Lecture 10. Bioceramic materials part1

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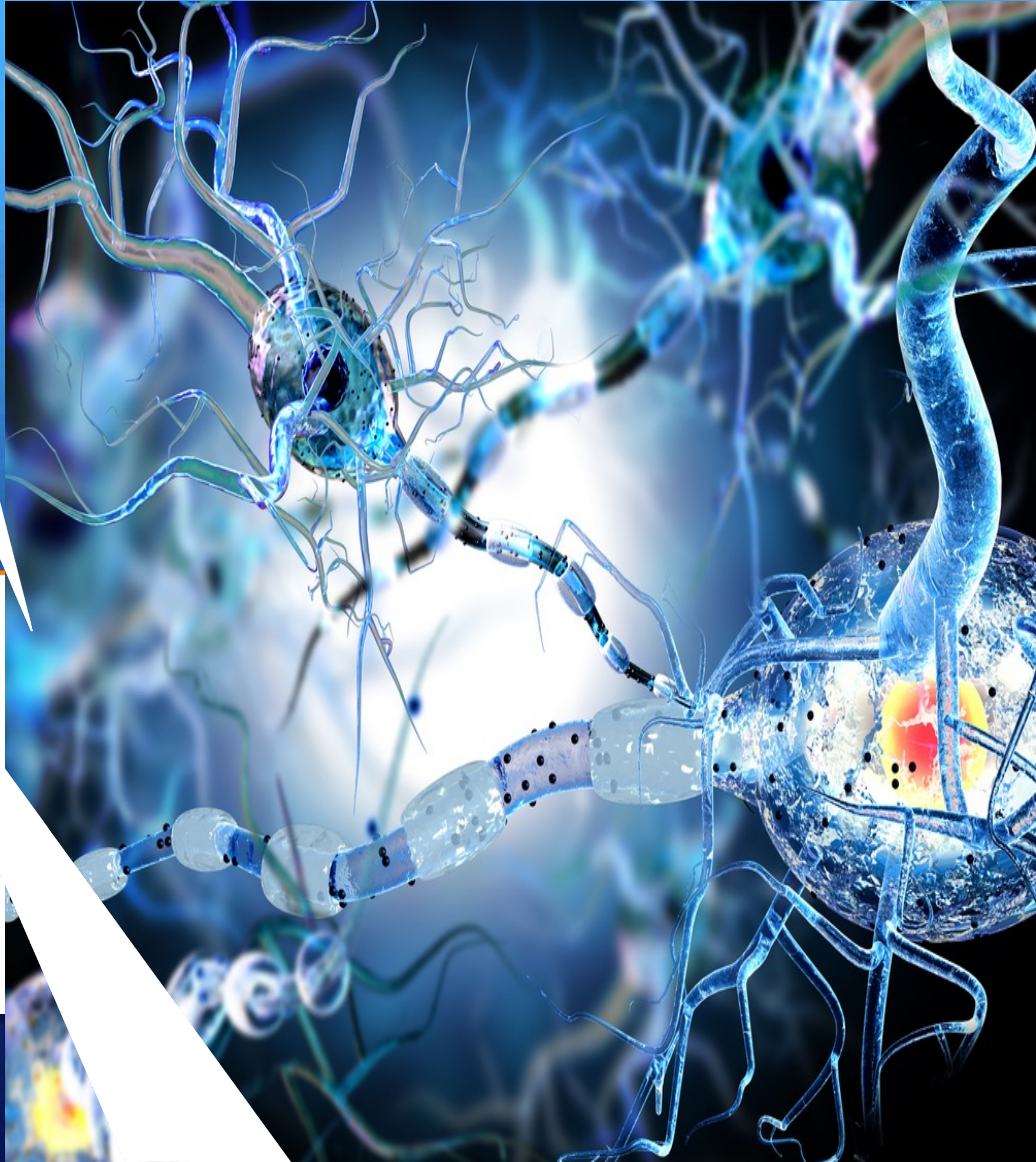


Outlines

- Define the ceramic materials,
- Properties of bioceramic
- Advantage and disadvantage
- Classify the bioceramic materials
- Some of clinical application s of bioceramics

Ceramics

- Ceramics are defined as the art and science of making and using solid articles that have as their essential component inorganic nonmetallic materials .Ceramics are refractory, polycrystalline compounds, usually inorganic, including silicates, metallic oxides, carbides and various refractory hydrides, sulfides, and selenides. Oxides such as Al_2O_3, MgO, SiO_2, and ZrO_2 contain metallic and nonmetallic elements and ionic salts, such as NaCl, CsCl, and ZnS with ionic or covalent bonds.

