COMPOSITE MATERIALS BASED MEDICAL APPLICATION

Day 3/ Nano composites

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What is nano materials:

Scientists **have not** unanimously settled on a precise definition of nanomaterials, but agree that they are partially characterized by **their tiny size**

Nanomaterials are substances that are, or have been, reduced in size to the range from 1 nm to ~ 100 nm or 1 to ~ 100×10^{-9} meters).

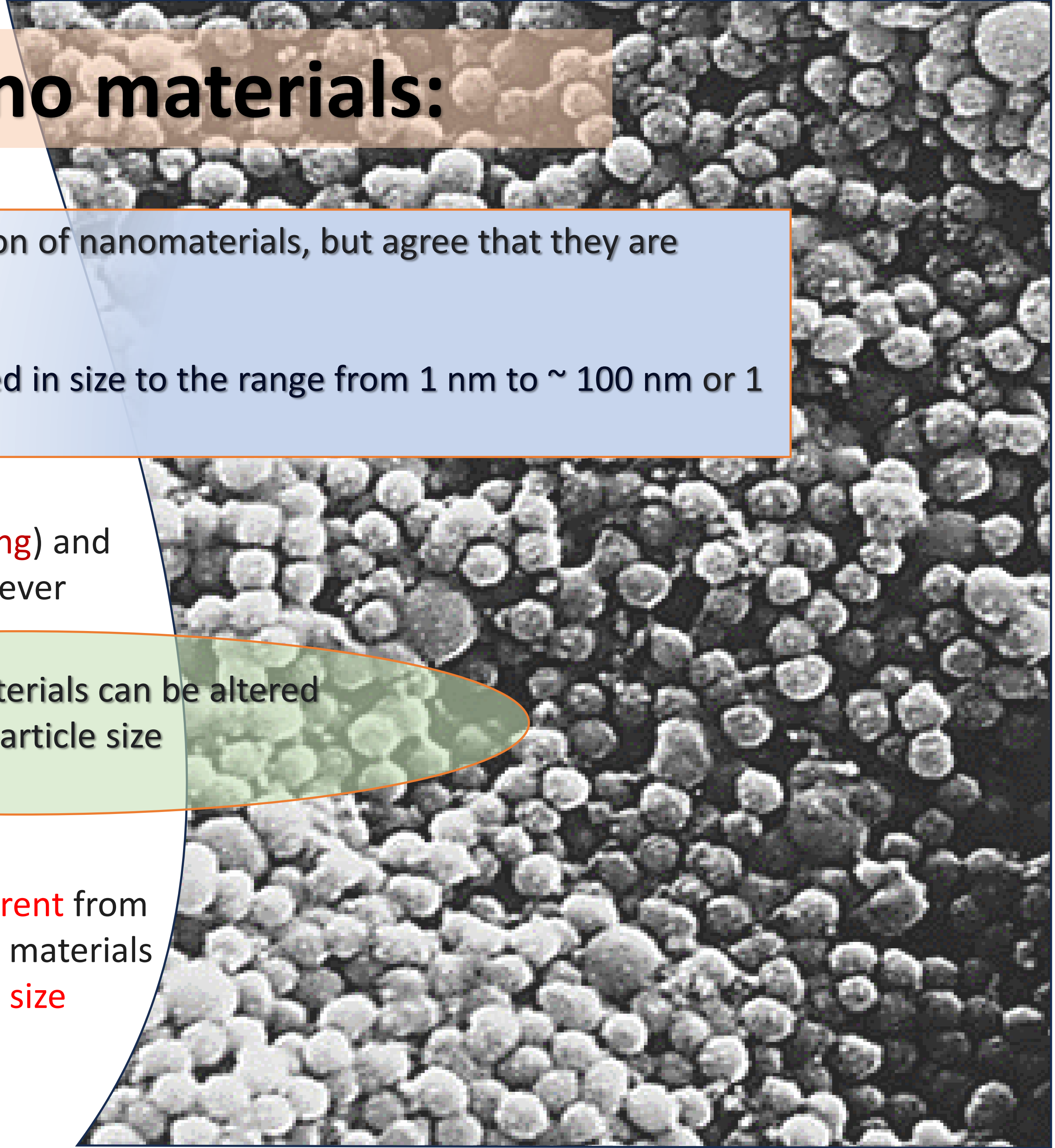
Nanotechnology is the science (synthesis, engineering) and applications of nano-materials, and is growing at an ever increasing pace.

the properties of materials can be altered dramatically by the particle size

Properties such as

- Solubility
- Reactivity
- Spectroscopy
- electrical and magnetic
- Optical
- transport through membranes etc.

are generally different from those of the same materials with large particle size



