Advanced Ceramics for Strategic Applications
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Lecture - 47
Bio ceramics

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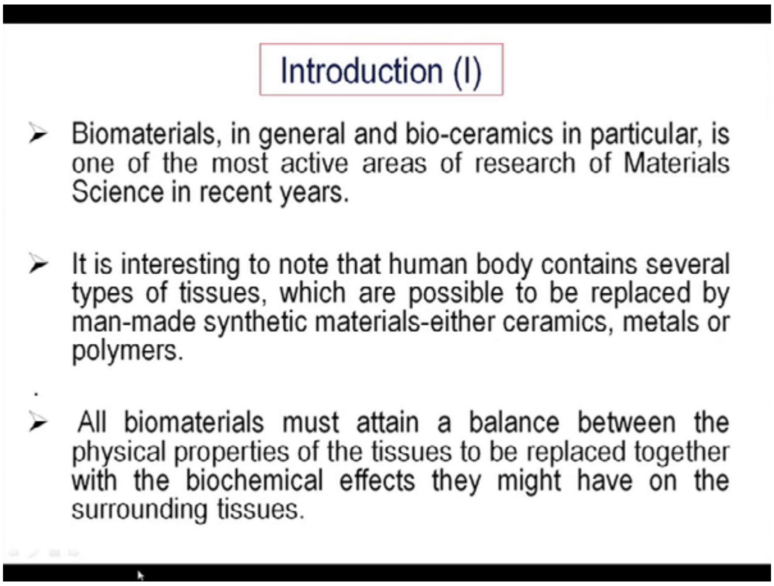

Welcome to this lecture. Today our topic is bio ceramics, which basically means a group of ceramic materials, which is used for biotechnology, primarily as implants in human or animal body. To introduce the subject, biomaterials in general and bio ceramics in particular is one of the most active areas of research of material science in recent years. Well, the name suggests the materials used for bio medical purposes; that means, the materials used in living systems. So, it is not only the ceramics which are useful for this purpose, there other materials like metals, polymers, composites, but our discussion today is basically ceramics, because this is a course on advanced ceramic materials. Very interesting to know, that the human body contains several types of tissues, which are possible to be replaced by man-made synthetic materials like ceramics, metals or polymers.

So, in our human body, we have many different in organic materials, which can be very easily be replaced by materials made by synthetic from the synthetic route, not necessarily everything has to be synthesized within the body, but it can synthesized outside the body and then get implanted into the body. So, all materials must attain a balance between the physical properties of the tissues to be replaced together with the biochemical effects, they might have on the surrounding tissues. So, it is obviously, a very challenging task, because well trying to do something very abnormal, trying to introduce or replace some of the natural body components by a synthetic material, which have been prepared outside the body of course.

We have to understand, what is the physical properties? What is the chemical properties? What is the biological properties? Then only one can replace or use some of the synthetic materials to replace this components, but as in the very first line it has been mention it is a very intense area of research and because health care has become a very, very important aspect of human society. And therefore, wherever possible one has to take care of your elements, the body elements by different ways not only by drugs, but it also requires mechanical replacements of some of the components and that is why the bio ceramics or biomaterials in general and bio ceramics in particular are very, very important.

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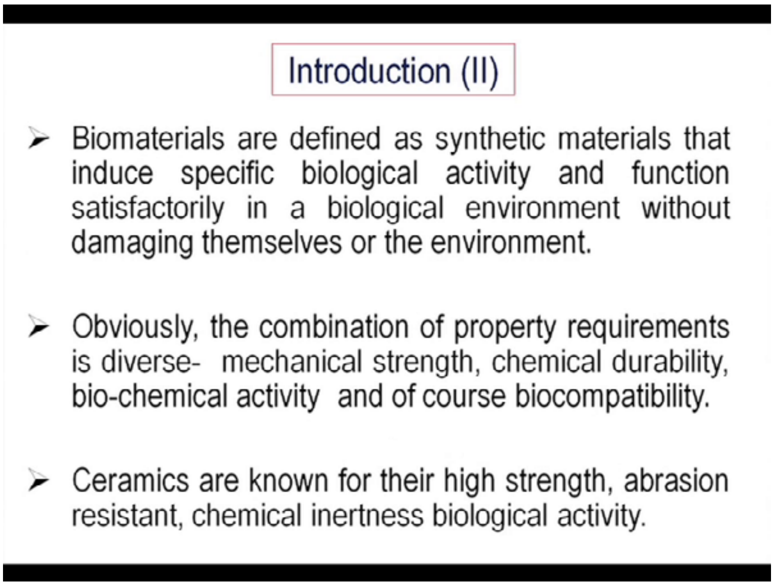

Biomaterials are defined as synthetic materials that induce specific biological activity and function satisfactorily in a biological environment, without damaging themselves or the environment. Because, you are putting foreign material inside the body and therefore, it has it is very important to understand or to evaluate. Whether, the materials themselves get damaged within the body environment within the biological environment or the environment gets damaged or changed by the foreign materials.

So, both are important; obviously, the combination of the property requirement is diverse, you need mechanical strength, chemical durability, biochemical activity and of course, the biocompatibility. Foreign materials, when goes into the living systems it must accept it must not reject it. So, there has to be a the amount of biocompatibility between the material. And the environment in which, it is put, ceramics are known for their high strength, this are general properties of ceramics there normally high-strength, although brittle, abrason resistance, chemically inertness. And in some cases, there are some chemicals ceramic materials inorganic materials which have some biological activity, we will discuss that later.

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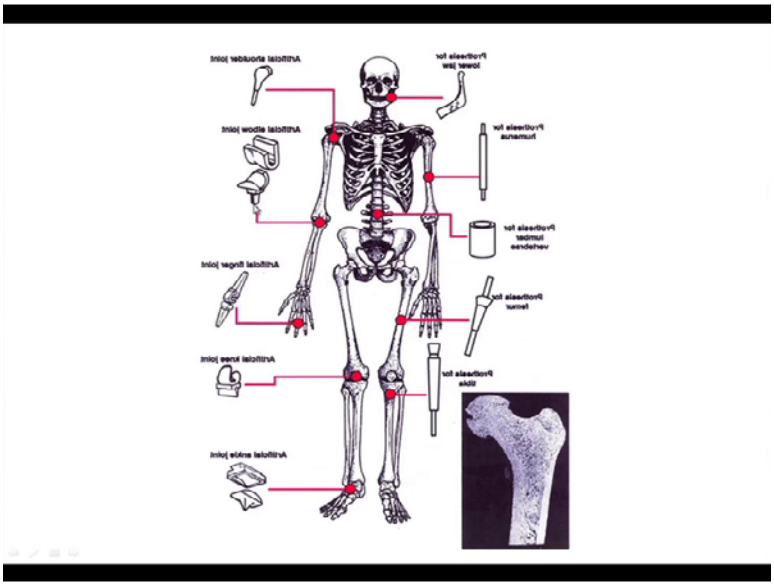

Now, this is a typical skeleton of a human body and particularly the bone structure and this bone structure basically, inorganic materials its certain amount of minerals are there. Of course, it is not the only the mineral, we look in to see what are the different things constitute the bone, but the whole lot of different kind of implants has been devised and has been in use for several decades. So, whether is a finger joint, whether is a knee joint, whether it is a hip joint, here the details of the hip joint are like this it's a ball and socket joint see. So, it is the actually carries the strength, or whole weight of the body and of course, it forms the skeleton for other components of this the body. So, but it includes a fair substantial amount of our human body the bone structure and major constituent of the bone structure is inorganic materials, will see what is that?

