Shroff S.R. Rotary Institute of Chemical Technology (SRICT)

Principal Supporter & Sponsor-UPL Ltd / Shroff family

Managed By Ankleshwar Rotary Education Society

Approved by AICTE, New Delhi, Govt. of Gujarat & GTU Affiliated

Introduction to Ceramic Materials

What is Ceramic material about?

- Ceramic materials are inorganic nonmetallic materials consisting of metallic – nonmetallic elements or two non metallic elemental solids (NMES) bonded together primarily by ionic bond and/or covalent bond.
- Compositions and structures vary widely.

Ceramics derived from “Keramos” a Greek word which means pottery or Clay work

In modern times, **Ceramics** is defined as those materials which can withstand high temperature, chemical resistance and can maintain structural integrity for mechanical applications. In general, they are hard and brittle (high compression) with little plastic deformation. They exhibit low toughness and low ductility.

Some common materials

Silicate based materials like Kaolinite, Pyrophilite, Montmorillonite, Talc,olivine,enstatite,Beryl etc

Alumina based materials like Bauxite, Diaspore, Bohemite, Sillimanite, Mullite etc. In modern day tabular alumina, fused alumina are being used extensively.

Carbide based materials like HfC ,TiC, SiC, WC, Al4C3, B4C3 respectively.

Oxide based materials like MgO,ZrO2, Al2O3,SiO2, TiO2

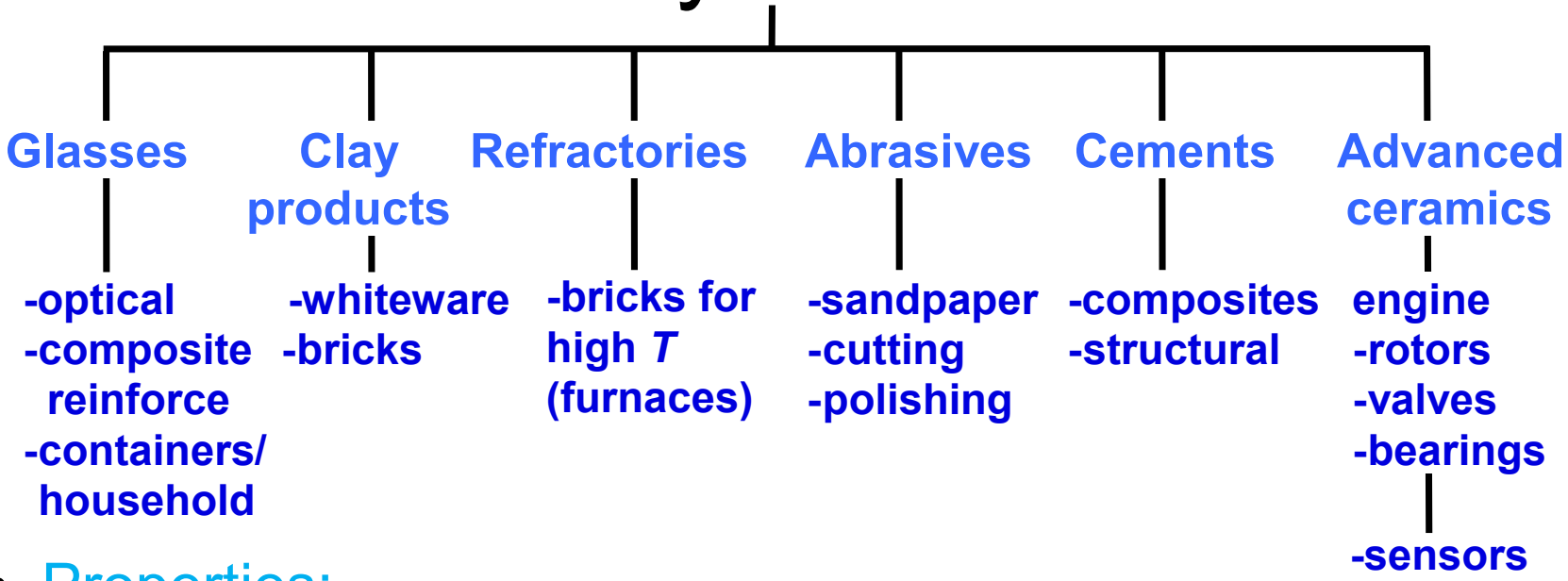
Nitride based materials like Si3N4, Al4N3, BN and others.

