Ceramics

Ceramics

A wide-ranging group of materials whose ingredients are clays, sand and felspar.

Clays

Contain some of the following:

- Silicon & Aluminium as silicates
- Potassium compounds
- Magnesium compounds
- Calcium compounds

Sand contains Silica and Feldspar or Aluminium Potassium Silicate.

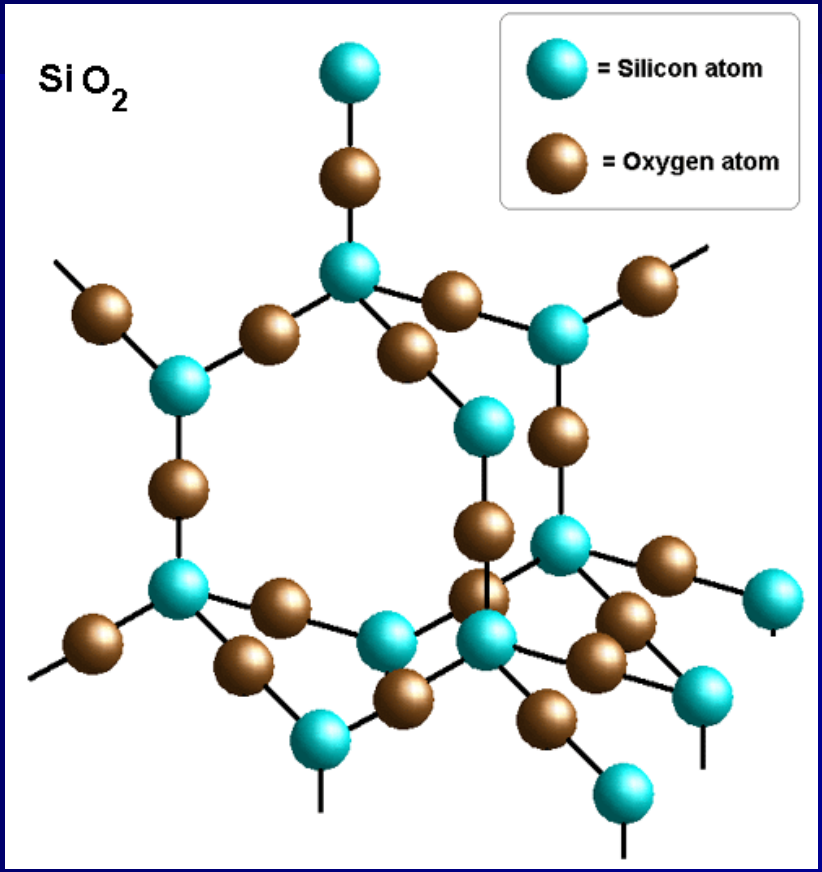
Types of Ceramics

- Whitewares
- Refractories
- Glasses
- Abrasives
- Cements

Comparison metals v ceramics

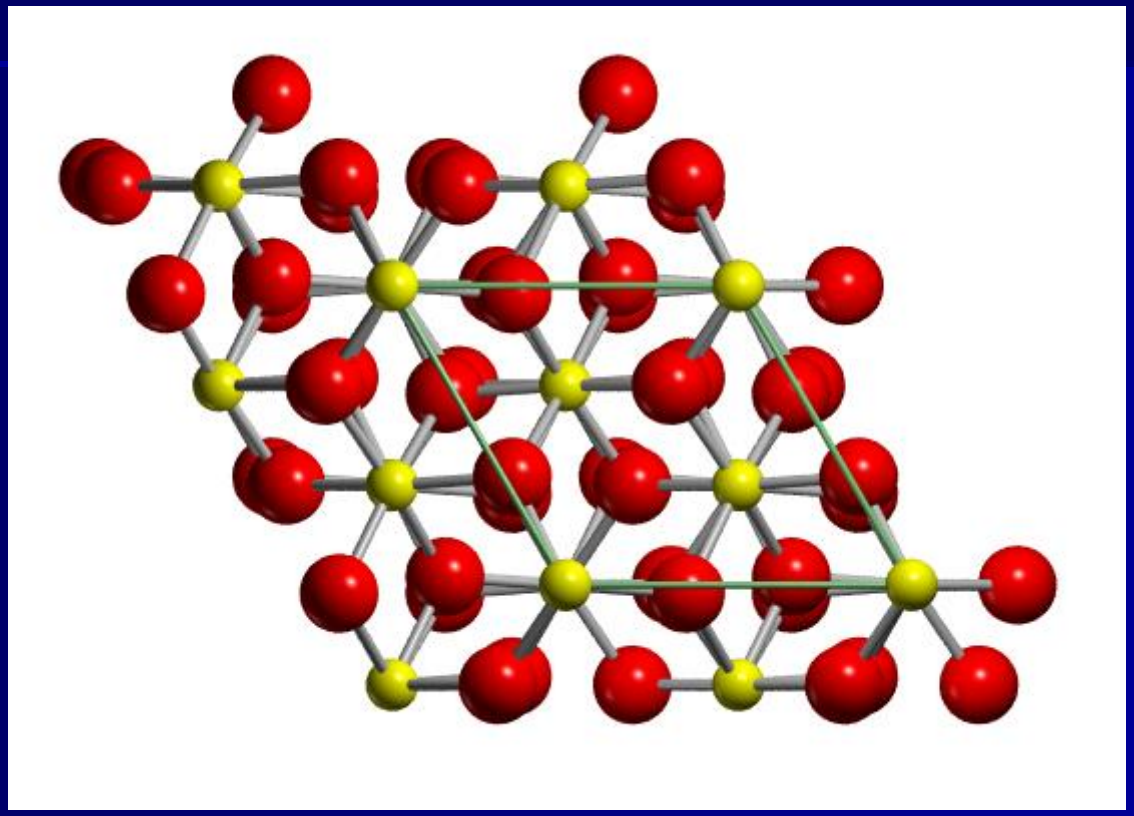
Metals	Ceramics
Crystal structure	Crystal structure
Large number of free electrons	Captive electrons
Metallic bond	Ionic/covalent bonds
Good electrical conductivity	Poor conductivity
Opaque	Transparent (in thin sections)
Uniform atoms	Different-size atoms
High tensile strength	Poor tensile strength[a]
Low shear strength	High shear strength
Good ductility	Poor ductility (brittle)
Plastic flow	None
Impact strength	Poor impact strength
Relatively high weight	Lower weight
Moderate hardness	Extreme hardness
Nonporous	Initial high porosity
High density	Initial low density

