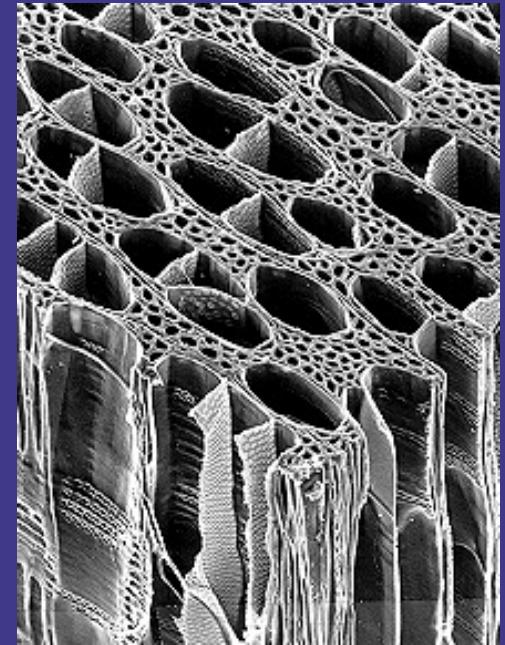


# Materials and Manufacturing

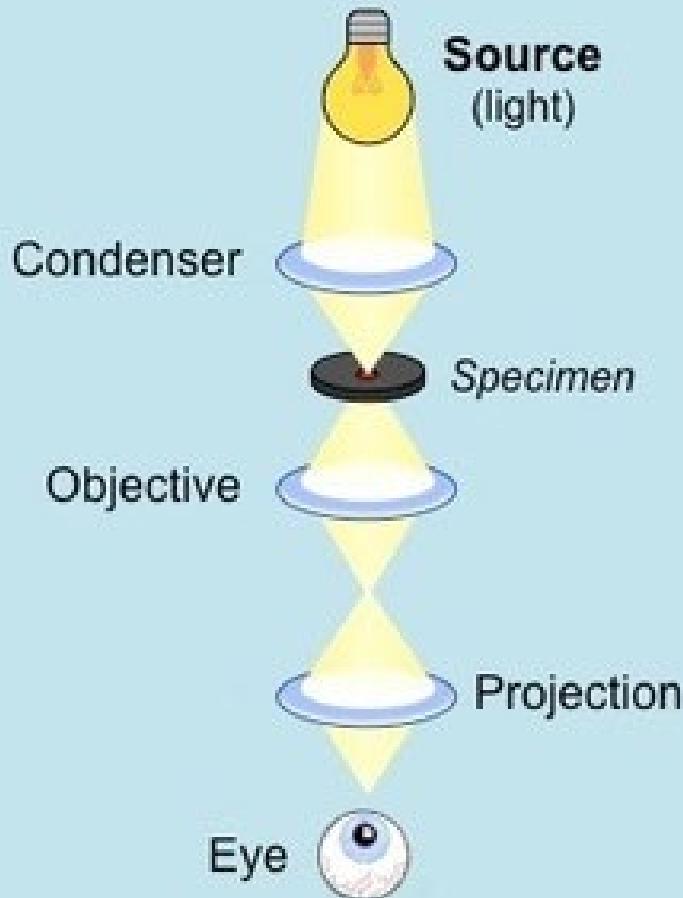
Introduction to material science

Dr. Billy Wu  
Course Leader  
Reader (Associate Professor)  
[billy.wu@imperial.ac.uk](mailto:billy.wu@imperial.ac.uk)

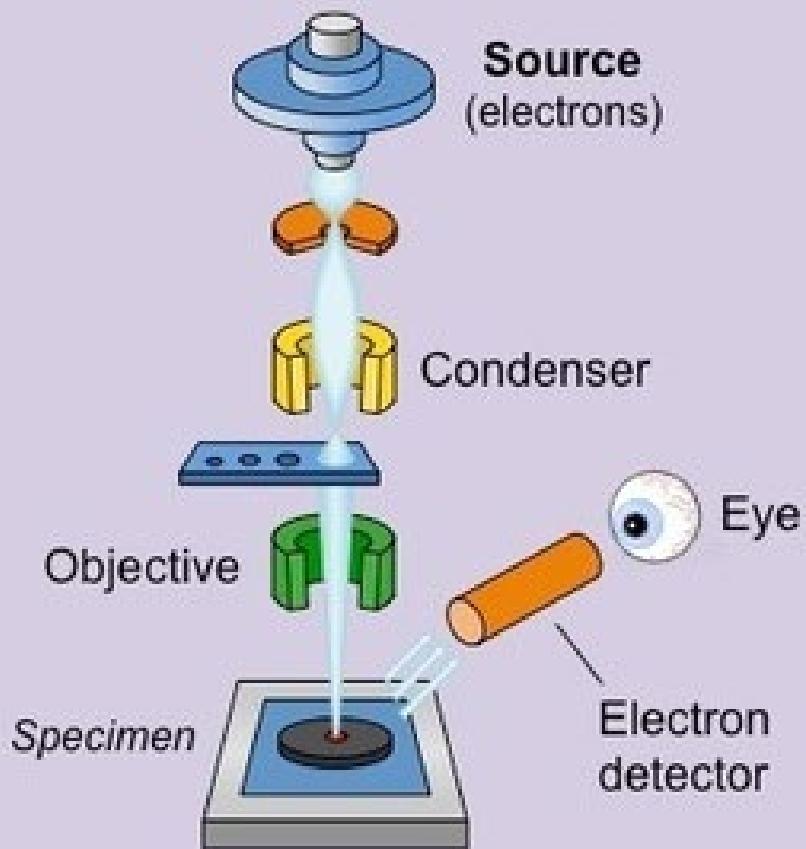


# The electron microscope

## Light Microscope



## Electron Microscope



# Last time on M&M...



- L1.2 – Introduction to material science
- L1.3 – Applications of advanced materials
- L1.4 – Mechanical properties of materials
- L1.5 – Materials experience
- L1.6 – Metals and engineering alloys I
- L1.7 – Metals and engineering alloys II
- L1.8 – Altering material properties
- L1.9 – Polymers
- L1.10 – Ceramics and glasses
- L1.11 – Composites
- L1.12 – Recycling, selection and design
- L1.13 – Material corrosion
- L1.14 – Material failure
- L1.15 – Case studies
- L1.16 – Materials overview