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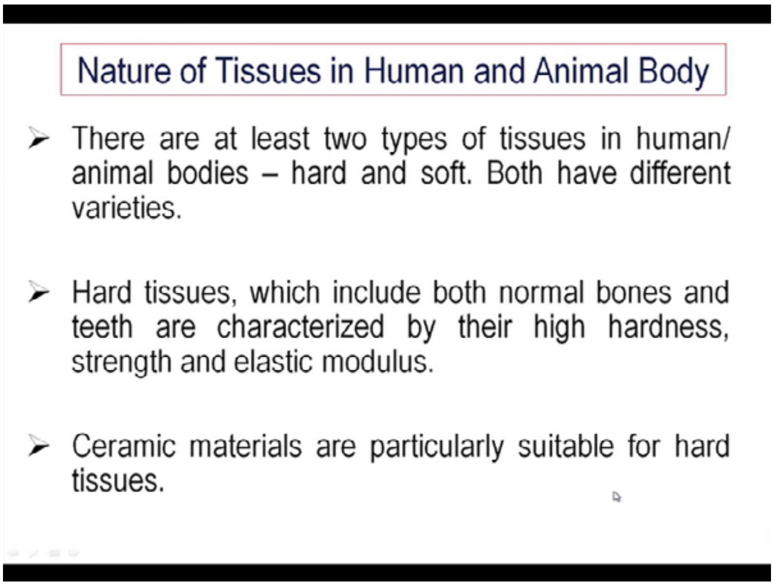

These are all different kind of tissues, which a human or animal body may have. There are at least 2 types of tissues in human body, human and animal bodies one is called hard tissue and the soft tissue. Both have different varieties, hard tissue also have a different varieties and also the soft tissues. Hard tissues, which include both normal bones and the teeth, which we have just now shown are characterized by their high hardness, strength and of course, the elastic modulus. Because that is the basic load-bearing element of the human body and therefore, it has a different role to play and; obviously, their strength is high and elastic modulus is high.

Because, there is no plastic deformation, but elastic deformation is quite substantial. And we will see later is basically, a composite structure, it is not a simple monolithic structure, is a composite structure and that is why it has so much of elastic modules. Ceramic materials are particularly suitable for hard tissues, ceramics as such are brittle than not much of flexibility. And therefore, it is the hard tissues not; obviously, not the soft tissues. Soft tissues can be replaced or a better material for soft better replacement for soft tissues; obviously, are polymers or different kind of composites. So, our interest is; obviously, in the hard tissues part of the body.

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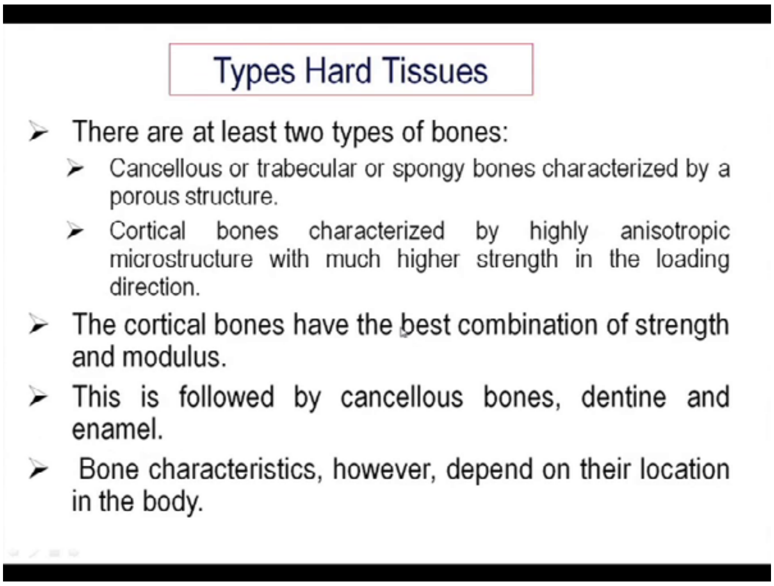

Different types of hard tissues as mention. There are at least 2 types of bones in our body; one is called the cancellous or trabecular or spongy bones characterized by a porous structure. Most of these bones; most of these bones are basically porous structure, they are not a completely hard monolithic structures. So, one is the cancellous or spongy bone, the other is cortical bones are characterized by highly anisotropic microstructure with much higher strength in the loading direction.

So, the cortical bones have the best combination of strength and modulus. The second variety, this is followed by cancellous bones like dentine and enamel so, the so far as the strength is concerned. So, this is a basically a composite structure will see, what are the different components of the composite and then you have cancellous bone, dentine and enamel particularly related to the tooth. So, bone characteristics; however, depend on their location in the body. All the bones are; obviously, not same they have a different kind of characteristic, different kind of structures different kind of constituents and they perform differently.

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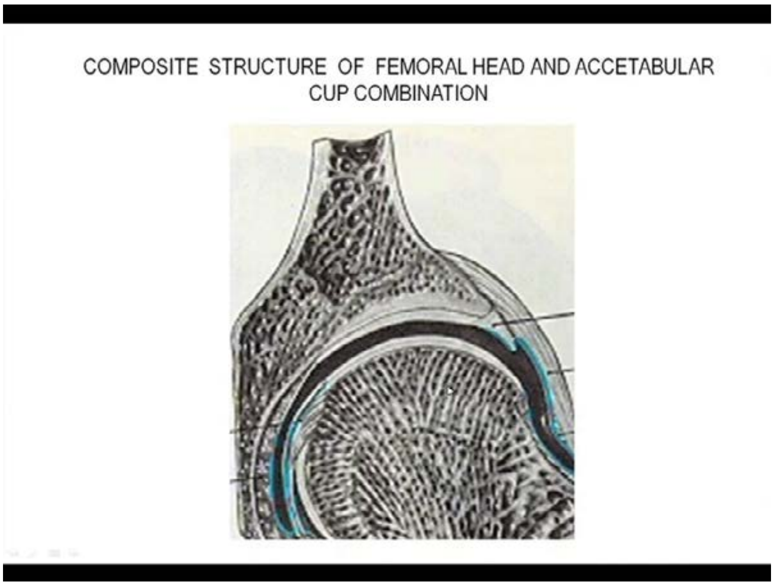

This a typical structure, composite structure of a femoral head; that means, the ball and socket joint at the hipand is just to show that is very complex structure. There are much more details, I have not going to the details of that, but basically it is a, it is a composite structure, like a fibrous composites.

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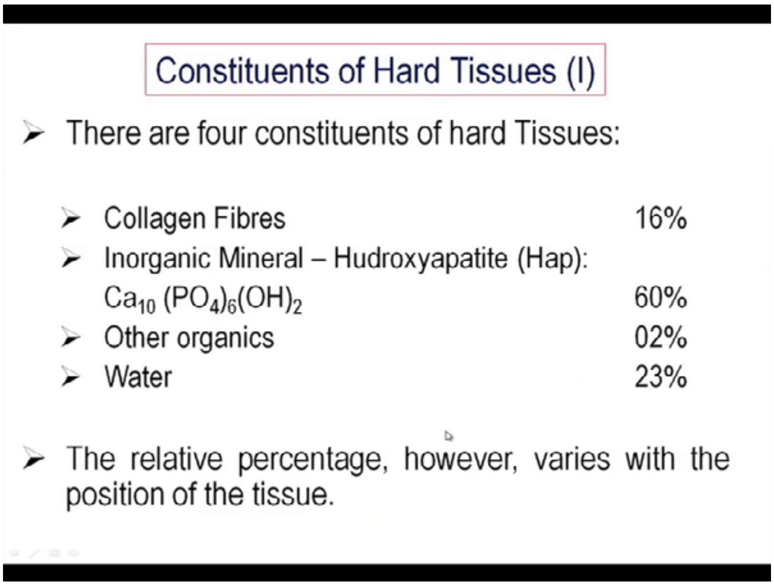

There are 4 constituents of hard tissues; one is the collagen fibre that is what we are talking about the fibers and the overall by weight it is about 60 percent, then you have inorganic minerals that is that is the main constituent of ceramics. The hudroxyapatite; it is called the hurdroxyapatite. Normally, this is not, this is H capital a right and the compound or the very, the formula which is close to this is actually C A 10, P O 4 6, O H twice. So, it is basically hydrated calcium phosphate, which is the hydrated calcium phosphate, which is the main constituents of our bone structure about 60 percent, other organics about 2 percent and water is about 3 23 percent. So, the relative percentage; however, varies with the position of the tissues has mention the bone structure itself changes. And therefore, the relative percentages also changes to some extent.