- Generally Ceramic materials are

- Inorganic

- Hard and brittle

- High compressive strength

- Range in biocompatibility from the ceramic oxides , which are inert in the body ,to the other extreme of resorbable materials, which are eventually replaced by the body after they have assisted repair.

Advantages and disadvantages of bioceramics:

Biocompatible

Wear resistant

Light weight

Low tensile strength

Difficult to fabricate

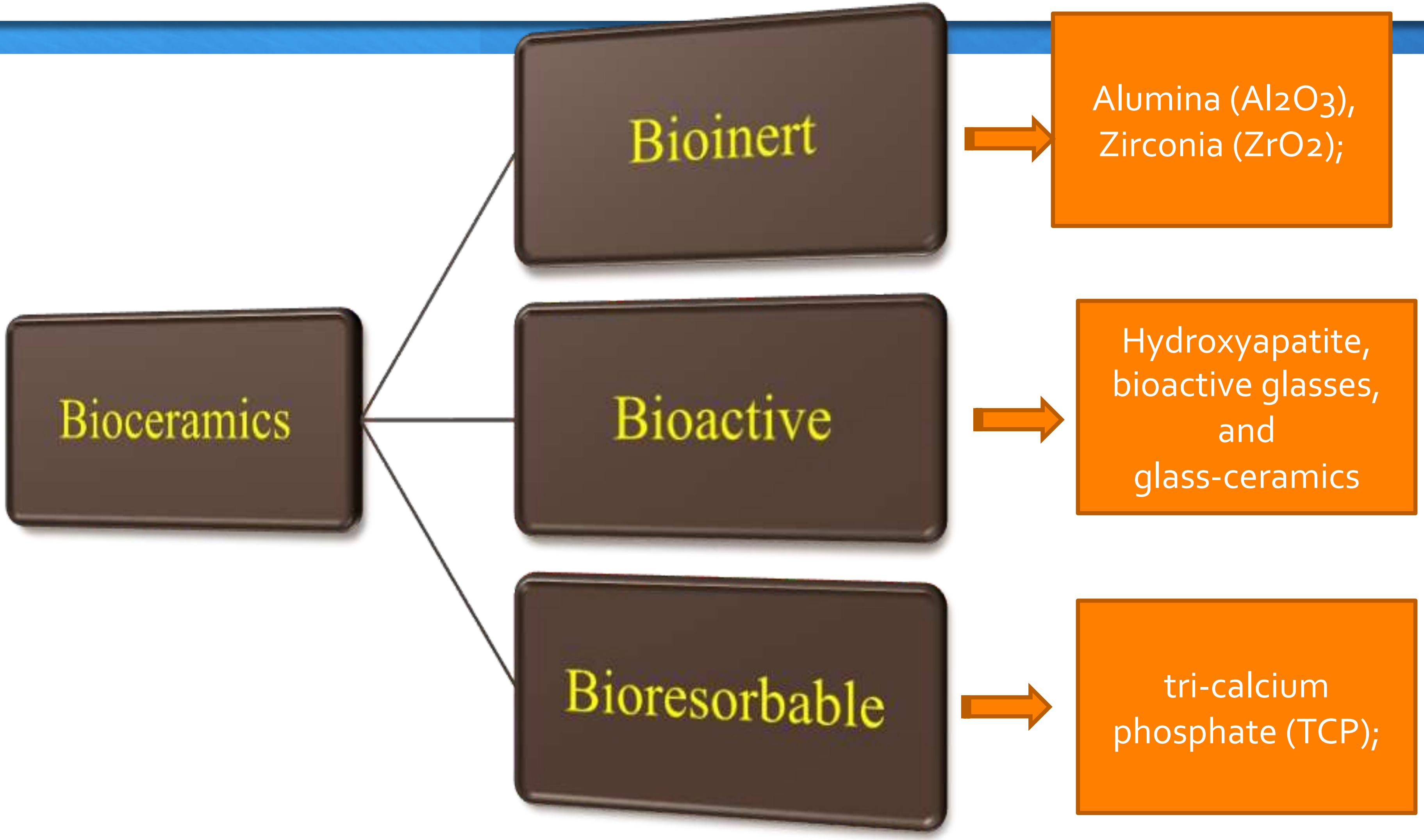
Low toughness

inherent brittleness

susceptibility to notches or micro-cracks

low impact strength.