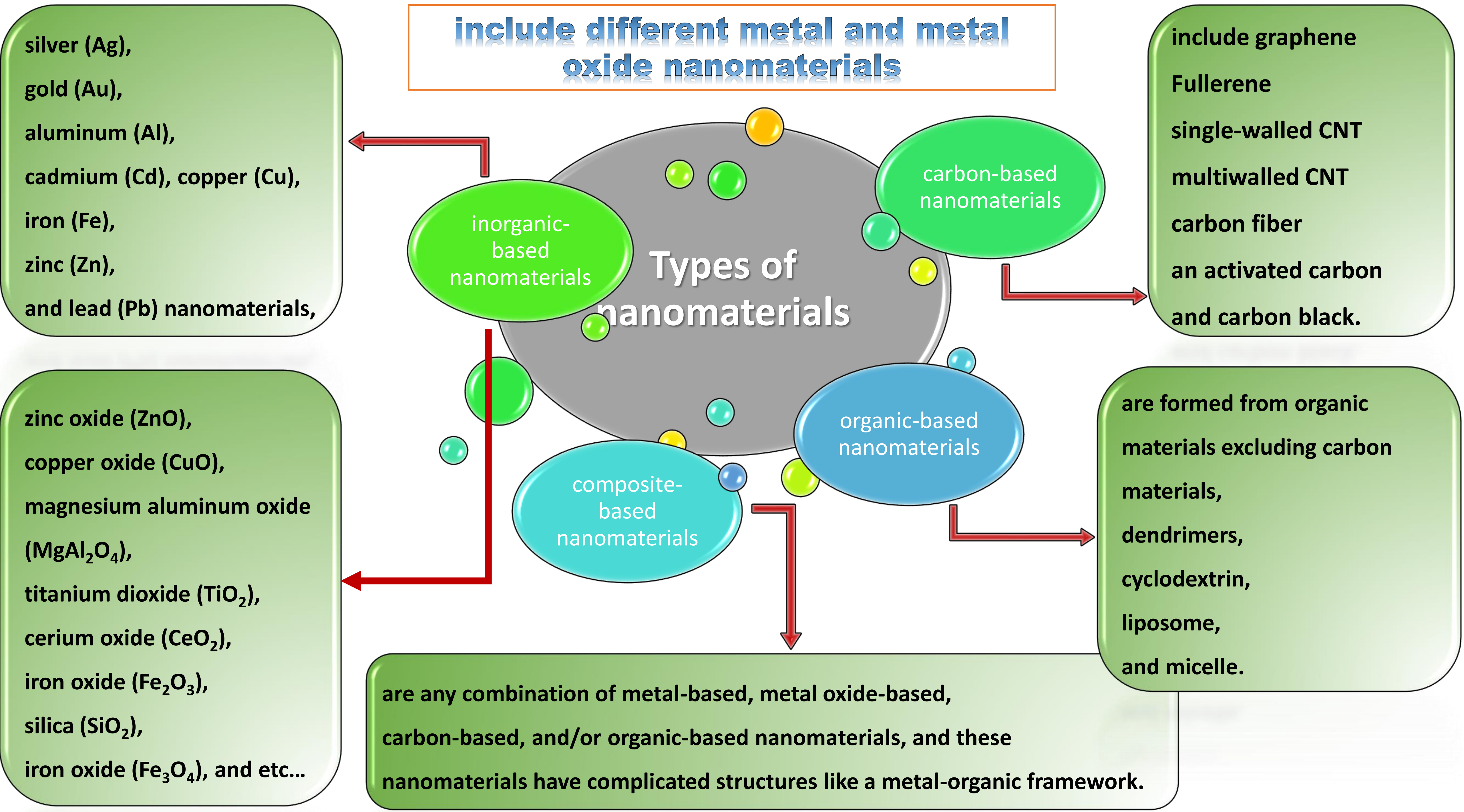
The applications of nano size materials

- health
- agriculture
- water
- Information and technology
- consumer products
- Energy
- Biomedicine
- Electronics
- Pollution
- Food engineering
- Transportation
- Coating
- Telecommunication
- Implant materials
- Etc…

it has been confirmed that the technology that uses nanomaterials is more effective than the technology that uses bulk materials.

Due to

the large surface area compare to volume of nano powder allows to carry more energy


include different metal and metal oxide nanomaterials
silver (Ag),
gold (Au),
aluminum (Al),
cadmium (Cd), copper (Cu),
iron (Fe),
zinc (Zn),
and lead (Pb) nanomaterials,
Types of nanomaterials
inorganic-based nanomaterials
carbon-based nanomaterials
organic-based nanomaterials
composite-based nanomaterials
include graphene
Fullerene
single-walled CNT
multiwalled CNT
carbon fiber
an activated carbon
and carbon black.
zinc oxide (ZnO),
copper oxide (CuO),
magnesium aluminum oxide ($MgAl_2O_4$),
titanium dioxide (TiO_2),
cerium oxide (CeO_2),
iron oxide (Fe_2O_3),
silica (SiO_2),
iron oxide (Fe_3O_4), and etc…
are formed from organic materials excluding carbon materials,
dendrimers,
cyclodextrin,
liposome,
and micelle.
are any combination of metal-based, metal oxide-based, carbon-based, and/or organic-based nanomaterials, and these nanomaterials have complicated structures like a metal-organic framework.

CLASSIFICATION OF NANOMATERIALS

based on the structural configuration/composition
(1) inorganic-based nanomaterials;
(2) carbon-based nanomaterials;
(3) organic-based nanomaterials; and
(4) composite-based nanomaterials.

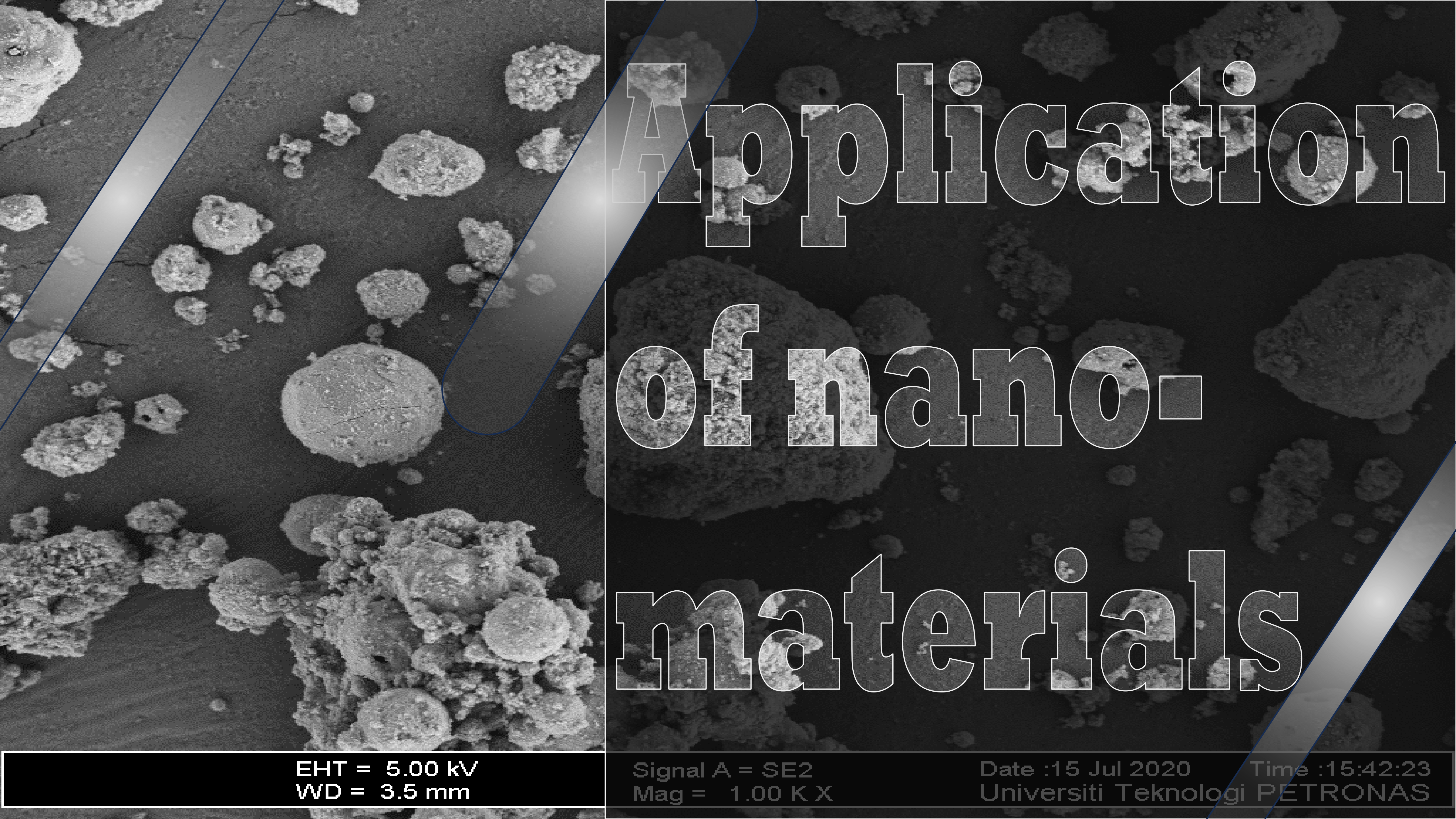
based on origin
Natural nanomaterials
Artificial nanomaterials

according to the number of dimensions
0D, 1D, 2D, and 3D

based on potential toxicity
Fiber-like nanoparticles,
persistent granular nanoparticles, and
CMAR nanoparticles (carcinogenic,
mutagenic, asthma genic, reproductive
toxin)