Other materials like Carbon based products, composites of fibre reinforced carbides, etc.

Classification of Ceramics

1) Traditional ceramics consists of clay based products like vases, astrays etc.
2) Whitewares like Floor tiles, Wall Tiles, Vitrified tiles, Sanitarywares, Tablewares, kitchenwares, Ceramic containers, Ceramic cars in Kilns, electrical porcelains etc.
3) Refractory products for lining in Ferrous & Non-ferrous Industries, Kilns for cement making, Glass melting practices etc.
4) Cement based products for construction and concrete making
5) Glass based compounds and Glass-Ceramic
6) Advanced Ceramics for High temperature applications, dielectrics, piezoelectrics, ferroelectrics, Structural, Abrasive & Cutting edge tool, Electronics etc.

Taxonomy of Ceramics



- Properties:
  -- T_m for glass is moderate, but large for other ceramics.
  -- Small toughness, ductility; large moduli & creep resist.
- Applications:
  -- High T, wear resistant, novel uses from charge neutrality.
- Fabrication
  -- some glasses can be easily formed
  -- other ceramics can not be formed or cast.

Advanced Ceramics

Advanced ceramic materials have been developed over the past half century

Widespread applications in mineral processing,seals, valves, adiabatic disel engines, abbrasives, cutting tools, heat exchanger, gas turbines.

Engineering applications are very common for this class of materials which include silicon nitride (Si_3N_4), silicon carbide (SiC), Zirconia (ZrO_2) and Alumina (Al_2O_3).

What is Glass

- Glass is an inorganic product of fusion that has been cooled to rigid condition without crystallisation.
- Glass is non crystalline amorphous product lacking long range order of atoms while the ceramics are crystalline materials with long range order.

General Glass types

Types of glass:

- fused silica glass- contains more than 99.5% silica.

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.

Some Common Glass Products

Flat glass (windows)

Container glass (bottles)

Pressed and blown glass (dinnerware)

Glass fibres (home insulation)

