# Introduction to Biomaterials

**Prof. Bikramjit Basu**
**Prof. Kantesh Balani**
**Department of Materials and Metallurgical Engineering**
**Indian Institute of Technology, Kanpur**

**Module No. # 01**
**Lecture No. # 18**
**Bioceramics**

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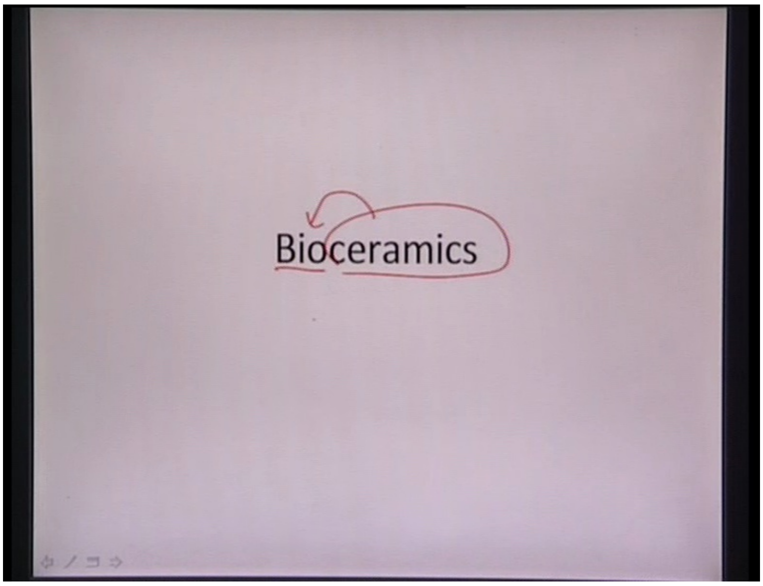


In this lecture, we will learn about bioceramics. As the term basically suggests, that we are utilizing ceramics which are basically a class of materials, as, materials for biomedical applications. In this particular lecture, we will learn about bioceramics, in which we are utilizing ceramics as some biomedical materials.

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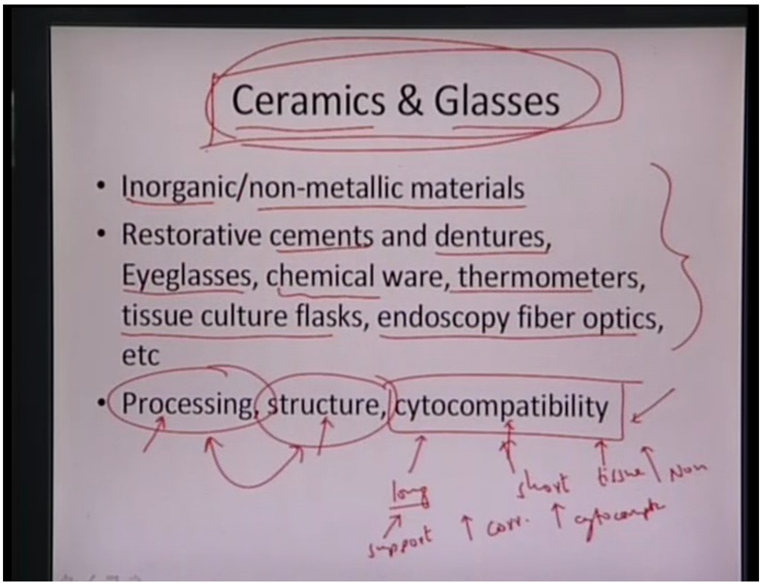


And again, bioceramics- we are also constituting ceramic as well as glasses. And ceramics and glasses constitute organic or nonmetallic materials, and these materials are very highly utilized for any restorative cements and dentures like, for oral implants, they can also be used for ocular implants as well as like an eyeglasses, they can also be utilized in say, chemical ware, thermometers, so, these can be, sometimes they can be contact type or non-contact type depending on their applications, they can also be utilized in the tissue culture flask, or maybe utilized in the tubes, or endoscopy fiber optics like in catheters. And again, these are some of the very important applicability of the ceramics and glasses, because, in case, we want to have some porous glasses, they can be very well utilized for cellulose carriers for either antigens or maybe any enzymes, and they offer the advantages that they are very inert in nature.

So, they can withstand any corrosive nature of the media of the surroundings environment, they can also be resistant to some temperature changes which are within normal body temperature, they can also be resistant to say, ph. So, these are all the things which ceramics and glasses, how they become as winners among the various classes of material among say, metals and polymers. So, that is the overall applicability of ceramics and glasses for serving as a biocompatible material. In addition, there are certain criteria as well as, such as processing, it can be the structure of the material, ceramics and glasses again, defining the cytocompatibility.

So, depending on the processing we can get various kinds of properties within the material. Again, depending on the structure it can also define, it can also be relevant to the processing what has been done to the material to achieve a particular structure. And again, then, cytocompatibility basically, it depends on what kind of cytocompatibility we need, it can be either long term or it can also be some sort of a short term applicability. At the same time, we also want to see whether the material can be divided again, in various class, whether we want, for long term either we need some sort of a support which will some, which will make the skeleton of the particular structure or it can also be utilized for maybe say, corrosion resistance or it can also be for inducing certain sort of cytocompatibility.

So, those are all various issues- whether it wants to have a kind of a non weighting surface or it also needs some sort of the weighting with the tissues or cells. So, there are various classes of cytocompatibile materials, which, particularly ceramics and glasses, suffice as serving as bio bio-implant materials.

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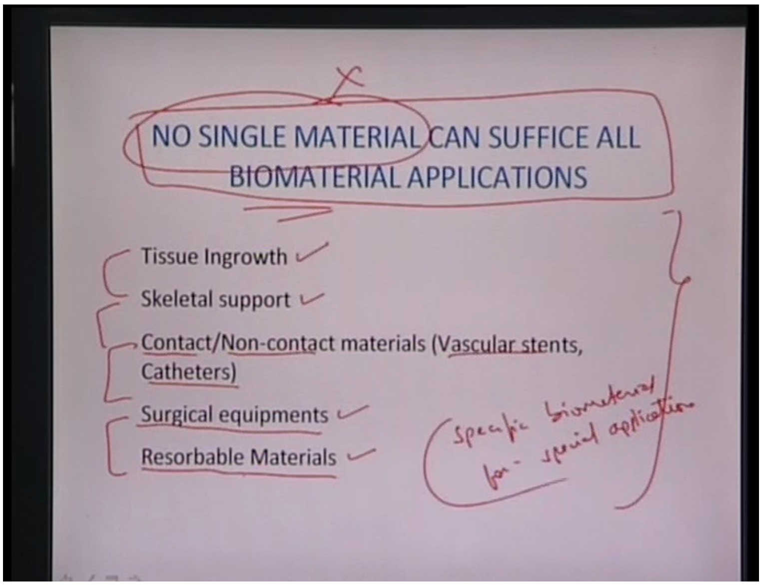


And, coming to basic point that no single material can suffice all the requirements which are being imposed by a biomaterial as an implant. So, that is the basic, essential component of biomaterial that we need to always have a mixture of materials, which can suffice a particular application, so if you want to go for certain specific application we need to choose a specific material for that. So, it cannot happen that one material which is a biomaterial can suffice all the applications of a particular bio-implant being applied as a bio-implant material.