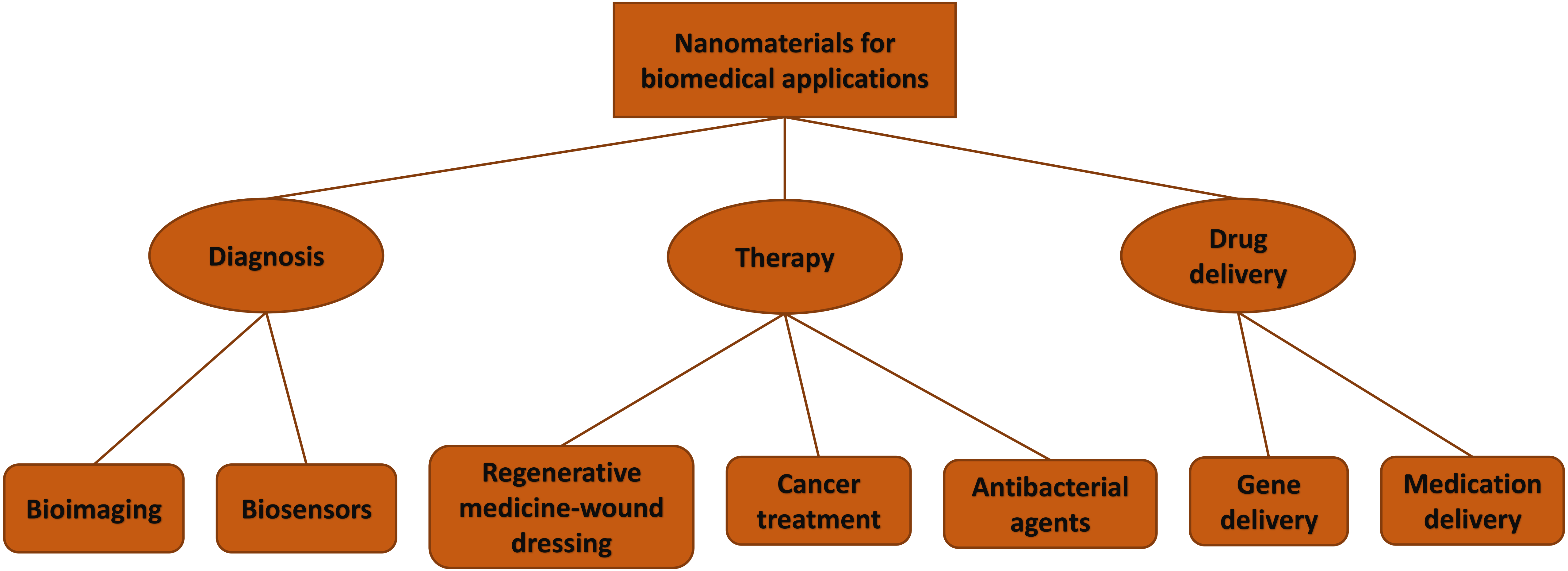
based on pore dimensions
micro porous materials,
mesoporous materials, and
macro porous materials.

Application of nano-materials



Nano materials are involved in all engineering fields, in which enhance and provide spectacular properties.

In the field of biomedical application, nanomaterials have been employed in:



Nanomaterials for orthopedic applications

The application of nanotechnology to bone substitutes is relatively a new frontier in orthopedic research.

natural tissues are nanometer in dimensions and cells directly interact with nanostructured extracellular matrices

nanomaterials attractive for orthopedic applications include:

- high strength-to-weight ratio,
- wear/corrosion resistance,
- antimicrobial/drug release potentials,
- and tissue integration/regeneration capabilities

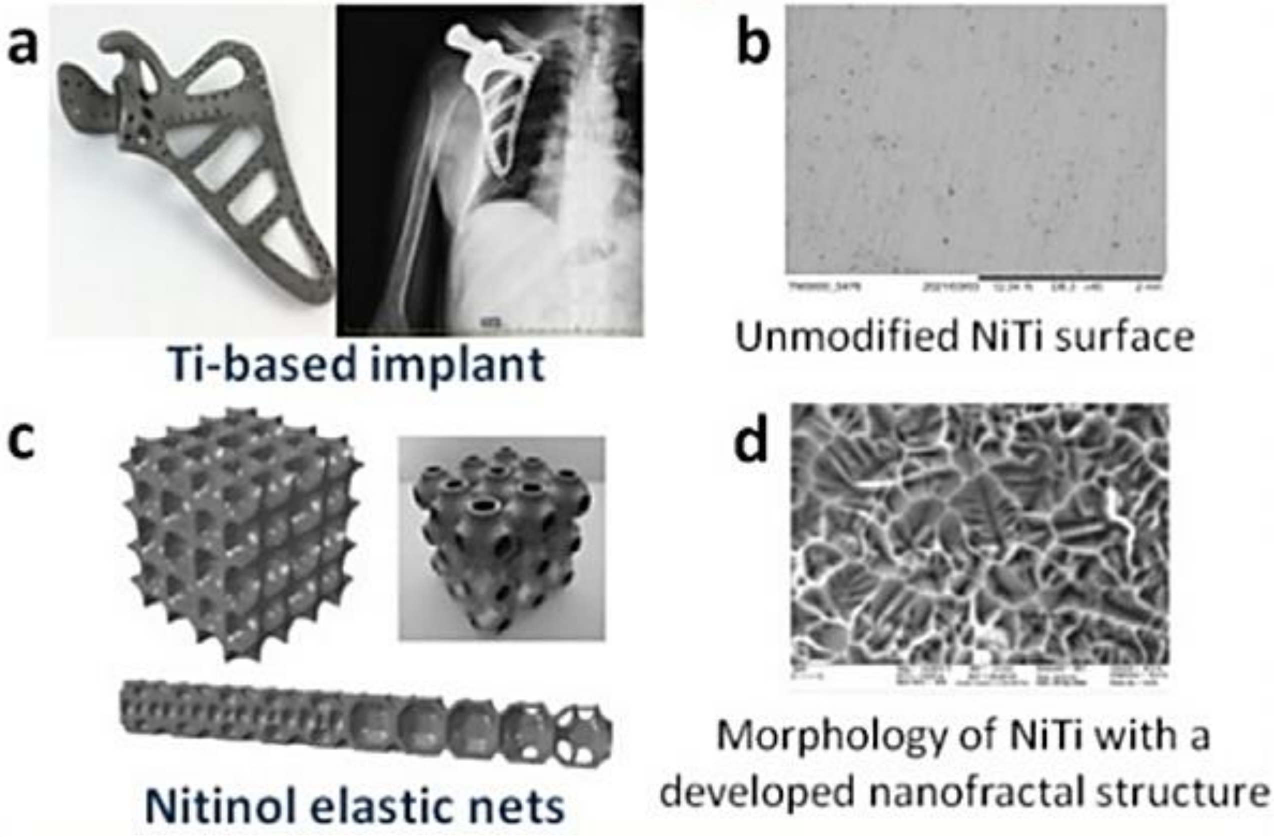
Table 1 Typical materials used in orthopedics, including nanostructures