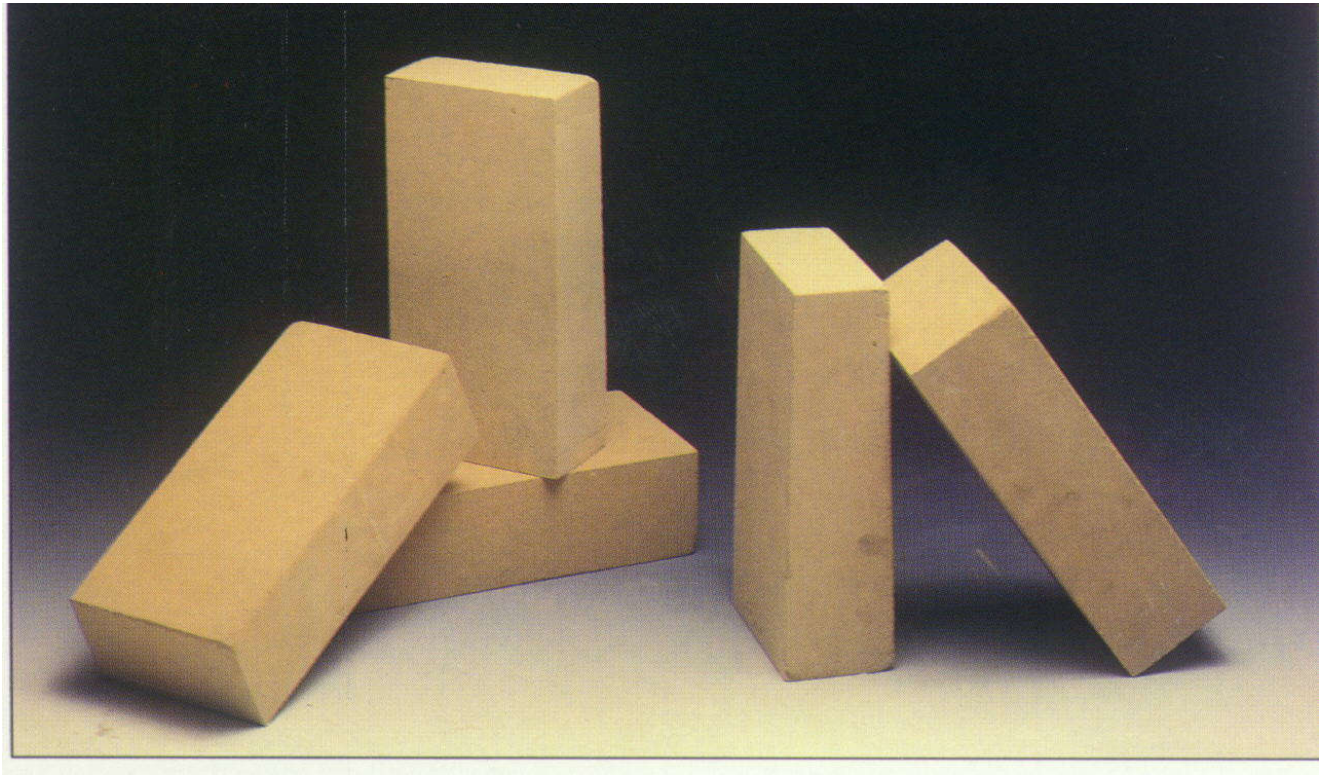
Advanced/specialty glass (optical fibres)