So, in certain cases we wanted to be contacting with the, being in contacting with the blood, sometimes we want the tissue growth, sometimes we want to metal to the material to get reabsorbed into the body, sometimes it has to supply the skeletal material to withstand a load for a permanent duration, sometimes we do not want any tissues to grow on that particular region. So, those are various requirements and they offer very wide, basically, arena of, wide arena of what is required, what is be expected from a particular material. So, that is a reason single biomaterial cannot really suffice all the applications.

So, for that, like some of the, some of the issues which involves such as tissue ingrowth. So, certain, in certain locations we want the tissue to grow on a surface of a material, so, we want the material to be compatible enough that cells, or tissues can really grow, they can adhere to the surface and then basically they can proliferate and basically they get anchored on to the implant material. Secondly, they can also be utilized for skeletal support. In this particular case within the material to serve as a skeleton, like, as a skeleton which can provide a overall infrastructure to the damaged part like, in case we have a permanent bone damage and that particular location we want an implant to serve throughout the life of the patient, so, in that particular case we want the material to remain as a support material throughout without getting the degraded with time. So, those are different, very different types of applications which are expected out of a biomaterial.

Again, these materials can be either contact type of or non-contact type. Those can remain, they can remain in contact with the blood, or sometimes we do not want any tissues to grow on them. Like, if your stents, if materials starts growing, if we supply a material as a stent, then basically it has to allow the blood to flow through it, so, if we start seeing that the cells, or the cardiac cells, they are getting basically cling, they are getting cling on to the stents, then basically it have a arterial clogging and then it will lead to ultimate collapse of the functionality of a heart.

So, that is what, sometimes we need the material to remain in contact, at the same time you do not want any cells to grow on to it. So, those are different type of properties which can be exploited again out of a biomaterial. Biomaterial, why? Because the stent has to survive in the arterial for a very long time, so that is the reason we, though it is in contact with the blood we do not want any sensitive to grow on it. And if we have a bone implant, then as soon as we inserting the implant into the body we want the cells to come along its surface and from a nice bond with the implant material to basically provide much more tissue growth, or tissue ingrowth out there. So, those are again contact materials or non-contact materials, which really require very different type of functionalities. Again, catheters, those are inserted into the body for various purposes, so, to supply either fluids or for endoscopic, so, those are again come in contact very briefly, or they are kind of non-contact with the blood. So, those are certain requirements of those materials.

Again, there can be some surgical equipment like, we all use knives and all that for surgical operations and, so, those are also basically required to get in touch with human body or may be the human blood, so, they should not induce any toxic effects out there. So, those are also very important class of biomaterial to suffice that they have to with stand that particular media without inducing any toxic effects to the body. And in certain cases we can also have something called re-absorbable material; this is utilized, this particular re-absorbable material is utilized in case when we want a temporary kind of a scaffold and that temporary scaffold should degrade with time so that the new cells, or the surroundings cells can take the place of that particular material which is getting reabsorbed into the body.

So, those are the various requirement which are imposed on biomaterial such as for tissue ingrowth, or it can also be for the skeletal support, those can be for contact or non-contact type of materials such as vascular stents, or it can be for catheters, or anything like that, and then it can also be surgical equipments, or it can also be the re-absorbable materials which can take, which can get replaced from a, which can replaced by the surroundings cells. So, these all are the requirements which are expected out of a biomaterial. And as we can see that these are very drastically different kind of property which has been expected out of a biomaterial, so a single material will not be will not basically suffice.

So, we need to have a specific biomaterial. So, we need to have a specific biomaterial for a specific application for specific application. So, in case when we are looking for a skeleton support may be re-absorbable material may not really work. So, that is the basic criteria which can be expected out of the biomaterial that if you are accepting it to provide a tissue ingrowth, it may not really have good contact or non contact type of applicability towards it. So, these are the various things which are basically stated out here. So, over all gist of the particular biomaterial is that we need to have a specific biomaterial for a specific bio-implant, or bio biomedical application.

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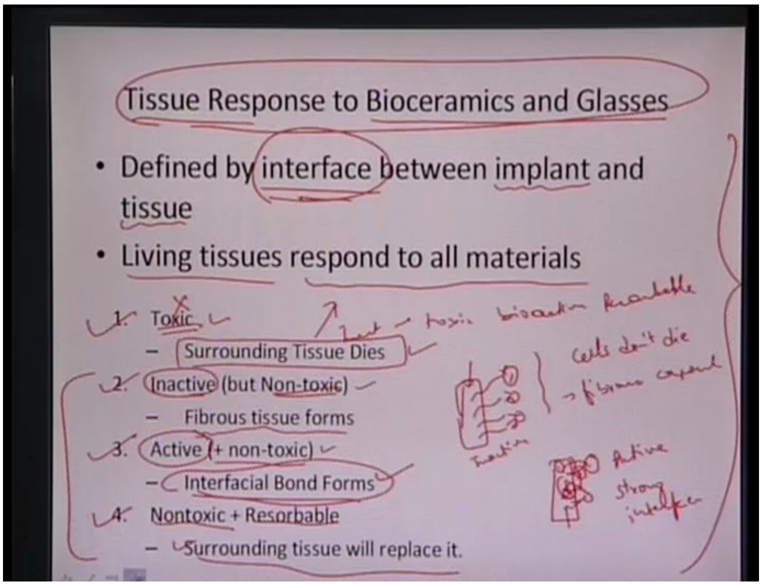


And again, the way the, once we have a material implanted into the body then, tissue can respond to those bioceramics and glasses in variety of ways, and the response of this particular tissue is defined by the interface it creates between the implant and the tissue. So, whenever we have a particular material and once we inserted into the body, the tissues will somehow react to it and that interfacial response is the basic factor which will decide what will be the overall effect of the body of the tissues, whether they will die or whether they will survive, or whether they will accept the material as an inherent part of their healing. So, those are all things which basically create, which basically create kind of a requirement for a biomaterial to stand up to.

