Strength of Materials

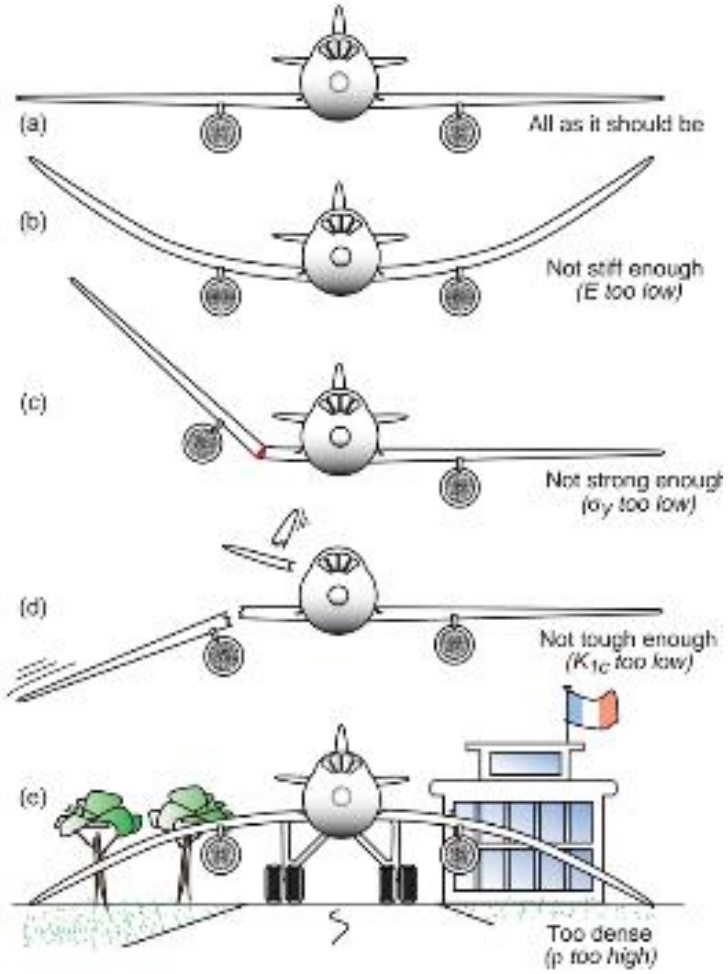
13. Engineering materials

Properties of materials

- Physical properties
- Mechanical characteristics
- Thermal behavior
- Electrical, magnetic and optical response
- Durability
- Processing and the way it influences properties
- Environmental issues

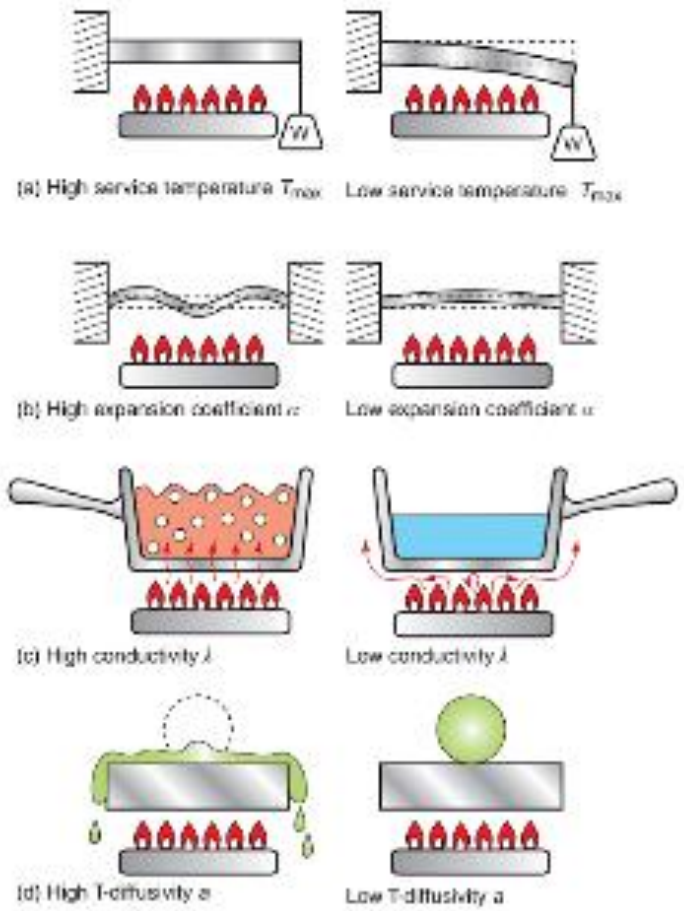
Mechanical properties of materials

- Young elastic modulus (materials intrinsically stiff with high E and soft with low E)
- Strength, σ_{max}
- Plastic deformations, ε_{pl}
- Fracture toughness, K_{1c}
- Density



Thermal properties

- Maximum and minimum service temperature
- Expansion coefficient
- Thermal conductivity
- Thermal diffusivity
- Fire resistance
- Specific heat capacity



Class of materials

1. Metals
   a) Steels √
   b) Cast iron √
   c) Al Alloys √
   d) Cu alloys
   e) Zn alloys
   f) Ti alloys
2. Polymers
   a) PE (polyethylene) √
   b) PP (polypropylene) √
   c) PET (polyethylene terephthalate)
   d) PC (polycarbonate) √
   e) PS (polystyrene)
   f) PEEK (polyether ether ketone)
   g) PA (polyamide) √
   h) Polyesters
   i) Phenolics
   j) Epoxies √
3. Elastomers
   a) Isoprene √
   b) Neoprene √
   c) Butyl rubber
   d) Natural rubber
   e) Silicones √
   f) EVA (ethylene-vinyl acetate)
4. Ceramics
   a) Aluminas √
   b) Silicon carbides √
   c) Silicon nitrides √
   d) Zirconias
5. Glasses
   a) Soda glass
   b) Borosilicate glass √
   c) Silica glass √
   d) Glass-ceramics √
6. Hybrids
   a) Composites √
   b) Sandwiches √
   c) Segmented structures √
   d) Lattices and foams √