# Last time on M&M...

Solidification processes

Metal working

Surface treatments,  
joining and assembly

Overview

L1.17 – Introduction to production technologies

L1.18 – Casting processes

L1.19 – Plastic processing

L1.20 – Polymer composite processing

L1.21 – Ceramic processing

L1.22 – Additive manufacturing

L1.23 – Fundamentals of metal forming

L1.24 – Sheet metal forming

L1.25 – Machining operations

L1.26 – Non-traditional machining processes

L1.27 – Surface treatments

L1.28 – Welding

L1.29 – Brazing, soldering and adhesives

L1.30 – Mechanical assembly

L1.31 – Real world applications

L1.32 – Revision lecture



# Learning objectives

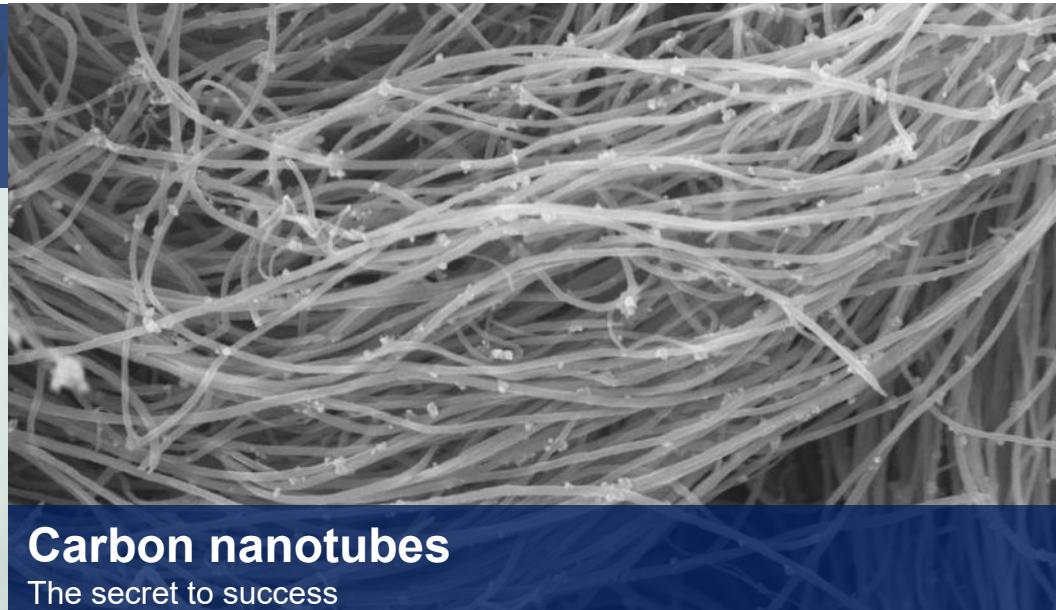
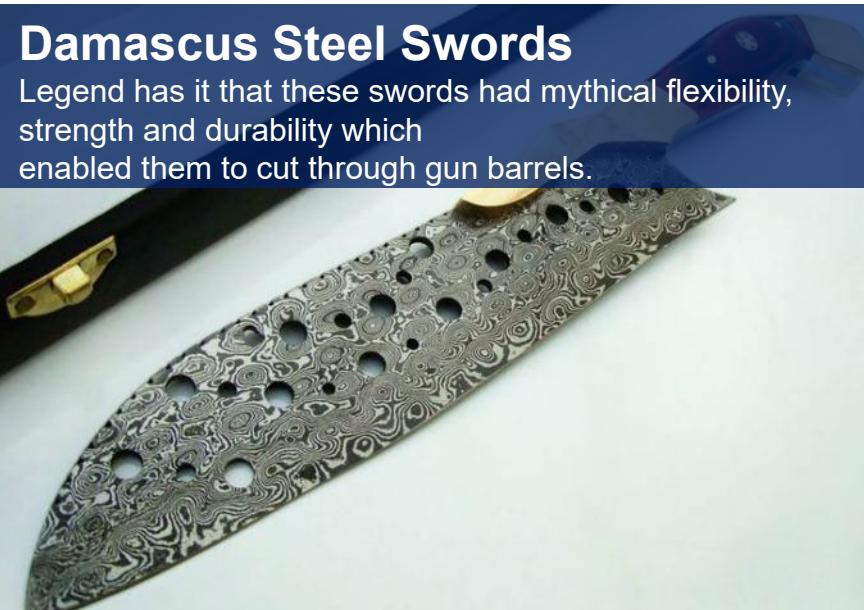
- Describe the different properties of materials that determine their applicability
- Understand the range of applications where material science is used
- Recognise the criteria that are important in the material selection process
- Define the primary classification of solid materials and their distinctive chemical features



# Magic or science?

## Damascus Steel Swords

Legend has it that these swords had mythical flexibility, strength and durability which enabled them to cut through gun barrels.