And again, one more thing is that living cells or tissues, they tend respond to all the materials in some manner, it can be either, they can be totally inert, they can also be toxic, they can be either bio-active, or they can be intermediate kind of thing between them. So, those are the couple of things which they can again be resolvable. So, there are varieties of ways in which particular material is, once it is inserted into the body, how living cells basically react to it. So, there are paradigms of various responses of how a material will basically behave. So, ideally no material is inert in nature, ideally, because there may be some sort of response which is given by the tissue, but there are certain are certain materials which are considered to be enough inert which can be implanted into the body without any drastic effects, without any side effects or any toxic effects.

So, this is overall thing out which basically go inside. So, first thing is if all those responses can be clubbed into couple of, couple these, so, first, if the effect is toxic, if the material implant is behaving in a way that the surrounding tissues basically die, then the material is basically toxic and we cannot use that material for biomedical application- so, if the material is toxic, we see that the surrounding tissues basically die. So, that can happen basically by blocking of the nutrients in all, or may be release of some metal ions which can basically limit the cells to survive and grow further. So, that is how metal, any implant can deteriorate the property of a cell and it can basically block its may be either nutrients, or some sort of growth, or maybe it can chemical interact with it and then that might lead to the death of a particular cell or a tissue, and in that case we considered the material to be toxic. It can also happen that material is inactive, it means it is inactive, but it is non-toxic, so it is not letting the cells to die, but at the same time it is not acting anywhere towards it, it is remaining inert, but the same time it is non-toxic in nature and in that particular case we see there is some sort of a fibrous tissue which really forms on the surface of the particular material.

So, we see that the material and we see some sort of a fibrous growth which can come out from the cells. So, we have cells and they extend some sort of a fibrous capsule around them to basically link themselves on to the implant material. So, we have this inactive material, this is inactive, so, in the same time it is non-toxic because it is not letting the cells to die. So, cells do not die, but at the same time they extend some sort of a fibrous capsule over this, over themselves, but at the same time the materials are not helping any way cells to grow on themselves, so, basic material is inactive. So, that is what the classification from going from toxic to inactive, but it is again non-toxic.

There can be another criteria as well that material is non-toxic as previous case, but it is somewhat active. It means it can form some sort, it can generate some sort of precipitation, or it can allow the cells to basically get attached to themselves and it can form some sort of a interfacial bond. So, we have a particular material and then we have cells and it can basically cling on to hair and cells can also get precipitated even on the implant surface. So, we have some cells which are basically nearby to the implant and some cell which can be basically get precipitated, or get nucleated on the implant material- so, that is what the material is active in nature. So, in this particular case we see very strong bonding of the strong interface which can form between the active material and which again, which is again non-toxic. So, we can see very strong interfacial bond which can form surface of the implant material in this particular case.

Or it can one more class of biomaterial, that material is non-toxic as in the previous three cases, but it is again re-absorbable, re-absorbable means that the surroundings tissues which is growing near the implant will start taking place of the material which is getting re-absorbable into the body. So, if I had an implant, it can be in certain ways, it can be toxic- it means the surroundings cells will start basically dying out; second class, it can be inactive or basically inert; so, it is not allowing cells to basically get benefited from itself, they will just ((themselves)) lie nearby and they would not hear any (( )), they would not get any (( )) from the implant material.

Third, it can be again active, it means that the cells, or the implant material will basically allow the cells to get precipitated on to its surface, so, to form a very strong interfacial bond with the nearby tissues or cells. And in third, in the forth class we also have non-toxic plus re-absorbable. In some cases it is very important, because in case we have a temporary injury and we want to replace a particular say, bone structure for temporary, for providing some temporary assistance to it, we introduce a material which can reabsorb, which can getting dissolved into the body while the new cell is basically repairing it. So, like what happens in the, basically, young children, that their bone growth is so rapid that they need a very temporary support and at the mean time while the material is getting reabsorbed into the material, into the body, it is getting dissolved into the body, and in the mean time we see that the cells, they tend to repair themselves, or heal themselves with time.

So, this class of material which is re-absorbable, it will allow the cells to grow at that particular place at which the material is getting degraded. So, that is the advantage of about non-toxic and re-absorbable material, that surrounding tissue starts replacing it. So, over all we have tissue response in variety of ways, that first of all, it generally forms, whenever we have a particular material it will try to form some sort of interface with the implant in the tissue and again, the living tissues they tend to respond to all the materials.

And as we saw that we can have four class of implant materials; first, it can be toxic, so, essentially all the cells around the particular implant will die, so, this is basically not really good for serving as an implant material; second case, we have inactive material, but again it is non-toxic, since it is non-toxic it would not let the cells to die, but again it will starts some very loose connections, or some fibrous tissues can generate around its interface and there can be lot of movement between the implant and the surrounding cells; third case, it can be active, but non-toxic, once it is active it can start forming some sort of a interfacial bond with the implant, the cells will form some interfacial bond with the implant material; and in forth case, the material itself can be re-absorbable, so, once you introduce in to the body you forget about it, there is no need to take it back or to remove it and automatically the surrounding tissues will start replacing it. So, these are the classes of materials, which can basically form out here following this particular category.

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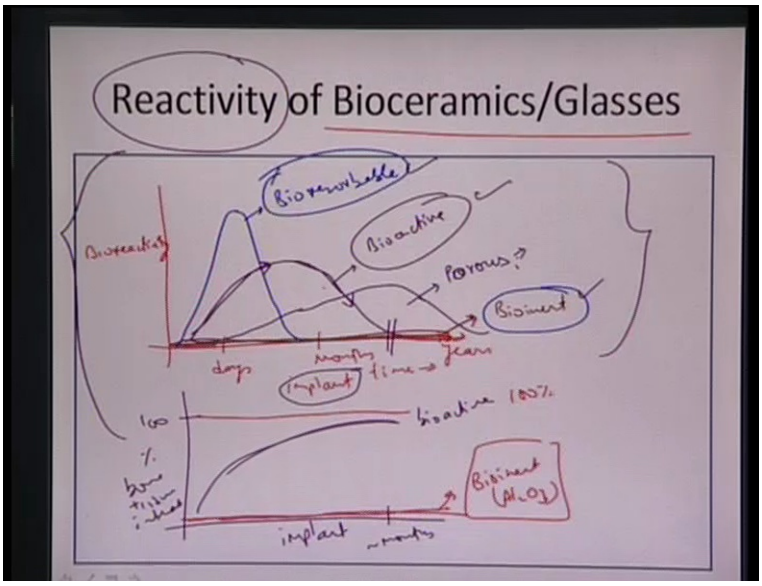