Processes: types

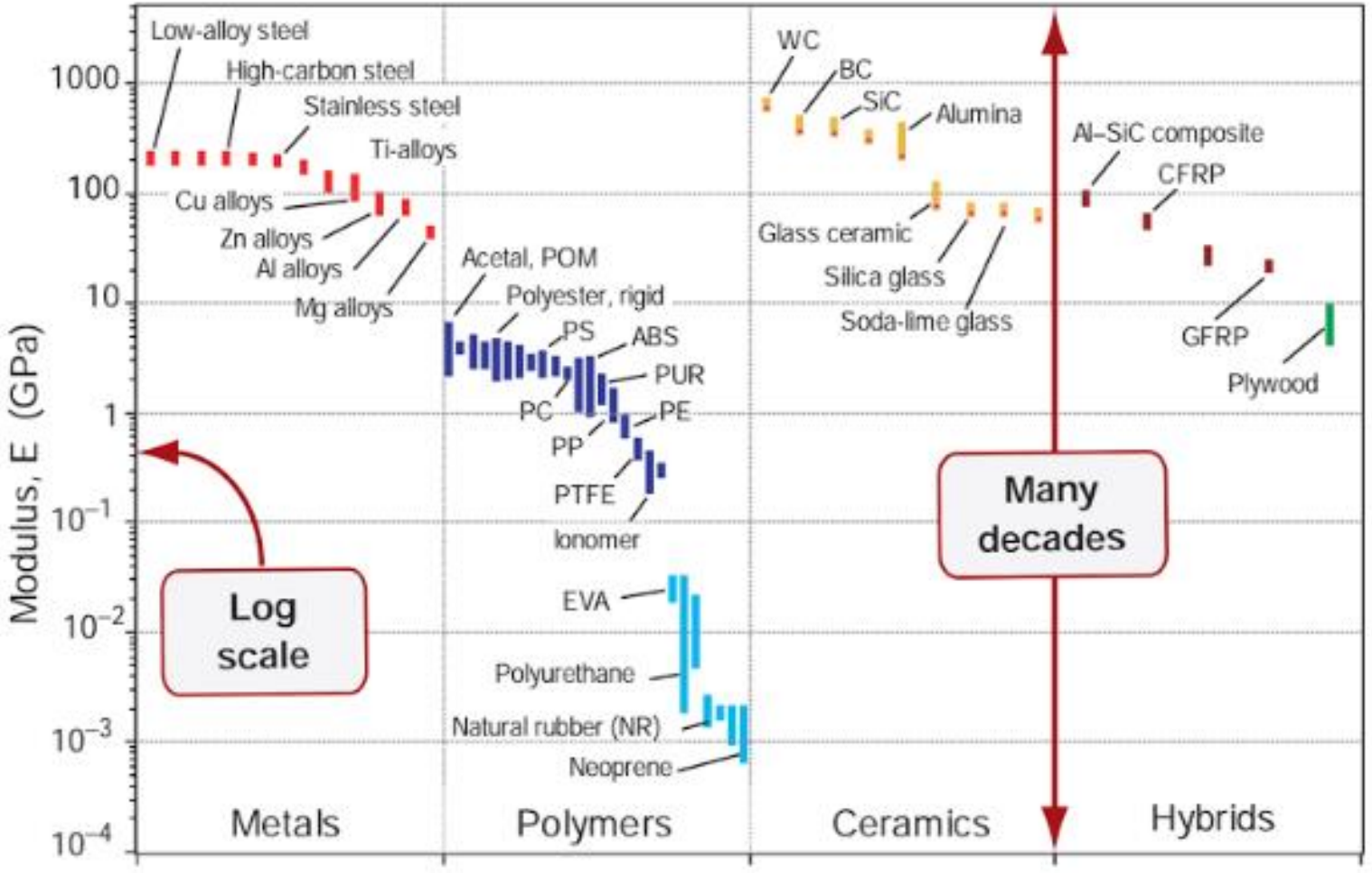
Primary shaping
- Casting methods (boarding, sand, die, investment)
- Molding methods (injection, concrete consolidation, compression, blow molding)
- Deformation methods (rolling, forging, drawing)
- Powder methods (n.a.)
- Composite forming (resin transfer molding, filament winding, handy lay-up)
- Special methods (prefabrication, concrete compression)

Secondary processes
- Machining (cut, turn, plane drill, grind)
- Heat and water treatment (vapor treatment of concrete, hardened glass)