Types of bioceramics:



1- Bioinert Ceramics

- Inert refers to materials that are essentially stable with little or no tissue reactivity when implanted within the living organism.
- Maintain their physical and mechanical properties while in host.
- Resist corrosion and wear.
- Have a reasonable fracture toughness
- When a biomaterial is nearly inert and the interface is not chemically or biologically bonded, there is relative movement and progressive development of a non-adherent fibrous capsule in both soft and hard tissues.
- Movement at the biomaterial-tissue interface eventually leads to degradations in function of the implant or the tissue at the interface or both.
- Examples of relatively bioinert ceramics are dense and porous aluminum oxides, zirconia ceramics, and single-phase calcium aluminates

Bioinert ceramics

- Bioinert Typically used as

- structural-support implant such as bone plates, bone screw and femoral heads.



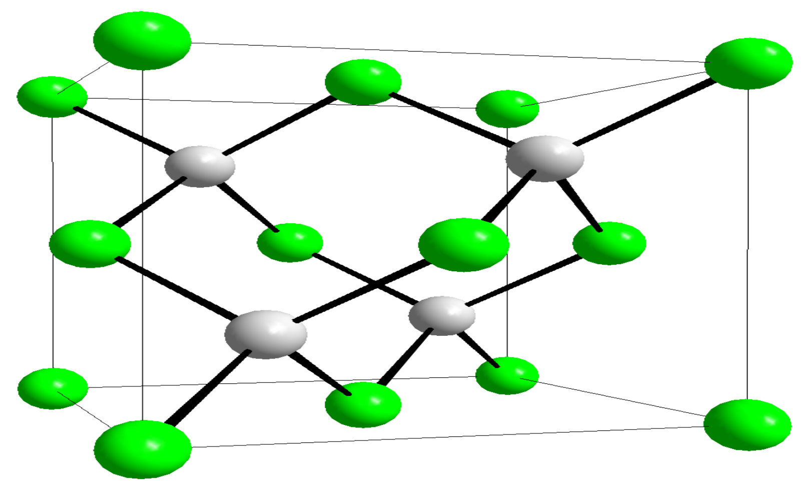
- Examples of non-structural support uses are ventilation tubes, sterilization devices and drug delivery devices

1. ALUMINA (Al_20_3):

- Alumina, or aluminum oxide, is a compound of molecular formula Al2O3 that has various crystalline forms.
- Its main source in nature is from bauxite ore, from which alumina is extracted through its processing based on the Bayer process of aluminum refinement .
- Alpha alumina (α-Al2O3) is the thermodynamically stable form of alumina at all temperatures and has a compact hexagonal crystal structure
- The strength of polycrystalline alumina depends on its grain

size and porosity. Generally, the smaller the grains, the lower the

porosity and the higher the strength .



1. ALUMINA ($Al_2 0_3$):

ALUMINA with

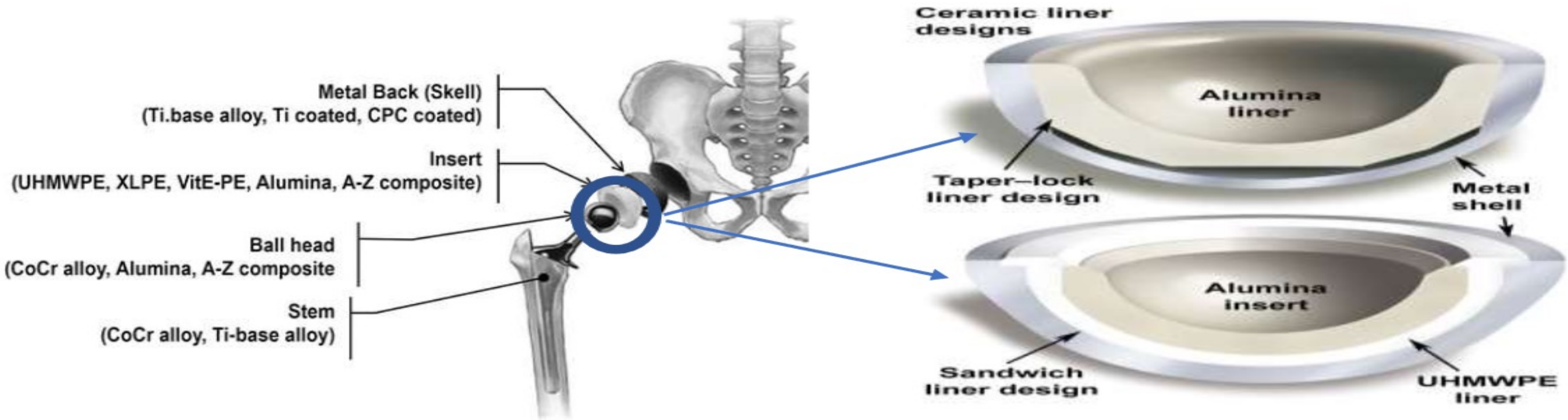
High hardness + low friction + low wear + inert to in vivo environment.