And again, the reactivity of bioceramics or glasses is one of the very highly critical aspects of biocompatibility, or how they can be utilized. So, overall we can see that once we can insert a material into the body, it can respond in couple of ways, if you see a particular bio-reactivity, it means how it is reacting with the surrounding cells, and we can see the implantation time, once we implant the material what is the time duration we are talking about out here. So, we can see certain class of material, they do not respond to the cells which are, cells do not respond any anyway to the material which has been stuck out there, which is in near in (( )) to them, it remains bio inert for very long time, but let it go for thousands of days, maybe, it can be from days to months to years, it remains as such, so, it does not get dissolved in to the body and this is called- let me actually draw it with the different color, so we can have feel of it- that we see particular material which will stay here for very long time without any degradation, or without any support to the particular surrounding cell and those are called bioinert.

And again we have a different class of material as well, like we can also have something which can start reacting with the body in order to supply some reaction, or some cell addition on its surface and then, later on within days it can get, basically, it can allows cells to grow on itself and soon it can start getting absorbed into the body, so the surrounding cells can start taking its place and this class of material is called bioreabsorbable. So, now, we have two class of material, one is bioinert, which does not respond at all, and the second class of material which is called bioreabsorbable, which will basically get dissolved in couple of days, which can maybe in tens of days, it can start getting absorbed into the body and then it can form a very nice bond with the surrounding cells.

But there can be intermediate class of these materials as well that that we can find. We can also have some sort of a bioactive growth which will allow the cells to grow on its surface, form a bond, but the material will not basically degrade with time and then, it will not, it will let the reactivity go down as soon as the starts, as soon as the cells will start taking the position on its surface they tend to lessen its reactivity and then, overall the material is basically of no more active any more. So, this class of material is called bioactive.

So, we can see these three types of responses; first of all we have bioinert, the material will not respond anyhow, it will basically, there will not be any interaction of the cell with the material, several forms, sort of a fibrous capsule around the implant material and that is out like, the implant material will not assist anyhow, the growth of the cell; and second case, we have bioresorbable and in the bioresorbable material we can see that the implant material will allow the cells to grow on itself and it will start getting dissolved in to the body, so, now cells will start taking its position and then basically, it basically gets completely dissolved in couple of days, that is how its overall reactivity is starts getting detonated with time and then it basically dies out in couple of days. And third class is bioactive material, and in this particular case we see that the reactivity will start increasing for couple of days then, it will saturated because its surface is totally occupied with the cells and the overall reactivity will start degrading, and with, after certain time maybe in a couple of months the overall material has basically become inactive.

And there can be one more class, that we can also introduced some porosity into the material, so now, the overall surface area has gone to a very high extent, the material can be mildly inactive or it can be mildly bioactive and so its reactivity will start increasing slowly and then, basically it will last much longer than the bioactive case. So, in this particular case we can also have some sort of a porous body and we can have porous in growth of cells out there and then it can keep going on like that.

So, we can see that how a bio, how bio-reactivity is being implemented from, as the implant is being inserted into the body; and bioresorbable material can stay in the body for couple of days, it can go from tens of days; bioactive material can be, it can go up to maybe couple of months; and porous implant material can, porous growth can be in order of even years as well. So, this is overall strategy of devising, or selecting a particular biomaterial depending on the application like, where it is being used, or may be what kind of person, who really requires this particular type of support, if it is old person, then the overall healing may not be that faster, so they may require a longer term support, so we do not really want the bio-absorbable material to get absorbed so quickly, so, we have to have certain considerations as well, and a person who is very young, the bone replacement may be very quick, so in that particular case we want the material to be getting reabsorbed in a very short duration of time. And again the kind of injury like, even if a person has a very permanent injury, so, we will require a material to withstand this, staying there for a very long duration of time. So, these all are certain considerations which decide the overall implantation time and then how basically they can be clubbed with the overall reactivity to provide certain functionality to a particular biomaterial.

And again there are various classes of materials and, no one really ideally behaves in this particular manner, we generally have materials which will basically have a growth like this, bioactivity versus implantation time, and then, those are some sort of a bioactive materials such as, bioglass, they can behave more or less liken in this particular way. The overall percentage of the interfacial bone tissues which really are getting generated, they occur in couple of time and then basically bioactive blast starts dissolving into the body and then overall basically, activity overall basically stops here. So, we see percentage of the bone tissue interaction and that is, approximately 100 percent can occur in maybe say, around couple of months, and that is how basically it can happen.

So, I will again, we can say that sometimes we can also have no response from a material like, in this particular case, I can show it with a different color, that in case, in certain cases we can have a basically zero response and those are nothing but the bioinert material such as, it can be such as alumina, they can also show a basically very flat response with the activity, or the interfacial activity of the bone and the bone tissue and the implant material and then go totally (()).

So, this sort of activity, we can see that bioactive glass can have approximately around 100 percentage of bone tissue interfacial reaction and whereas, it can go even zero percentage for the alumina. So, that is how the various classes of biomaterials fall into, going from very reactor, which can be even bioreabsorbable material, or it can be very bioactive material to highly inert material such as alumina, which may not show any interaction or any bonding with the surroundings cells.

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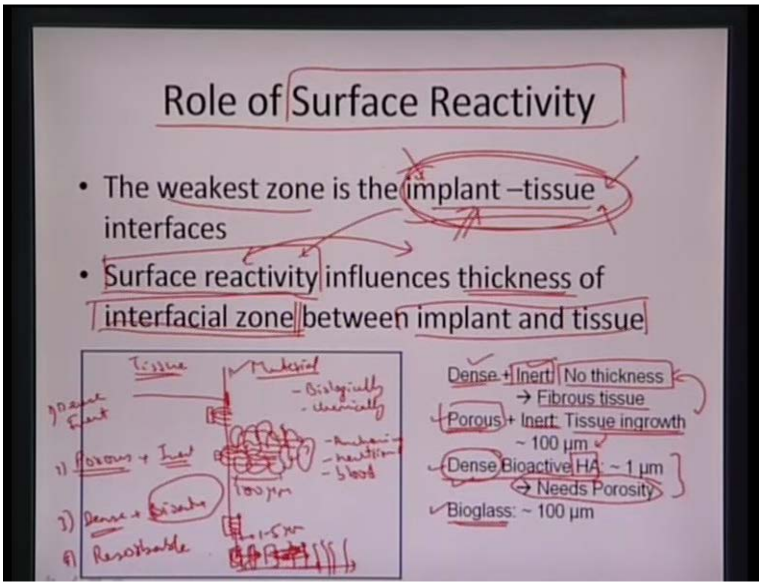

And again, coming back to the, the overall the role of surface reactivity. So, surface reactivity is highly important because we just realized that depending on the various classes of materials how a particular response is being achieved, or being delivered from the tissue to the implant. So, if you have particular toxic material, we see the cells trend to basically die out; if a bioactive material, we see some sort of a bonding which happens between the biomaterial and the cells; if it is a bioreabsorbable material, the cells basically replace the material in certain duration of time.