Joining
- Fastening, riveting
- Welding
- Snap fits
- Cements, adhesives

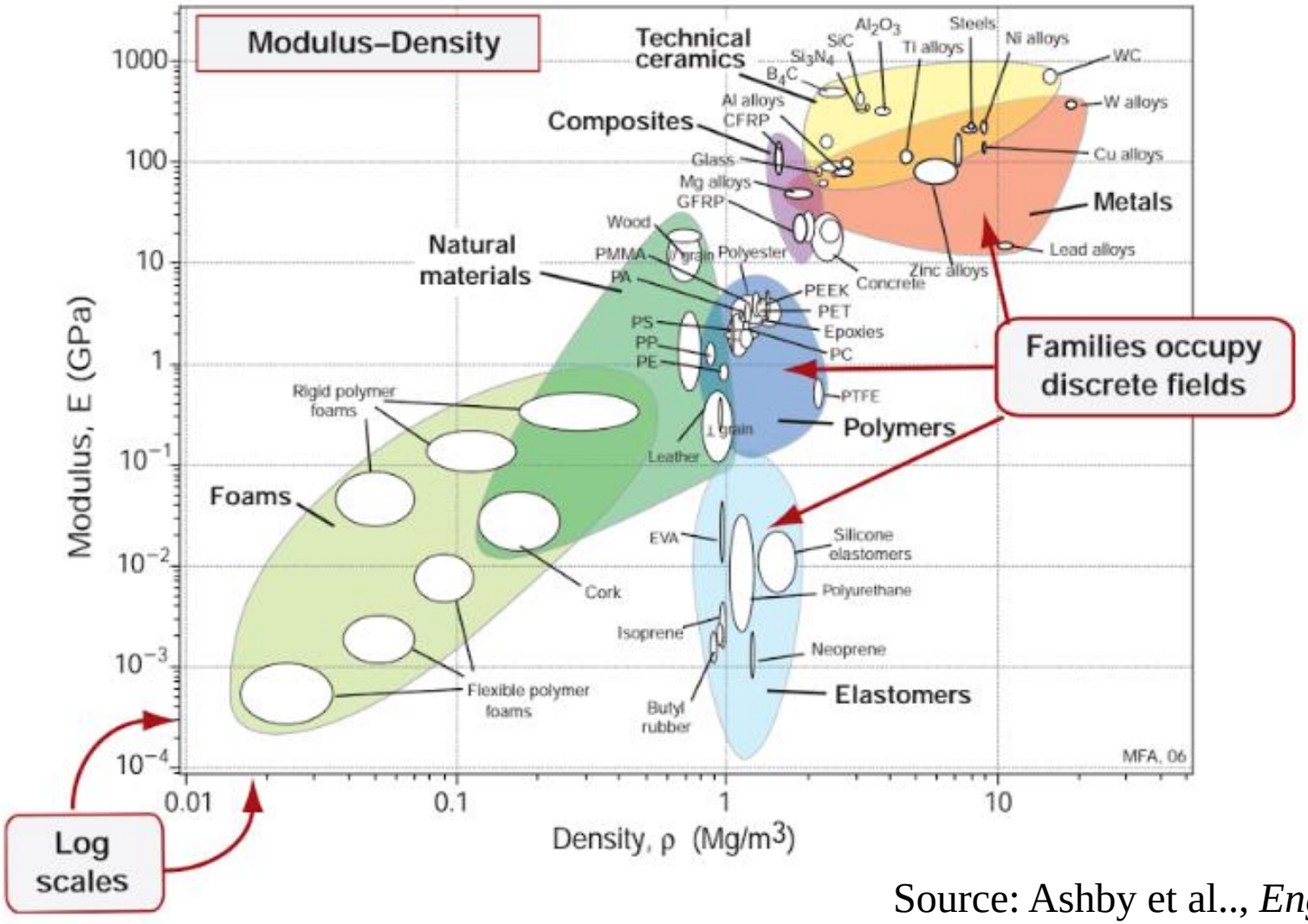
Surface treatment
- Polishing, texturing
- Painting

A bar chart of modulus



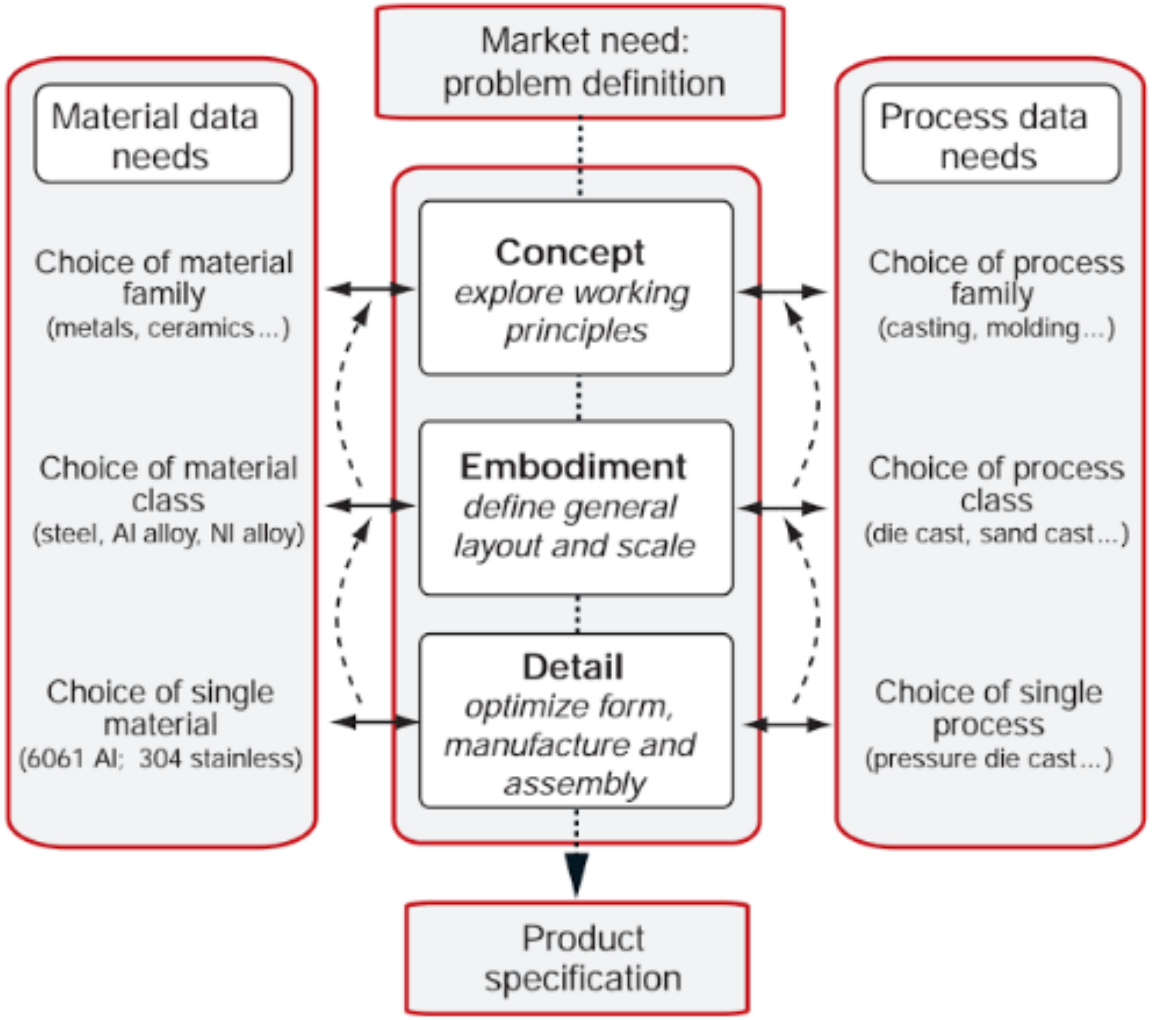
Source: Ashby et al.., *Engineering materials*

