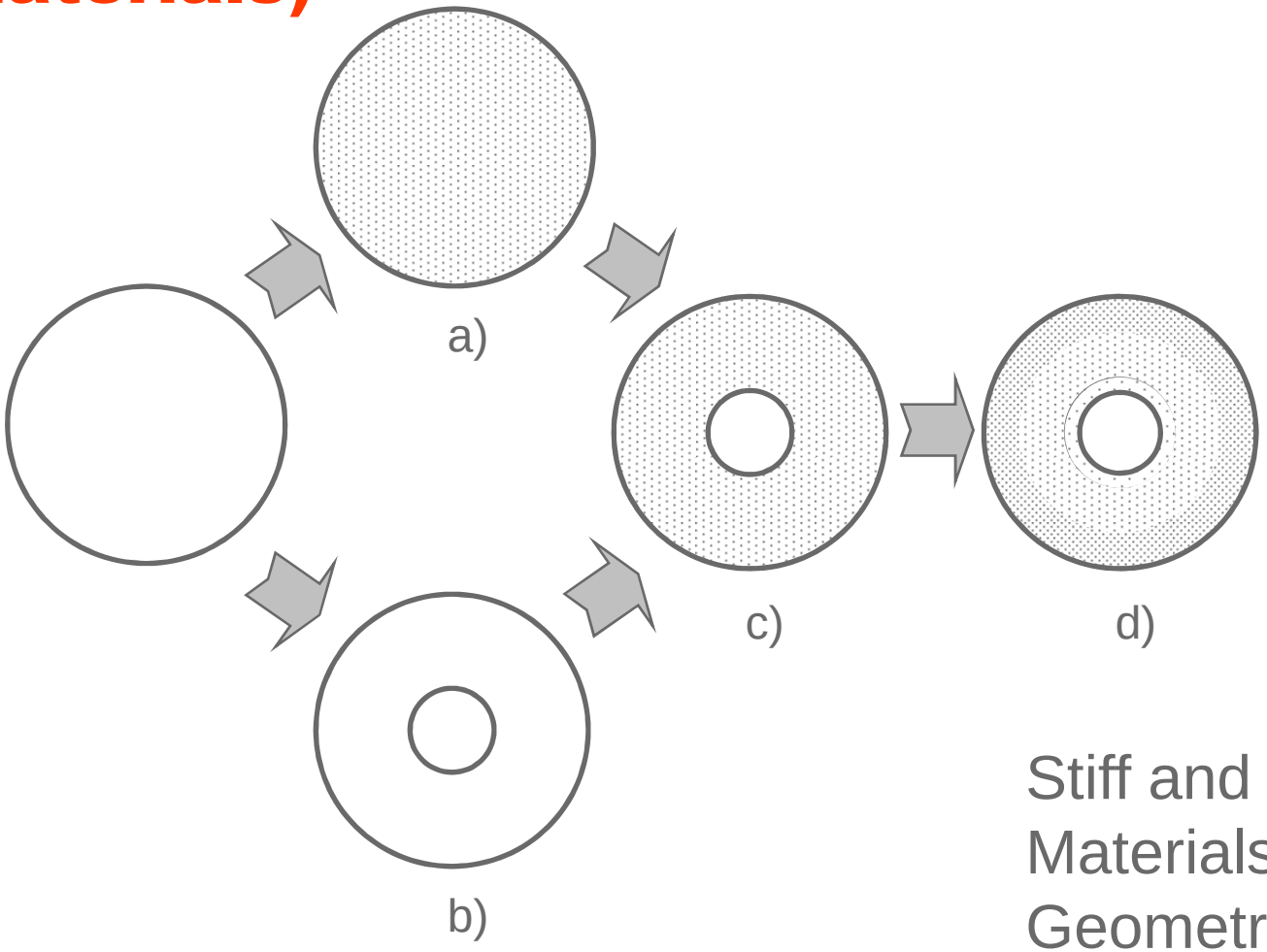


The pure mechanical solution to improve specific stiffness



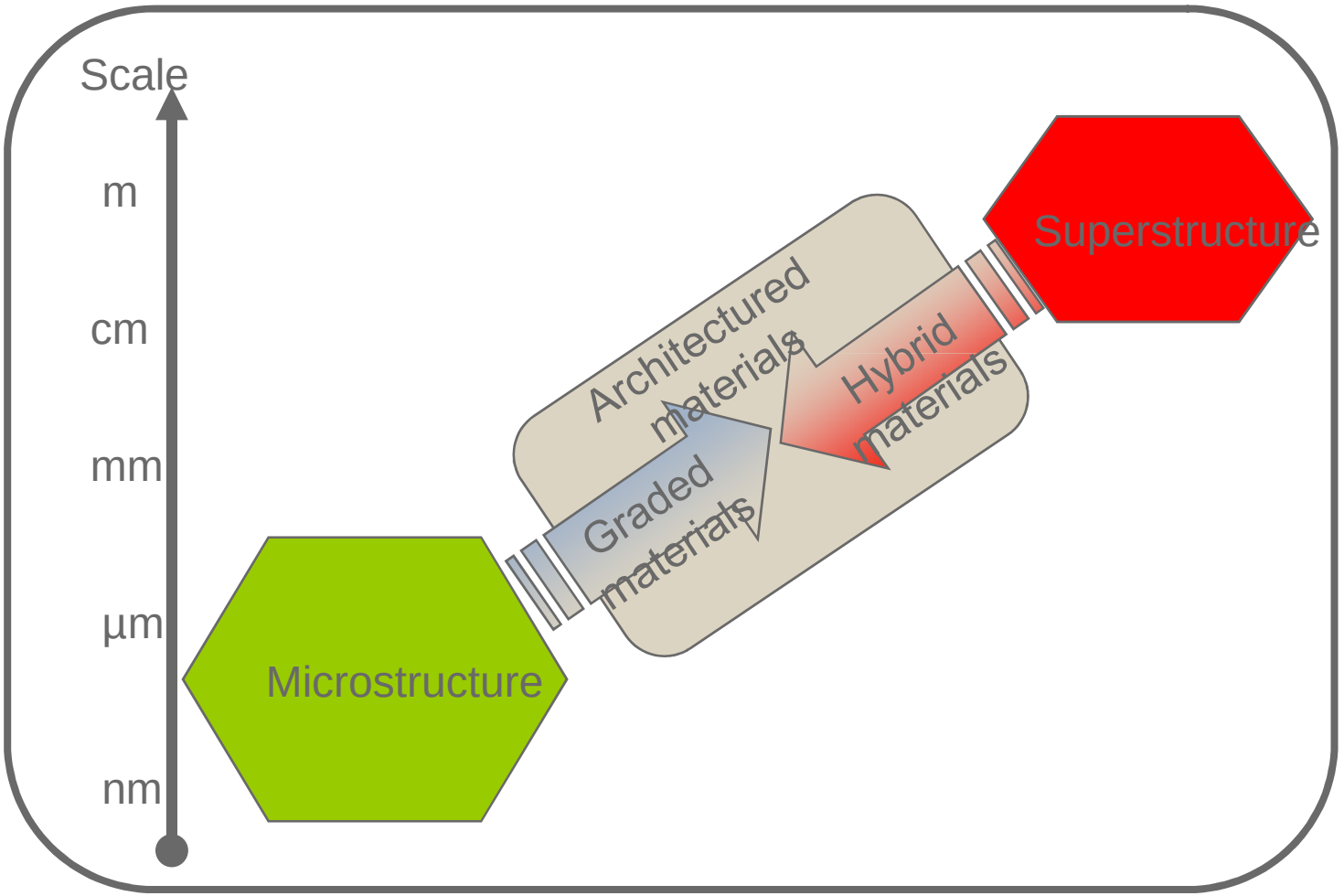


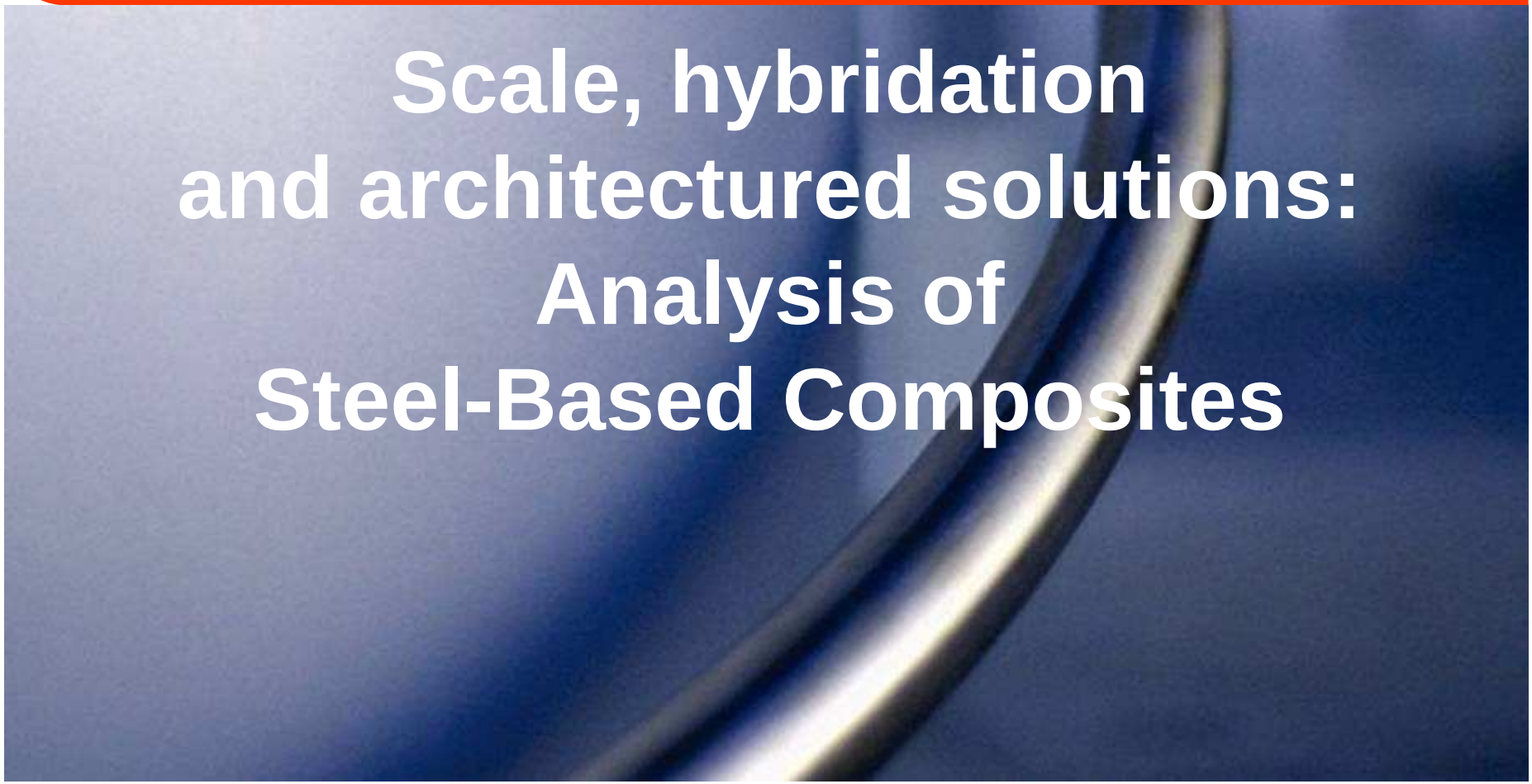
Mechanical or metallurgical solution (1) : toward a mixed approach (architectured materials)



Stiff and light :
Materials
Geometry
Graded solution

Mechanical or metallurgical solution (2) : toward a mixed approach (architectured materials)