So, again, the sort of bonding which forms between the implant and the tissue is also one of the very critical issues in the biomedical industry. And basically, coming to it that the weakest zone is basically the implant tissue interface. So, implant tissue interface is the one which will decide how a particular response is being attained and how we can utilize particular biomaterial for certain application, and the weakest zone comes out to be implant and tissue because it has been widely studied that (( )) occurs because tissues are not able to get clung properly or get anchored properly with the implant surface. So, that is the weakest zone which has been absorbed via various researches.

And again, so, and this particular interface gets affected directly from the surface reactivity. So, if we have a particular implant material and I insert it into the body and the kind of bonding which will form between cells and implant material, that will decide how an implant will serve its life duration. If there is much movement between, there is no good connectivity between the cells and the implant material obviously, that implant is, it will not stay in its place and it will start loosening up and we will require one more surgery to fit it back.

So, that is the overall problem in terms of having a very poor bonding between the cells and implant material of the cells and tissue. So, surface reactivity is one of the very critical issues which needs to be settled down, and this surface reactivity decides the overall thickness of the interfacial zone, and this particular part, the surface reactivity, it again depends on the class of materials, either metal is very toxic or not, whether reabsorbable or not, and again what kind of surface treatment has been given to it, as in a material is very dense or the material is very porous, material is very active or non-active, those are the such issues which need to be studied in much more detail to decide what is the overall thickness of interfacial zone we want to attain and why.

And again, these are, they have to be compatible with the cells so that the cells, or the tissues which are growing on to it should not die out. And again, this interfacial zone has to be much stronger once you want the implant to serve a little longer life and cells to really get anchor on to it, so we can attain a good anchoring and good position of the implant into the body. So, we can see that once a material is very dense, but it is inert, inert means it is not allowing (()) cells to assist in certain manner, it is not letting the cells die, but it is not assisting cells to grow on its surface, but at the same time the material is very dense. So, what happens? We see that is very, there is no thickness which can really form on to it because in this particular case we can see that the particular implant, if we see, there is a some, if we have material on one side and we have say tissue on the side, which can grow onto it, for the inert material we see that tissues can grow within itself, but as soon as they encounter the material they do not know where to go because the material is friendly, but it does not have any porosity, they can go mechanically go or in a biological compatibility. So, both biologically and chemically they are not being supported at the interface.

So, we see that, there is only some sort of a fibrous tissue which can form on to it. So, we see particular tissue and it can extend its fibrous arms to basically get cling on to the material, so, we have, in this particular case we have dense inert material. So, in this particular case we can see that at the interface, interface of tissue and a material, we can see that cells, they will just extend their fibrous arms along the material surface. So, there is very weak interface which can really result from this particular kind of combination when the material is inert and again it is very dense.

But it becomes totally reverse in case when we have a porous material. So, we are seeing a same inertness, the material is inert, but it is very porous. So, once a material is very porous we can see that tissues can really grow onto it surface and they can pass through the porosity and they can extend up to as high as minimum of 100 microns of penetration. So, we see, in the second case, once we have basically porous material plus inert, we see that the cells which are growing out here, they can basically penetrate into the material, much deeper into the material. So, they, it can extend up to as high as maybe say, around 100 microns. Because in this particular case we have porosity available which is to the size of the cells themselves, so cells can pass through those pores and they can extend deep into the material, and now they can create some anchoring out here, so, we can see some sort of an anchoring. And secondly, the pores are big enough so that they can basically get, the overall nutrition can be supplied to them, so nutrition can be, nutrition can reach out there, same time the blood supply does not get chocked in this particular case.

So, when some material is porous, same material is inert, we can see that all the porosity is being now filled up by the cells, so, cells can extend themselves into the material, they can cling on to itself, at the same time they can keep the supply of blood or the nutrients alive- so, that is the advantage, once we have inert material. And going on to inert material plus some porosity, so, dense material cannot support because in dense material there is no pore, there are no pores available to let the cells get into the material, but once the material has become much more porous, because though the implant material itself is not asking, or not allowing, it is not supporting, in the sense that it does not have any support for the cells, but the same time it is not hindering the cells as well to grow into itself. So, that is the advantage of porosity, (( )) porosity into an inert material, that it can allow cells to cling on to itself and form a nice bond kind of thing, it is only mechanical, but it is always there, so, it can cling itself in the porous regions and be still alive.

So, that is the advantage of this porous and inert material. So, now, coming out of the dense bioactive material again, once the material is becoming very dense then, again cells do not have any where to go, but the surface is so friendly that they want to get into it. So, in this third case once we have a dense, but bioactive material. So, in this particular case we see that cells, they are out here, but at the same time they cannot really get into the material because the material itself is very dense. But since the surface is very friendly for itself, it can allow cells to get anchored to it biologically and then they can penetrate up to say, distance of may be around 1 to 5 micro meters deeper.

So, ideally we can see that even when the material is more bioactive, but dense, it is not allowing the cells to grow into it. So, for a good anchoring we need a good inter good surface reactivity and we need a good interfacial zone between the tissue and a biomaterial. So, we need, we need to make the material much more porous.

So, that is the advantage of porosity, that we can have a dense material then, basically we are hindering the cells to get into the material, so, even when the material is much more bioactive in nature and it is not able to penetrate deeper into the material, so, the overall bonding can be little weaker. But in this particular case when the material is more bioactive it is also encouraging the cells to get precipitated on to it surface and to form a stronger bond with the implant material. So, when the material is more bioactive we can also introduce some porosity into it, a controlled porosity which can allow the cells to grow again deeper into pores and also get, apart from getting mechanically clung to the surface of the implant surface it it will also get biologically clung to the biomaterial surface. So, that will form a very strong bonding of the cells with the nearby bioactive materials. So, that is the overall advantage of this particular material, that we can have controlled porosity and we can at the same time attain a bioactive hydroxyapatite, which is HA, and it can form, it can go much deeper into the material.