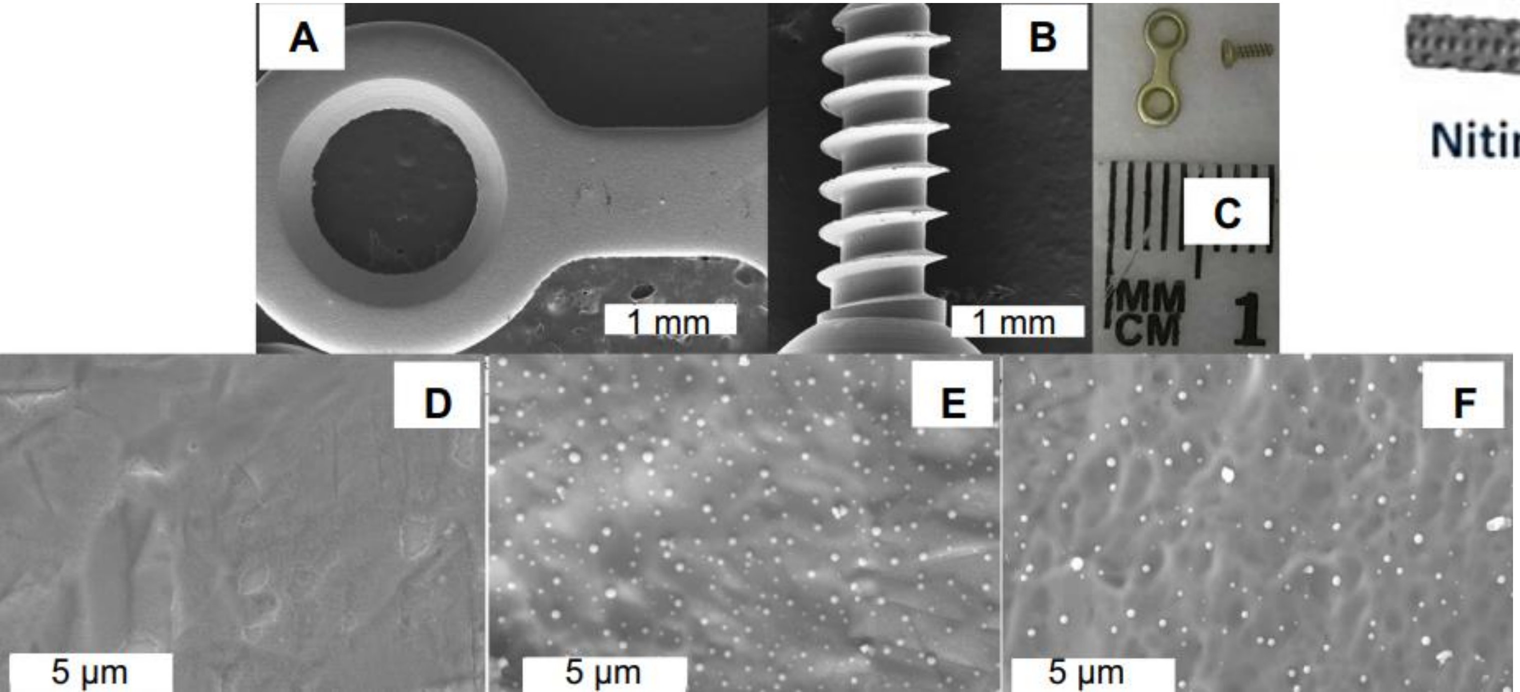
Materials	Features
Polymers	
Natural polymers	
Collagen[13,14]	Low immune response; good substrate for cell adhesion; chemotactic; low mechanical properties
Chitosan[15,16]	Hemostatic; promotes osteoconduction and wound healing
Hyaluronic acid[17–19]	Chemotactic when combined with appropriate agents; low mechanical properties; minimal immunog
Silk[20–22]	Promotes cell migration, vascularization, and osteoconduction; high compressive strength
Synthetic polymers	
Poly-lactic-co-glycolic acid (PLGA)[23–25]	Biocompatible; tunable degradation rates; good mechanical properties; process ability; approved for use in humans
Poly(e-caprolactone)[26–28]	Low chemical versatility; degradable by hydrolysis or bulk erosion; slow degrading; bioresorbable
Polymethylmethacrylate (PMMA)[29–31]	Brittle; biocompatible; thermoplastic; low ductility; used as bone cement
Poly(lactic acid) (PLA)[32]	Biodegradable; bioabsorbable; thermoplastic; suitable mechanical properties
Polyetheretherketone (PEEK)[33,34]	Good mechanical properties; chemically and physically stable; biologically inert and safe; poor osteoi
Metals	
Titanium alloys[35–37]	High corrosion resistance; osteoconductive
Cobalt–chromium alloys[38,39]	Excellent friction resistance; high corrosion resistance
Silver[40–42]	Antimicrobial/antiviral properties; used as anti-infection coatings
Stainless steel[43,44]	Low cost; excellent fabrication properties; resistant to a wide range of corrosive agents
Tantalum[45]	Anticorrosive; biocompatible; cost effective; ductile
Ceramics	
Calcium phosphates[8]	Improved cell differentiation; osteoconductive
Hydroxyapatite[46,47]	Slow biodegradation rate; low fracture toughness; good osteointegration
Bioactive glass[27,48]	Brittle and weak; enhanced vascularization
Metallic oxides (eg, alumina, zirconia, titania)[49]	Favorable wear and corrosion properties; good biocompatibility
Carbon materials	
CNTs/CNFs[50,51]	Excellent electrical conductivity and mechanical strength; low density
Graphene/graphite[52]	High tensile strength; thermal and electrical conductivity; reflexivity
Diamond[53]	Superior mechanical and tribiological properties
Composites	
Ceramic nanophase in a ceramic or polymer matrix[54–56]	
Carbonaceous nanophase in a ceramic or polymer matrix[50,57]	Better osteoconductivity; tailorable degradation rate; enhanced mechanical and biological properties supporting cell activity
Metallic nanophase in a ceramic or polymer matrix[58–60]	
Polymer–polymer composites[61,62]	