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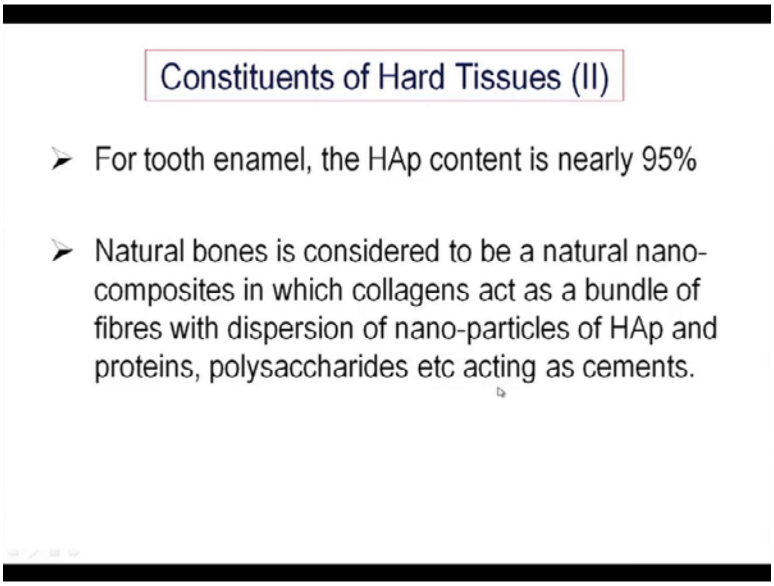

For example, for tooth for example, the HAp content is almost 95 percent here in general, it is 60 percent, but if in case of tooth it is 95 percent. Natural bones is considered to be a natural nano composites in which collagens act as a bundle of fibers, with dispersion of nano particles of HAp and proteins polysaccharides act etcetera acting as the cements. So, it is a very, very complex structures and nature has done a wonder in designing this particular material.

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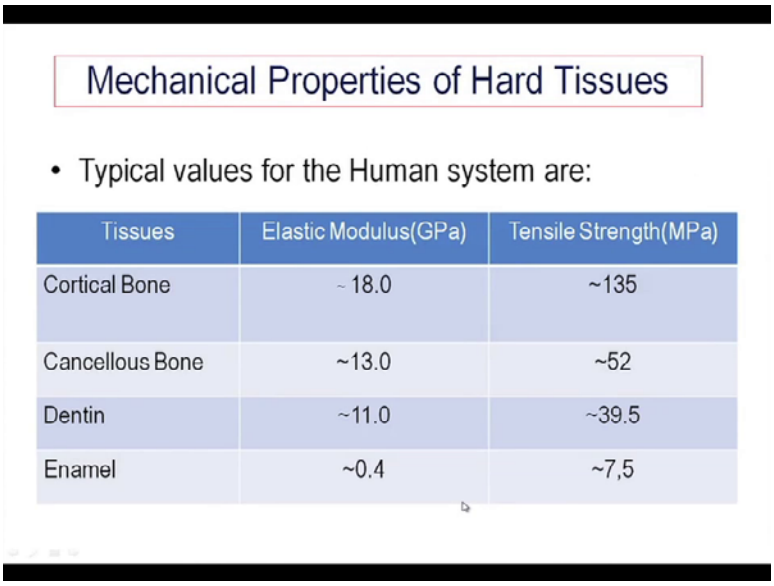

Tissues	Elastic Modulus(GPa)	Tensile Strength(MPa)
Cortical Bone	~ 18.0	~135
Cancellous Bone	~13.0	~52
Dentin	~11.0	~39.5
Enamel	~0.4	~7,5

The mechanical properties or like this, a typical values for the human system or about; approximately, 18 GPa. The cortical bone the cancellous bone is about thirteen GPa slightly less, Dentin is about 11 and Enamel is only 0.4 enamel. Of course, is only a coating on the dentin? So, it is in the in general in the order of 10 to 20 GPa, that is the value for the elastic module. The tensile strength for the Cortical bone is quite large 135 MPa, cancellous bone is about 52, less than half of that Dentine is much less and Enamel is still less. So, this is more or less, the property, the mechanical property of the human bones of different types.

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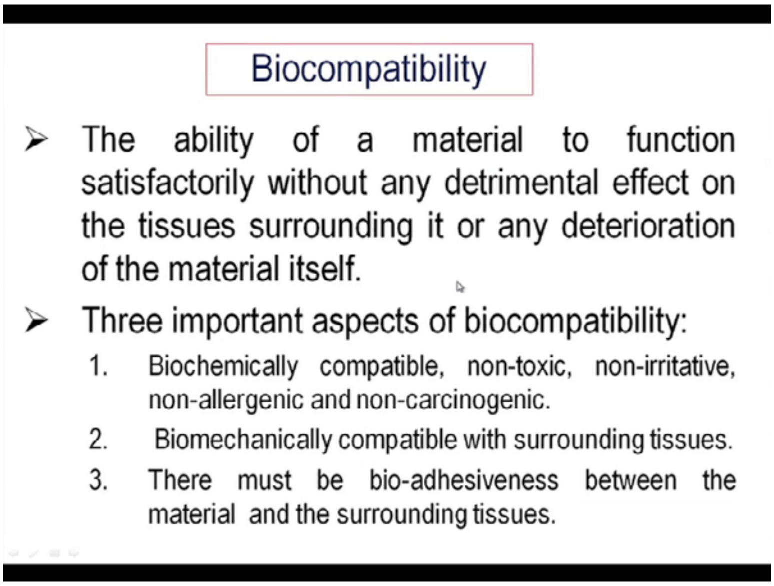

Of course, as I mention as mentioned earlier when you are trying to replace any of these components, any of these materials, or the composite material. In the human body, one has to very carefully evaluates its biocompatibility, whatever material you want to introduce into the human body, it must be acceptable by the body, the surrounding tissues and the material. So, need not or should not material should not get damaged by this tissue themselves. So, the ability of a material this is defined by a biocompatibility is normally defined as the ability of the material to function satisfactorily, without any detrimental effect on the tissues surrounding it or any deterioration of the material itself. So, it, it may it may what both ways, the tissue may get damaged or the tissue damages the materials, the foreign material. So, neither is accepted.

So, biocompatiblity means both will be interact and both will accept each other. 3 important aspects biocompatibility is biochemically compatible. So, it is; obviously, within the body fluid, which is a no doubt a chemical and the body fluid must accept it. So, must be compatible with the body fluid or the tissues as mention it must be non toxic, non irritative, non allergenic and non carcinogenic. Non carcinogenic is very important. Of course, both all of them are very important, none of this variations are acceptable, biochemically compatible with surrounding tissues that is obvious mentioned several times. There must be bio adhesiveness between the material and the surrounding tissues there are some kind of adhesiveness because, that provides the strength without these adhesive property the basic strength cannot be developed and therefore, bio adhesiveness is also an important aspect. There must be growth of cells on the surface, the surface must be have the right kind of environment or the properties. So, the cells can grow on the surface or inside into the surface into the carvises of the surface.