## Carbon nanotubes

The secret to success

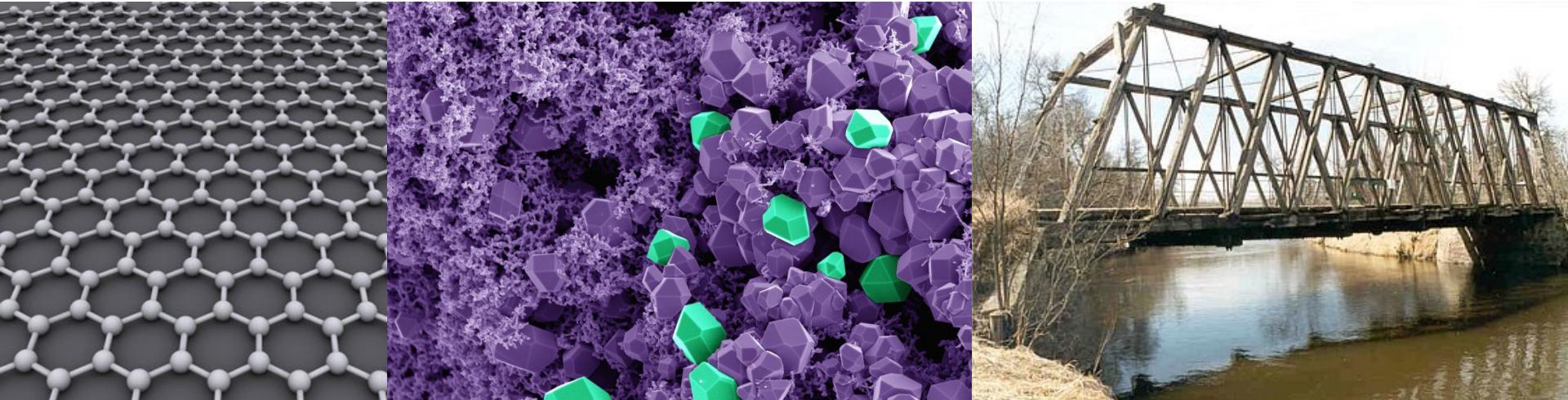


## Special Ingredients

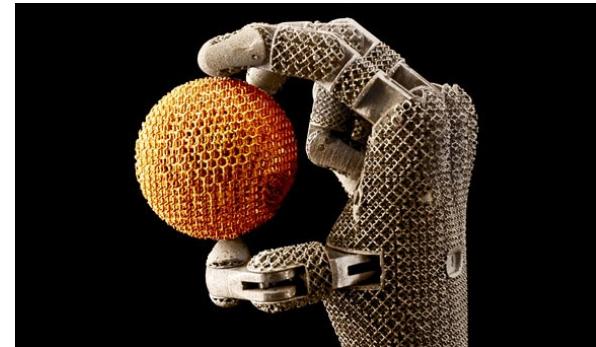
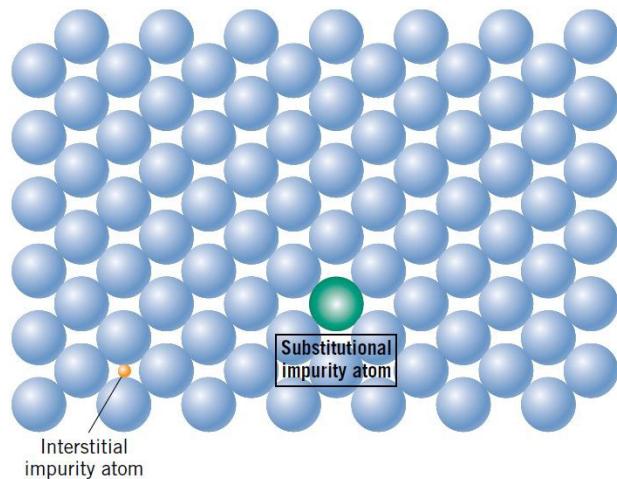
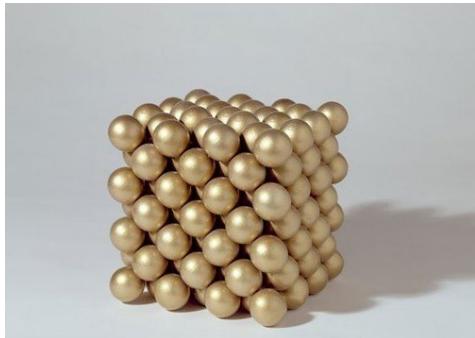
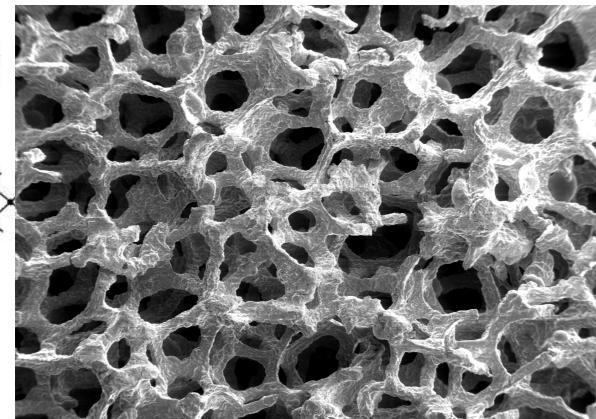
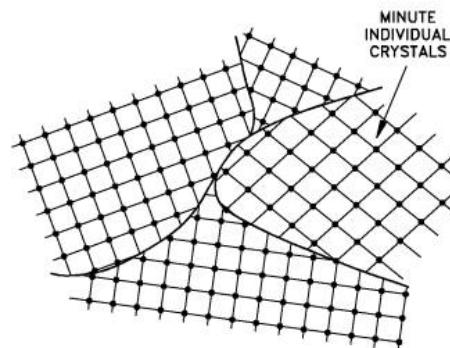
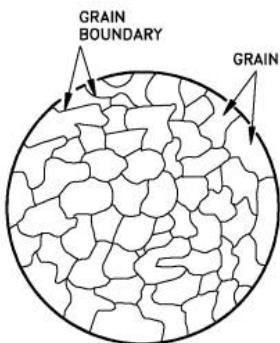
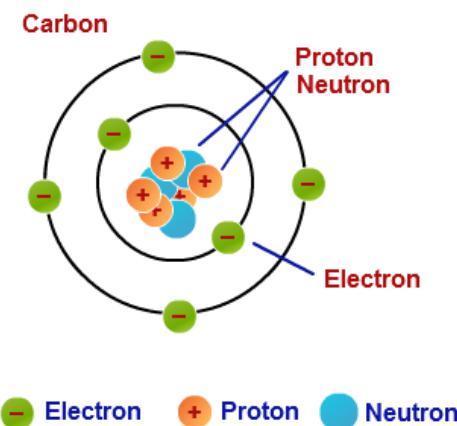
This steel could only be made from a certain type of rock and a certain type of wood