There can be one more class, which is again the bioreabsorbable material, which is nothing but bioglass, and as we see, as we have known that it will basically tend to shift the tissue material interface, so, we had tissue which is near the surface, so this fourth case is reabsorbable material. So, in this particular case we see a tissue and material interface, and this interface itself starts moving because the overall material will start degrading with time.

So, we can see that this bioglass, or the bioreabsorbable material, it can start getting much more acquainted with the cells and it will start getting reabsorbed into the body, and the cells will start now growing further towards the material side. So, we can see a very nice, basically, interaction between the tissue and material in terms of forming a bonding between them, because our bioreabsorbable material is getting dissolved into the body and the cells are basically occupying its overall, it is basically replacing the reabsorbable material with time. So, that is the overall interaction we can see among all four.

And this specifically tells how important the surfaces activity is, if material is highly inert and if you make it highly dense, then we do not see any ingrowth of the cells into the material because there is no place for the cells to grow in, so the idea is we can make it much more porous. Once you make it porous, cells can extend their arms and they can survive into the pores while getting the nourishment and also blood supply. Again, we can see that the bioactive material such as hydroxyapatite, even when it is dense it would not allow cells to grow much deeper into it, so the idea is to keep the surface coating of hydroxyapatite much more porous. Or they can, one more class of bioreabsorbable material and basically the cells, they start taking the position of this bioreabsorbable material with time and that is how it induces the interaction with the material.

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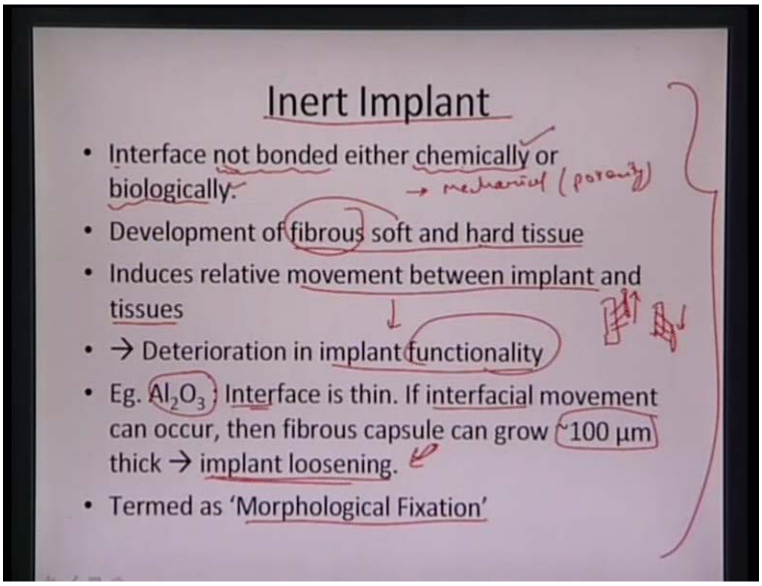


So, once we have inert implant we can see that the interface is not bonded, so, that is the overall criteria that it is not biologically bonded also, it is not chemically bonded, so, we are seeing two different parts of a, there is no chemical interaction, no biological interaction, so, only interaction which is possible is more of a mechanical, so, that can be induced via having certain porosity into the material. And what happens when one does not have chemical or biological bonding? It starts extending some fibrous soft and hard tissues around it. So, we see more sort of fibrous arms which extend to the biomaterial and that basically induces certain movement between them, since there are certain fibers and the fibers can again go up and down and that basically will start loosening the implant.

So, the overall movement between the implant and tissues can be induced because of those fibrous kind of nature of the soft and hard tissues, and that can basically deteriorate the implant functionality because whence there is certain movement between them, so we can see those fibers can basically align themselves like this, or the same fibers can go down like this. So, we have movement up, movement down, and that can basically deteriorate the overall functionality of the implant material. And this particular implant, (( )) implant can occur in the case of aluminum oxide and in this particular case over interface is very thin, and once we have the interfacial movement then the fibrous capsule can grow as high as around 100 microns and that it will basically leads to the implant loosening.

But again this type of fixation which can occur between them, which is much more mechanical, it is called morphological fixation. So, this particular case happens with the inert implants, that they can develop fibrous hard and soft tissues around itself and that can lead to the relative movement between the implant and the cells, and this type of fixation is called morphological fixation, and, but that can lead to much more of a implant loosening because it does not really forming a bond either chemically or biologically.

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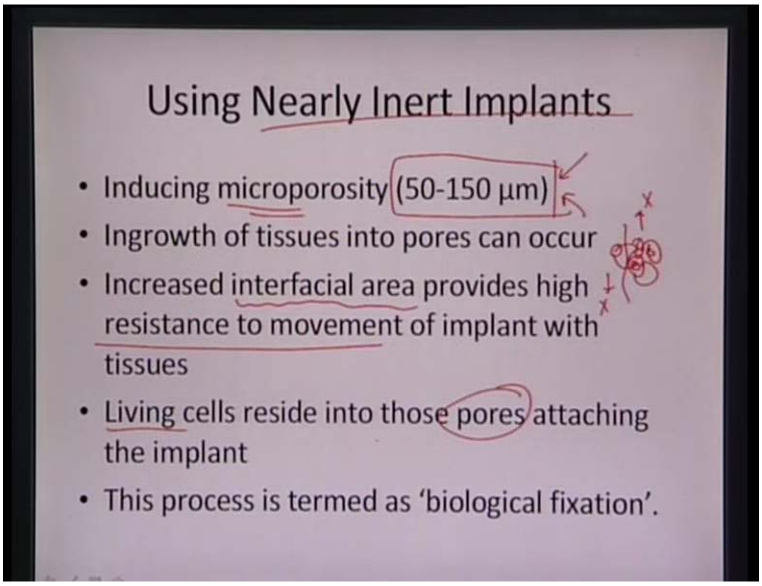


So, the next idea is to use nearly inert implants, but via inducing certain microporosity. But the problem with microporosity is it can also lessen, reduce the strength of the material, and the microporosity has to be in the order of 50 to 150 microns so that the blood supply cannot get restricted, it is not really, basically, kill the cells and the nutrient should also reach the cells while their into the pores. So, in, both of pores should occur and into the pores should really occur and they enhance interfacial area because which arises from the microporosity and it now anchors the cell to the implant material and that resists the movement of the cells with the implant.

So, once we have certain porosity which is available for the cells to anchor, now, once cells are basically attaching themselves they also go into the pores, so the overall relative motion between the implant and the cells, it gets restricted and rest living cells can also start residing into the pores, so, they can remain there as such and this particular type of growth in which the cells are surviving into the material, it is called biological fixation, because now cells are also surviving, into the material they are getting proper nourishment proper blood supply.