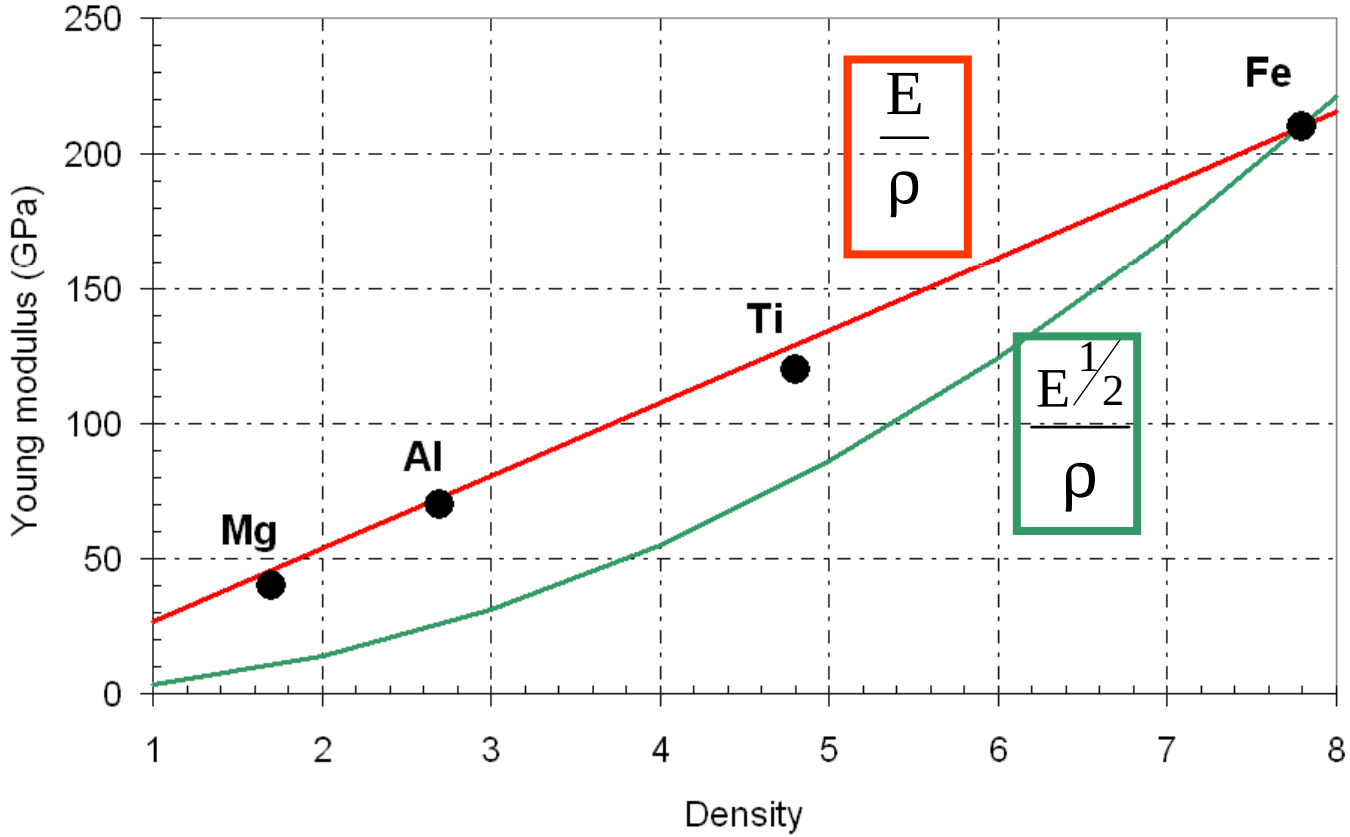




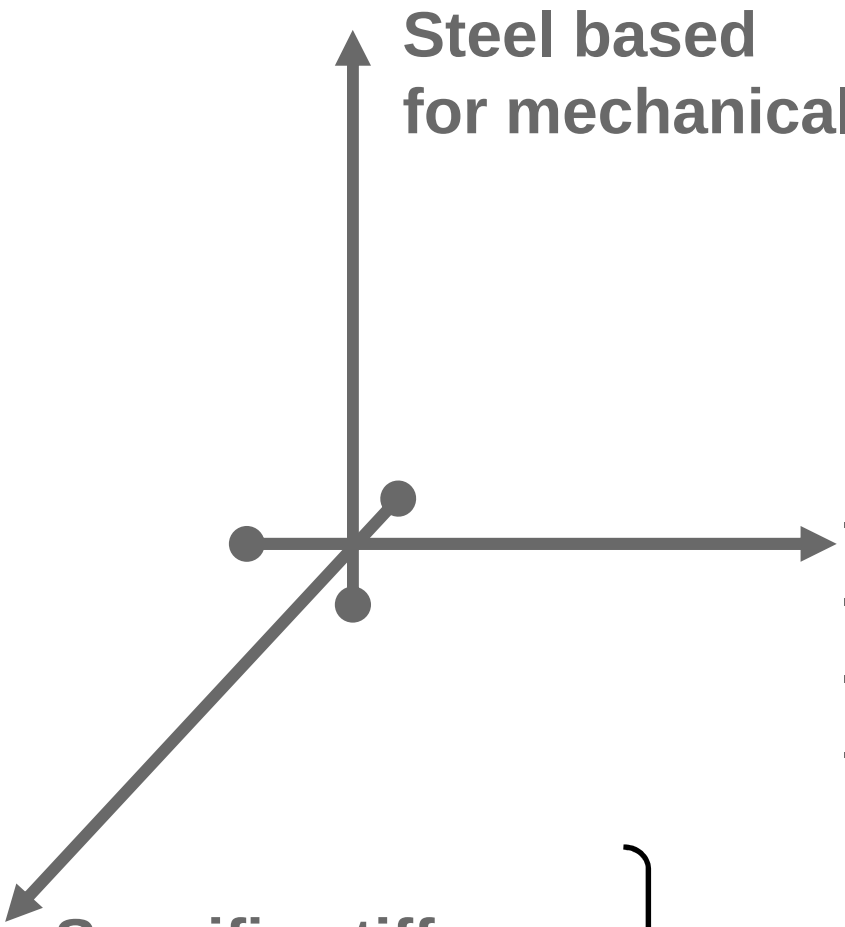
Scale, hybridation and architectured solutions: Analysis of Steel-Based Composites

The main limitation for lightening with steel

- The performance of steel is very high concerning the strength especially including cost
- The situation for specific stiffness is a threat



Main driving forces for steel based composite



Steel based
for mechanical strength

main advantage

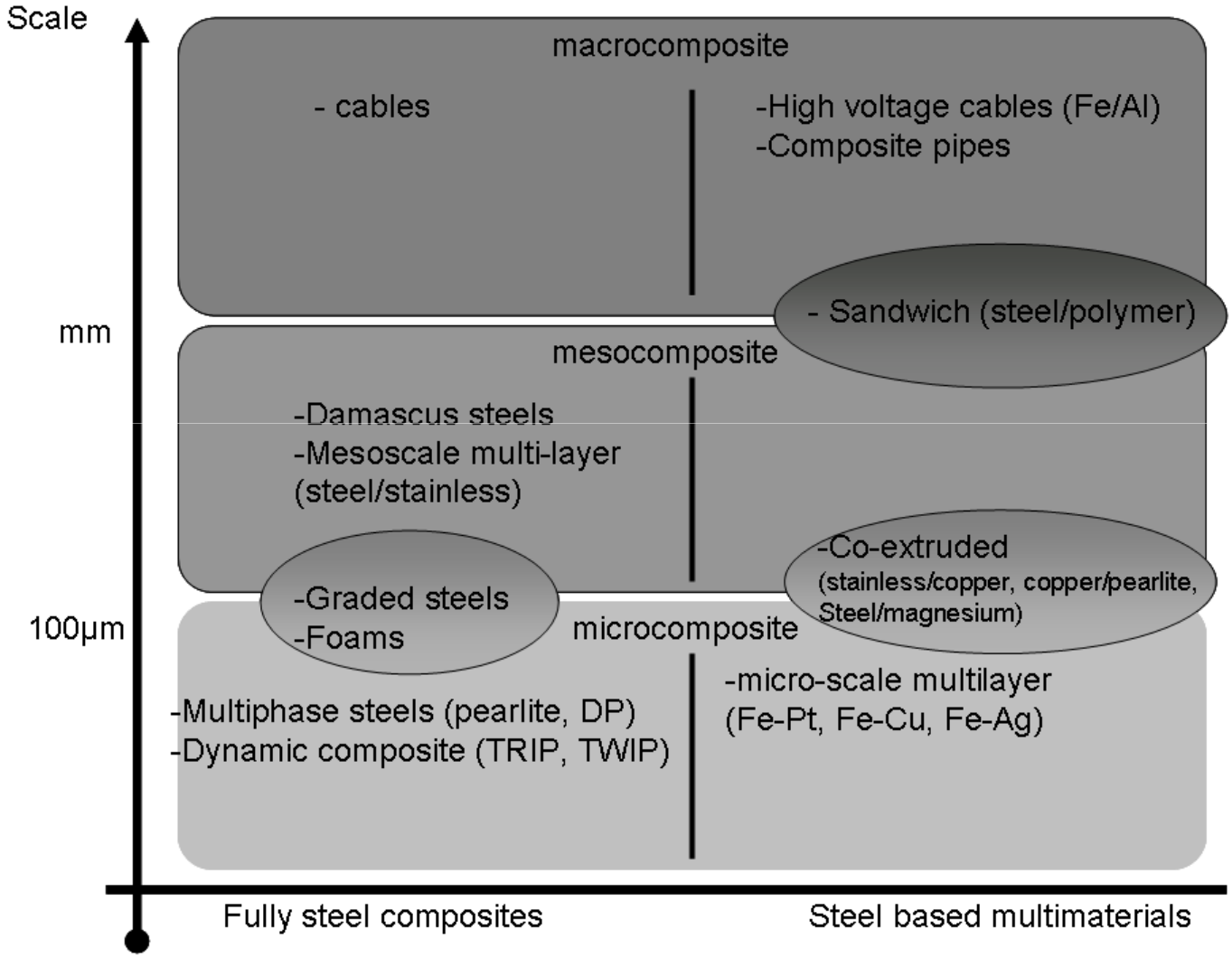
Functionnal properties :
-thermal
-electrical
-magnetic
-chemical

