Introduction to multidisciplinary materials science

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- With contribution from various other people (Jessell, Gottstein, etc.)

Questions on polyphase materials*

- How many strawberries, how large in the *charlotte aux fraises*? How to characterise their distribution?
- How should one put pears (aspect ration, distribution, …) in the *charlotte aux poires*?
- What are the internal stress in the strawberries in the *charlotte aux fraises*?
- What is the failure mode of a *millefeuille* at different temperatures?

* Yves Bréchet, NATO Advanced Research Workshop on Polyphase Materials and Plasticity, Palm Springs, USA 1993

Overview of this talk

- Brief introduction of myself
- Address what drives Materials Science
  - What are the approaches?
  - What are the differences/similarities between technical and natural sciences?
- Some remarks on historical and future perspectives
- The language of materials science
  - Is it like one Europe, but many customs and languages?

Many different materials

- Natural materials
  - Rocks
  - Ice
  - Biomaterials
- Engineered materials
  - Metals
  - Ceramics
  - Polymers
  - Biometarials

Many similarities, but different questions and applications

What drives material science research?

- Main aim of technical sciences is to develop
  - Materials with better (& cheaper) performance and properties
  - Better (& cheaper) synthesis and processing techniques

    →Emphasis on DESIGN and DEVELOPMENT

- In natural sciences (geology, medicine, biology), performance and properties are usually given
  - What are the performance and properties?
  - How were the materials synthesised and processed?

    →Emphasis on PREDICTION and FORENSICS

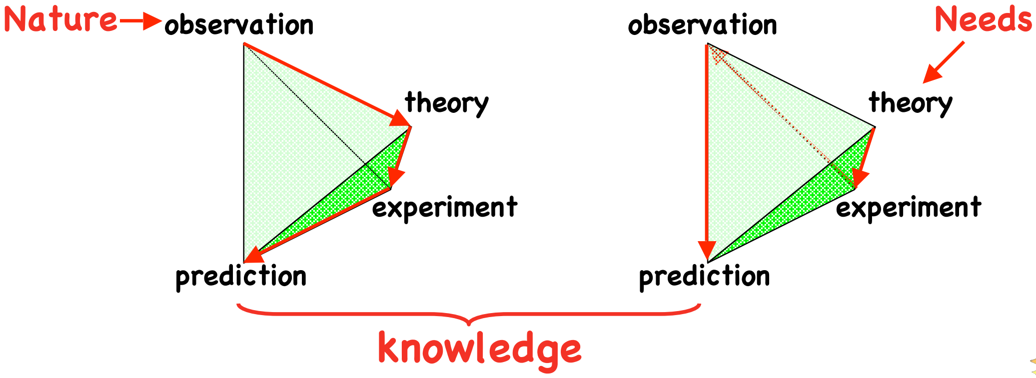
Different approaches

- Natural sciences are driven by observation:

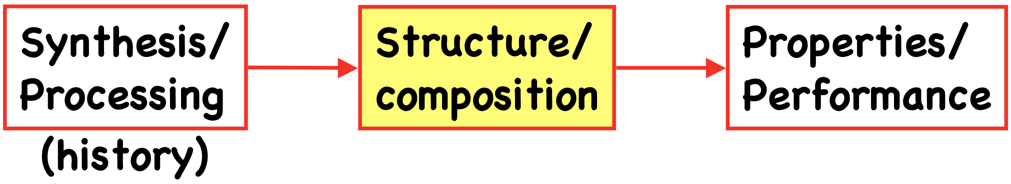
  Nature → Observation → theory → experiment → prediction

- Technological/engineering by needs:

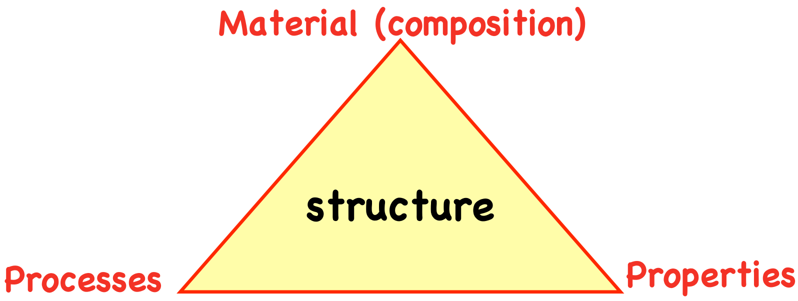
  Needs → theory → experiment → observation → prediction



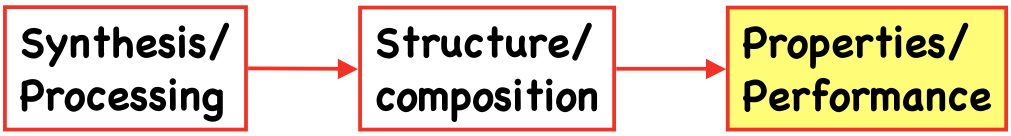
Common link



- Gottstein 2005: "[Micro-] structure is the state variable of materials properties"



Properties and performance



Mechanical:
- Tensile strength, fracture toughness, fatigue strength, creep strength, hardness, etc.