Optical lenses for microscopy and view

Structural long flat glass products in modern buildings

Engineering Applications

Engineering Applications



Common Refractory Bricks

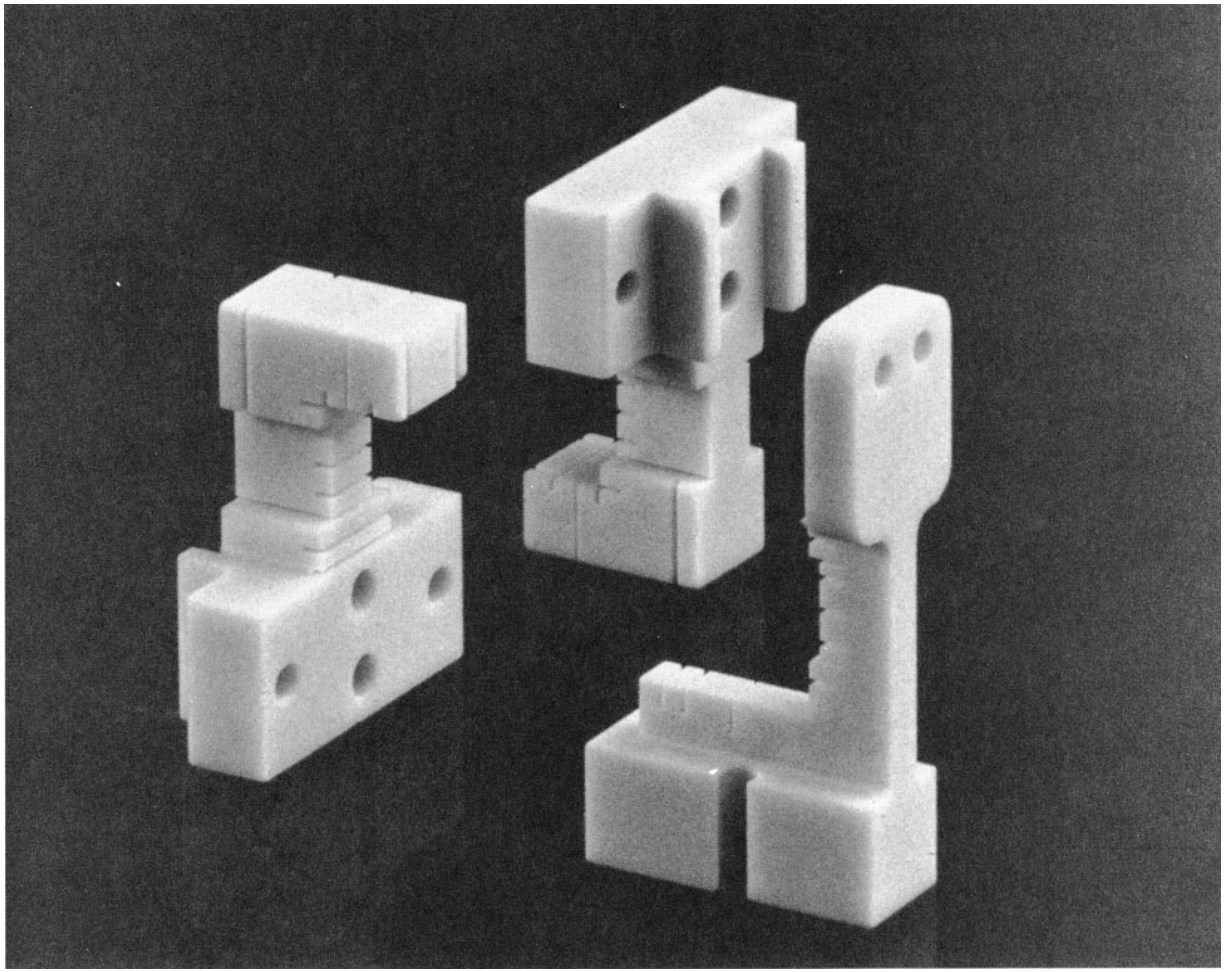
Engineering Applications

Various Glass Containers

Engineering Applications

Structural Glass for modern Buildings

Engineering Applications



Alumina Ceramic Components for Engineering applications

Engineering Applications

Thermal Protection System

- Application:

Chapter-opening photograph, Chapter 23, *Callister 5e* (courtesy of the National Aeronautics and Space Administration.)

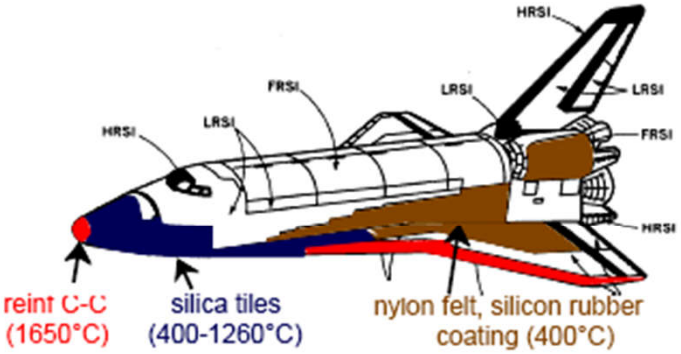
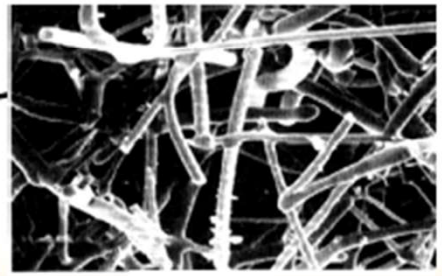


Fig. 19.2W, *Callister 6e*. (Fig. 19.2W adapted from L.J. Korb, C.A. Morant, R.M. Calland, and C.S. Thatcher, "The Shuttle Orbiter Thermal Protection System", *Ceramic Bulletin*, No. 11, Nov. 1981, p. 1189.)