Modulus – density chart



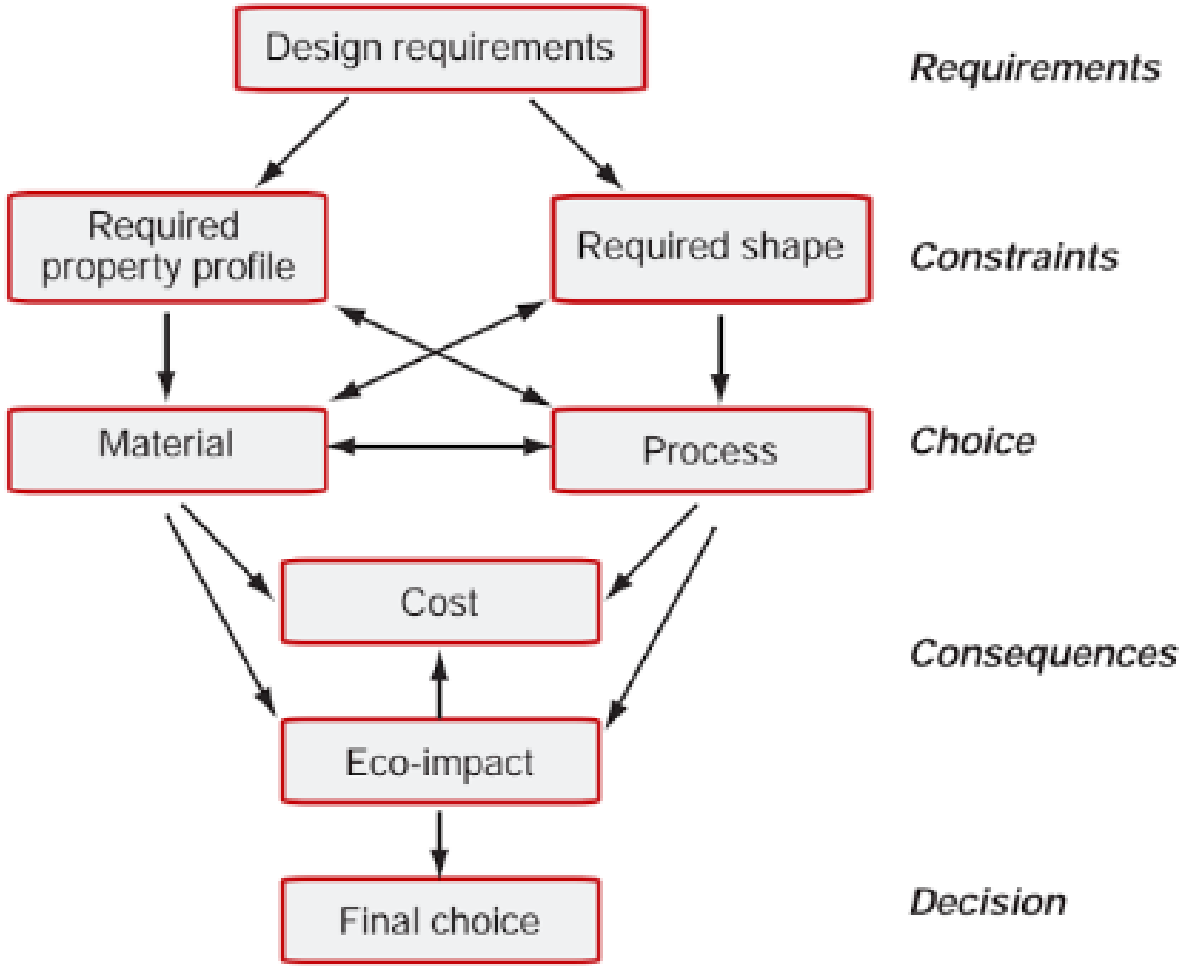
Source: Ashby et al.., *Engineering materials*

Design process



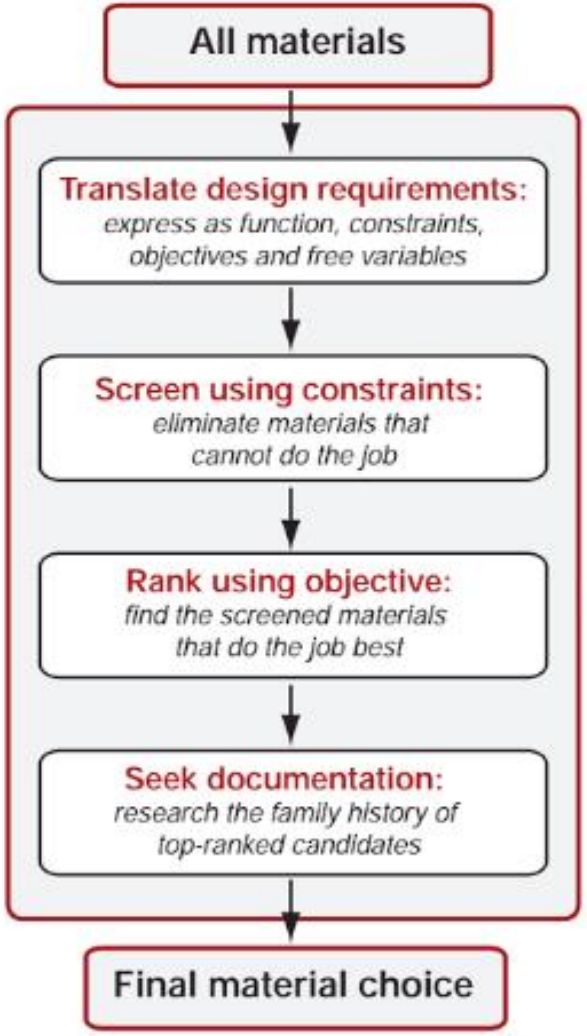
Source: Ashby et al.., *Engineering materials*

Design: phases



Source: Ashby et al.., *Engineering materials*

Choice of material



Source: Ashby et al.., *Engineering materials*

Choice of material – cont.