Electrical:
- Conductivity or resistivity, ionic conductivity, semiconductor conductivity, etc.

Magnetic:
- Magnetic susceptibility, Curie Temperature, Neel Temperature, saturation magnetization, etc.

Optical and Dielectric:
- Polarization, capacitance, permittivity, refractive index, absorption, etc.

Thermal:
- Coefficient of thermal expansion, heat capacity, thermal conductivity, etc.

Environmental Related:
- Corrosion behavior, wear behavior, etc.

Biocompatibility:
- Toxicity, stability

Synthesis and processing (history)

Synthesis/ Processing → **Structure/ composition** → **Properties/ Performance**

Solidification Processing (utilizes the liquid state in the process)

- The structural processing of most metals begins by forming an alloy in the molten state.
- Formation of rocks from magmas.

Powder Processing (utilizes powders in the process)

- Slip casting, powder pressing, hydroplastic forming followed by drying and firing or hot pressing
- Snow accumulation followed by conversion of Ice from firn,
- Sedimentation followed by compaction in sedimentary basins.

Deposition Processing (utilizes evaporation and/or condensation in the process)

- Electroplating, spray coating, sputtering, laser ablation, chemical vapor deposition (CVD), etc.
- Mineralisation around volcanic vents

Deformation Processing (utilizes crystal plasticity or a viscous flow in the process)

- Rolling, forging, drawing, extrusion, spinning, cutting, turning, milling, etc.
- Glacier flow, mountain building

Geological Processing

- Solid-state chemical reaction (metamorphism)
- Water related mechanical, biological and chemical segregation of materials

Historical perspective

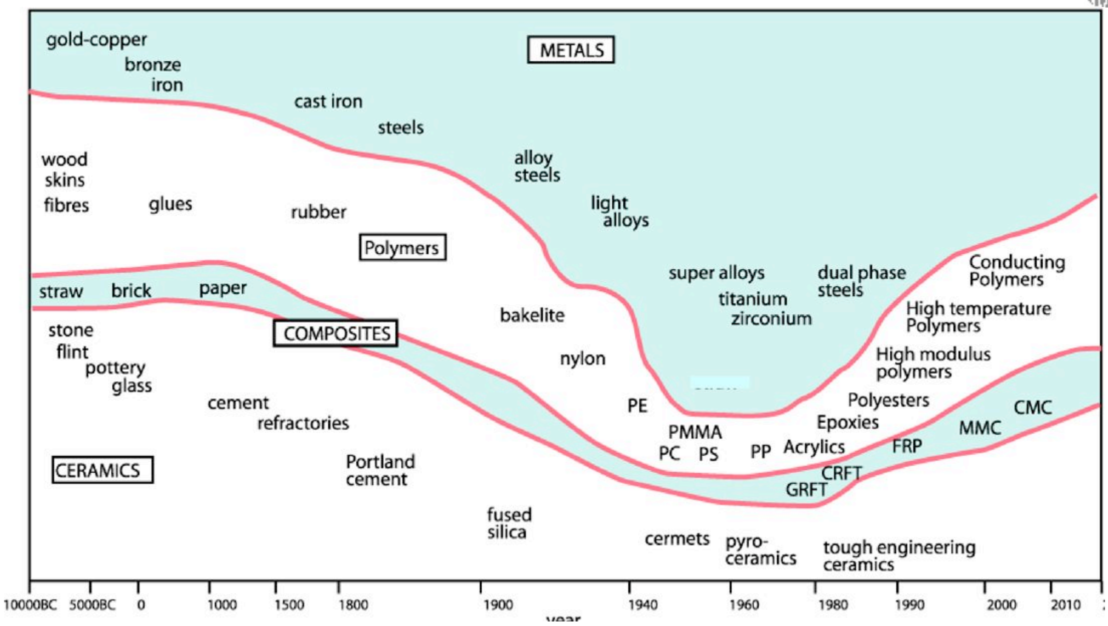
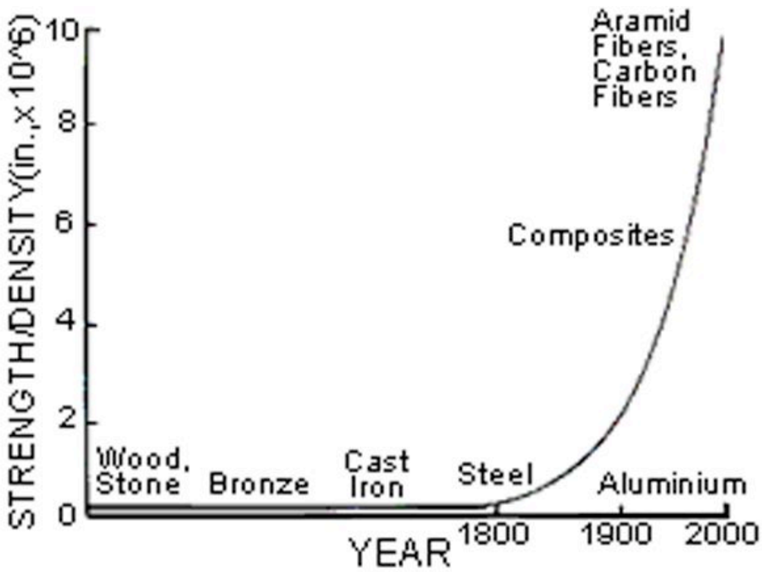