- Silica tiles (400-1260°C):
  --large scale application

Fig. 19.3W, *Callister 5e*. (Fig. 19.3W courtesy the National Aeronautics and Space Administration.)

--microstructure:



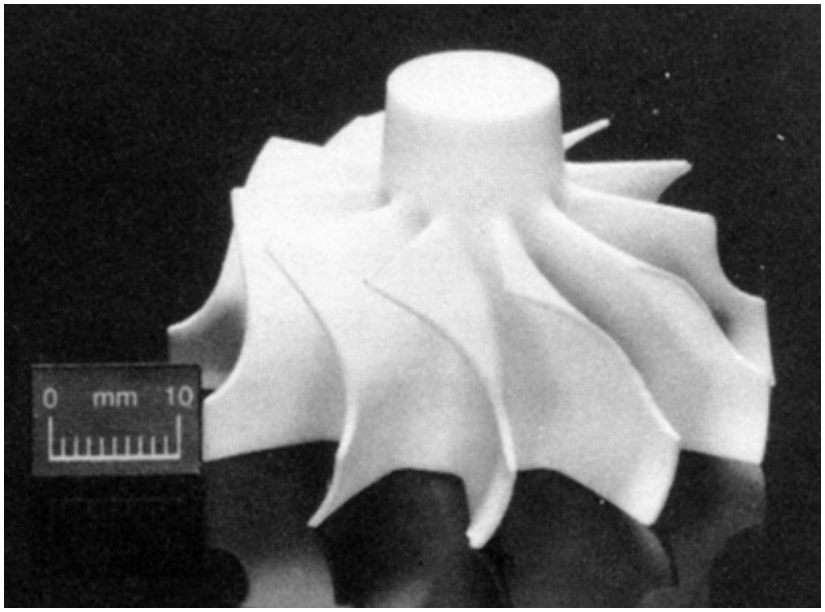
~90% porosity!
Si fibers bonded to one another during heat treatment.

Fig. 19.4W, *Callister 5e*. (Fig. 219.4W courtesy Lockheed Aerospace Ceramics Systems, Sunnyvale, CA.)

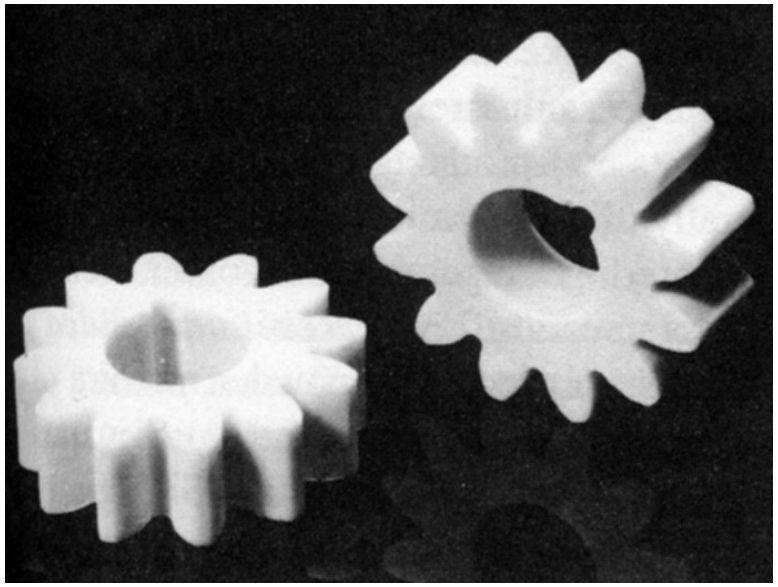
Engineering Applications

Armoured Glass for security. It remains intact even after hitting with balls, bat or rods. It can also withstand high energy projectiles discharged from sources from certain height and distances.