Nanomaterials for orthopedic applications

Nanostructuring of metallic implantable devices **enhances** their mechanical properties and biocompatibility.
Nowadays, bulk nanocrystalline (NC; <100 nm) and ultrafine-grained (UFG; ~100 – 500 nm) metals including titanium (Ti) and their alloys can commercially be fabricated by severe plastic deformation (SPD) techniques and powder metallurgy (P/M)

Metal implants

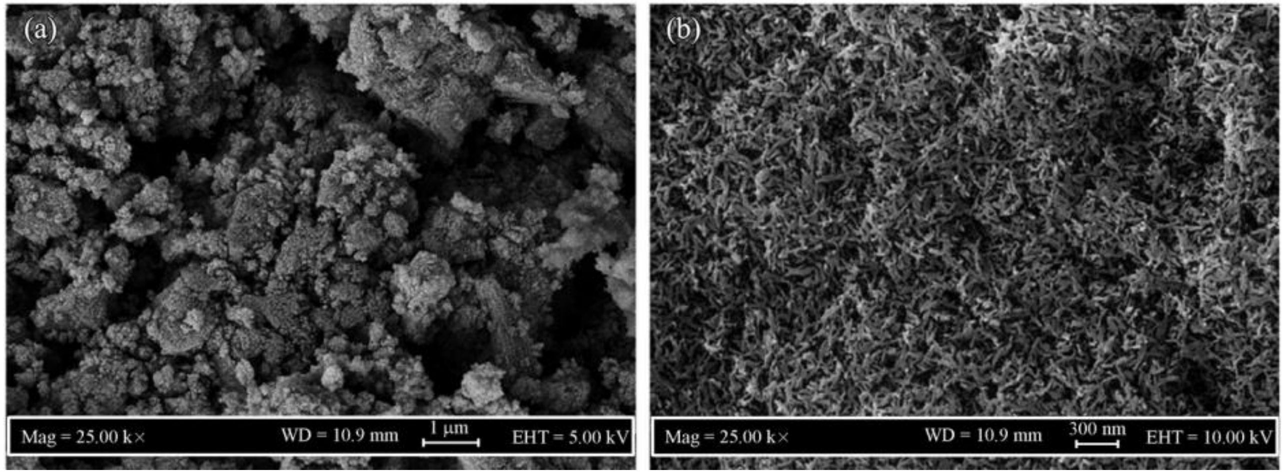


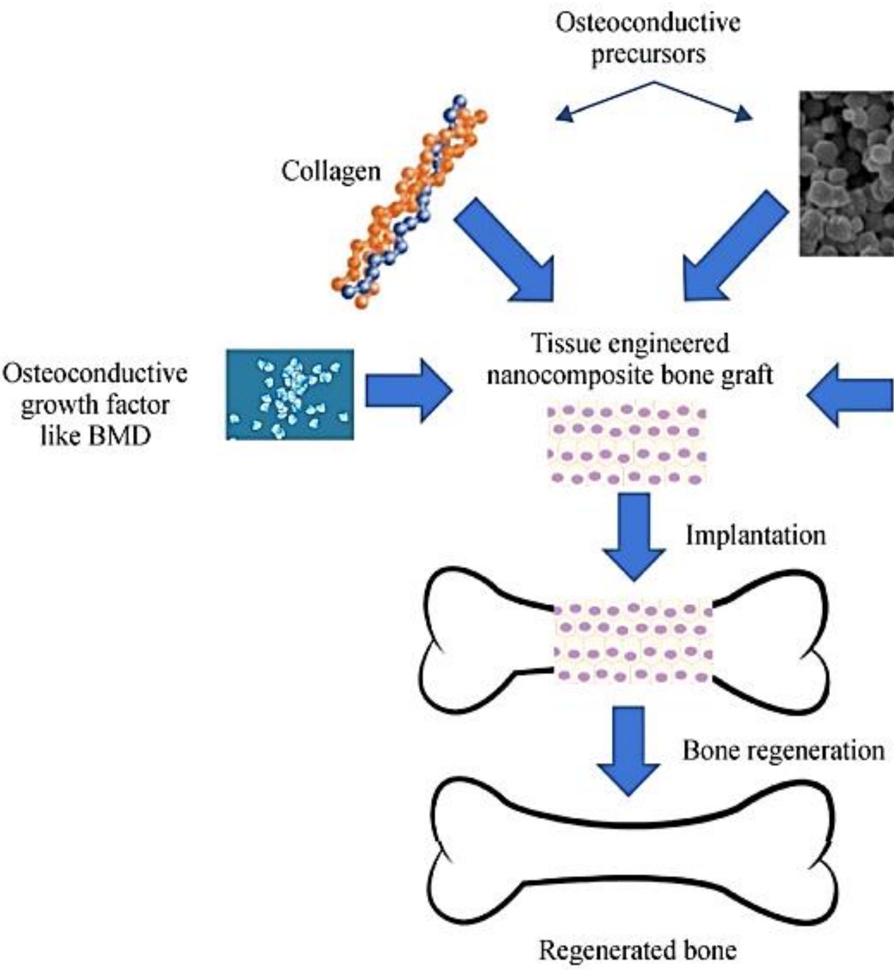


Selenium: has potential anticancer chemistry. Unlike titanium, selenium is an essential trace element in the human body. In vitro research has shown the **inhibitory effects** of selenium on the growth of many **cancerous cell** lines

Nanomaterials for orthopedic applications

Bioceramics are the most demanding materials for orthopedic applications, although their inherent brittleness prevented their use in some applications.





Nanophased ceramics could offer advantages of improved fracture toughness with an ability to promote biofunctionality.

Recent advances include nanostructuring of various bioceramics including:
zirconia,
titania,
alumina,
calcium phosphates,
bioactive glass (BG), and
HA.

Studies have shown that nanostructuring yields higher mechanical strength with improved ductility and toughness as the finer grains hinder dislocation slip and cause crack blunting

Nanomaterials for orthopedic applications

Polymer matrix nanocomposites (PMNC) consists of a polymer or copolymer

This new class of nanocomposite materials has been received significant attention in biomedical applications owing to

lightweight, ease of production, and some ductile nature

Poly(vinyl alcohol) or PVA is one of the vinyl polymers with high hydrophilicity, flexibility and biocompatibility which has been widely employed in biomedical applications.

