Biomaterials

Biomaterial is a science/engineering discipline for studying and developing matters, surfaces, and structures (excluding pharmaceuticals) that interact and are compatible with biological systems. Biomaterials science, which has a history of about 50 years, encompasses elements of medicine, biology, chemistry, physics, and tissue engineering.

Accreditation Board for Engineering and Technology (ABET) Criteria for Biomedical Engineering

> The structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program. The program must prepare graduates to have: an understanding of biology and physiology, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology; the curriculum must prepare graduates with the ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems.

Classification based on biocompatibility

Biocompatibility is concerned with the acceptance of an artificial implant by the surrounding tissues and by the body as a whole.

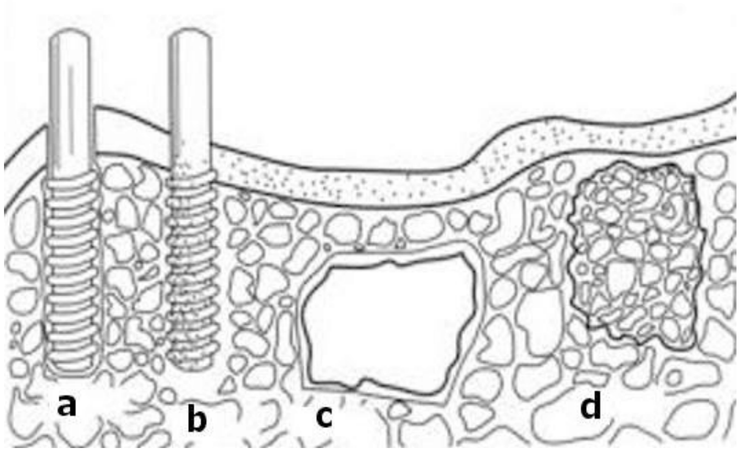

Figure 1. Classification of biomaterials according to their bioactivity (a) bioinert alumina dental implant, (b) bioactive hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] coating on a metallic dental implant, (c) surface active bioglass and (d) bioresorbable tricalcium phosphate ([$Ca_3(PO_4)_2$] implant. Source: <www.azom.com.com/ article.aspx?ArticleID=2630>.

1. Bioinert

The term bioinert refers to any material that once placed in the human body has minimal interaction with its surrounding tissue, examples of these are stainless steel, titanium, alumina, partially stabilized zirconia, and ultra high molecular weight polyethylene. Generally a fibrous capsule might form around bioinert implants hence its biofunctionality relies on tissue integration through the implant (Figure 1b).

2. Bioactive

Bioactive refers to a material, which upon being placed within the human body interacts with the surrounding bone and in some cases, even soft tissue. This occurs through a time – dependent kinetic modification of the surface, triggered by their implantation within the living bone. An ion – exchange reaction between the bioactive implant and surrounding body fluids – results in the formation of a biologically active carbonate apatite (CHAp) layer on the implant that is chemically and crystallographically equivalent to the mineral phase in bone. Prime examples of these materials are synthetic hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$], glass ceramic A-W and Bioglass® (Figure 1b and c).

3. Bioresorbable

Bioresorbable refers to a material that upon placement within the human body starts to dissolve (resorbed) and slowly replaced by advancing tissue (such as bone). Common examples of bioresorbable materials are tricalcium phosphate [$Ca_3(PO_4)_2$] and polylactic–polyglycolic acid copolymers. Calcium oxide, calcium carbonate and gypsum are other common materials that have been utilized during the last three decades (Figure 1d).

Classification based on material source

1. Natural

Autograft – tissue transplanted from another part of the body pf the same individual
Allograft – from a donor of the same species
Xenograft – from a donor of a different species
Isograft – from am identical twin

2. Synthetic – Metals, ceramics, polymers

Uses of Biomaterials

Uses of Biomaterials	Example
Replacement of diseased/damaged part	Artificial hip joint, kidney dialysis machine
Assist in healing	Sutures, bone plates, screws
Improve function	Cardiac pacemaker, intra-ocular lens
Correct functional abnormalities	Cardiac pacemaker
Correct cosmetic problem	Mastectomy augmentation, chin augmentation
Aid to diagnosis	Probes and catheters
Aid to treatment	Catheters, drains

Materials for Use in the Body

Materials	Advantages	Disadvantages	Examples
Polymers nylon, silicon rubber, polyester, PTFE, etc	Resilient, easy to fabricate,	Not strong, deforms with time, may degrade	Blood vessels, sutures, ear, nose, soft tissues
Metals Ti and its alloys, Co-Cr alloys, stainless steels	Strong tough ductile	May corrode, dense, difficult to make	Joint replacement, bone plates and screws, dental root implant, pacer, suture
Ceramics aluminum oxide, calcium phosphates including hydroxyapatite carbon	Very biocompatible, inert, strong in compression	Difficult to make, brittle, not resilient	Dental coating, orthopedic implants, femoral head of hip
Composites carbon-carbon, wire, fiber reinforced bone cement	Compression strong	Difficult to make	Joint implants, heart valves

Tissue Engineering

Tissue engineering is concerned with the use of a combination of cells, engineering and materials methods, and suitable biochemical and physio-chemical factors to improve or replace biological functions. (Tissue Engineering has the tendency of growing out of the biomaterials field to become a separate field.)