Specific stiffness
Damage tolerance

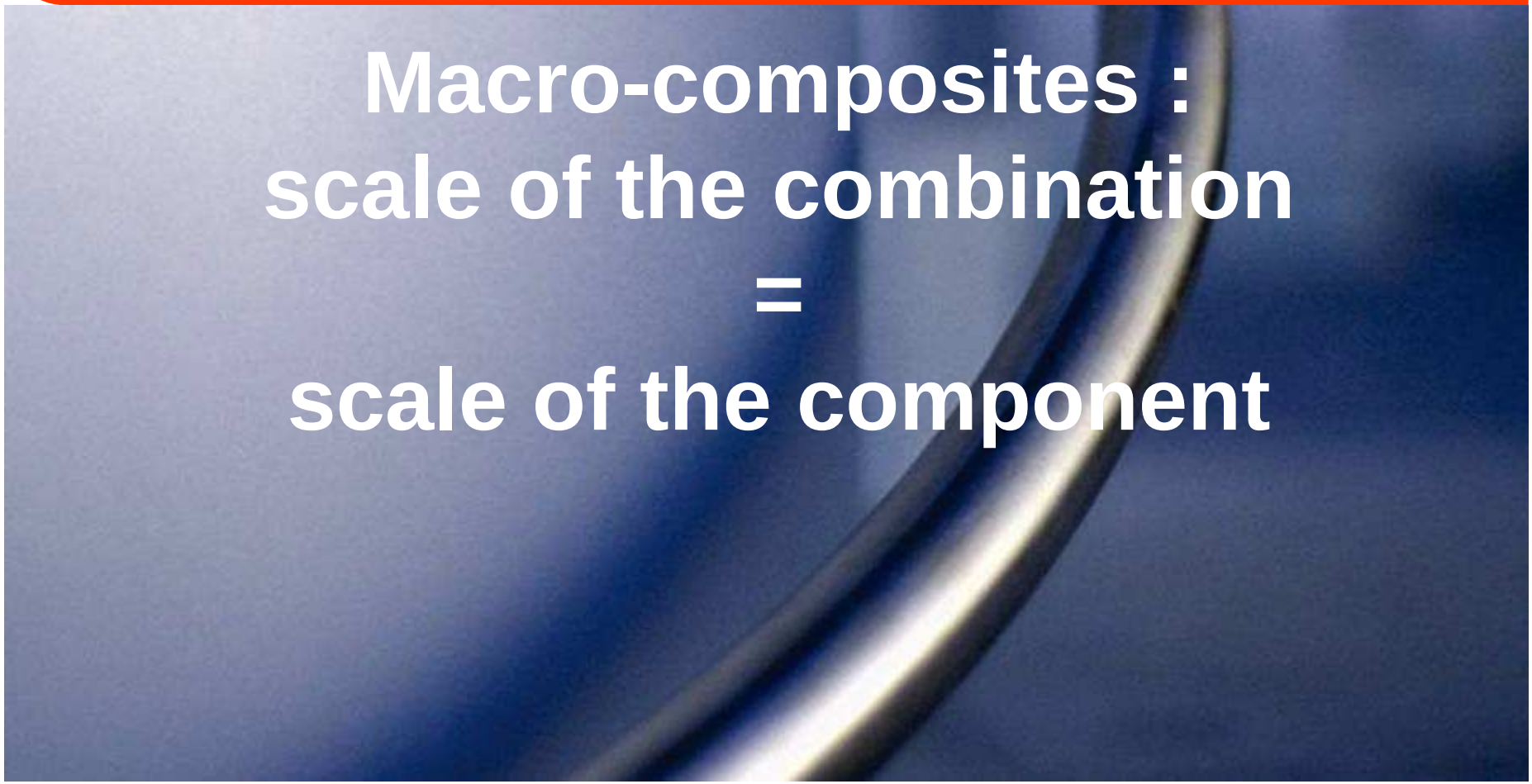
main limitations

[Embury&Bouaziz, Annu. Rev. Mater. Res. 2010. 40:20.1–20.29]

Classification : scale and hybridation

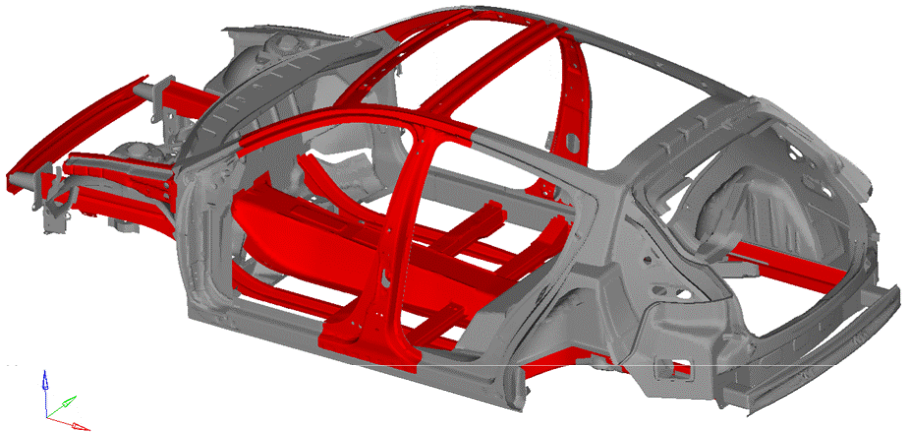


[Embury&Bouaziz, Annu. Rev. Mater. Res. 2010. 40:20.1–20.29]



Macro-composites : scale of the combination = scale of the component

Automotive applications



Pillar of a body in white for car industry made by laser welding of an HSLA (high-strength, low-alloy) steel with an ultra high-strength martensitic steel