So, overall thing, it is biologically surviving, it is biologically fixed with the implant, now, because there is much more collection within the particular material, implant material to let the cells grow in itself, so, that is called biological fixation.

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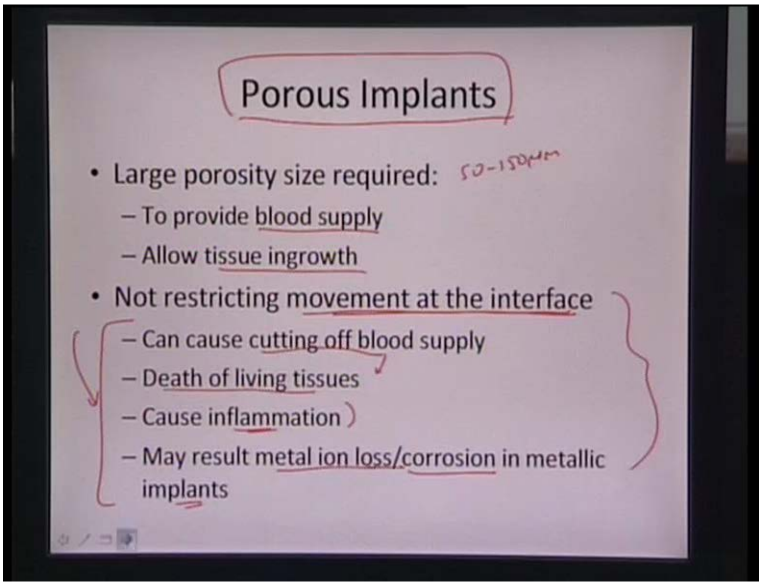


So, ideally, we require a porous implant surface and this large porosity, which is to the order of 50 to 150 microns, that is required so that it can provide blood supply, it can also provide nourishment and it can also allow the tissue ingrowth into the implant surface. But if we cannot restrict the movement at the interface, because the interface has to be strong enough so that it does not allow any relative movement between the implant and the surrounding cell otherwise, it can cause cutting off of the blood supply, it can thereby lead to the death of the living tissues and ultimately it can also lead to the inflammation, and again, it might also lead to the metal ion release as it gets in contract with the nearby blood and it can also cause corrosion in the metallic implant. So, that is the overall problem in case we cannot limit the interfacial movement of the implant in the surrounding tissue. So, ideally we want to restrict this particular movement.

So, in that particular case we need to have some certain kind of a coating as well which can assist this particular strategy, but we need to have a porous implant, but since porous implant can reduce the overall strength of the material and it can also induced some sort of cutting off the blood supply if you are not able to restrict the movement of the interface.

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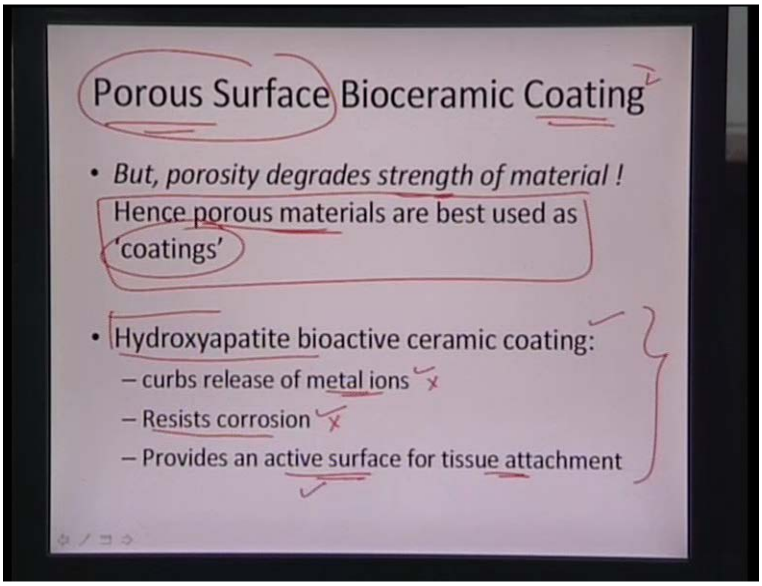


So, ideally, these porous surfaces can also act as some sort of a coating, because porosity will tend to degrade the strength of the material, so they can be utilized best once they are used as the coating. So, we can use porous materials mostly as a coating because we can realize that once the material is not porous, it will degrade the strength that means, the strength is degraded, we cannot have good movement, we cannot have a restriction of movement between the cells and the implant material and then, it can lead to the corrosion part near the metallic implants, it can lead to inflammation as well.

So, ideally, we can use this porous surface as coating, so, that is the overall idea behind it. And ideally hydroxyapatite is the bioactive ceramic, which is utilized as a coating material, because it is highly biocompatible, cytocompatible, so, it can allow the cells to grow on itself it, curbs the release of metal ions into the body also, it is a ceramic, it resists corrosion, at the same time it can also provide an active surface for the tissue attachment.

So, these are the overall important advantages of utilizing a bioceramic coating, that it can take out all the negative effects of a particular material, porous material and it can just serve as a coating, and that coating will limit the release of metal ions because metals, biometallic materials serve as the implants generally and it will restrict the release of metal ions into the body, it can provide a corrosion resistance coating onto the metallic implants, at the same time it serve a some sort of a active surface so that tissues can attach themselves and they can grow comfortably on its surface.

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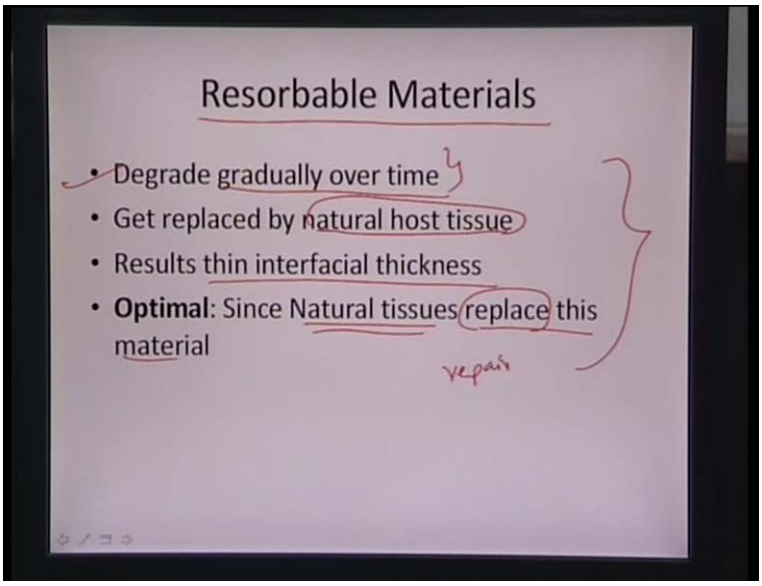


Coming to the different class of biomaterials, reabsorbable materials, and as we talked earlier that they degrade gradually over time. So, in the mean time, once they are getting degraded they are getting replaced by the natural host tissue.