# Multi-scale features

- **Atomic**
  - Protons, neutrons, electrons, bonding, dislocations, impurities
- **Microscopic**
  - Grain structure, porosity, cracks
- **Macroscopic**
  - Lattice structures, beam profiles



# From atoms to applications



# Real world applications

## Fizzy drinks containers

### Design requirements

- Must be able to prevent the passage of CO<sub>2</sub>
- Must be non-reactive, non-toxic and preferably recyclable
- Have good impact resistance
- Optically transparent (optional)



**Aluminium cans**

Impact resistant but opaque

**PET bottles**

Transparent, inert and have good impact resistance, however are less able to prevent gas diffusion

**Glass bottles**

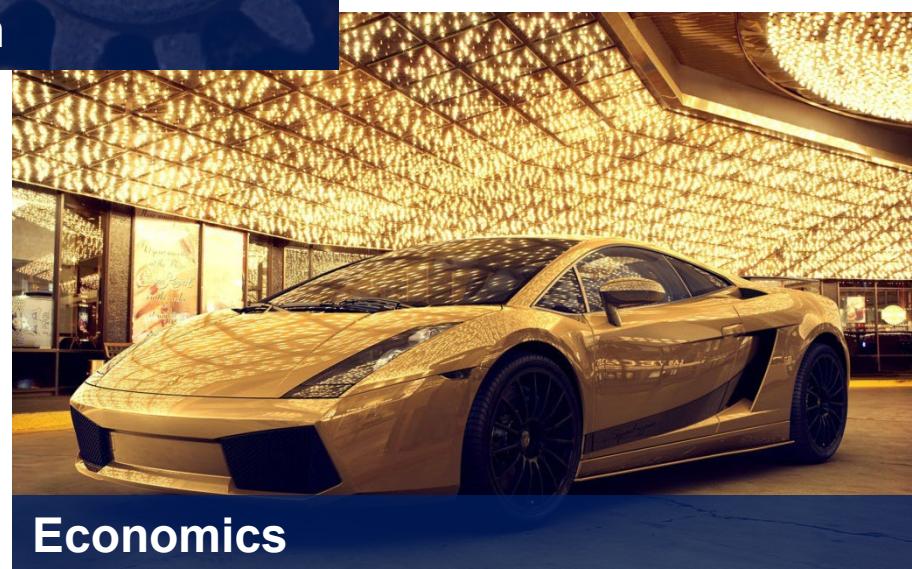
Transparent and prevents gas diffusion but brittle

# Material selection

In-service conditions



Deterioration



Economics

# In-service condition

- What stresses are they applied under
- What temperatures are they expected to operate in



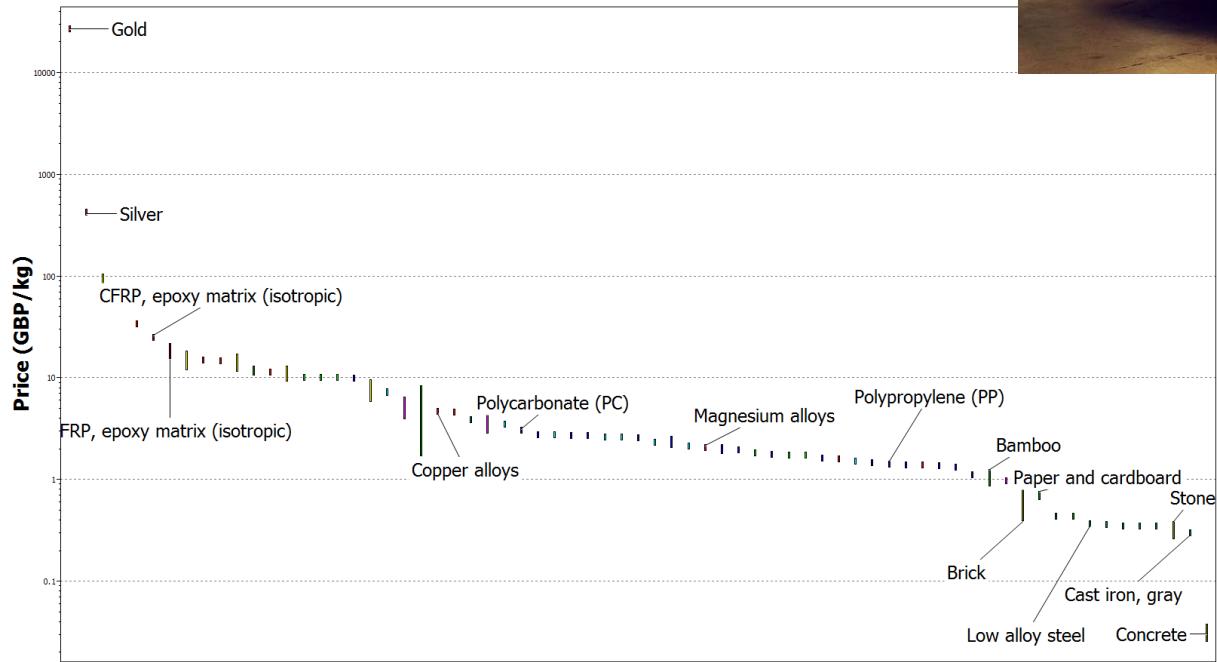
# Deterioration

- In-service condition
- How might the environment affect the lifetime of the material
- How fast is this corrosion