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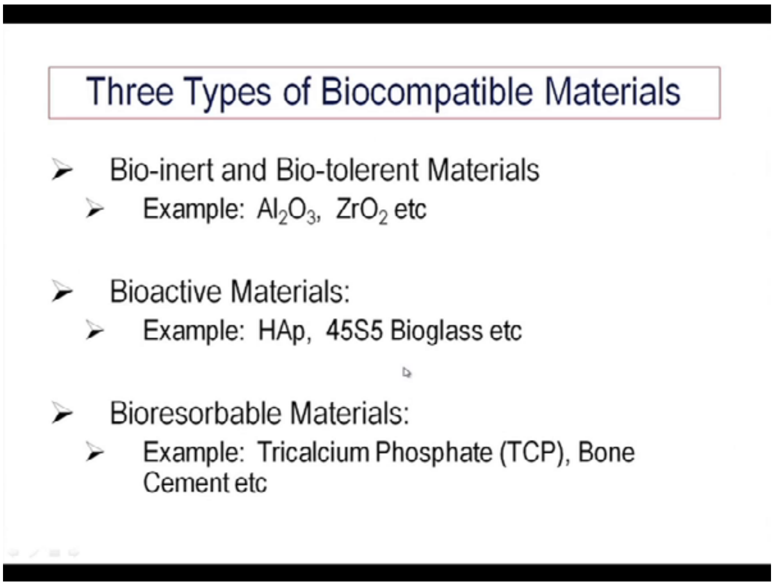

Three types of biomedic, biocompatible materials are available I mean the way they interact to the living system. We can accordingly divide subdivided in 3 different groups; one is bio inert and bio tolerant materials that means, they although they are biocompatible. But they do not take part in chemic any chemical reaction with the body fluid, or the surrounding tissues. So, the examples are aluminum oxide so far as the bio ceramics are concerned aluminum oxide and zirconate these are two more most important compounds which are use quite extensively has bio inert materials and as we know they are quite high strength material also.

So, wherever a, strength is important, these are, these kind of bio inert materials are quite useful as implants. Where are there is second group is called bio active materials or the bio active will discuss more about it. The examples are HAp, the hydrated calcium phosphate and then there is a range of bioglass, it is not only the ceramics, polycrystalline Ceramics like HAp or aluminum oxide or zirconium dioxide. But some of the glass ceramics, these are specific glass ceramics 4 or 5 s 5 it is a commercial material actually available and this is bio glass or bio glass ceramics. These are bioactive materials, which interacts with the tissues and interacts with the cell of the body and they get a good attation and therefore, there is a good attation part of it. Actually become a integral part of the body system and, the third variety is bioresorbable, bioresorbable material, example are tricalcium phosphate, tricalcium phosphates or in sort it is TCP or the bone cement. So, these are bio reservable materials will discuss little more about this properties later on.

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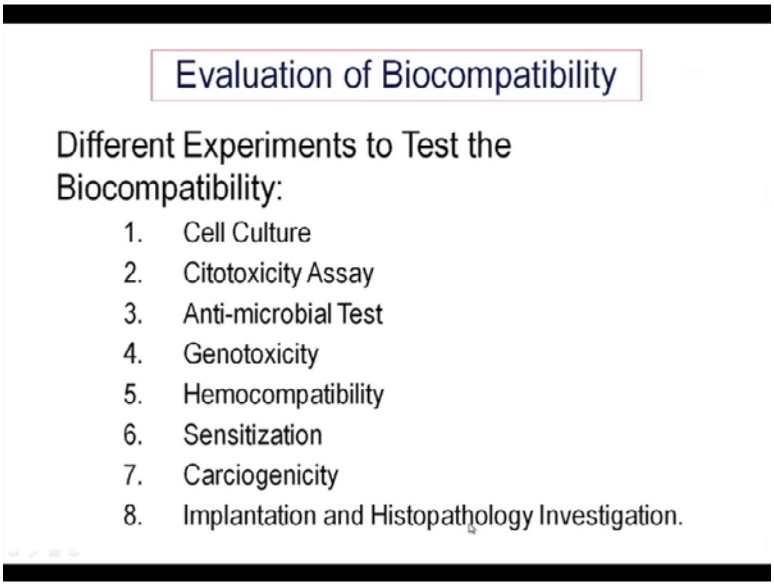

So far as the evaluation of the biocompatibility is concerned, there are different kind of tests, we are not going to the details of those, but these are different kind of test must be carefully conducted. So, that any new material, becomes acceptable, before is actually put into the system. Different kind of experiments to be to test, the biocompatiblity are like this cell culture, citotoxicity, citotoxicity assay, antimicrobial tests, genotoxicity, hemocompatibility, sensitization, carcinogenicity, and implantation and histopathology investigation. So, all this, of course, for any new material to be inserted into the human body, it needs a tremendous amount of lengthy procedure. And proceed different kind of tests must be carried out before one can really use it for any implant whether, it is small or big. This test, I am not going to details of that.

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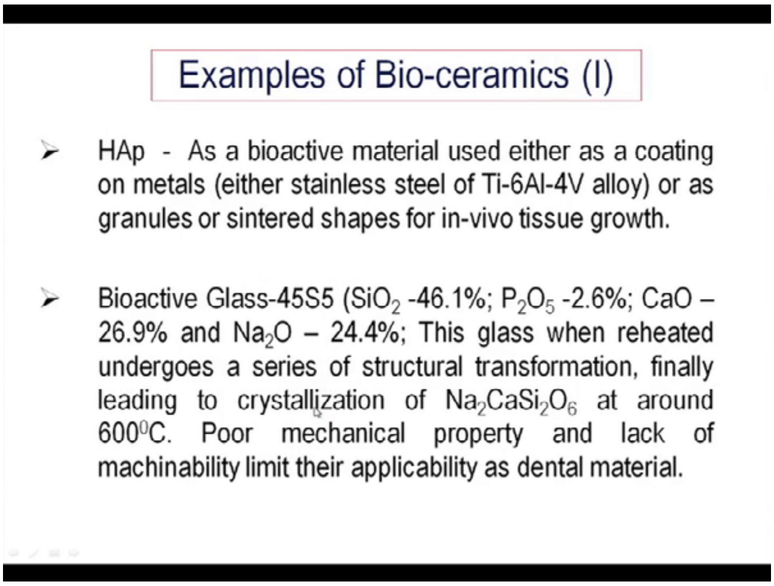

Well, coming back to the examples of bio ceramics, different kind of materials or normally used currently have, that is your hydrated calcium phosphate. This is a bioactive material, used either as a coating on metals. Coating on metal like any implant, which maybe I made of either stainless steel or more common alloy, which is biocompartable and extensively used for replacement of bones are actually titanium or which is used for many other purposes, Titanium 6, aluminum 4, banadium alloy or as granules this is for. So, far as the, HAp is concern either it can use a coating material on these metallic implants or as granules or sintered shapes for in vivo tissue growth.

So, will discuss, what is in vivo and there is a another norm, which is called inhetero. So, N C 2 tissue growth; basically, one can say within the living system in vivo; basically, within the living system. So, this is a bioactive material which actively take part in the tissue culture, tissue growth within in the material within the particularly in the porous structure of the HAp. bioactive glass, I mentioned already the specific composition is given here, silicon is about 46 percent, phosphorus P 2, P 2 O 5 is about 2.6 percent, calcium is about 26.9 percent and sodium oxide 24.6 percent. As you know as, all of us know that the one of the major constituents or the mineral constituents of bone is calcium or calcium oxide. So, all bio active materials, must content some calcium oxide and that is what it given here also in the glass it contains considerable amount of calcium oxide. This glass, when reheated undergoes a series of structural transformation.