Structure of Ceramics



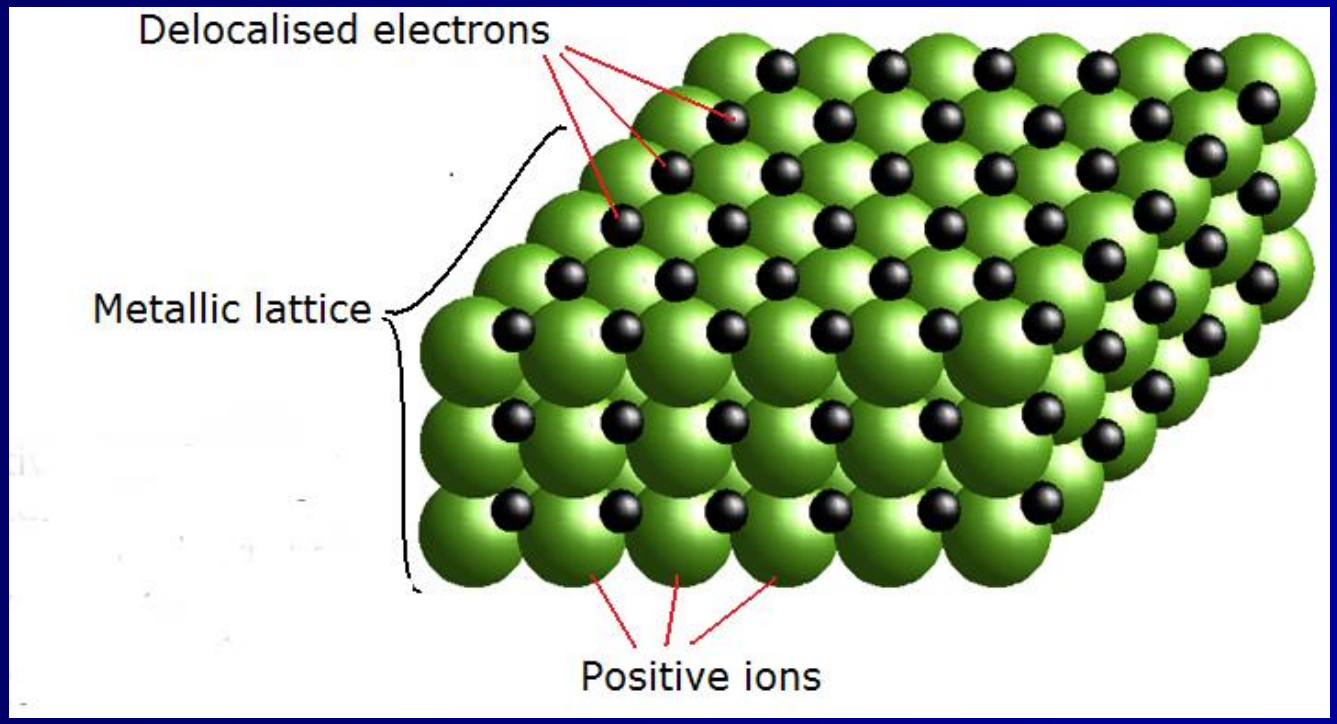
- Silicon Dioxide (Silica) – most common form Quartz
- Covalent bonding (electrons are shared)

Aluminium Oxide (Alumina)



- Al_2O_3 – Alumina
- Ionic bonding (electrons are transferred)

Metals



- Positive Ions form crystal lattice
- Delocalised electrons move freely
- Dislocations occur due to stress allowing slip (plastic deformation)

Bonded Clay Ceramics

Made from natural clays and mixtures of clays and added crystalline ceramics.

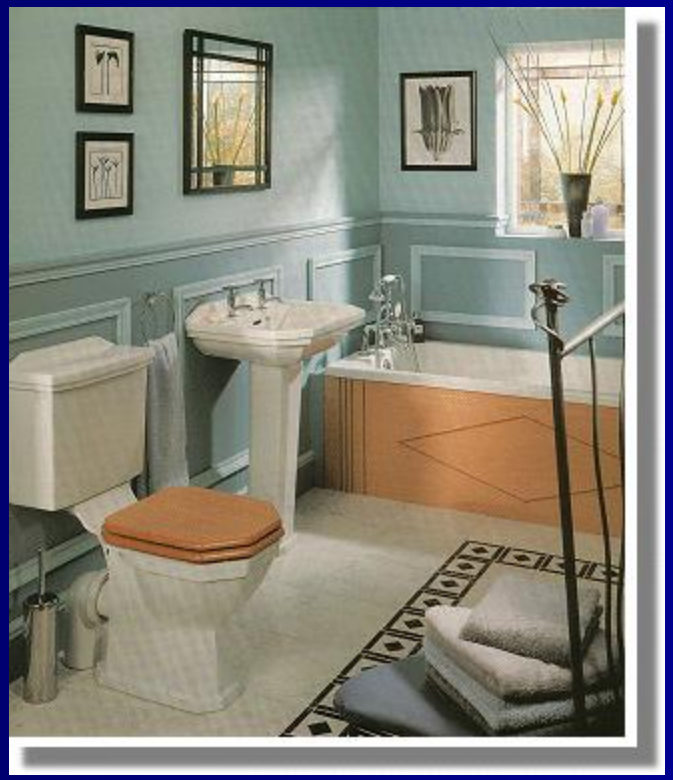
These include:

- Whitewares
- Structural Clay Products
- Refractory Ceramics

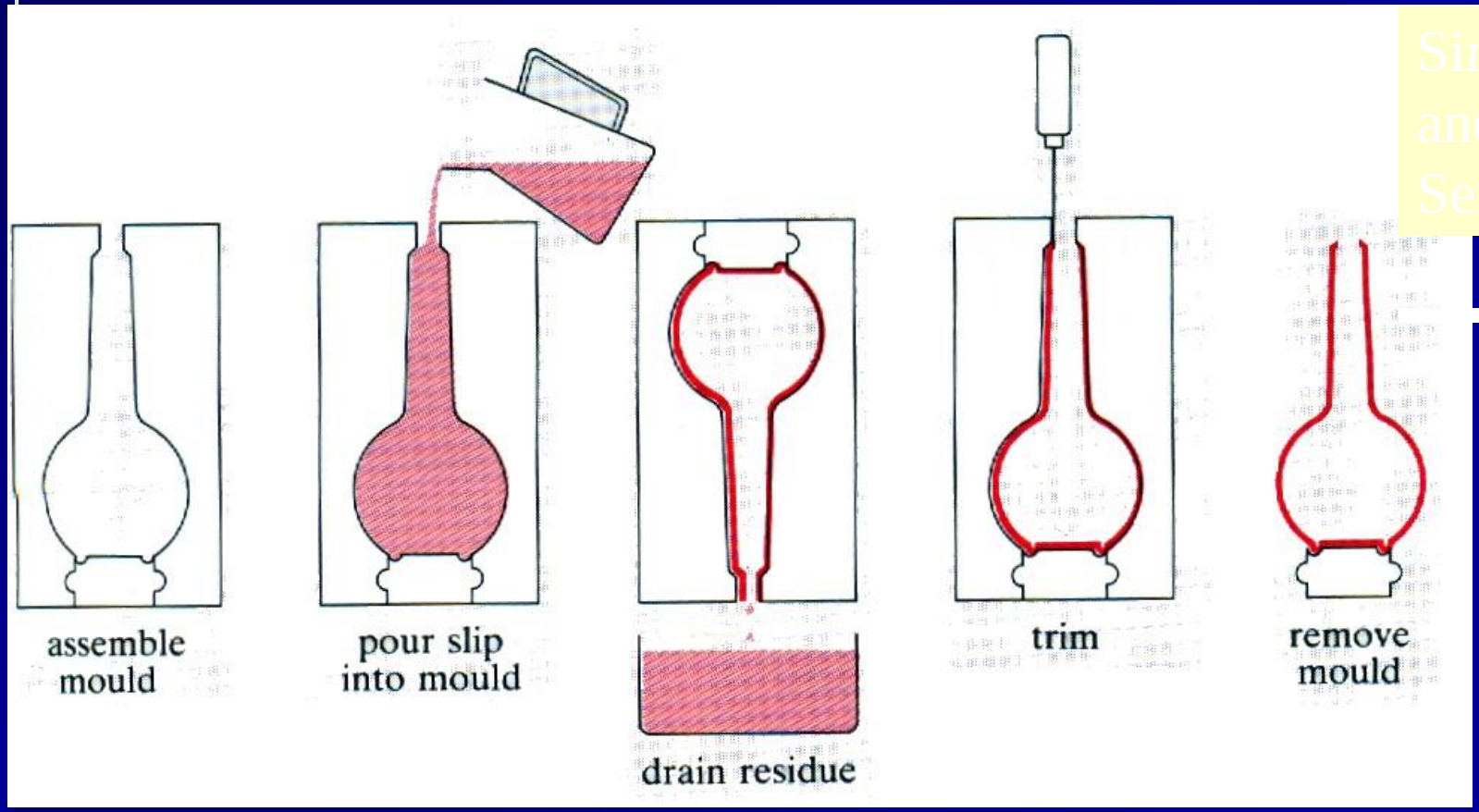
Whitewares

- Crockery
- Floor and wall tiles
- Sanitary-ware
- Electrical porcelain
- Decorative ceramics

Whiteware: Bathrooms

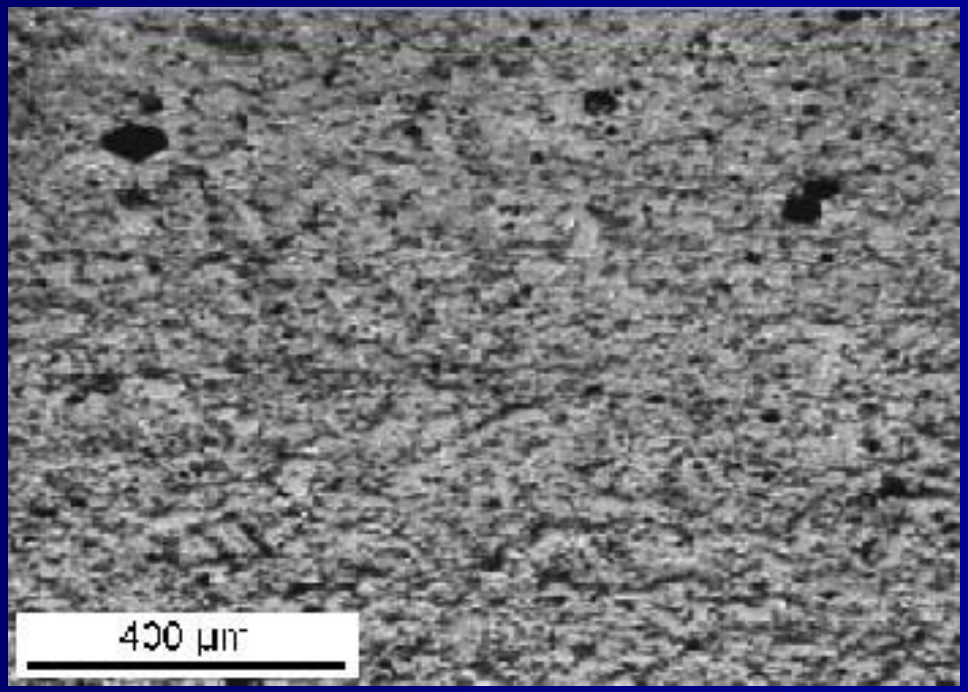


Slip Casting



Sinter and Serve

Whitewares



- https://www.youtube.com/watch?v=W1YCRs6QtEY
- https://www.youtube.com/watch?v=FZzOTX9Ihqs

Thickness of cast

- The thickness of the cast (L_c) depends on a number of factors:
  - K_c - permeability of the cast
  - P - the pressure difference across the cast (assumed to be constant)
  - t – time
  - V_c – volume fraction of solid in the cast
  - V_s – volume fraction of solid in the slurry
  - η_L – viscosity of the liquid