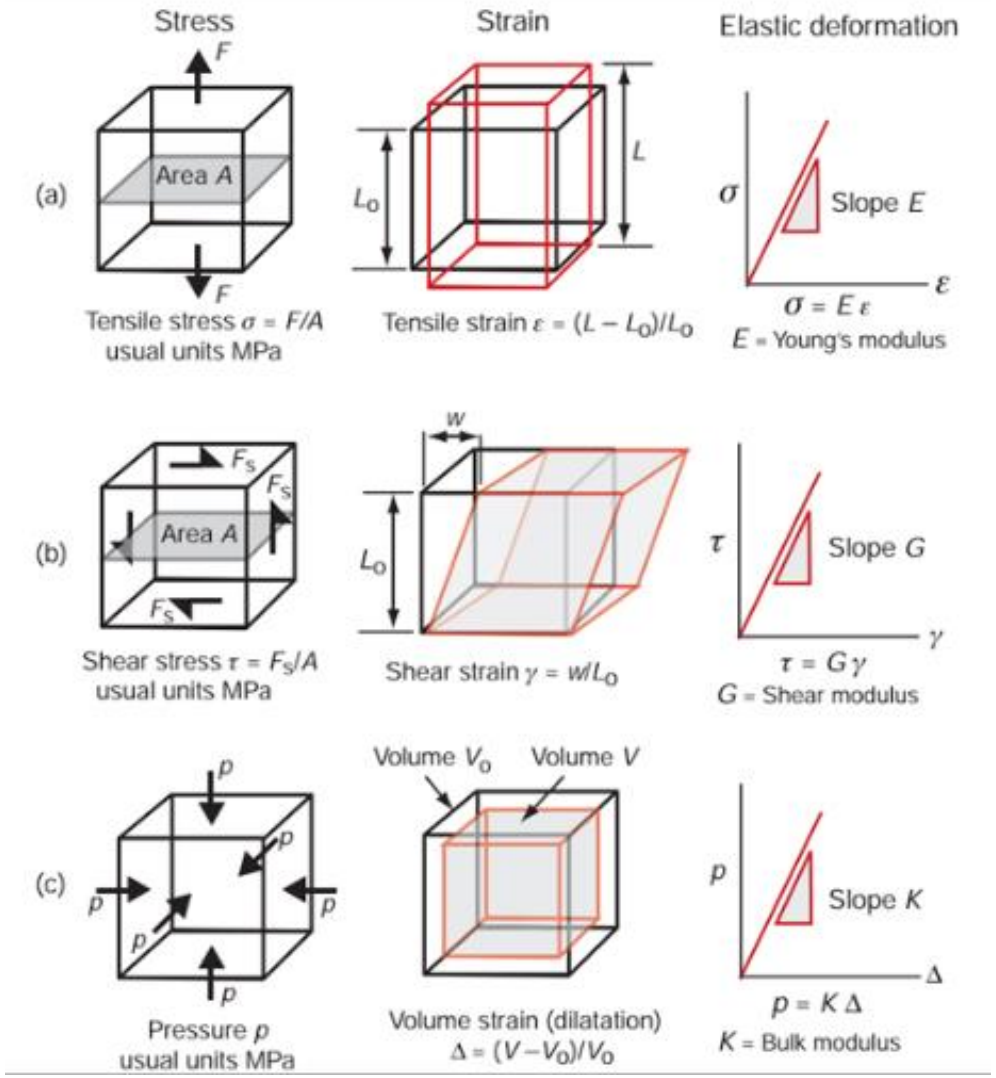
Common constraints: meet a target value of

- Stiffness
- Strength
- Fracture toughness
- Thermal conductivity
- Room acoustics
- Insolation
- Resistance to environment actions
- Cost
- Mass
- Service life

Common objectives

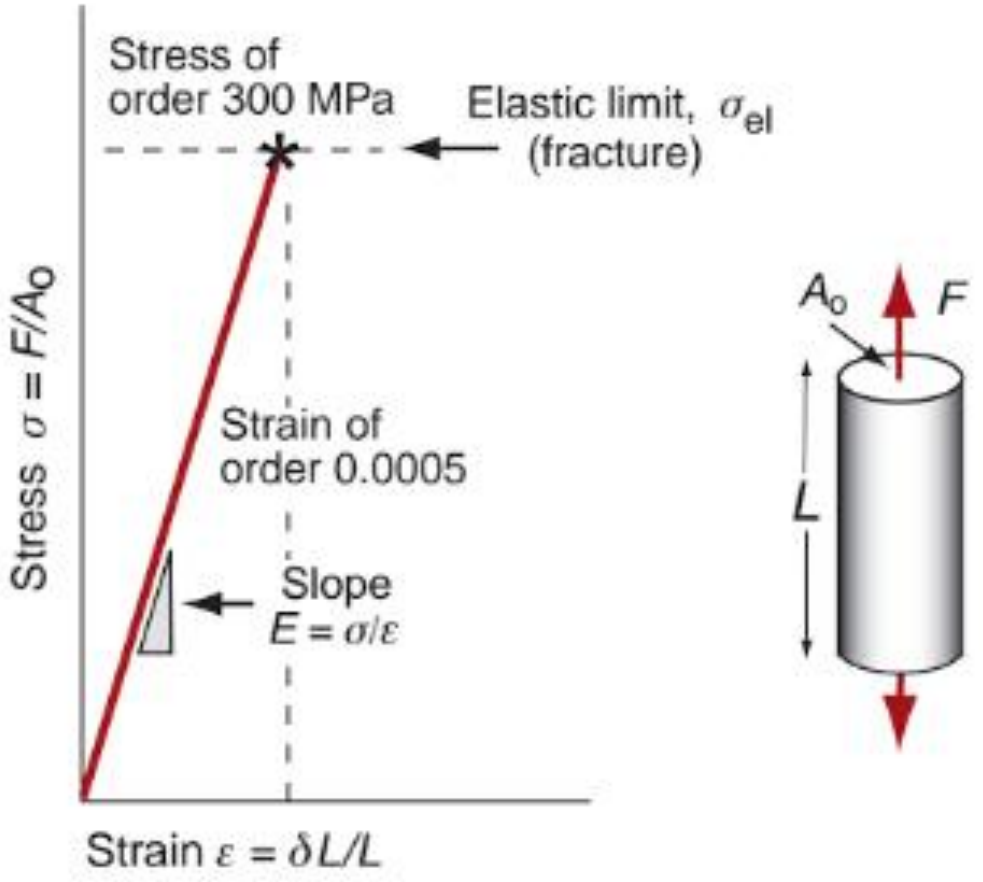
- Minimize cost
- Minimize impact on the environment
- Minimize heat loss
- Maximize soundproof
- Maximize endurance