Ultrahigh molecular weight polyethylene (UHMWPE), polyethylene (PE),

poly(lactic acid) (PLA)

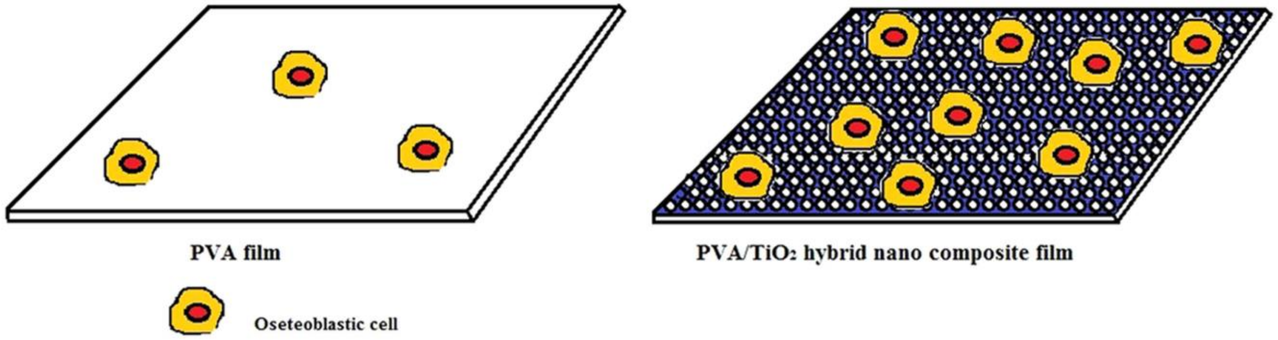
polyurethane (PU)

silicone rubber (SR), polyetheretherketone (PEEK)

polytetrafluoroethylene (PTFE)

polyethylene terephthalate (PET)

Polyacetal (PA), polymethylmethacrylate (PMMA)



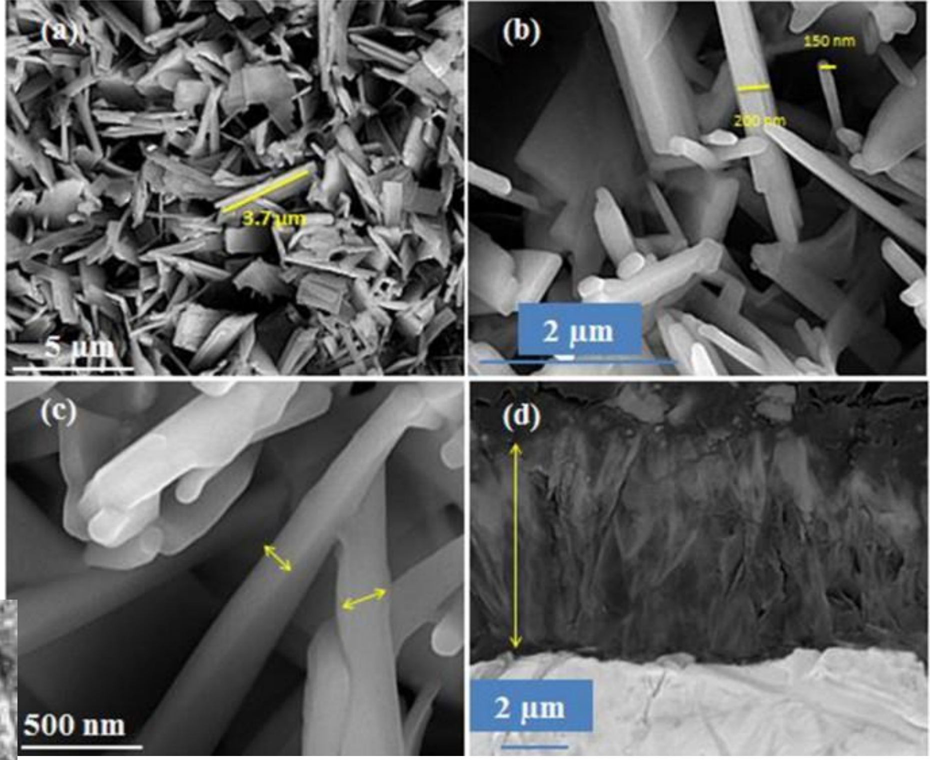
PVA mainly reinforced TiO_2 nanoparticles to improve thermomechanical stabilities, surface properties and osteoblastic cell adhesion

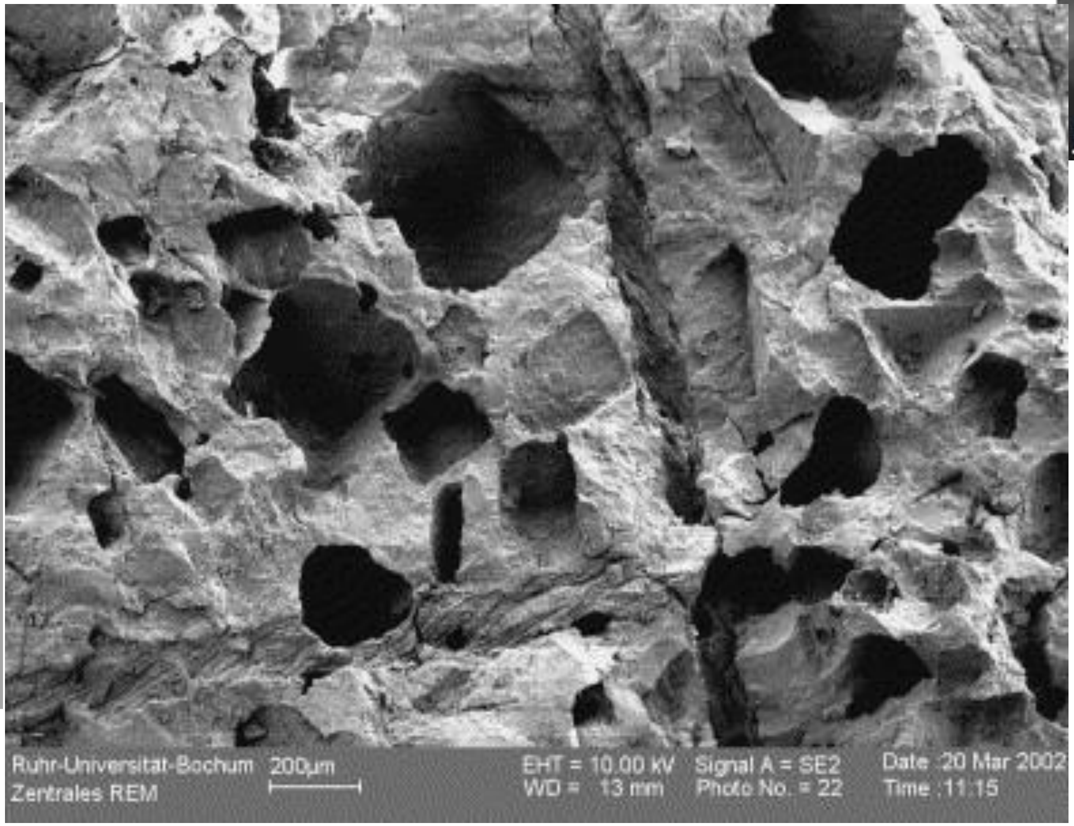
Nanomaterials for orthopedic applications

nanoceramics and **nanopolymers** are mostly used as **coating constituent materials** for orthopedics or can be **combined** with other biomaterials to form nanocomposites for implant applications

Common nanocomposites for bone tissue regeneration consist of:

- ceramic nanophase in a ceramic matrix
- carbonaceous nanophase in a ceramic or polymer matrix
- ceramic nanophase in a polymer matrix