Refractories

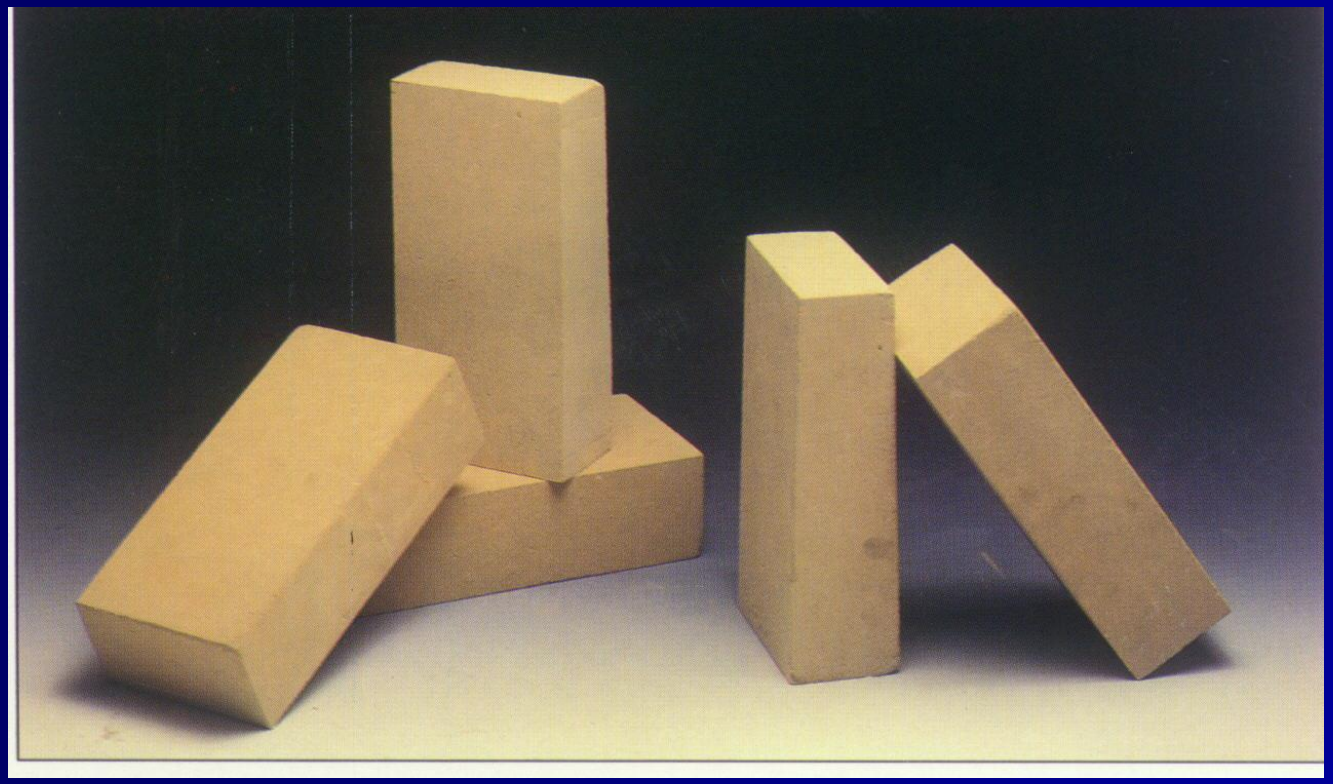
Firebricks for furnaces and ovens. Have high Silicon or Aluminium oxide content.

Brick products are used in the manufacturing plant for iron and steel, non-ferrous metals, glass, cements, ceramics, energy conversion, petroleum, and chemical industries.

Refractories

- Used to provide thermal protection of other materials in very high temperature applications, such as steel making (T_m=1500°C), metal foundry operations, etc.
- They are usually composed of alumina (T_m=2050°C) and silica along with other oxides: MgO (T_m=2850°C), Fe_2O_3, TiO_2, etc., and have intrinsic porosity typically greater than 10% by volume.
- Specialized refractories, (those already mentioned) and BeO, ZrO_2, mullite, SiC, and graphite with low porosity are also used.

Refractory Brick



Amorphous Ceramics (Glasses)

- Main ingredient is Silica (SiO_2)
- If cooled very slowly will form crystalline structure.
- If cooled more quickly will form amorphous structure consisting of disordered and linked chains of Silicon and Oxygen atoms.
- This accounts for its transparency as it is the crystal boundaries that scatter the light, causing reflection.
- Glass can be tempered to increase its toughness and resistance to cracking.

Glass Types

Three common types of glass:

- *Soda-lime glass* - 95% of all glass, windows containers etc.
- *Lead glass* - contains lead oxide to improve refractive index
- *Borosilicate* - contains Boron oxide, known as Pyrex.