Loading type

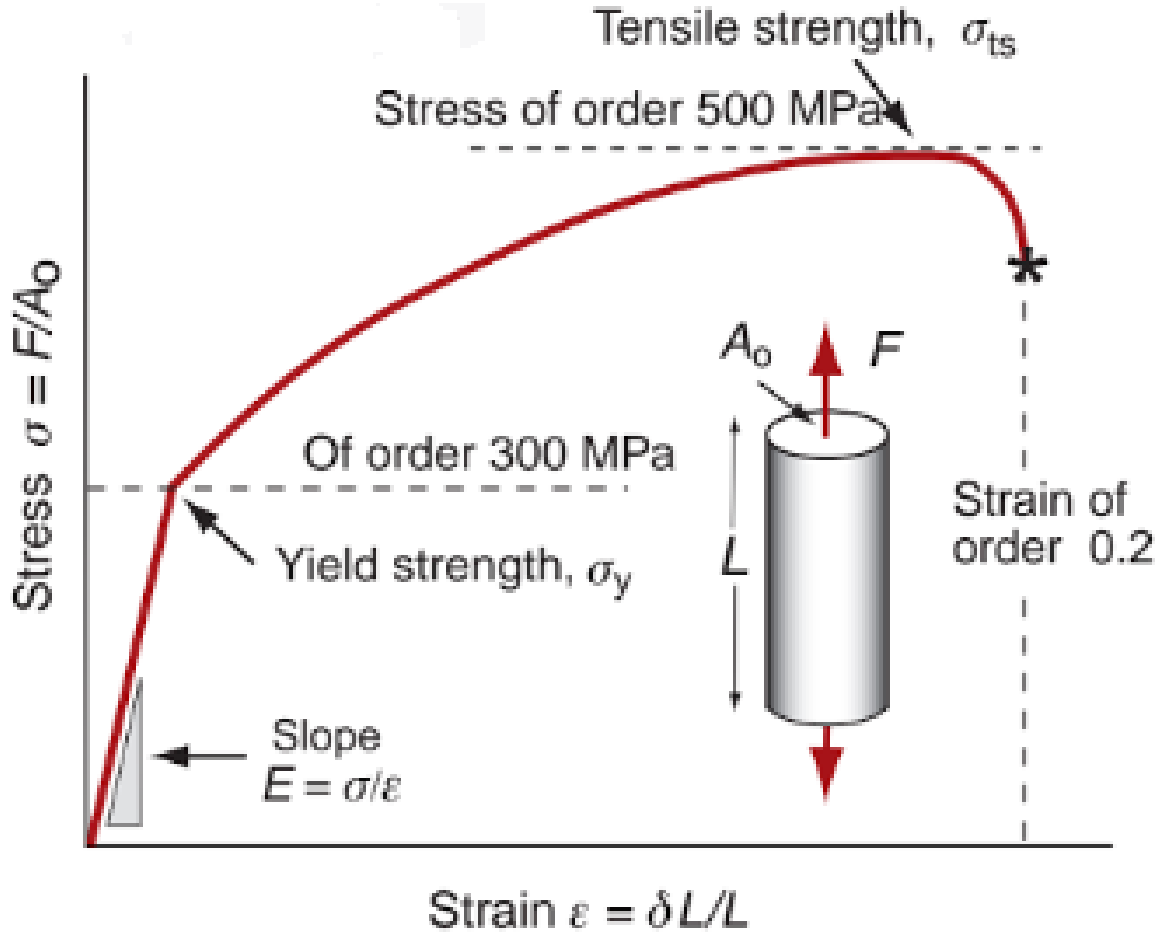


Source: Ashby et al.., *Engineering materials*

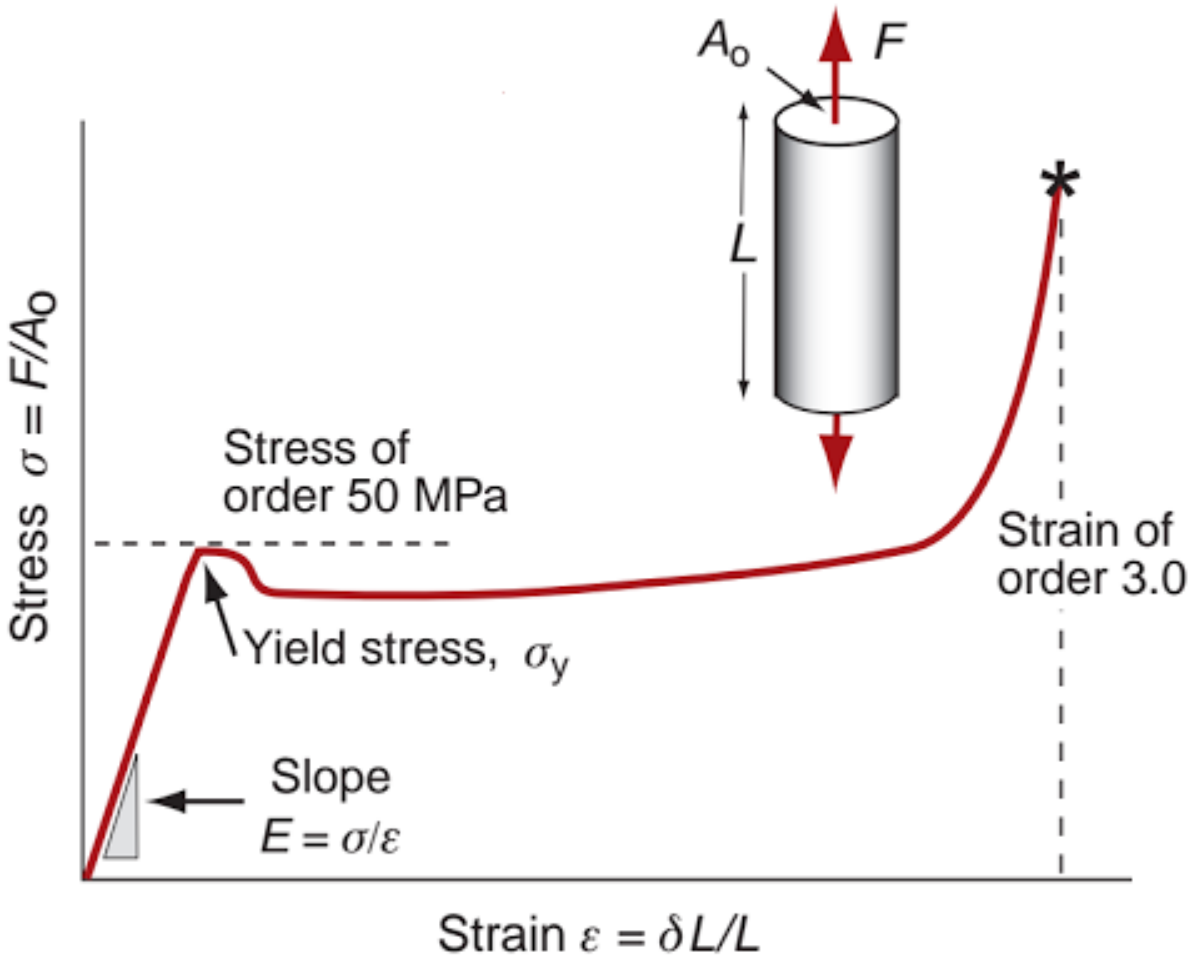
Tensile test: ceramics



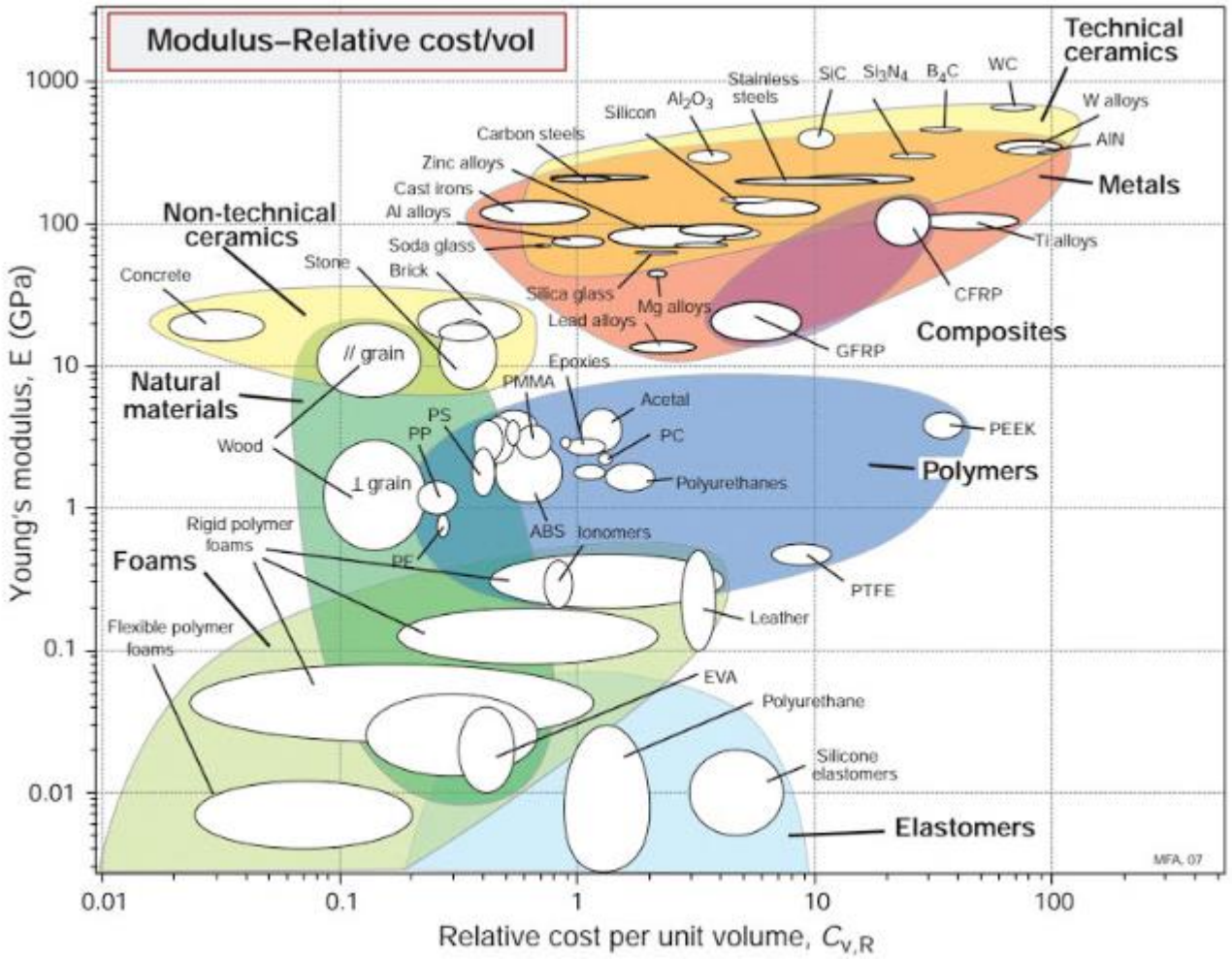
Tensile test: ductile metals



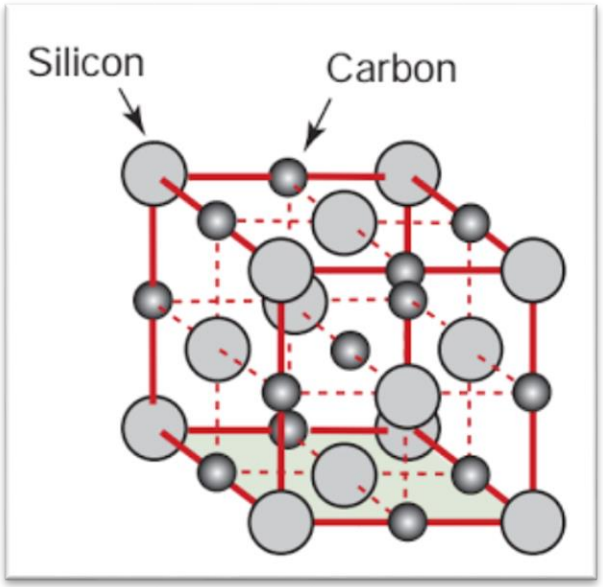