In fact, it is not a glass; actually, it is a glass ceramics and possibly, it is known that glass ceramics is different from glass. So, actually a finely crystalline, crystal, crystalline ceramics within a matrix of glass. So, that is what we called glass ceramic, it is a nano composite of glass and ceramics. This is leading to crystallization, because glass is a unstable phase or unstable material, which undergoes crystallization when heated. And this is the crystal or ceramic nanocrystalline which comes up at around 600 degree centigrade. So, the poor mechanical property and lack of mechanical machinability limit, their applicability as dental material although, there are other materials which can be use for as a dental replacement or dental implant.

But this is a very one of the first bioactive glass, which was developed quite some time back and it’s been used extensively, but it has certain limitations that is what I have been mention. Here poor mechanic relatively, poor mechanical property it is not absolutely, useless materials it is a very much useful material, but relatively poor mechanical property and lack of machinability. That is true for most of the classes and ceramics, but there are machinable glass ceramics also. So, if because some of it are used in dental implants and there because of his complex saves machinablity is a an important consideration.

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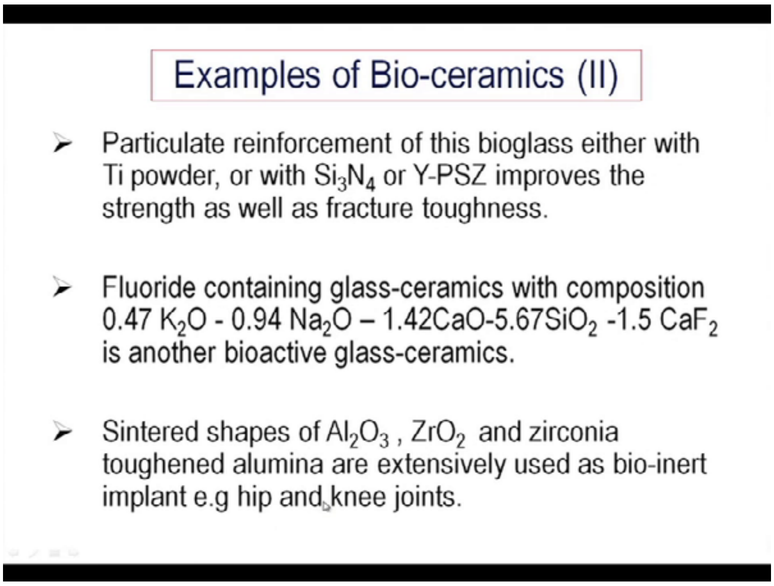

Particulate reinforcement of this bioglass either with titanium powder, because mechanical properties is relatively low. So, there has been attempts to improve the mechanical property by these techniques like, particulate reinforcement of titanium powder, which is titanium is another biocompatible material, which is been extensively used for different kind of bone replacements or bone repair. Wherever, there is a fracture titanium is one of the materials always used, but that is a metal and.

So, to improve the mechanical properties of the bioglass, one can use some of the compatible ceramics or metals like titanium powder or ceramics like silicon nitride and yittria adopt partial stabilized zirconia, yittria Y P S Z is yittria adopt partial stabilized zirconia improves the strength as well as a facto fracture toughness. As you know both Ceramic Silicon Nitride and P S Z partially stabilize, stabilized zirconia has a improved or fairly large fracture toughness compared to normal ceramics.

So, they act as a reinforcing agent for the glass ceramics. They fluoride containing glass ceramics with compositions like 0.47 K 2 O, 0.94 N A 2 O, 1.42 C A O and this kind of a composition 5.76 S I O 2 to 1.5 C A F 2. This kind is another bioactive glass in addition to what we have discussed just now. Sintered shapes of A L 2 O 3 and Z R O 2 and zirconiate toughened alumina, these are pure alumina, this is pure zirconia, but a combination of that is also use is a composite material, where zirconia is used as a toughening phase in allumina are extensively use bio inert implants as present some hipand knee joints. So, where primarily for joints which are basically needs some friction and lot of moment their, this kind of high strength ceramics relatively high strength ceramics, but inert materials are more useful.

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A Few Mechanical Properties of the Important Bio-ceramics

Material	Elastic Modulus (GPa)	Tensile Strength (MPa)	Compressive Strength(MPa)
Alumina	380	350	4500
Bioglass-Ceramics	20	60-80	500
HAp	40-110	70-190	500-890
Pyrolytic Graphite	20-30	275-560	510

We have earlier discussed about the mechanical properties of different bones in the body. Here are some the comparison, but the mechanical properties of some of the biomaterials or bio ceramics in particular, which been listed here. In terms of the elastic modulus tensile strength has also the compressive strength alumina is of course, a very high values both the elastic the tensile, as well as compressive strength bioglass relatively week; obviously, HAp is also relatively weak zirconia of course, is not given here. But zirconia is more or less comparable to that of alumina and there is a one new material which has not been given discussed so much 25 graphite, pyrolytic graphite is also to some extant fairly biocompatible material.

But it has its own limitations inside the body so far as the biocompatibility it is concerned. As you can see, alumina although is extensively used for a limited type of implants, because of its highly mechanical strength particularly, as I mentioned joints, but it is not a; it is not a bioactive or bio resolvable material. So, it does not really integrate with this system. So, well, on the other hand other materials although they have a relatively low mechanical properties, but when they are get in integrated with the; with the tissue systems or the cell system are the leaving system or the human body. Certainly there overall strength increases whenever there is an implant I think there is in you one as to remember that a compatibility or a comparable elastic modulus is important with the existing system otherwise, the incompatibility will be there and the more stress will be developed in the existing bone system than the implant. So, there is always a need for having comparable elastic modulus of the implants, as well as the natural bones.

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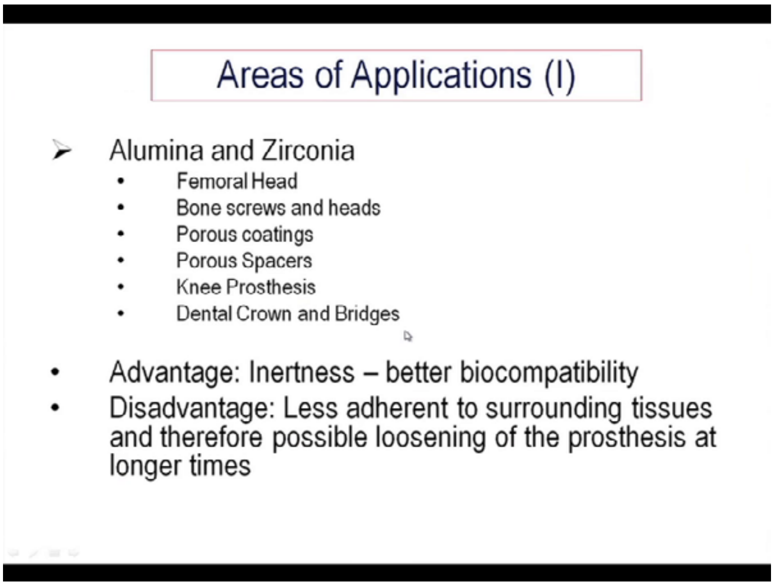

Well, where all these materials can be used for example, alumina and zirconia. The 2 most important area of application is Femoral Head or the hipjoint and also the knee prosthesis. In addition of course, it can be used for many other joints and also dental crown and bridge. So, the list is given here, bone screws and Heads to join 2 different components of the bone, one can use them has a screw or hins. Porous coatings also use; occasionally, porous spacious particularly at the different joints, knee prosthesis has mentioned and then dental crown and bridges also mention earlier.

Advantages inertness; this one way its advantageous and therefore, better biocompatibility, chemically their inert, but disadvantages less adherent to surrounding tissues because, its inert it does not integrate. So, well of the surrounding tissues or the cells and therefore, possible loosening of the prosthesis is at a longer time. So, their maybe that limits actually, they life of the prosthesis. So, if it is a bio inert, it has its own advantages, but certain disadvantages are also there. On the other hand, which is more bioactive, it has its again, it has its own advantages and disadvantages. So, for some purpose bio inert material is more useful for other applications bioactive materials are more useful.