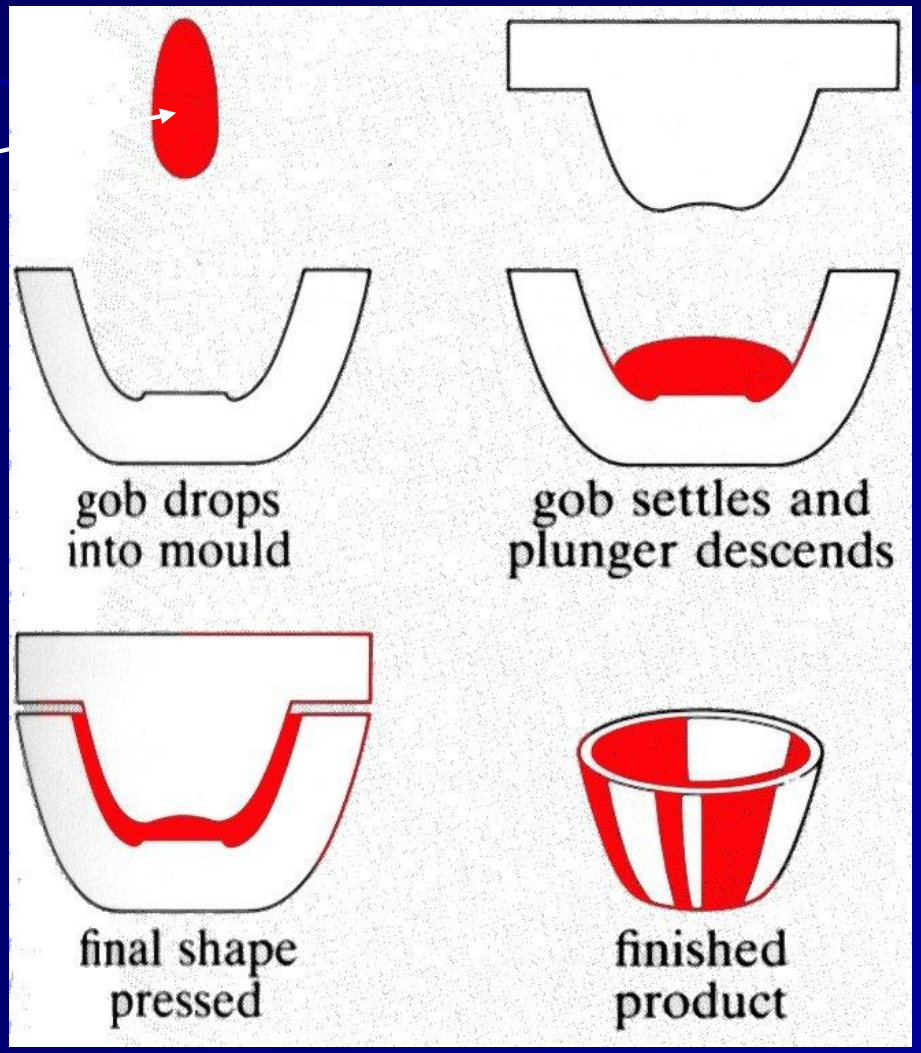
Glasses

- Flat glass (windows)
- Container glass (bottles)
- Pressed and blown glass (dinnerware)
- Glass fibres (home insulation)
- Advanced/specialty glass (optical fibres)