Engineering Applications



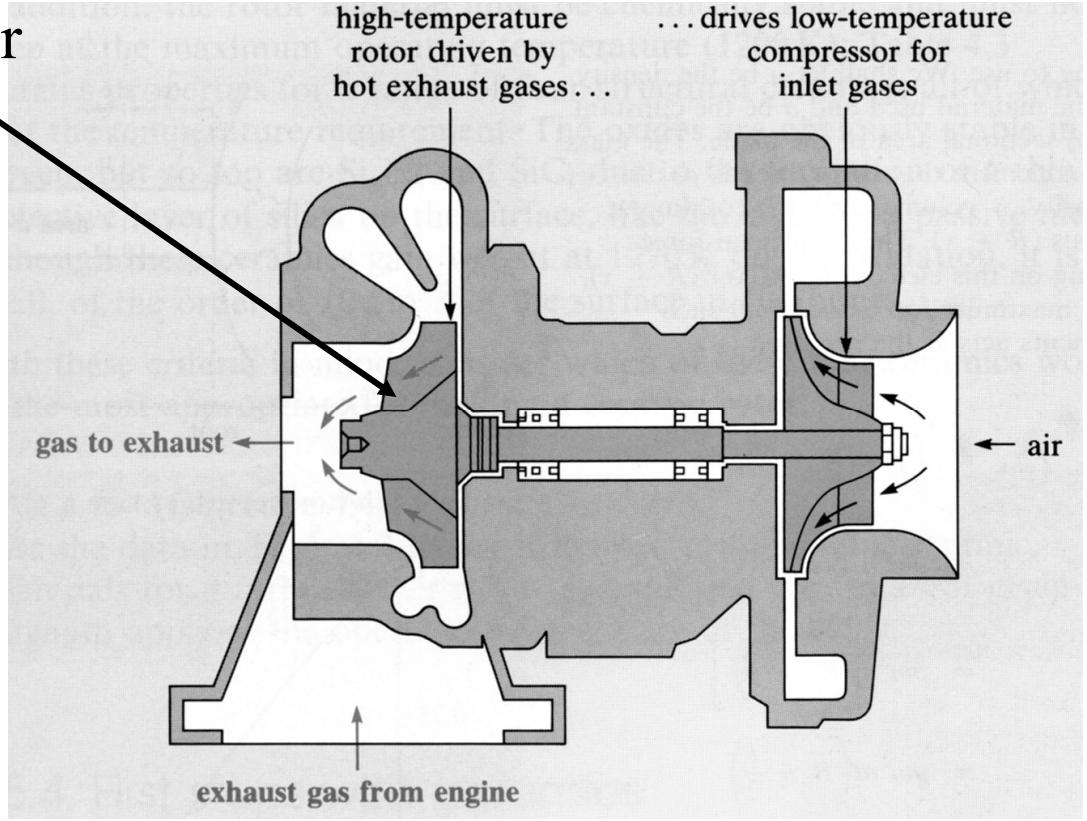
Rotor (Alumina)



Gear (Alumina)

Engineering Applications

Ceramic Rotor



Ceramic rotors are used in modern Turbochargers

Engineering Applications

Ceramic Brake Discs for modern Automobiles

Engineering Applications

WHY CHOOSE CERAMIC AS BIOMATERIALS?