Diagram by Ashby (Cambridge, UK)

Increasing performance



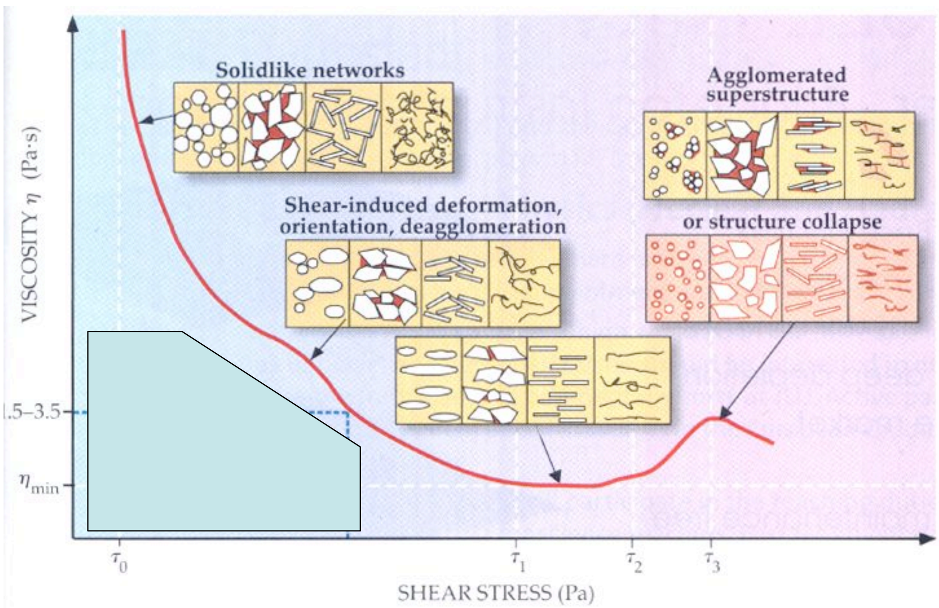
http://www.crc4mse.org/what/MSE_history.html

Where will Europe stand in 2010?

Technology sector	EU	USA	Japan
ICTs	2+	4	3
Life sciences	2+	4	2
Energy	3	3	3
Environment and clean products	3	3	3
Materials	2	4	3
Transport	3	2+	3

"Technology Map" Institute for Prospective Technology Studies Futures Report, Series No: 11. E. Cahill & F. Scapolo. Published by the European Commission, Research Directorate General, Joint Research Centre. December 1999. Joint Research Centre.

Materials technology chart



- Many disciplines address similar questions
  - What are the different languages?
  - Are there unique aspects to certain disciplines
  - What are the different scales?

Questions to you

- What do you call (components, scale; e.g. <10 nm):
  - Nanostructure?
  - Microstructure?
  - Macrostructure?
- What are the dominant processes in your area?
  - E.g. dislocation creep, crystal growth, etc.
- From which other discipline do you expect to learn most?And which other discipline do you think can learn most from you?
- What do you think will be the most significant step forward in the science of polyphase and composite materials