HA/ZrO_2 better compressive strength and elastic modulus than that of porous monolithic HA

JOINT REPLACEMENT

Hip and knee joints are so-called cartilaginous joints

The joint surface is covered by a smooth articular surface that allows pain-free movement in the joint

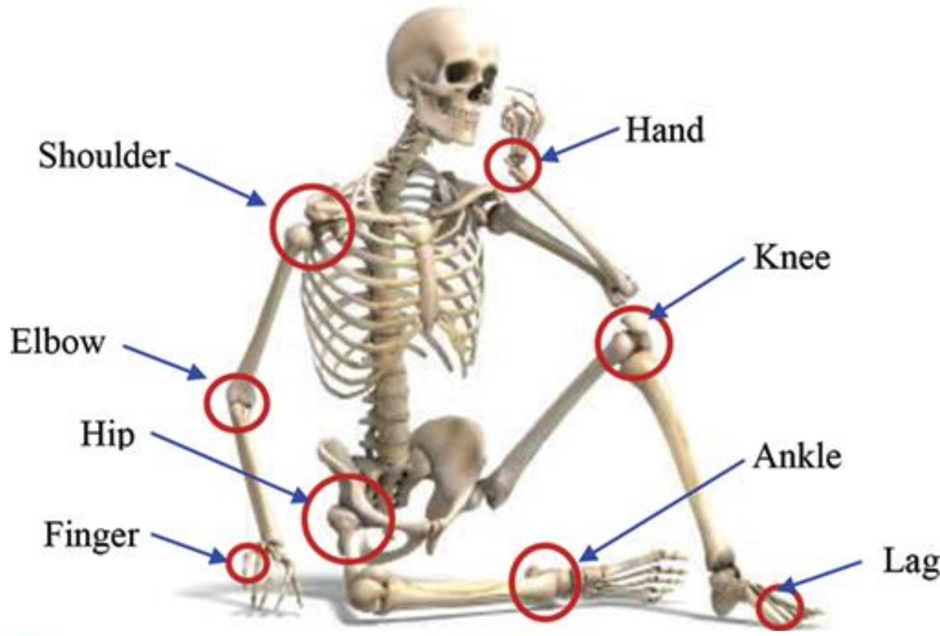
So to reduce the wear debris Nano technology has been introduced

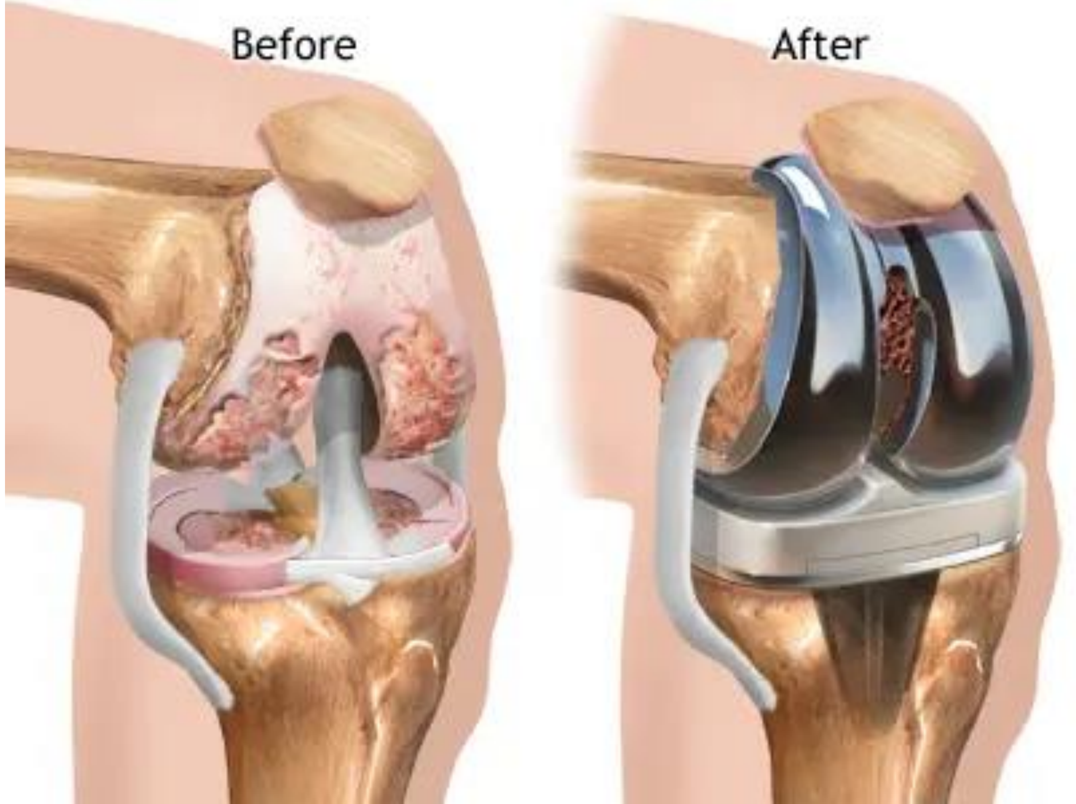
by implementing a thin film or coating on the implant material

nano coatings on knee implants reduces friction and wear, ultimately improving the implant’s lifespan

(UHMWPE) material reinforced with functionalized (f-SWCNTs)

cell viability enhancement with good cell growth





Maxillofacial prostheses

The **Aim** of Maxillofacial Prosthetic is **reconstruct** of missing parts in maxilla, mandible and face with prosthesis.

Maxillofacial prostheses are removable means of treatment used to cover tumor associated surface defects with replace missing facial or oral structures.

To achieve:

1. **Preservation of residual structures.**
2. **Reconstruction of function**
3. **Improvement in esthetic.**

Maxillofacial prostheses

The ideal properties of maxillofacial prosthetic material should have :

- Physically and mechanically like the replaced tissue
- Suitable with human tissue and adhering to human tissue
- Both intrinsic and extrinsic Coloring can be done
- The material should be suitable for maxillofacial prosthesis and capable of help the patient at least one year with maintaining those properties.

- Acrylic resin
- Acrylic co-polymers.
- Polyvinyl chloride
- Chlorinated polyethylene.
- Polyurethane elastomers
- Silicon elastomers.
- Foaming silicones.
- A fiber-reinforced composite prosthesis

Nano materials reinforcements used in maxillofacial prosthesis

nanoparticles were incorporated and resulted in increase in tensile strength, tear strength, and percentage elongation of the maxillofacial silicone material

In order to improve their shortcomings such as:

low color stability, antimicrobial adhesion and mechanical properties

Nano reinforced	Silica dioxide nanoparticles that increases the surface hydrophobicity.
	zinc oxide nanoparticles that result significant decrease in polymerization shrinkage.
	Ag coated on silicone elastomers showed good antifungal activities without any adverse reactions on human dermal fibroblast cells in vitro
	Nano layer of TiO_2 will be effective in reducing color degradation

Prosthetic dentistry

Prosthetic dentistry is the replacement of missing teeth, which may have been lost for a **variety of reasons**, with either fixed or removable dentures. Natural teeth may have lost due to caries (dental decay), periodontal (gum) disease, or trauma

Requirement of Clinically Denture Base Materials

1.durability

2- Satisfactory thermal properties

3- Fabrication accuracy and dimensional stability

4- Good chemical stability

5- Insolubility and low sorption of oral fluid

6- Absence of taste and odor

7- Tissue biocompatibility

8- Natural appearance

9- Color stability

10- Good retention

11- Easy to clean.