Ideal material for use in:

- ✓ Orthopaedic joint replacement component, e.g. femoral head of hip implant.
- ✓ Orthopaedic load-bearing implant.
- ✓ Implant coating.
- ✓ Dental implants.

Total Hip replacement

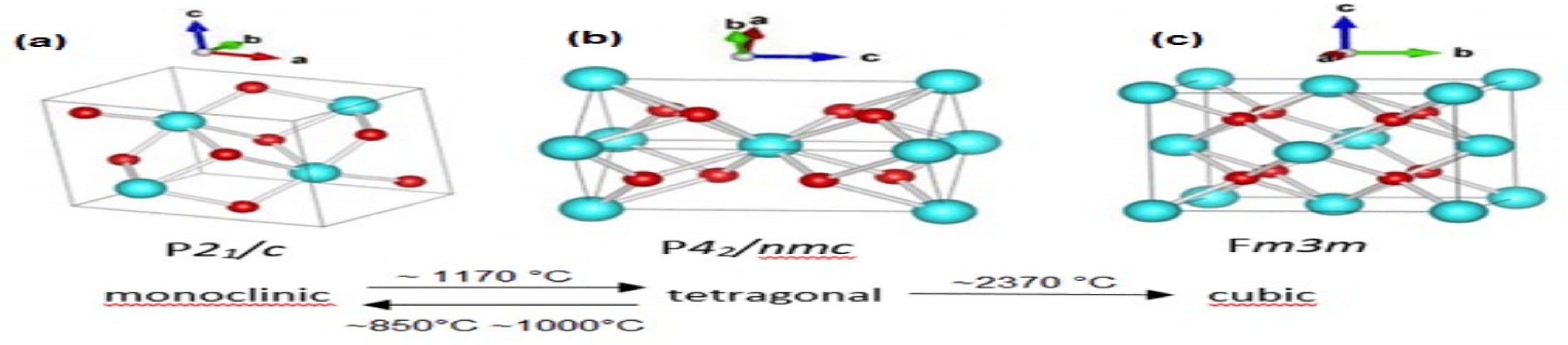
Low wear rates have led to wide spread use of alumina non-cemented cups, press fitted into the socket of the hip. The mating femoral ball surface is also of alumina, which is bonded to a metallic stem. Though long-term results in general have been excellent, it is essential that the age of the patient, nature of the disease of the joint, and bioceramics of the repair be considered carefully before any prosthesis is used. The primary use of alumina is for the ball of the hip joint, with the socket component being made of ultrahigh molecular weight polyethylene (PE).



2-Zirconia

- Zirconia or zirconium oxide is a compound of the molecular formula ZrO2 which can be obtained from the decomposition of two ore sources: zirconite (ZrSiO4) and badeleite (is a rare zirconium oxide mineral) from chemical or thermal processing .

- Structurally, zirconia has three polymorphic phases: monoclinic, tetragonal and cubic, Under atmospheric pressure, the phase of the monoclinic crystal structure is stable from room temperature to about 1170 °C. With heating, from this temperature, structure undergoes transformation to the tetragonal phase, which remains stable until temperatures around 2370 °C. From 2370 °C, zirconia undergoes further transformation to a cubic crystal structure phase, and thus remains until the melting point, around 2680 °C.