Glass Containers

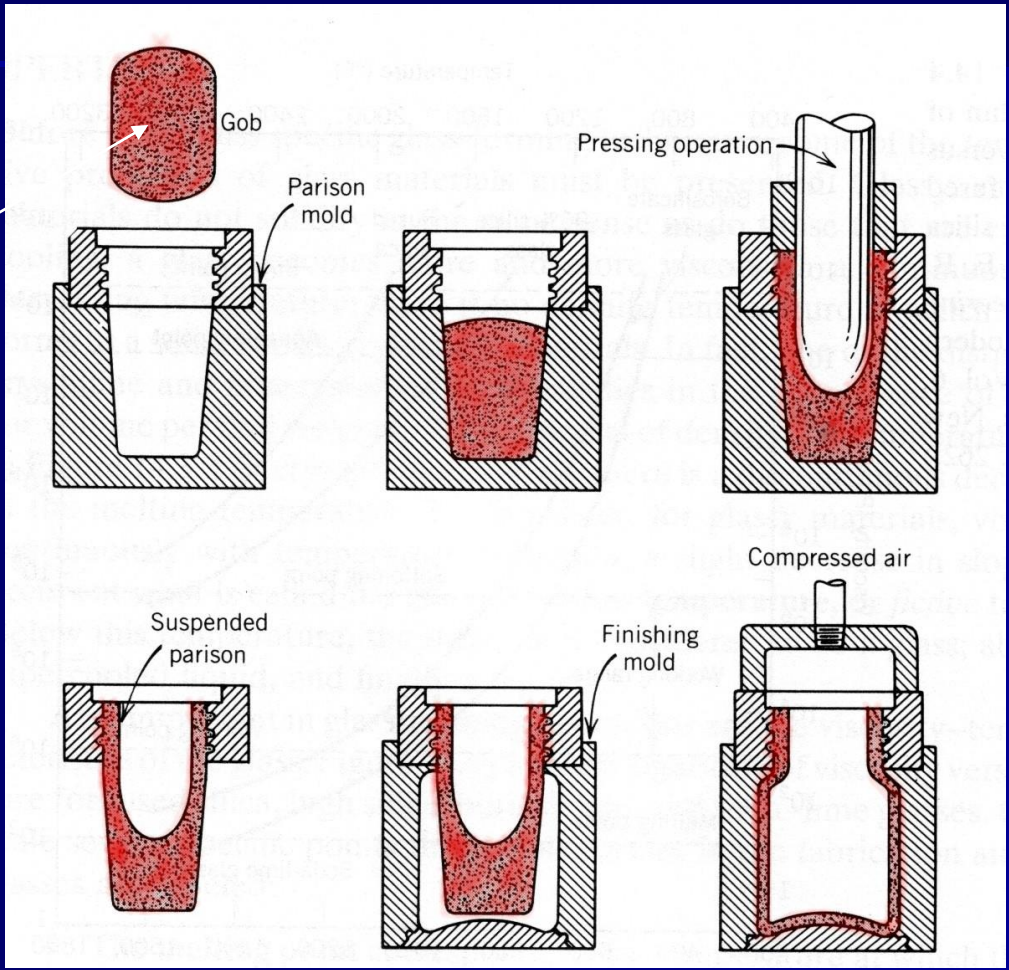
Pressed Glass Processing

Softened Gob



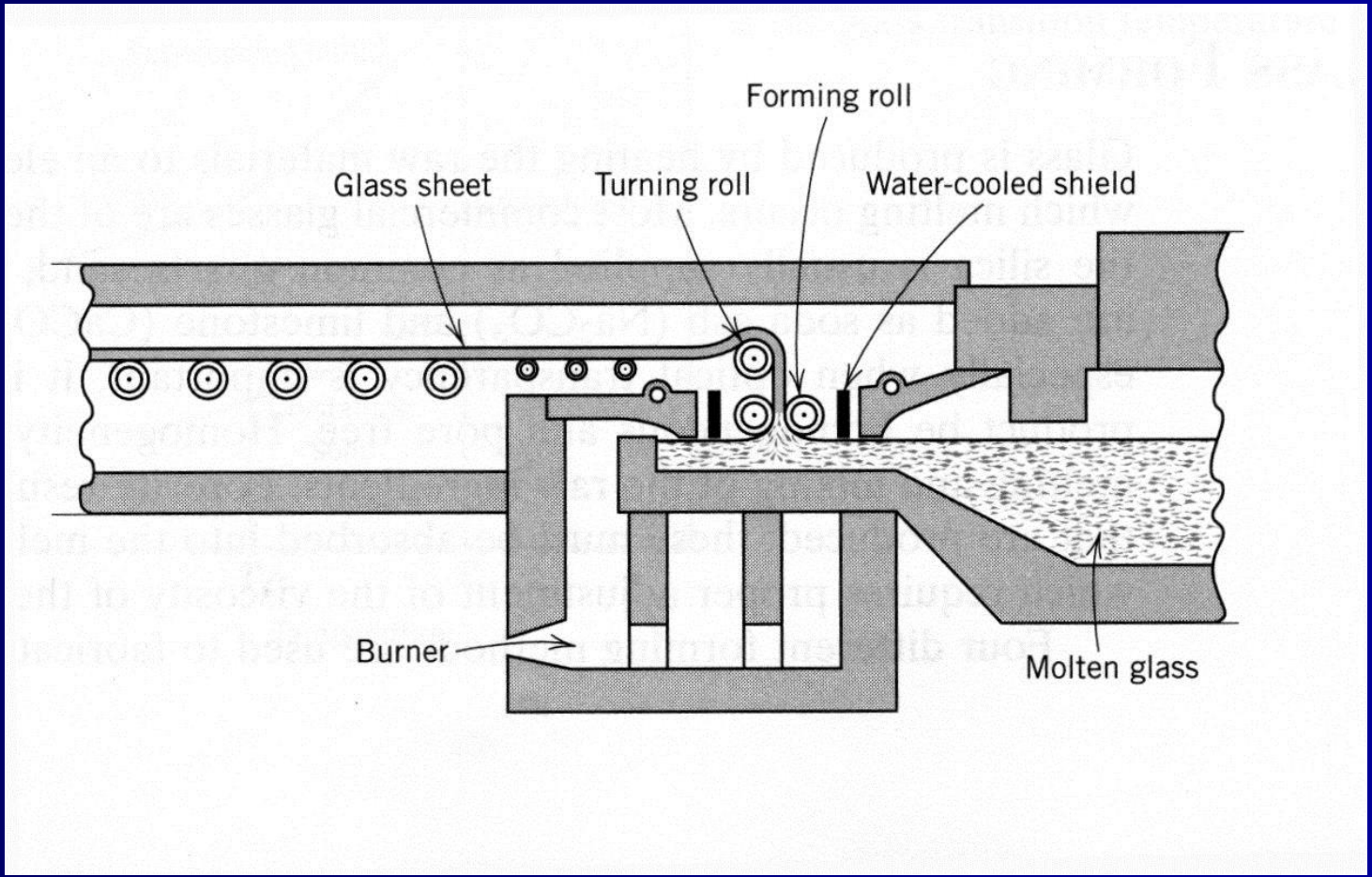
Blow Molding

Softened glass



Glass in Buildings

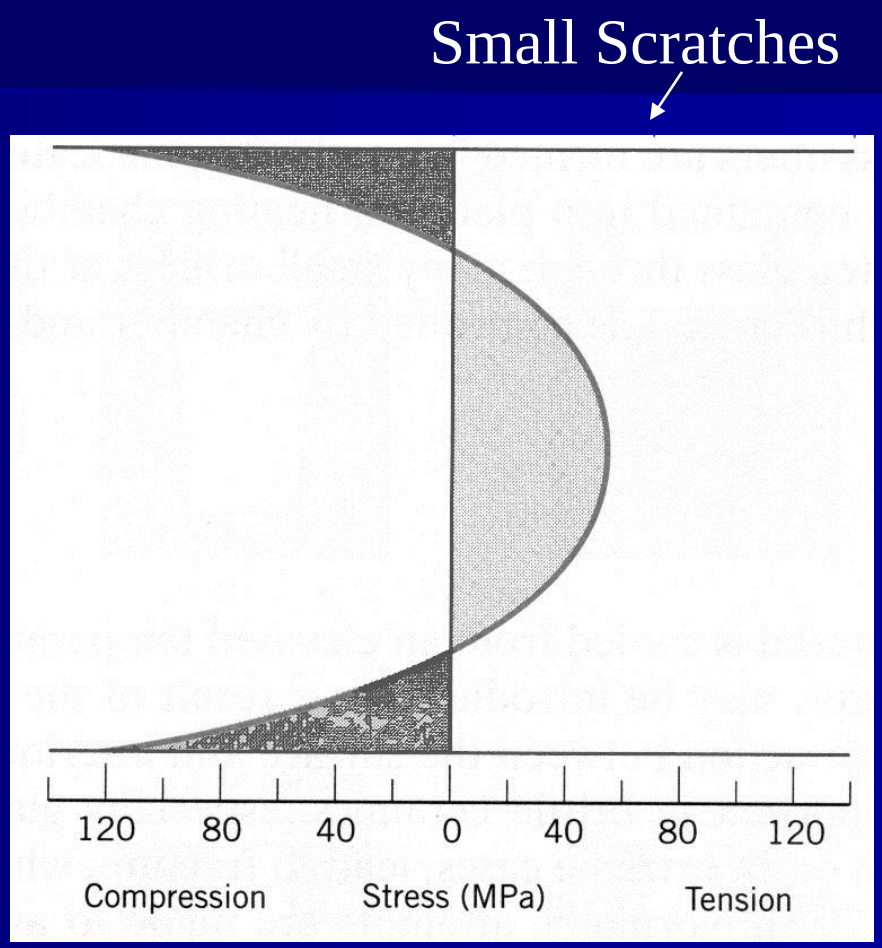
Plate Glass Drawing Processes



Tempered Glass

The strength of glass can be enhanced by inducing compressive residual stresses at the surface.

The surface stays in compression - closing small scratches and cracks.



Hardening Processes

- Tempering:
  - Glass heated above T_g but below the softening point
  - Cooled to room temp in air or oil
  - Surface cools to below T_g before interior
  - when interior cools and contracts it draws the exterior into compression.