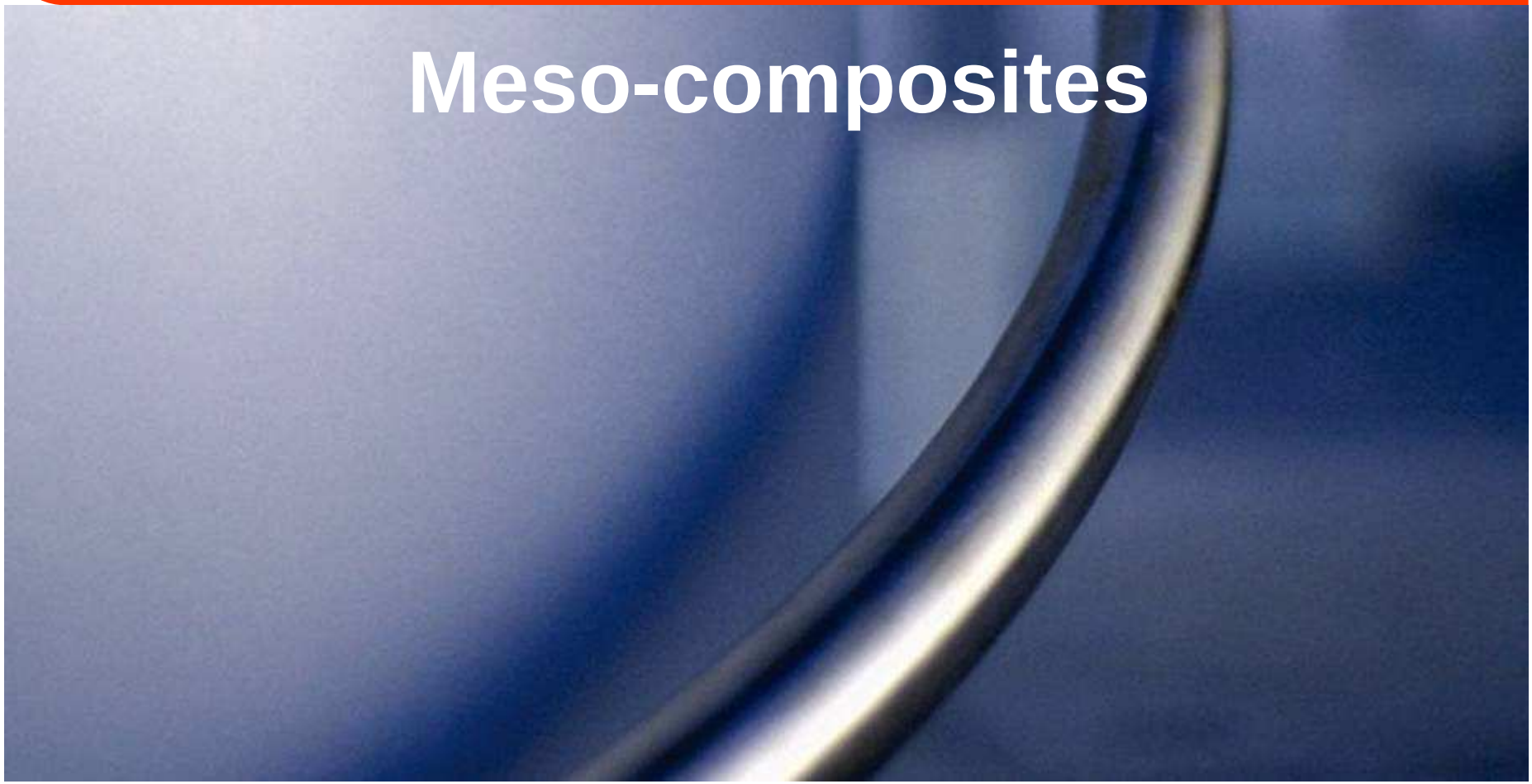
Other examples

hardness for piercing/corrosion

strength/conductivity

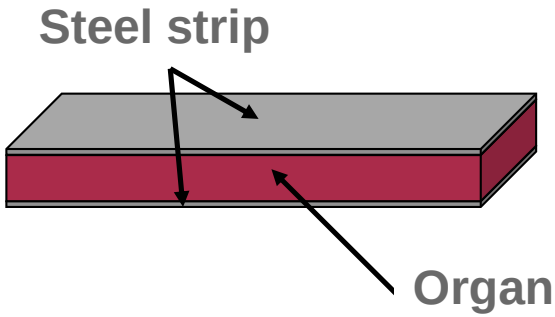
ArcelorMittal

Meso-composites

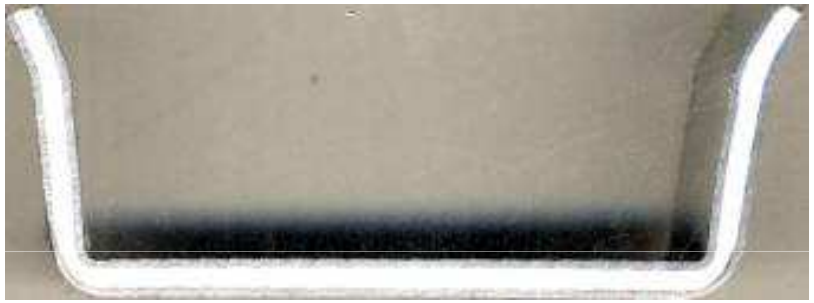


Automotive applications

- Objectives : strong weight saving by specific rigidity improvement with other functions as low thermal and phonic conductivity
- Ways : light core sandwich with steel strips

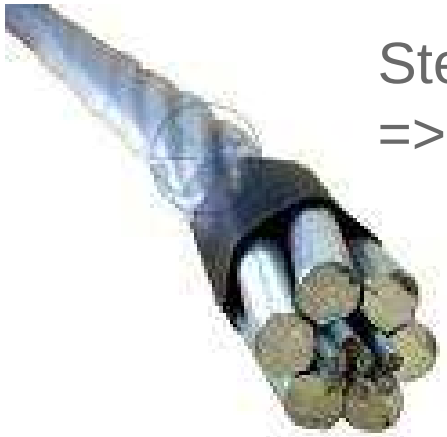


- Rigidity is improved by 30%

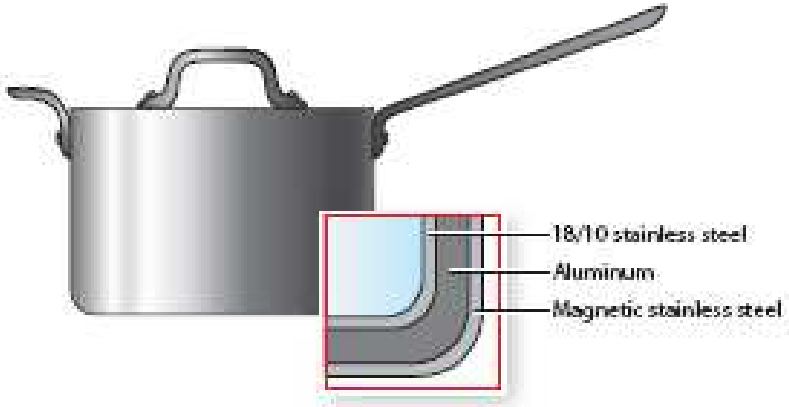


[Usilight-ArcelorMittal]

Other examples

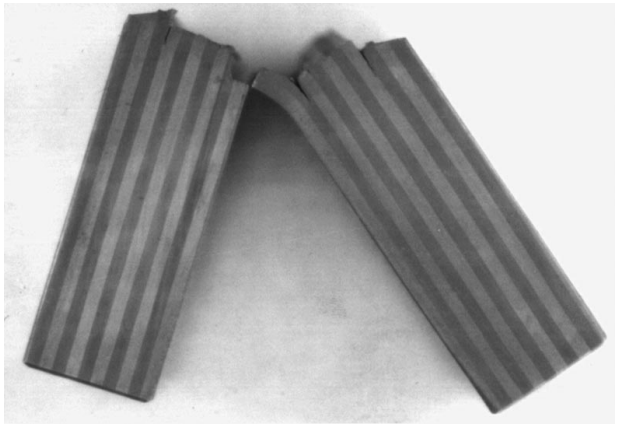


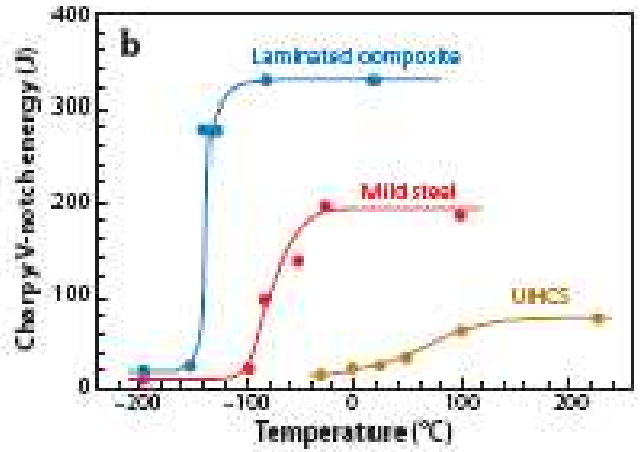
Steel/Aluminium high-voltage cable
=>strength/conductivity