Tensile test: ductile polymers



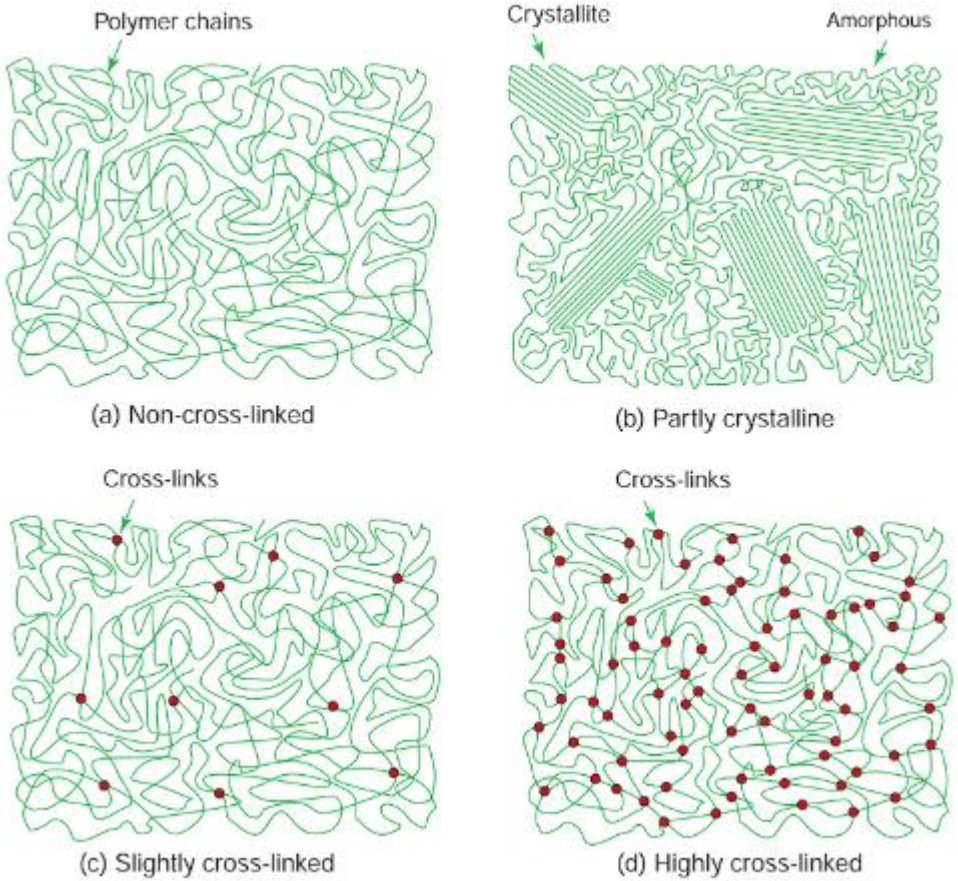
Young modulus vs relative cost



What determines density and stiffness?

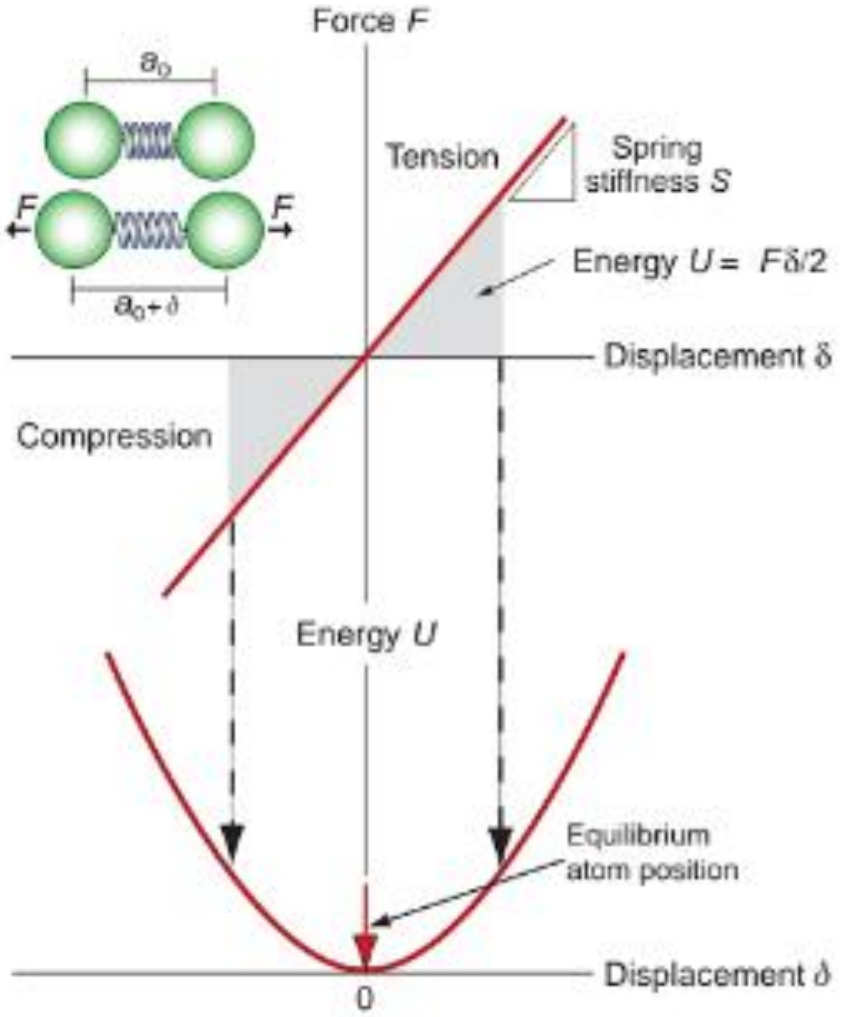


The silicon carbide unit cell



The chains in polymers

Atomic bonds



Types of bonds

Bond type	Examples	Bond stiffness [N/m]	Young's modulus [GPa]
covalent	carbon-carbon bond (diamond)	50-180	200-1000
metallic	all metals	15-75	60-300
ionic	sodium chloride	8-24	32-96
hydrogen bond	polyethylene	3-6	2-12
Van der Waals	waxes	0.5-1	1-4

Thank you for your attention!