- Chemical Hardening:
  - Cations with large ionic radius are diffused into the surface
  - This strains the "lattice" inducing compressive strains and stresses.

Armoured Glass

- Many have tried to gain access with golf clubs and baseball bats but obviously the glass remains intact ! From time to time a local TV station intends to show videos of those trying to get at the cash!!

Leaded Glass

Crystalline Ceramics

Good electrical insulators and refractories.

- Magnesium Oxide is used as insulation material in heating elements and cables.
- Aluminium Oxide
- Beryllium Oxides
- Boron Carbide
- Tungsten Carbide.
- Used as abrasives and cutting tool tips.

Abrasives

- Natural (garnet, diamond, etc.)
- Synthetic abrasives (silicon carbide, diamond, fused alumina, etc.) are used for grinding, cutting, polishing, lapping, or pressure blasting of materials

Cements

- Used to produce concrete roads, bridges, buildings, dams.

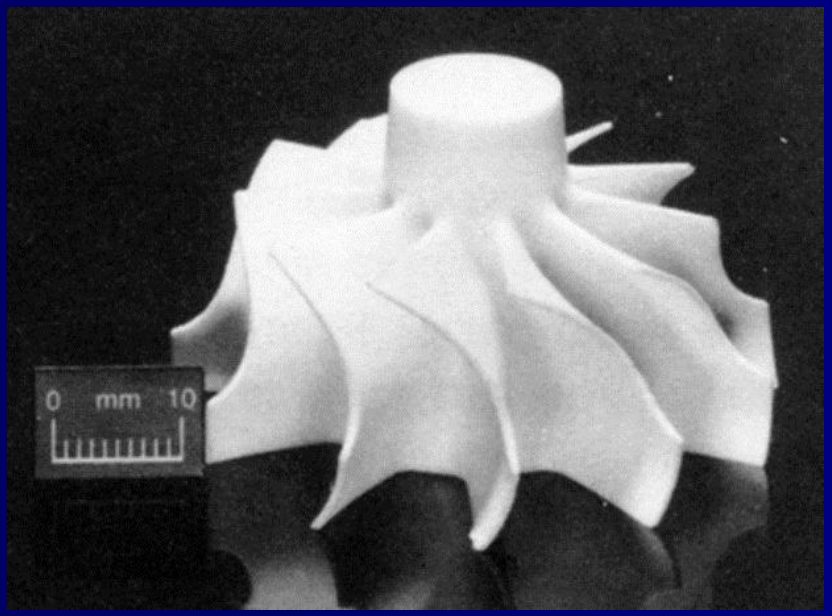
Advanced Ceramics

- Advanced ceramic materials have been developed over the past half century
- Applied as thermal barrier coatings to protect metal structures, wearing surfaces, or as integral components by themselves.
- Engine applications are very common for this class of material which includes silicon nitride (Si_3N_4), silicon carbide (SiC), Zirconia (ZrO_2) and Alumina (Al_2O_3)
- Heat resistance and other desirable properties have lead to the development of methods to toughen the material by reinforcement with fibers and whiskers opening up more applications for ceramics

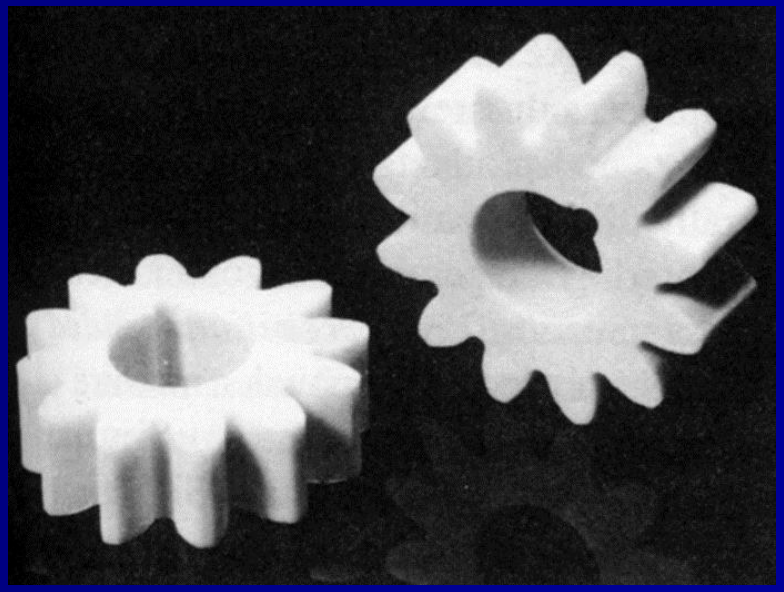
Advanced Ceramics

- *Structural:* Wear parts, bioceramics, cutting tools, engine components, armour.
- *Electrical:* Capacitors, insulators, integrated circuit packages, piezoelectrics, magnets and superconductors
- *Coatings:* Engine components, cutting tools, and industrial wear parts
- *Chemical and environmental:* Filters, membranes, catalysts, and catalyst supports