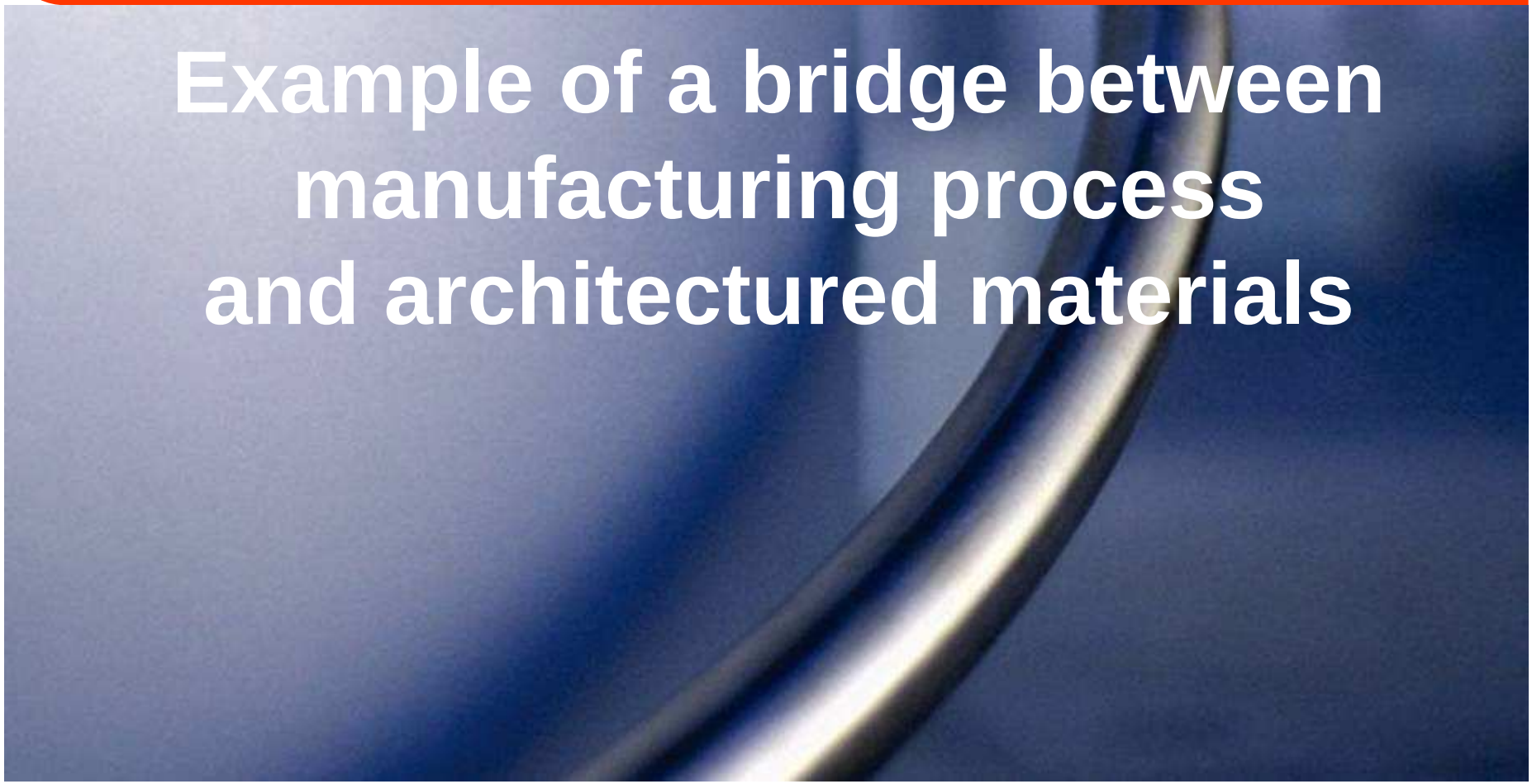


Magnetic stainless : compatibility with all induction cooktops
Aluminium : heat conduction
Austenitic stainless steel : bio-compatibility

Toughness improvement



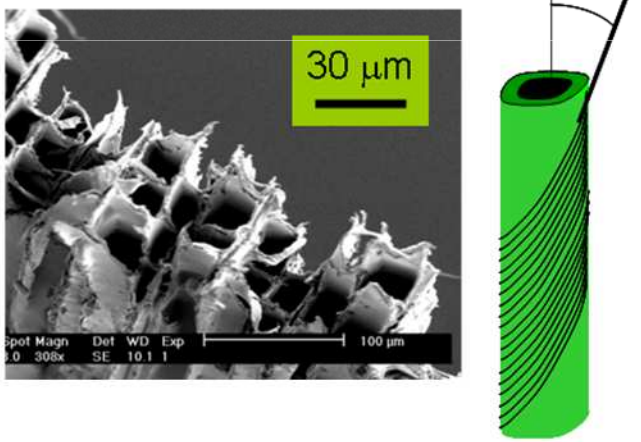


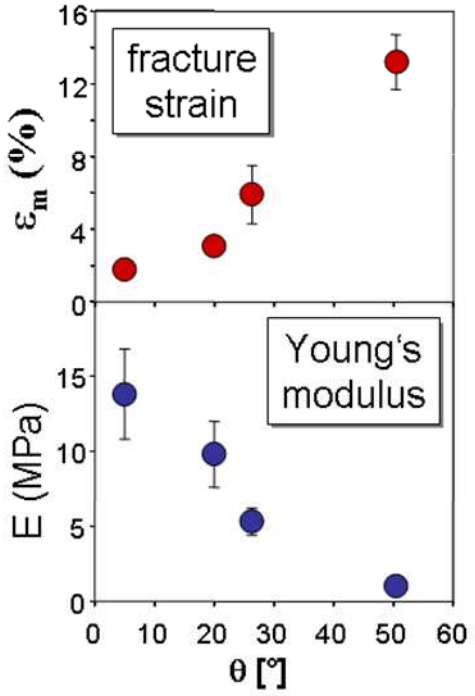


Example of a bridge between manufacturing process and architectured materials

Striffness, strength and stretchability of tubular structures (1)

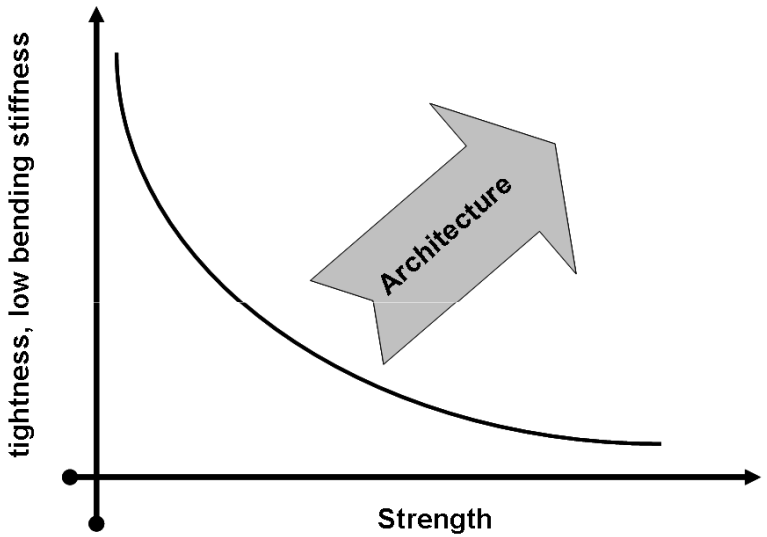
- Motivations
  - One of the main challenge for architectured materials is the manufacturing process
  - Expectation for improved tubular solutions is very high