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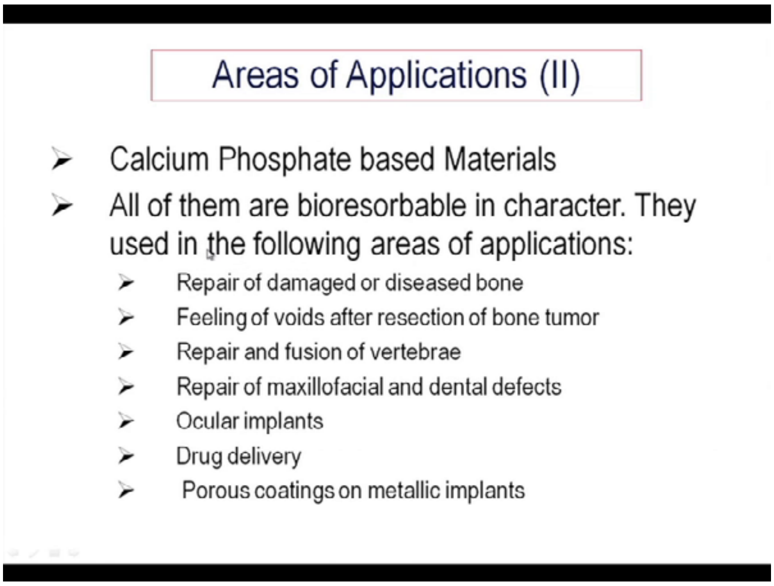

So, calcium phosphates based. The next group is calcium phosphates or HAp kind of compounds, all of them are bioresorbable in character or bioactive also, and the use of following, you there, they are used in following areas of application. Let me correct that the applications are repair and damage or the disease; repair or damage or diseased bones, feeling of voids after resection of bone tumor. There are many cases of bone tumor, where the bones can be scrapped of and then to strain them that you can fill it up with the HAp powders or porous HAp, repair and fusion of vertebrae, that is also impact here also, one can use allumina discs, but this is primarily for the repair work.

Alumina cannot be used for the repair work, because as I mention earlier that tissue growth, does not take place the integration, does not take; does not take place. And therefore, the inert materials are not for not good for repair they are good for replacements, but not good for repair. repair of maxillofacial and dental defects. Well is basically, the jaw maxillofacial, maxillofacial basically a jaw part, when there is a distortion in the jaw or some operation takes place in the jaw. Particularly, in cancer patients, you need to repair these jaws and there this HAp kind of compounds are quite useful. In fact, not only for this purpose, repair work can be done in 2 different ways; one you can use the granules and you can put them and after some time they get integrated with the tissues, body tissues. So, it becomes a integral part of the existing system. The other is either in the form of granule or it can be use in the form of a injectable fluid.

A whiskers fluid mixed with some kind of polymers or some organic compounds, it can be lead delivered it can be delivered in the form of a pest. So, that is there are different ways these basically, bone mineralizer can be used implace. Even ocular implants the eye part, of the eye I will give you an example later on a defective eye can be replaced eyeball, eyeball can be constructed. Actually, out of the hap material once again it is a porous material and the cell growth takes place the tissue growth takes place and it becomes integral part of the body. Another very important area of the HAp or the Porous systems fine or nano porous systems is kind of granule is a drug delivery system. Drug delivery has been used for quite some time not only with ceramics, but with polymeric.

Basically, it is a encapsulation of certain specific drugs which can be delivered at the particular site. So, it is not by any kind of deception or any kind of operation, but with the body fluid system, one can delivery it and there are it is possible on that they goes to the targeted site. So, drug delivery is another very important area particularly, when it combines with the nanotechnology. So, nano particles or nano porous materials can be used a can be filled up with certain kind of drug and they can be delivery at a particular sides.

So, drug delivery is a very important area of biotechnology or biomedical engineering. Porous coatings and metallic implants, it is another very important aspect, where calcium phosphate base materials are used particularly, HAp kind of materials are used. We will see, how they are coated, what are the different techniques by which this coating can be done, but metals being bio inert where as the HAp kind of bioactive. This combination plays a very important role. So, when you are talking about bioactivity it is basically the surface activity is important. So, a inert material can be always coated with the bioactive material like HAp and one take advantage of the high strength of the metal, the inert materials and the surface activity of the biomaterials, of the HAp.

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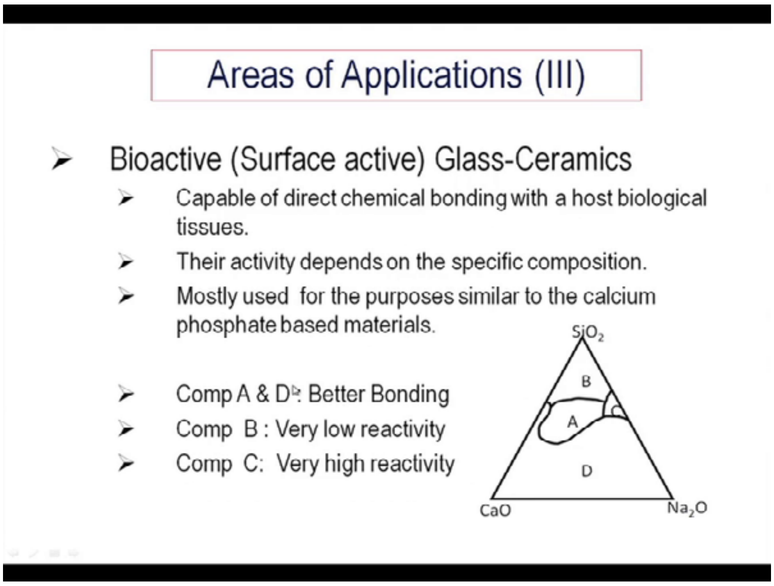

Another area I have mentioned already, but little more details of that bioactive or surface active glass ceramics that has been mention. The capable of direct chemical bonding with the host biological tissues once againb very similar to the HAp, only thing we are composition are different they are prepared in a different way, one of the advantages; obviously, of glass ceramics is the setting is little bit easier any glass can be shaped relatively easily in a complicated shapes or structures, which is not possible. So, much with ceramic materials, there activity depends on the specific composition. There is a range of composition and mostly use for the purposes of similar to the calcium phosphate based materials. And the composition depending on the competition, there bonding capacity is different in a turn any diagram like silica calcium sodium or soda lime silica.

Basically, there are different areas have been identified here, like A B C D composition in the ranges of A and D are having a better bonding capacity. So, lower is the content lower is the silica content is separated with the bonding capacity with calcium, the higher or sodium been higher composition B is very low reactivity, higher is the silica reactivity with the body fluid or the tissues are low. So, less bonding and composition C somewhere in between by there be a highly reactive and highly reactive and. So, again is not a preferred composition. So, one as to find out, what particular composition is suitable for what specific purpose.