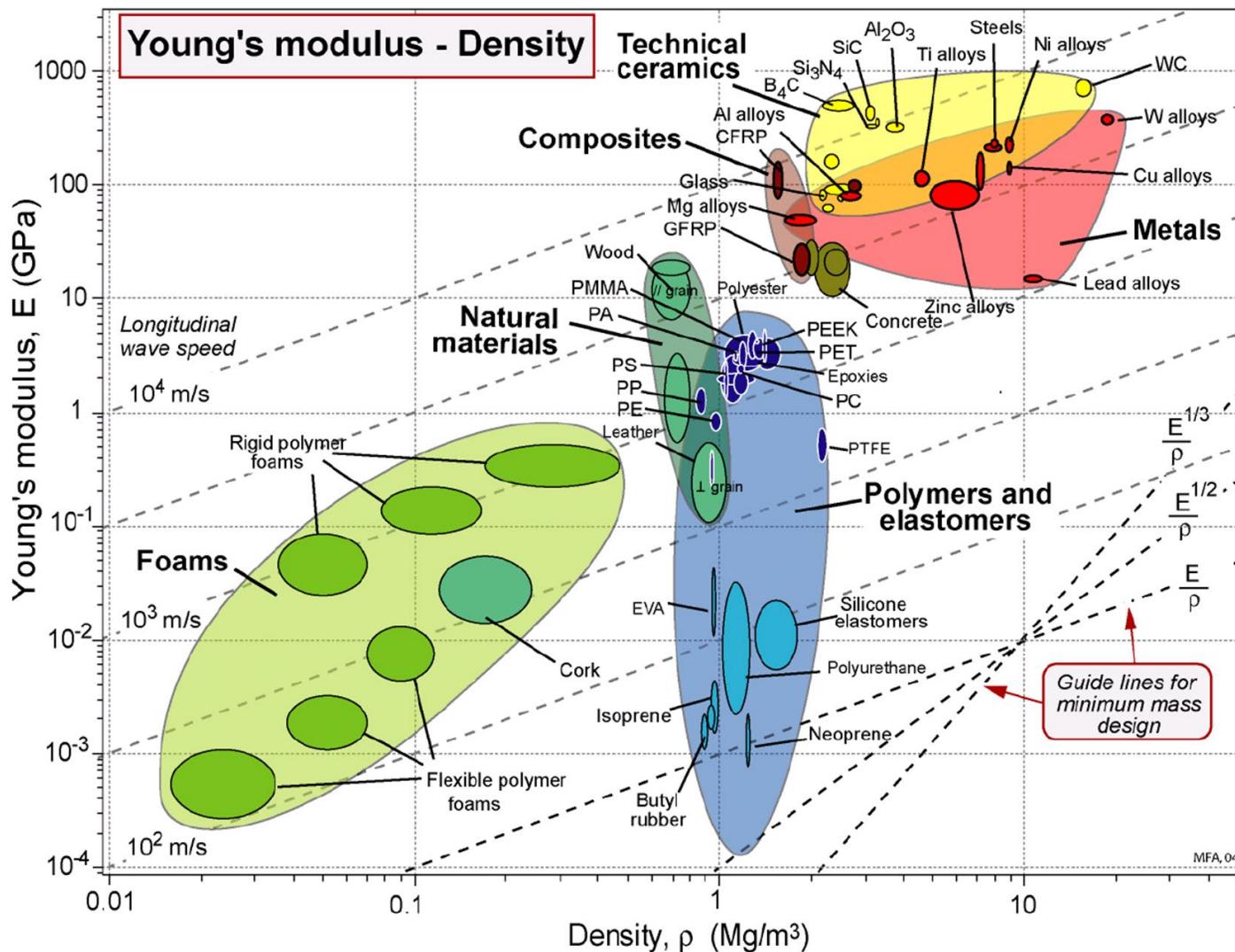


# Economic

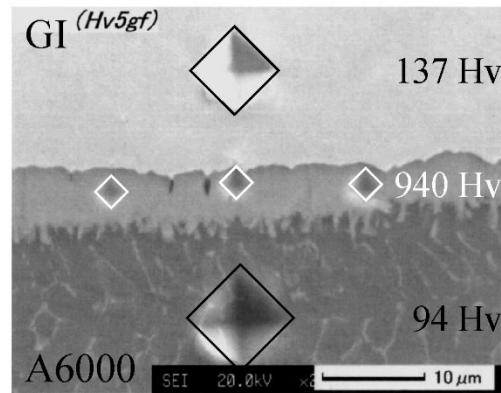
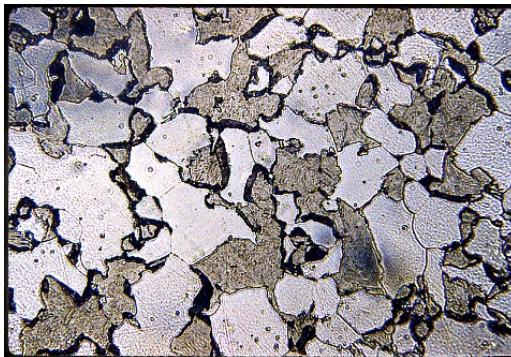
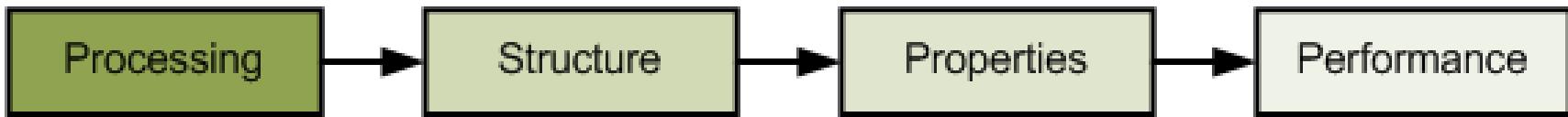
- In-service condition
- Deterioration
- How much will it cost?