Engine Components



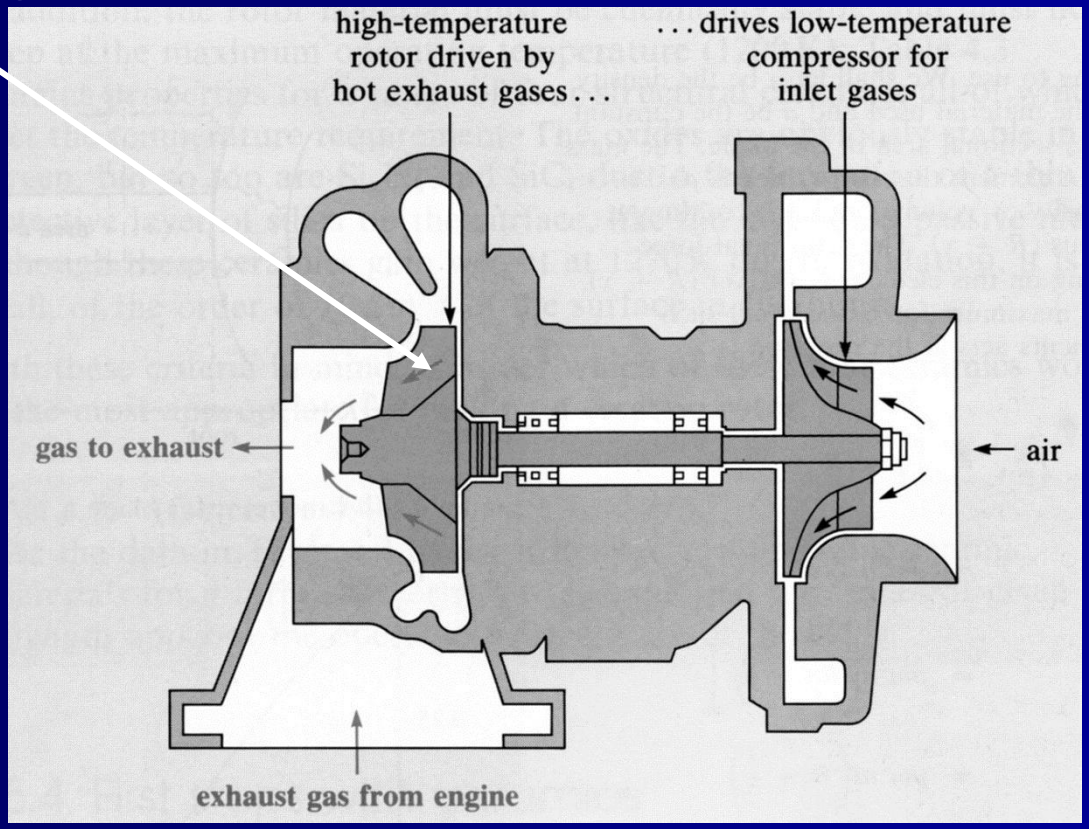
Rotor (Alumina)



Gears (Alumina)

Turbocharger

Ceramic Rotor



Ceramic Brake Discs

McLaren Mercedes Benz

Silicon Carbide

Automotive Components in Silicon Carbide

Chosen for its heat and wear resistance

Ceramic Armour

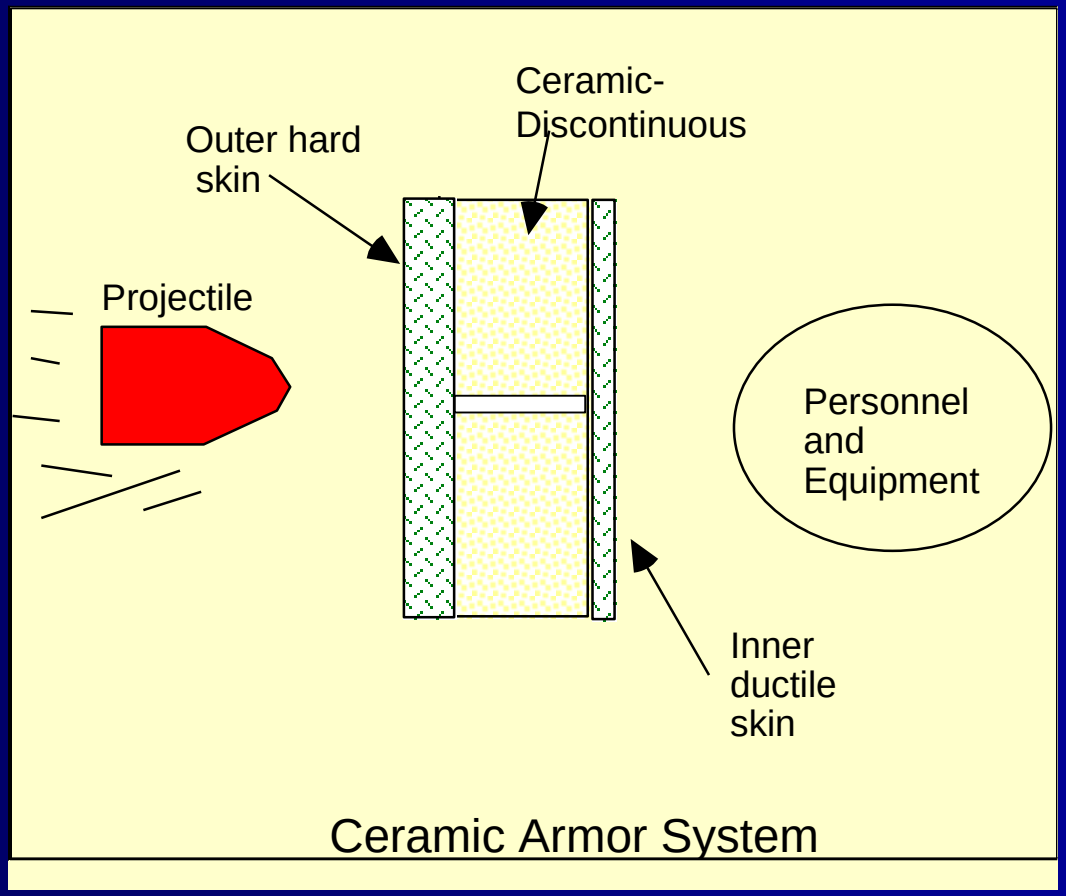
- Ceramic armour systems are used to protect military personnel and equipment.
- Advantage: low density of the material can lead to weight-efficient armour systems.
- Typical ceramic materials used in armour systems include alumina, boron carbide, silicon carbide, and titanium diboride.
- The ceramic material is discontinuous and is sandwiched between a more ductile outer and inner skin.
- The outer skin must be hard enough to shatter the projectile.

- Most of the impact energy is absorbed by the fracturing of the ceramic and any remaining kinetic energy is absorbed by the inner skin, that also serves to contain the fragments of the ceramic and the projectile preventing severe impact with the personnel/equipment being protected.

- Alumina ceramic/Kevlar composite system in sheets about 20mm thick are used to protect key areas of Hercules aircraft (cockpit crew/instruments and loadmaster station).

- This lightweight solution provided an efficient and removable/replaceable armour system. Similar systems used on Armoured Personnel Carrier's.

Ceramic - Composite Armor



Silicon Carbide

Body armour and other components chosen for their ballistic properties.