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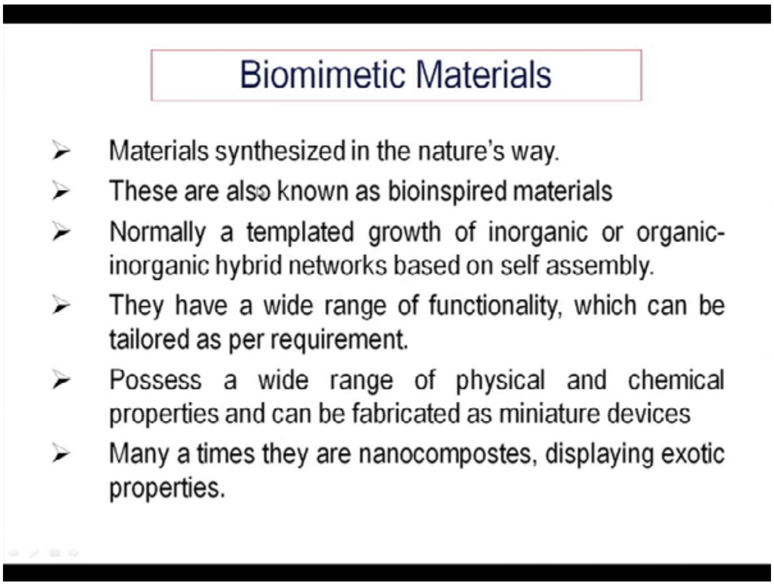

Well, biomaterials synthesis, how to prepared different biomaterials. So, material synthesis in basically, a in the nature sorry, this is something different this is biomimetic materials, not biomaterials. Biomimetic materials are another group of biomimetic actually and the way we synthesize its almost mimicking, the nature, the way the nature is prepares it because the synthetic materials are prepared in a different way within the lab. Whereas, the same materials when they are prepared by nature the processes quite different. So, biomimiking is just to mimike the nature, that is why a group of materials is called biomimetic materials. The material synthesized the basic characteristics are the material synthesized in the natures way, the way nature prepares it we also trying to mimik that.

These are also known as bio inspired materials that is basically the synthesis process are the preparation technique is inspired by understanding the natural process. So, that is why there also called bionspired materials. Normally, a templated growth of inorganic or organic inorganic hybrid networks based on self assembly is use for this purpose. We use a certain amount, certain templates and that actually, activate the process. They have a wide range of functionality, which can be tailored as per requirement one can introduce different kind of, because it is a self assembled process of some kind of nano technology and they have a wide range of functionality, which can be tailored as per requirement. So, within the same material, one can introduced different properties by controlling their way of synthesis, this structure developed up to synthesis, or the chemical composition.

Sometimes a chemically gradient materials also used and the structures because of the self assembly, this structure is also can be tailor. So, the, they poses a wide range of physical and chemical properties and can be fabricated as miniture devices. So, that is what the biomimetics is concerned, many a times there are nano composites displaying exotic properties. So, it is a kind of deviation or the variation of the nano synthesis process normally, but since we are mimiking the natures natural process the pro materials met by this kind of a technique is called biomimetic materials.

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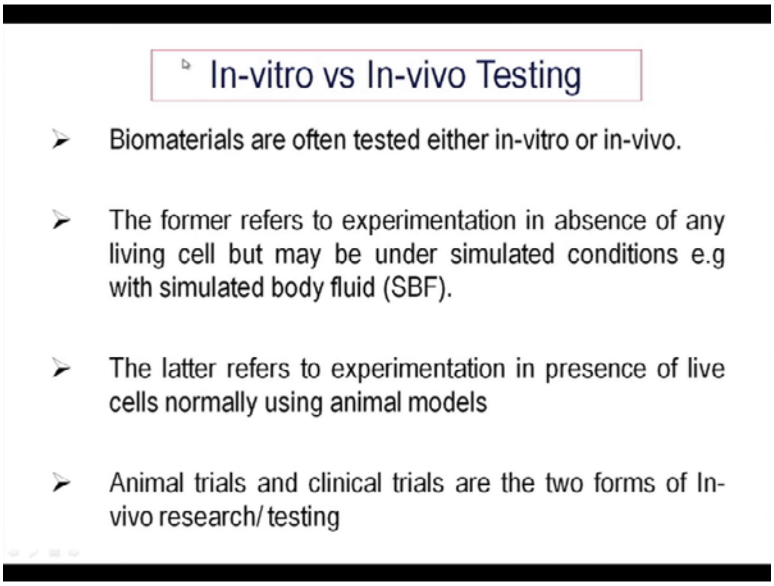

Well, we are talking about biomaterials has we have mention that they are test procedure is quite rigorous and we have to go through a variety of different kind tests, before a implant can actually be used or implanted in the human body. Now, there are 2 very distinctive type of tests, one is called in vitro, the other is called in vivo. So, the biomaterials are often tested either in vitro or in vivo. These are the two very distinctive steps in which they have to be tested, the former in vitro refers to the experimentation in absence of any living cell. That means, outside the human body or, the outside the animal body, or not in presence of living cell. That is what we called in vitro test and, but maybe under stimulate simulated conditions such as simulated body fluid SBF is a very common name in when somebody is talking about biomaterials, that is the simulated body fluid.

We have in our body a lot of fluid which contains different kind of cells organisms and, one can always similar that, in the laboratory condition and that can be used as for testing purposes. So, that is in vitro testing, the in vivo refers to the experimentation in presence of the living cell or life cell, normally used in animal models. So, one can use a animal model, animals actually for making the in vivo tests. So, the animal trials and clinical trials are the two forms of in vivo research or testing. So, one is outside the living system and another is inside the living system and in presence of living system. So, these are the two things once every tests become successful in the in vitro then one must include must go to the in vivo system before there are actually certified for use.

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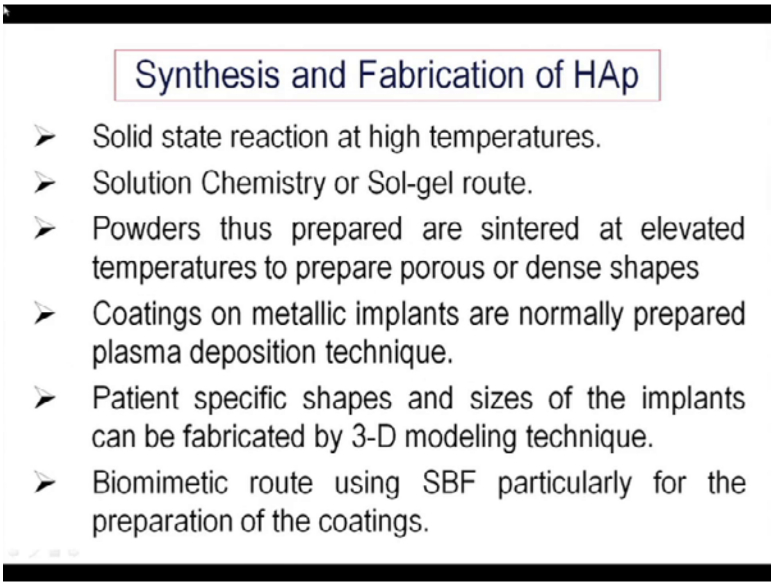

Now, HAp is the one of the compounds which is extensively used and it is synthesized outside the body system. It can also be it is being synthesized in the within the human body, but in a different way, but outside the body within the system. In the laboratory it is synthesized in a completely different way. So, like any other powders any other inorganic material, inorganic materials or ceramic materials a solid state reaction because it is a combination of different compounds like calcium, calcium Oxide E T O 5 exectera. So, one use a solid state reaction at high temperature. So, one calcium compounds and the phosphorus compounds can be allowed to react at a, at high temperature, that is one of the simplest way to make some powders, synthesized powders or one can use Sol-gel chemistry route like Sol-gel route.

So, that is also a very common technique for preparation of advance ceramic materials are same thing can be use for preparation of HAp as well. Powders thus prepared or sintered at delivered temperature to prepare porous or dense shapes. Sometimes these powders are used in granules or in other shapes and sizes. So that can be normal ceramic fabrication techniques can be used for the sample for the purpose. Coatings on metals implants are normally prepared by plasma deposition techniques. There are many different applications where this ceramic powder are actually coated as a porous coating on metallic implants, nonporous metal implants and that can be done one of the simplest way or the convenient way do is plasma deposition technique deposits or plasma coating technique. In recent times, patient specific shapes and sizes of implants can are fabricated by 3 D modeling technique.