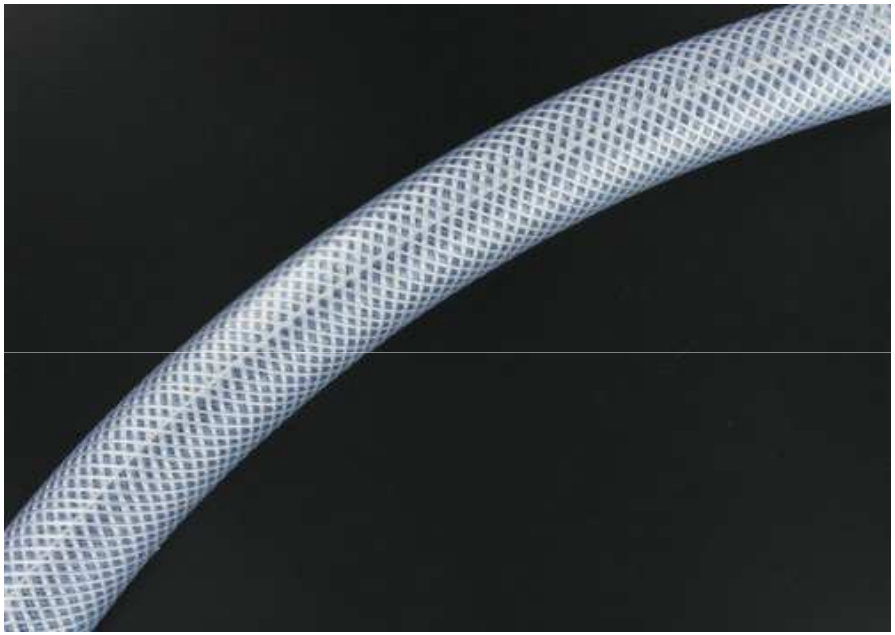


Response of Nature

Stiffness, strength and stretchability of tubular structures (2) : polymer

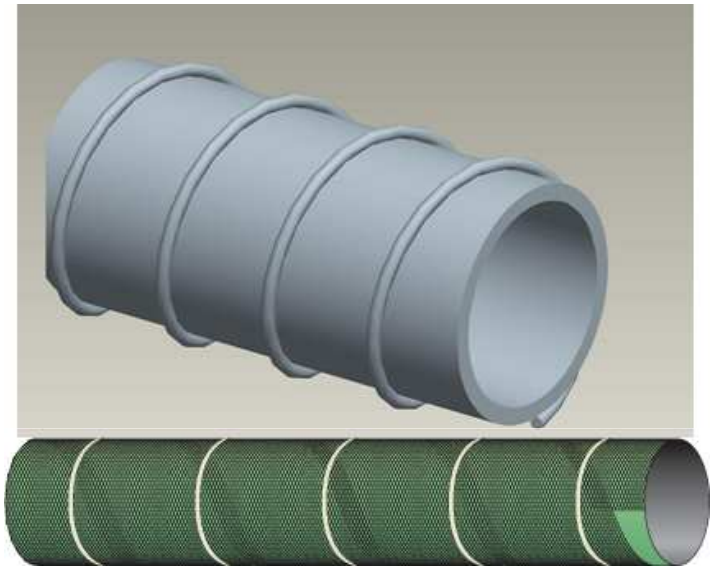


Analysis of functions



Response from Engineers

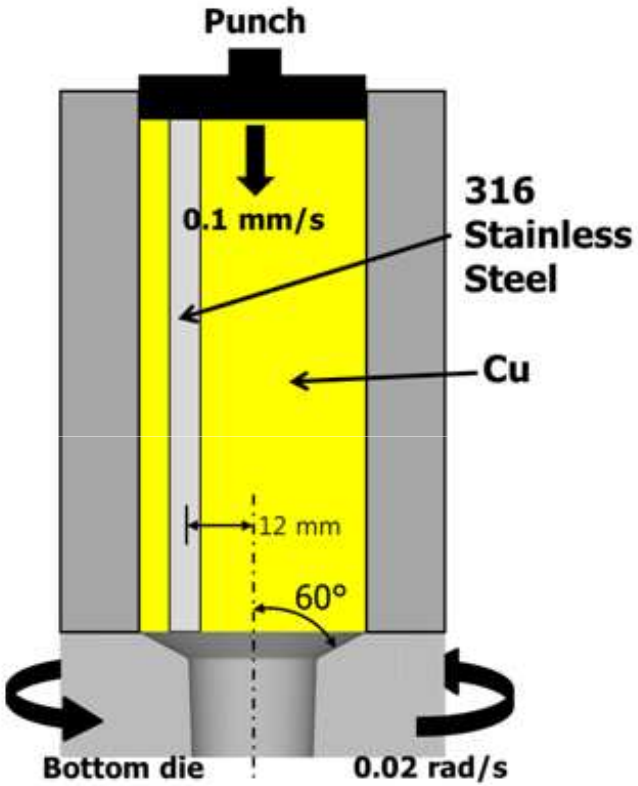
stretchability of tubular structures (3) : metal

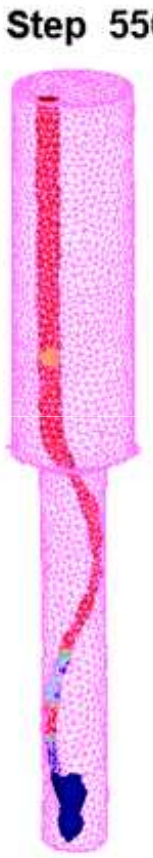


Response from Enginneers

- Only external helical architectured reinforcements for metallic structure (wrapping)
- Is it possible to do developed internal helical architectured reinforcement in a metallic structure with a reasonable process?

Exploitation of the SPD process of torsion-extrusion

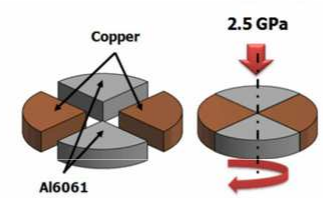




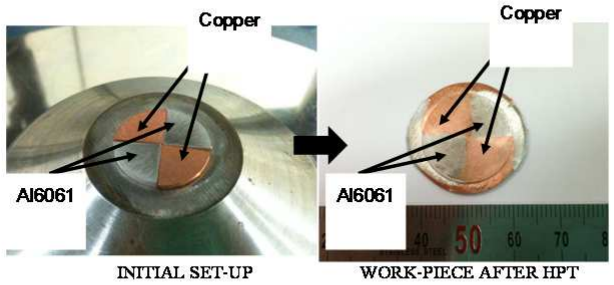
[O.Bouaziz, H.S. Kim, Y. Estrin, Adv. Eng. Mat., in press]

First real illustration

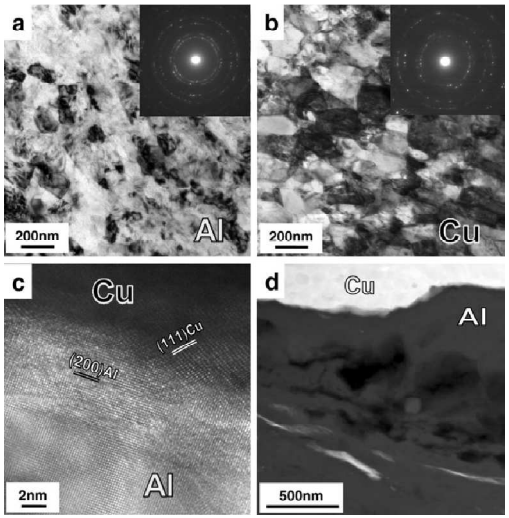
- High-Pressure Torsion is one of the most common SPD process for producing nanostructured metallic alloy (ultra-fine grain)
- HPT process can be extended for having a simultaneous architecturation and nanostructuraltion

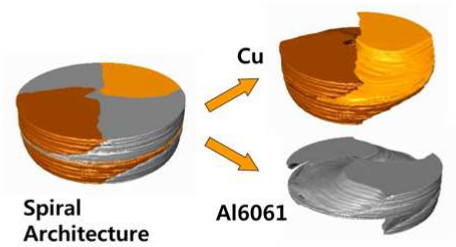


(a) Four-piece HPT for Cu-Al6061 specimen (schematic).

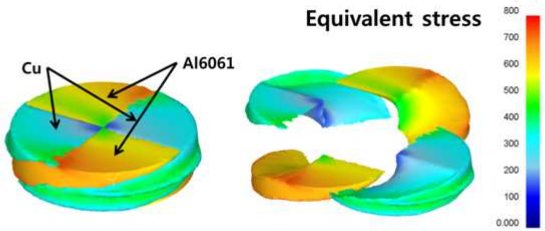


(b) Initial four-piece Cu-Al6061 specimen prior to HPT test (left) and after a full turn of HPT anvil.





(b) Reconstructed 3D image of the HPT-processed four-piece Cu-Al6061 specimen after a full turn of HPT anvil.