12- Inexpensive with good shelf life

Denture Base Materials (Matrix)

1-Polyamide nylon

2-Polyoxymethylene (acetale)

3-Urethan methacrylate (UDMA)

4-Poly methyl methacrylate (PMMA)

5-Poly ethylene (PE)

6-Polyvinly chloride (PVC)

7-Phenol formaldehyde

Types of Prosthetic Denture Defects


Porosity

Fracture of removable dentures is an unresolved problem and occurs frequently during service through heavy occlusal force or accidental damage.

With denture fracture ,patient may be affected esthetically, functionally, and psychologically

Fractures in dentures result from
- impact
- flexural fatigue


Crazing


Denture Warpage

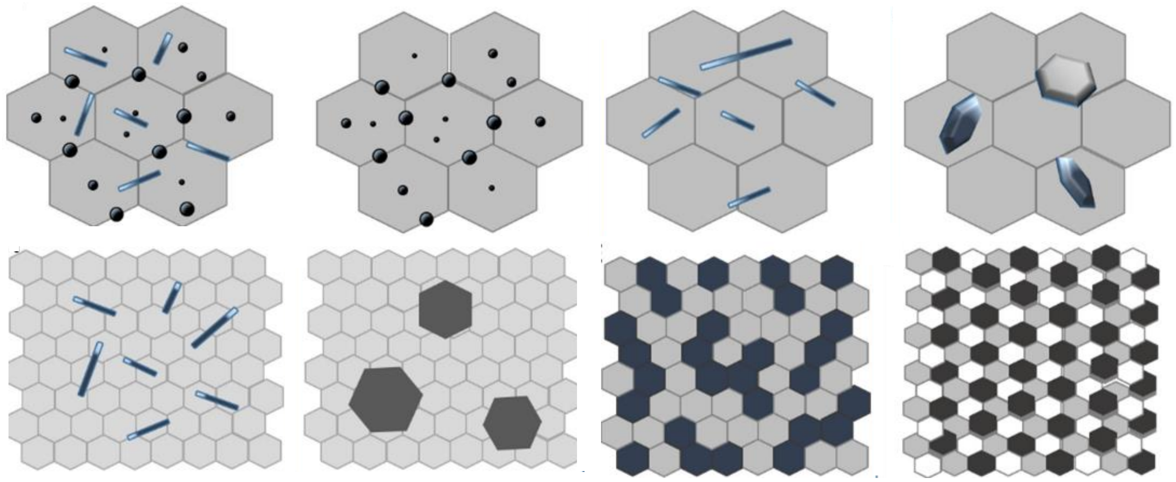
Types of Prosthetic Denture Defects

The introduction of nanotechnology led to the discovery of nano-filler particles

efforts were being made to achieve considerable advances in tackle issues like

- polymerization shrinkage
- achieve patient satisfaction in terms of the aesthetic appearance
- wear resistance
- micro hardness
- Good physical properties

Nano fillers



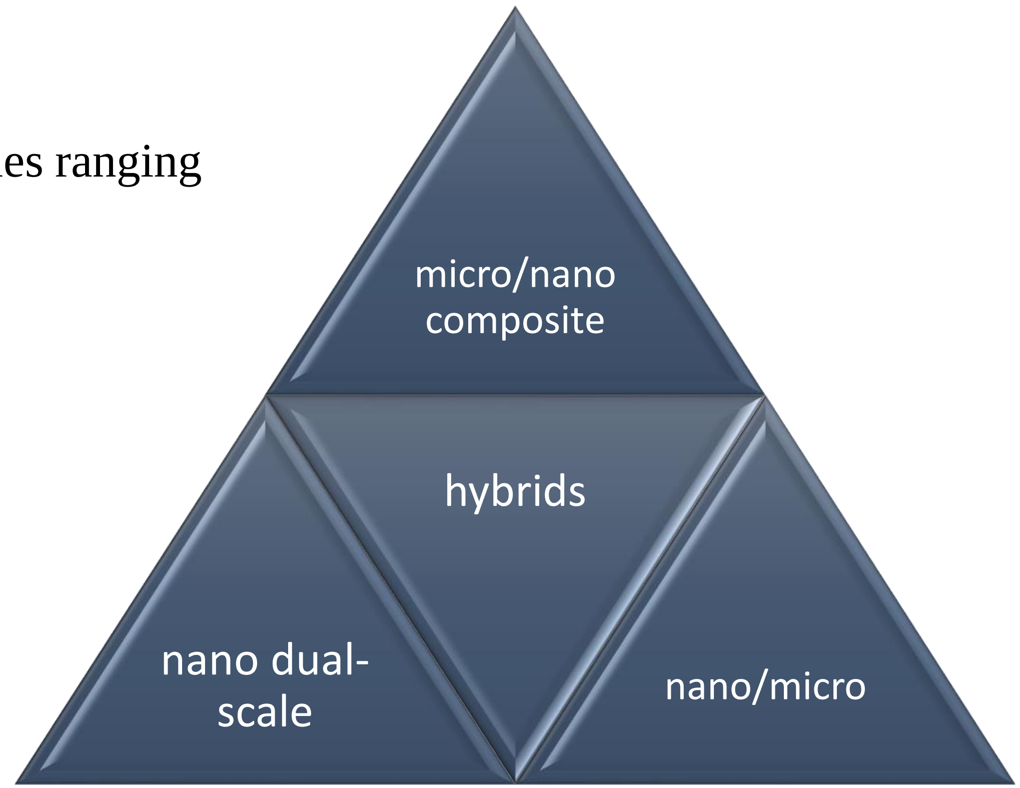
Two different types of more commonly available Nano composites

Nano fills

Nano hybrids

comprised of larger particles ranging from 0.4 to 5 µm

dominated by the presence of 1 to 100 nm size particles mainly



The Nano materials reinforcements used in Prosthetic Denture

suggested to improve the properties of PMMA denture base.

Nano-gold (Au)

improved the flexural strength and thermal conductivity to almost double the value of pure PMMA.

platinum (Pt)

improve mechanical properties of PMMA and provide antimicrobial effect.

It was found that platinum significantly increased the bending deflection of PMMA .

palladium (Pd) Nano-gold (Au) and platinum (Pt) NPs

Palladium improved the bending strength, which showed the lowest value of bending strength.

Addition of gold and palladium improved Vickers hardness of PMMA and was decreased with the addition of platinum.

THANK YOU