Zirconia structure

- The transition from the **tetragonal to the monoclinic** phase is accompanied by a 3-5% volume variation in cooling, resulting in the production of **micro cracks.**
- This transition is also known as **martensitic transformation**, due to the similarity to the transformation that occurs during the tempering of steel, However, volume expansion in tetragonal to monoclinic transformation can be used as a tool to improve the **toughness and mechanical strength of ceramics.**
- therefore, a **dopant oxide such as Y_2O_3** is used to stabilize the high temperature (cubic) phase.
- Zirconia produced in this manner is referred to as **partially stabilized zirconia**
- in the last five decades, the use of yttria-stabilized zirconia ceramics (Y-TZP) has been distinguished in the biomedical area due to its **good mechanical properties**, **high chemical stability, biocompatibility** and **adequate aesthetic appearance**

Zirconia Applications

- Zirconia has some advantages over alumina ceramics, such as **higher flexural strength, higher fracture toughness and lower modulus of elasticity**

- Zirconia is also mostly used in the manufacture of **orthopedic prostheses for heads** and **acetabulum in femoral implants**

- in the area of dentistry, very wieldy used in teeth, especially crowns, and has been preferred over metals, and the reason is due to

- since zirconia implants are white, you will never see any metal color by the gum-line when you smile.

- Since zirconia does not conduct electricity or react electronically, it will never react with other metals in your mouth.

- Metal things in your mouth all have an electronic charge. Things such as silver amalgam fillings, metal crowns, titanium implants, partial dentures. The issue with different metals is they react with one another in a reaction called a galvanic reaction.

- During these reactions, there is corrosion, flow of electricity and magnetism. All these reactions are not good for the immune system or nervous system

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Carbons

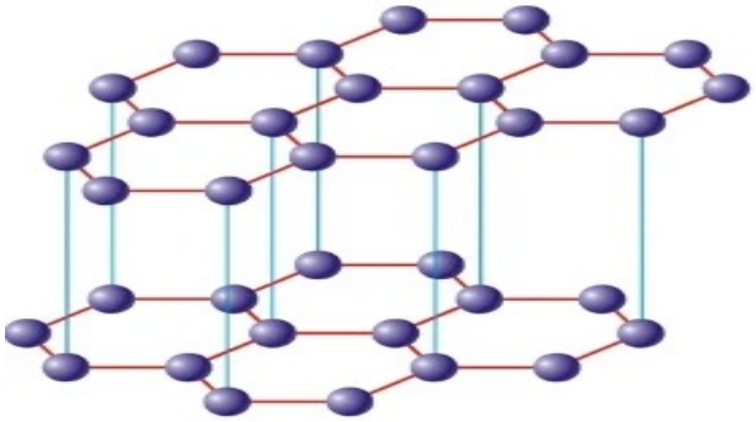
- Carbons can be made in many allotropic forms: **crystalline diamond**, graphite, **noncrystalline glassy carbon**, and pyrolytic carbon.
- Among these, only **pyrolytic** carbon is widely utilized for implant fabrication; it is normally used as a surface coating. It is also possible to coat surfaces with diamond.
- Although the techniques of coating with diamond have the potential to revolutionize medical device manufacturing, they are not yet commercially available
- The crystalline structure of carbon, as used in implants, is similar to the graphite structure
- The planar hexagonal arrays are formed by strong covalent

bonds in which one of the valence electrons or atoms is free to move,

resulting in high but anisotropic electric conductivity.

Since the bonding between the layers is stronger than the van der Waals

force, it has been suggested that the layers are cross-linked.



graphite

Carbon

- The mechanical properties of carbon, especially pyrolytic carbon, are largely dependent on its density,.
- The increased mechanical properties are directly related to increased density, which indicates that the properties of pyrolytic carbon depend mainly on the aggregate structure of the material .
- A composite carbon which is reinforced with carbon fiber has been considered for making implants.
- Carbons exhibit excellent compatibility with tissue. Compatibility of pyrolytic carbon-coated devices with blood have resulted in extensive use of these devices for repairing diseased heart valves and blood vessels .
- Recently, success was achieved in depositing pyrolytic carbon onto the surfaces of blood vessel implants made of polymers. This type of carbon is called ultra-low-temperature isotropic (ULTI) carbon instead of low-temperature isotropic (LTI) carbon. The deposited carbon has excellent compatibility with blood