# Material selection



# Material selection



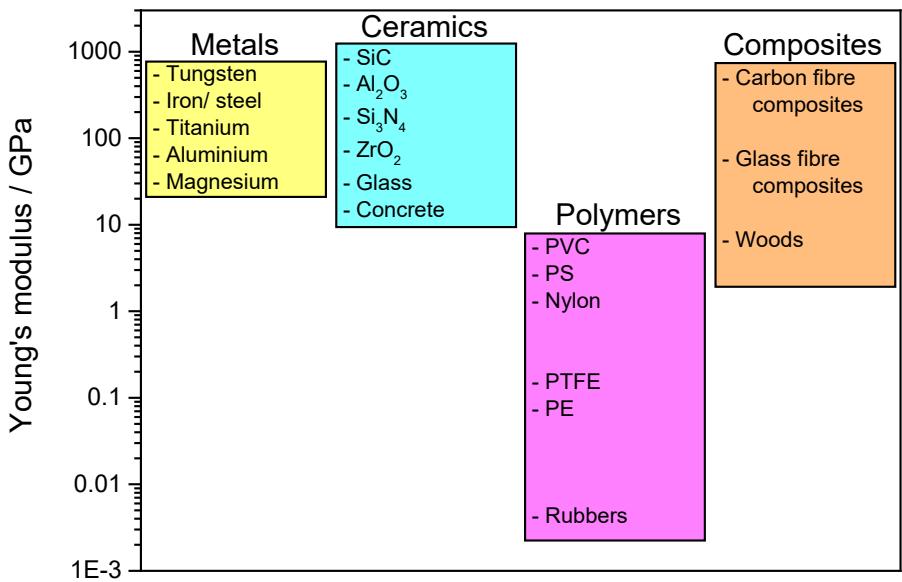
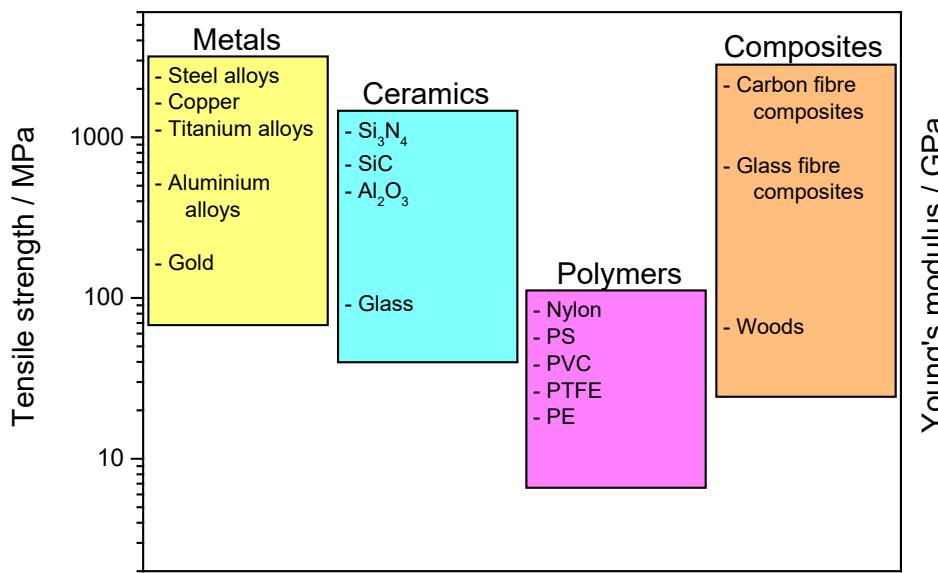
Cup-and-Cone Surfaces  
Ductile Materials



Flat Surfaces  
Brittle Materials

Fracture Surfaces

# Engineering materials



# Properties

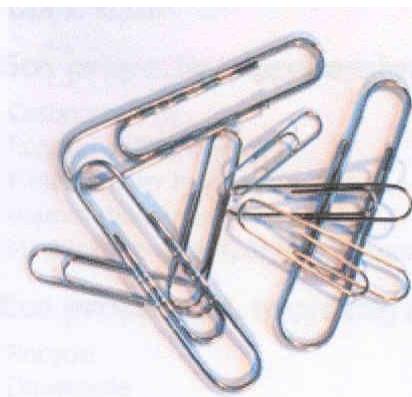
- **Mechanical**
  - Applied force - elastic modulus and strength
- **Electrical**
  - Electric field - electrical conductivity and dielectric constant
- **Magnetic**
  - Electromagnetic field - Magnetic field strength
- **Thermal**
  - Temperature - heat capacity and thermal conductivity
- **Optical**
  - Electromagnetic or light radiation - index of refraction and reflectivity
- **Deteriorative**
  - Environmental - chemical reactivity



# Metals and engineering alloys

Materials in this group are composed of one or more metallic element (e.g iron, aluminum, copper, titanium) and often smaller amounts of non-metallic elements (e.g. carbon, nitrogen, oxygen etc.).

- Stiff
- Strong
- Ductile (capable of large amounts of deformation without fracture)
- Ferrous and non-ferrous



**Low carbon steels**



**High carbon steels**



**Grey cast iron**

# Ceramics

Ceramic materials are compounds composed of metallic and non-metallic elements which are most frequently oxides, nitrides or carbides.