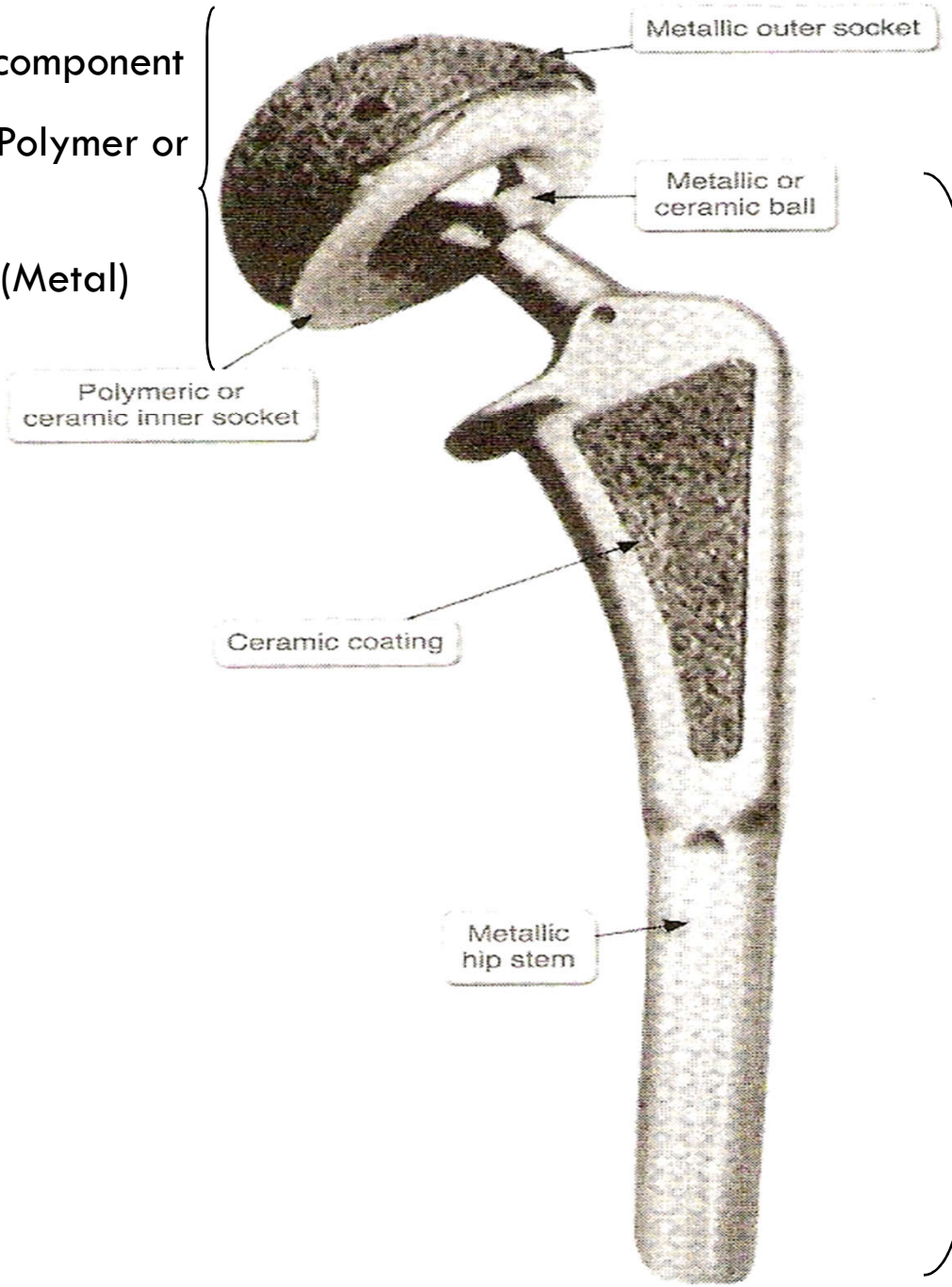
- Have an appropriate mechanical properties for particular medical application such as dental crowns.
- Biocompatible:
  - Relative inertness to the body fluid.
  - More resistant to degradation.
- Have a similar chemistry and mechanical properties with natural bone → more often used as a part of orthopaedic implant (coating material) or as dental materials (crowns, dentures).
- High wear resistance

Engineering Applications for Physiology of Humans

- DENTISTRY
  - Dental filling, Dental crown, dentures
  - Why widely used in dentistry
    - Relatively inert to body fluid
    - High compressive strength
    - Aesthetically pleasing appearance
- ORTHOPAEDIC IMPLANT
    - Femoral head/ball of hip implant
    - Coating of hip stem
    - Acetabular inner cup of hip implant
    - Bone plates and screw

Acetabular component

- Inner cup (Polymer or ceramic)
- Outer cup (Metal)



Femoral component

- femoral stem (metal)
- neck (metal)
- head/ball (metal or ceramic)