So, a 3 D modeling technique is also used for patient specific depending on the X ray digitized X ray data one can the determine the shape and size and then a section by section deposition can be used and a specific size can be made. Almost, not by placing sintering etcetera, but in C 2 sintering in C 2 deposition and sintering not within the human body, but outside the body and then can be implanted into the body. So, the shapes and sizes can be more specific and more exact in nature. As we have mention biomimetic route using BSF, ASBF the simulated body fluid particularly for the preparation of coatings in addition to plasma deposition technique, one can use this kind of biomimetic route for deposition of the coatings has well.

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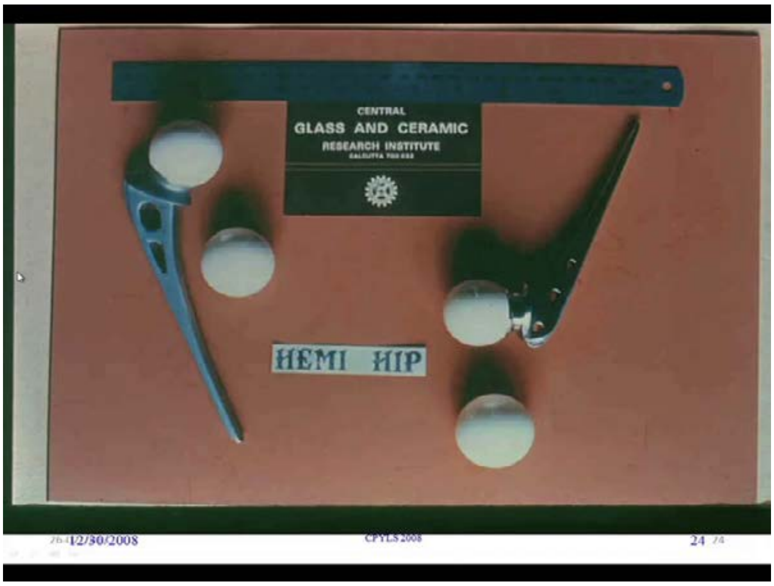

Well, come to the end of my discussion here are these are very specific examples, examples prepared by central glass and ceramics research institute, just to give you an idea. What kind of implants are actually used, this is a femoral head the hip joint, this is a stem, what we call the stem. So, metallic stem and then there is a ceramic ball over there the femoral head is basically a ball and socket joint at the hip and that is the load bearing joints and flexible joint. So, this is the ball part and the socket part of course, is not there. These days both the socket as well as the ball part can be made of ceramics, but the steam cannot be made of ceramics. Steam is still a metallic implant, but it can be coated with a ceramics either, normally it is coated with HAp.

Again, this is alumina or zirconia, zirconia can be used or alumina can be used, but here the coating, this maybe primarily of HAp coating either by plasma spraying or by biomimetic coating can one can also use, but also by Sol-gel coating. So, different kind of coating techniques can be used, but the most convenient or useful is plasma coating are the steam can be use either of stainless steel or the titanium alloy. So, that is the general design of there are various different designs are possible different companies are making different kind of designs, but the steam has to be because it needs lot of tensile strength, ceramic is poor in tensile strength. So, this part cannot be made of ceramics only the, ball part at the socket part and that is most important because, you need a lot of friction there. Because of the friction the wire is more important. So, the metallic ball is not that good, but are the life is relatively low whereas, a ceramic ball and ceramic socket as a much longer life. So, these is a typical hip joint prepared by central glass and ceramic institute.

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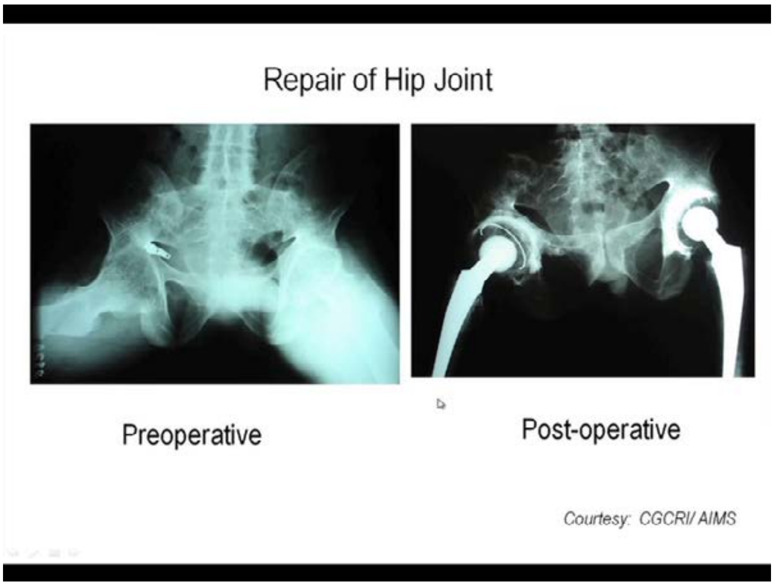

These are the X ray patterns; these was before the operation. In fact, one person as both the joints were defective and they had been replaced by the artificial Hip joints. So, this is actually the socket; here is the socket and this is the ball. So, both of them have been replaced and it has been in a successful operation.

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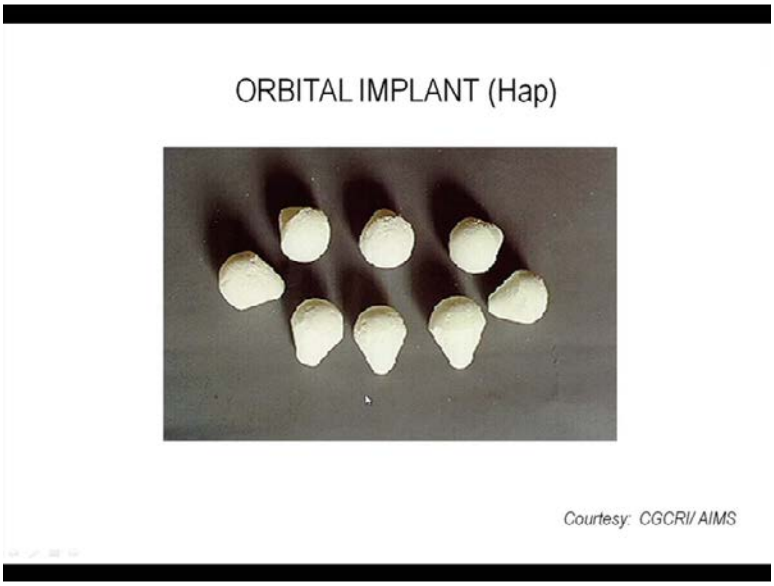

Lastly these once again another application of HAp, this is an orbital implant, it is actually, this is an orbital implant where a defective eye ball actually, defective eye ball has been replaced by hap. It is a highly porous highly porous of 60 to 70 percent porous and it is intentionally made porous. So, that the tissue growth can take place inside the pores and finally, it becomes a skeleton or a composite material which it gets integrated with the body or the eye ball. So, it is not a active eye ball, it is basically the filling up of the cavity, but one can make it movable.

Normally, the eyeballs are not movable, but in this case, because of the very lightweight. This is 1 of the very first of its kind prepared once again by central glass and ceramic which institute and it is a or what they call orbital implant movable orbital implant and made of hydroxyapatite. Once again, the powder have been synthesized and made into a porous shape like this. I think that is brings us to the end of this discussion as well, we have discussed various aspects of bio ceramics and different forms of bio ceramics, different compositions, there different purposes and the different implants which can be made out of that. So, it is a brief discussion about the biomedical aspects of advance ceramics. So, with this I conclude my discussion and.

Thank you very much for your patience hearing.