- Stiff
- Strong
- Brittle
- Creep resistance
- Fatigue resistance

## Traditional ceramics

Clay-based bricks, tiles, porcelain, pipes and crockery

## Modern, high performance (engineering) ceramics

Ionic metal oxides, (e.g.  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{ZrO}_2$ )

or

Covalent non-metals (e.g.  $\text{SiC}$ ,  $\text{SiO}_2$ ,  $\text{Si}_3\text{N}_4$ , diamond, graphite)



## Applications

- Abrasives
- Cutting tools
- Armour
- Insulation
- Nanoparticles
- Solid oxide fuel cells

# Polymers

A polymer is a long molecular chain mainly made up of carbon, hydrogen and other non-metallic elements (i.e. O, N, Si).

- Low density
- Ductile
- Pliable (plastic)
- Tend to soften and/or decompose at modest temperatures, which, in some instances, limits their use
- Normally chemically resistant
- Thermoplastics, thermosets and elastomers

## Applications

- Disposable cutlery
- Tires
- Bottles
- Pipes
- Domestic appliances

Polycarbonate



Synthetic rubber



Silicon rubber



# Composites

A material formed by the combination of two or more phases to achieve superior properties than either constituent acting alone

- Glass fibre
- Carbon fibre



Front suspension

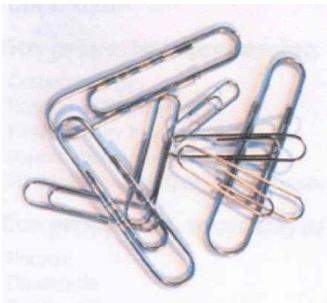
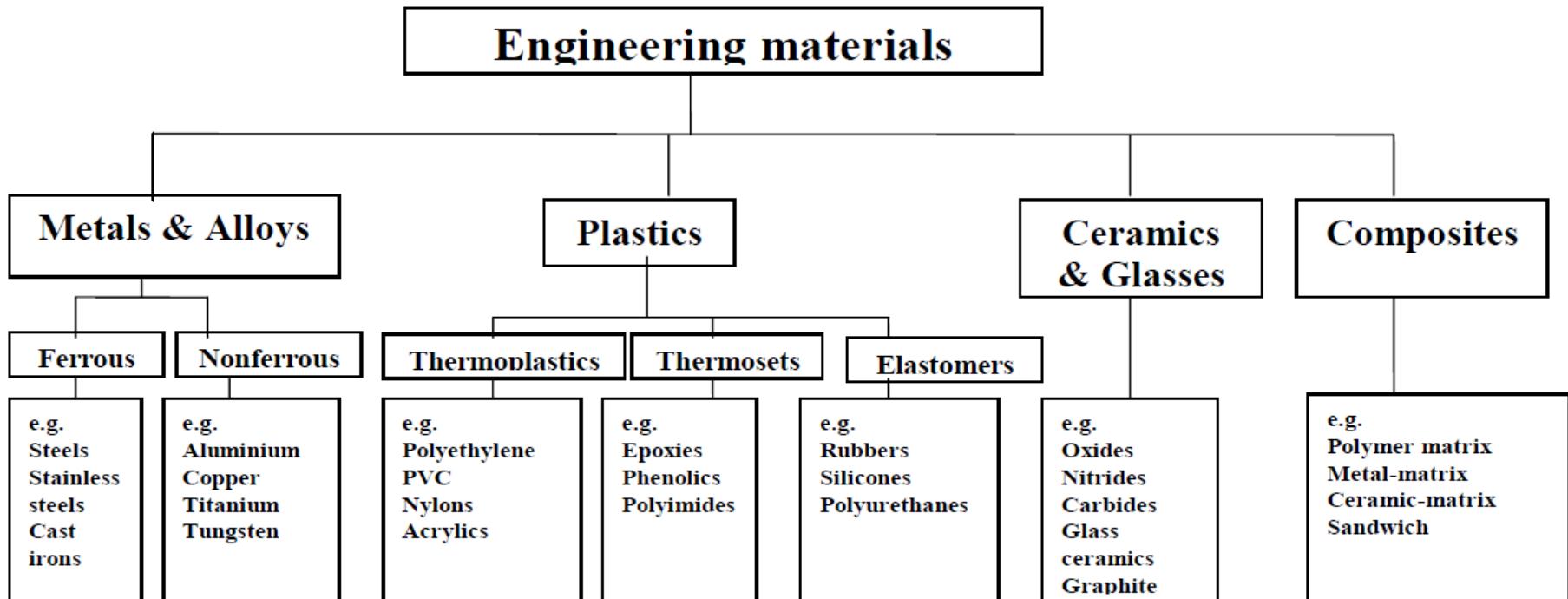
## Applications