(c) Distribution of the equivalent von Mises stress (in MPa) after a half-turn of HPT anvil (FEM simulation).

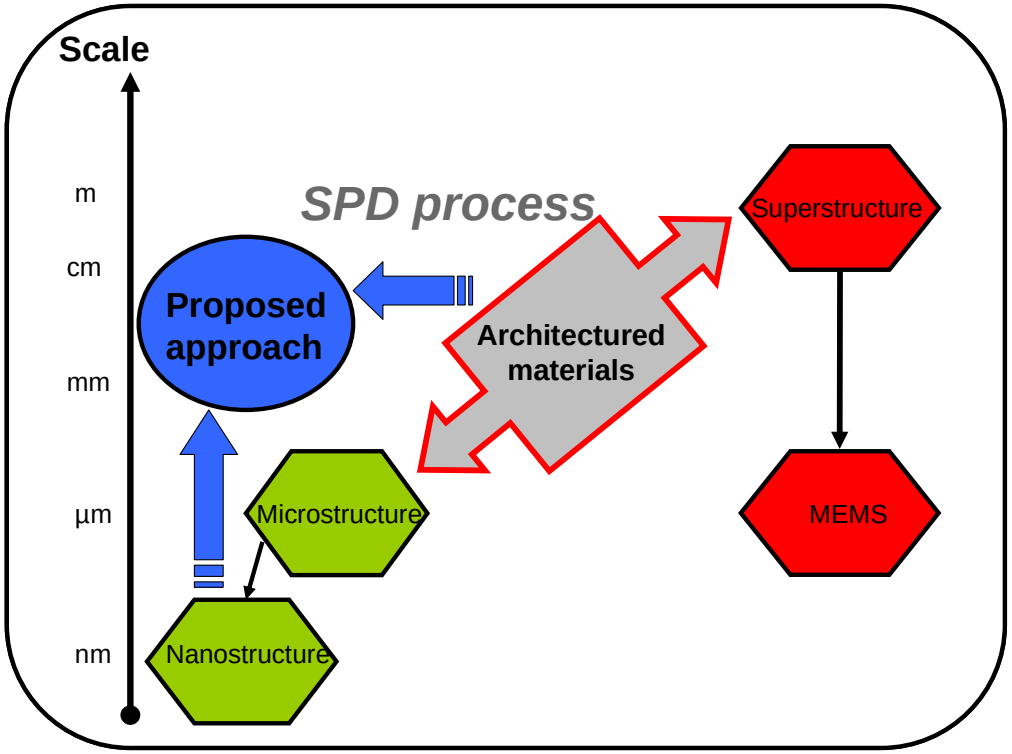
O. Bouaziz
2012 October

[O.Bouaziz, H.S. Kim, Y. Estrin, Adv. Eng. Mat., in press]

Example of bridges : process/architecture

ArcelorMittal

- A lot of processes to produce bulk nano-grained materials have been developed in the last 20 years based on Severe Plastic Deformation
- It is now possible to keep advantages avoiding limitations by including simultaneous architecturation



Conclusions and scientific challenges

- The requirements analysis using tools as Ashby's indexes is a crucial step to know if it useful to propose an archtiectured solution
- Challenge : Development of Ashby's indexes for combined solicitations (tension/bending/torsion…)
- Confusion between : hybrid, composite and architectured materials have been highlighted : *mesoscopic composites seems to be generally architectured*
- The manufacturing processes of architectured materials have to be carefully investigated
- Challenge : Interface control in architectured solutions
- Challenge : assembly of architectured materials (welding, mechanical joining……)

Conclusions : promotion of interactions

- Transversal new field of research promoting collaboration between:
  - mechanic/materials Science
  - metallurgy/plasturgy
  - mtructural/functional materials
  - natural and engineered materials
  - industry/academy
- Attractive field for students
- A clear and surprising french leadership

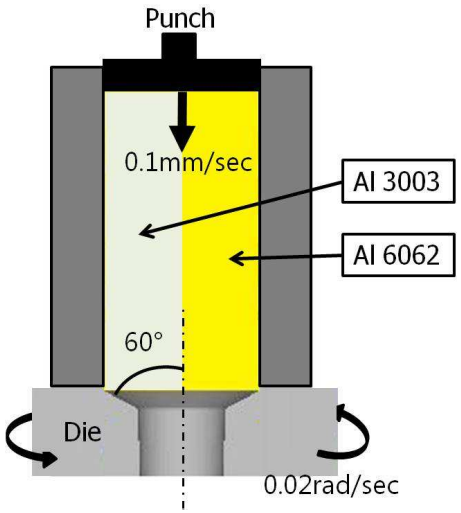
Challenge : sustain the dynamic!!!

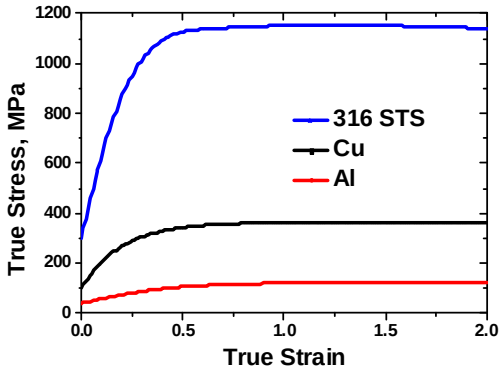
- Dedicated events
  - Symposium in MRS2009 (San Francisco, April 2009)
  - Session in JA2010 SF2M(Paris, June 2010)
  - Symposium Jacques Cartier (Lyon, Oct.2010)
  - First school « ARCHIMAT » (Autrans, May 2011)
  - Special issue Scripta Materalia (viewpoint set 2012)
  - New commission SF2M/MECAMAT (2011)
  - Symposium in JA2012 SF2M (Paris, oct. 2012)

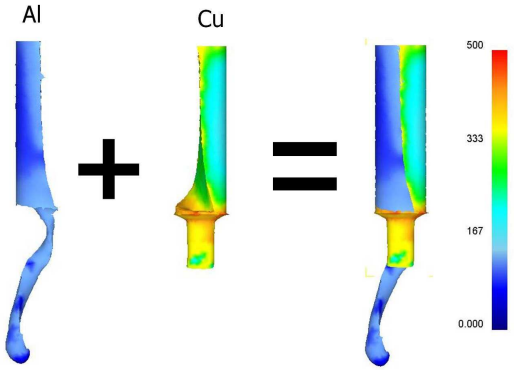
- Subsidied french projects
  - CPR MAM (2008-2011)
  - ANR MANSART (2009-2012)
  - LABEX Grenoble (2012)
  - GIS Lyon-Grenoble

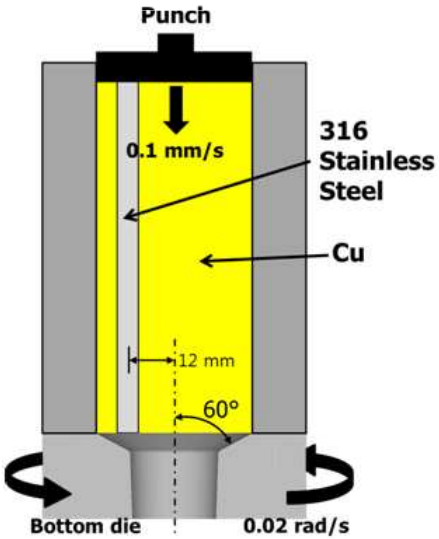
- 2nd « ARCHIMAT» school in Autrans (may, 2013)
- Other proposals for future are welcome

Exploitation of the SPD process of torsion-extrusion









[O.Bouaziz, H.S. Kim, Y. Estrin, Adv. Eng. Mat., in press]