- Aerospace
- Buildings
- Automotive
- Bikes

Survival pod

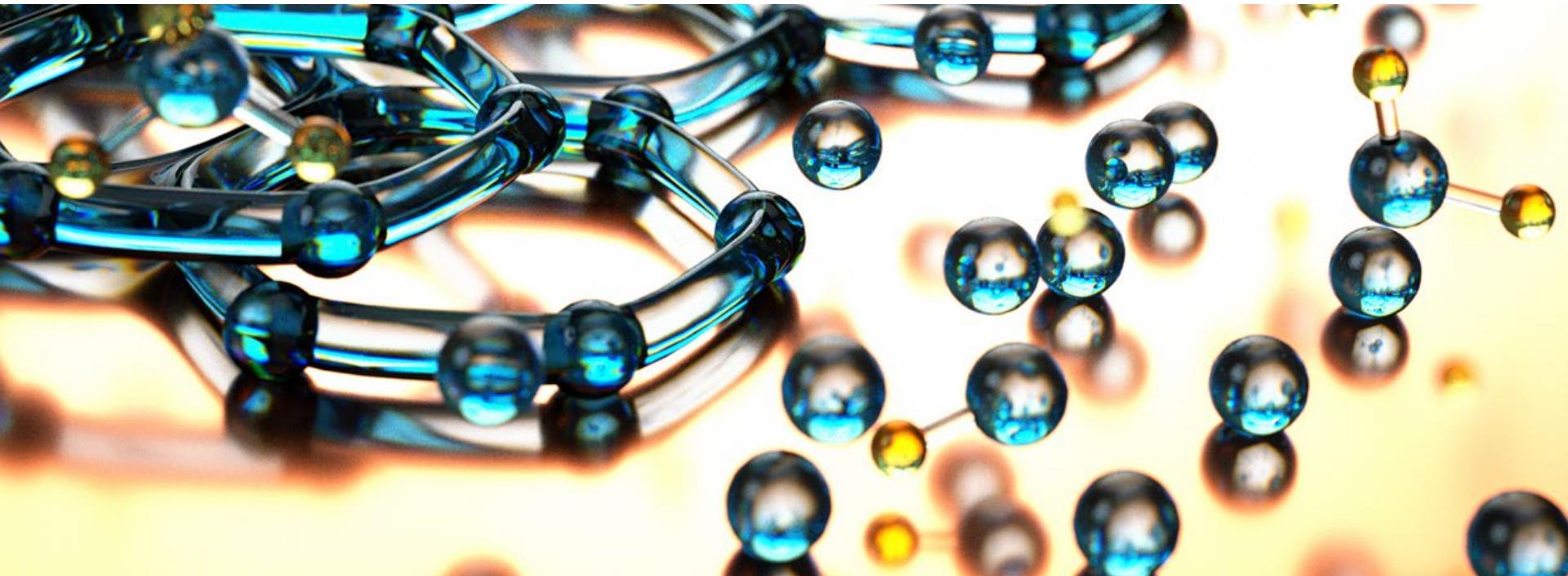


# Materials overview

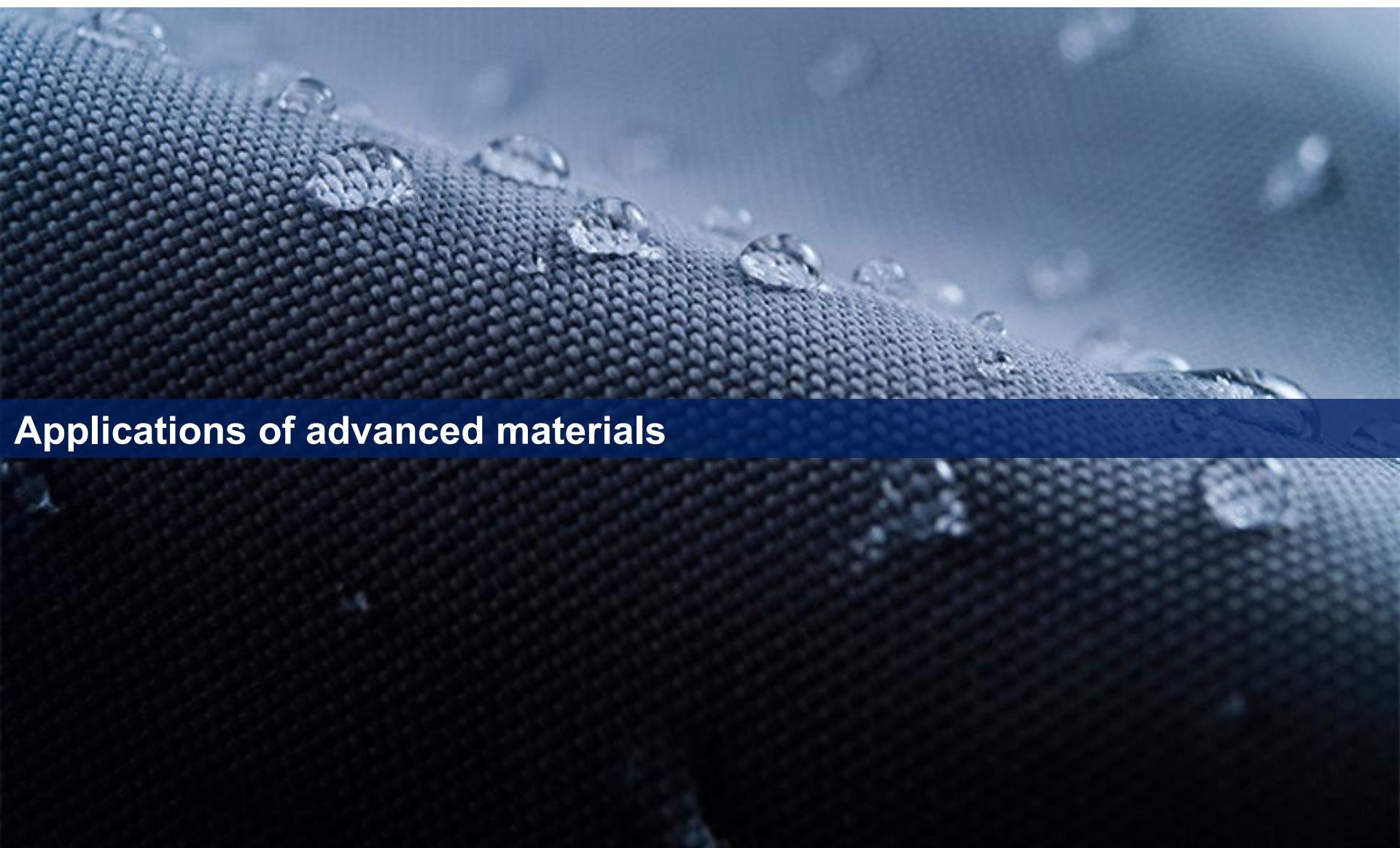


# Summary

- Describe the different properties of materials that determine their applicability
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# Next time on M&M...



**Applications of advanced materials**