So, that is the most advantage of the reabsorbable materials that once they are inserted them into the body they start getting degraded and the surrounding tissue starts taking place of that particular degraded material. So, that results in a very thin interfacial thickness, but it is very optimal because our natural tissue itself is taking care of itself in terms of repairing the damage and replacing its particular material. So, this particular type of material is highly sought for because it is getting degraded with time and is at the same time getting replaced by a natural material, so, this, a basically results in the replacement and the repair of the part by this particular material. So, that is the advantage of reabsorbable material

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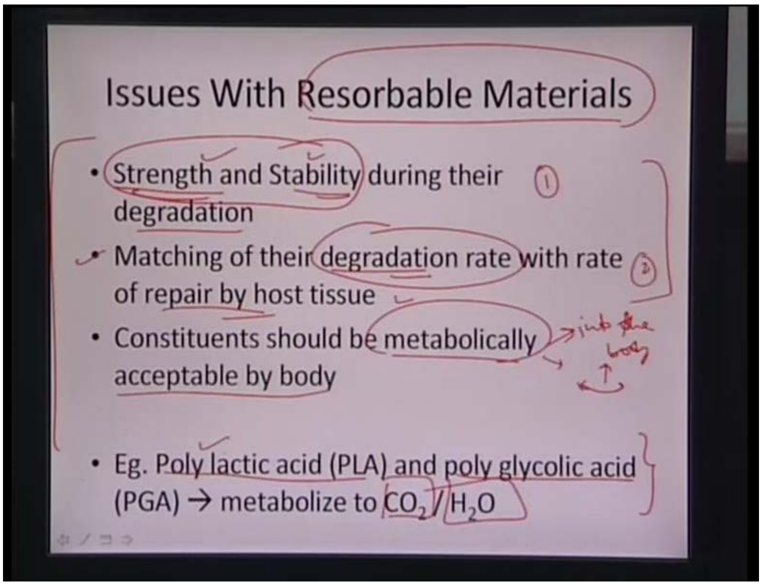


But there are certain problems with the reabsorbable material. First thing is that once we are inserting into the body and if the rate of dissolution of this material is not in conjunction with the various cells that are getting adhered or getting replaced, then it will lead to the degradation of the strength.

So, strength and stability during the degradation is one of the very highly critical issue with the reabsorbable material, at the same time there has to be perfect match between the degradation of the material with the rate of repair by the host tissue. So, thus this is the second most criteria, sometimes has been encountered with the reabsorbable material. At the same time once this particular material, the reabsorbable material is getting dissolved into the body, it should be metabolically acceptable by the body because everything is getting dissolved into the body. So, once it is going into the body then it should be comfortable, the body should be comfortable in terms of taking all the constituents.

So, that is the problem, there are certain problems which are associated with the reabsorbable material. First of all strength and stability is an issue while they are degrading and that degradation rate should also match with the rate of repair by the host tissue, and third thing is the degraded elements, which are basically coming out, or the constituents which are coming out form the reabsorbable material, they should be metabolically acceptable or should be compatible with the body. And the certain examples of reabsorbable materials such as poly lactic acid and poly glycolic acid, why, because they tend to metabolize into CO2 and H2O, which has stable components and they can be easily accepted by the body.

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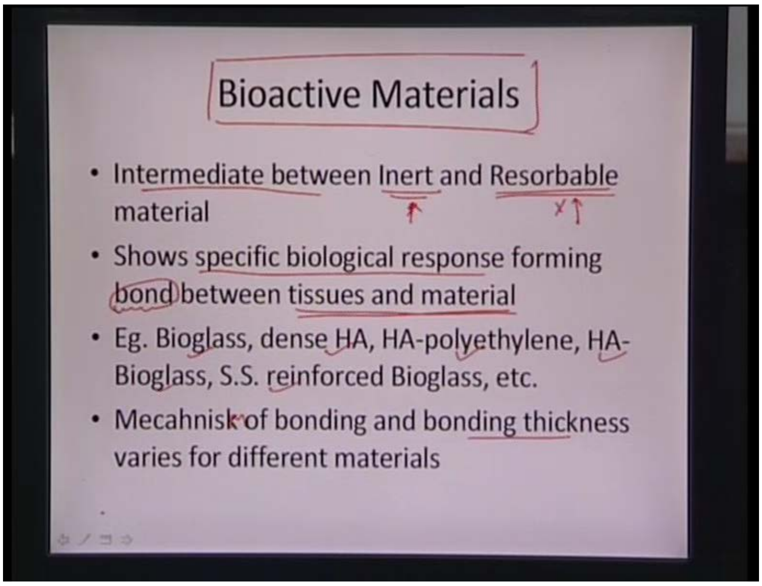


So, those are certain issues with the reabsorbable materials and these are certain examples which can take care of this particular aspect as well.

And there is final class of materials, which are called bioactive materials. So, we learnt about the inert materials then, something about the bioreabsorbable material, now, coming on to the bioactive materials, we can see that these are basically intermediate materials between inert and the reabsorbable material. So, they show a response which is not totally inert and not totally reabsorbable, but they show very specific biological response by forming a bond, that is a overall essential thing because reabsorbable material also form a very thin bond, inert material do not form a bond at all, so, that is the overall thing with the inert and reabsorbable material.

In case of bioactive material, we can see a formation of a very bond between the tissues and materials. And certain examples of this bioactive material can be bioglass hydroxyapatite, which is very dense, hydroxyapatite in polyethylene, hydroxyapatite with bioglass, stainless steel reinforced bioglass and many more. And again, the mechanism, it is a mechanism of bonding and the bonding thickness, it can vary for different materials depending on how they are being processed, what is the kind of surface treatment given to it, what kind of a density they have. So, there are certain parameters which are associated with the bioactive material.

But bioactive material they fall into the class between inert and the bioreabsorbable. And depending on how they can show a biological response, specific biological response, they can form some sort of a coating or the interfacial layer between the host and the host tissues and the implant material. And there are certain examples which can be given out here.

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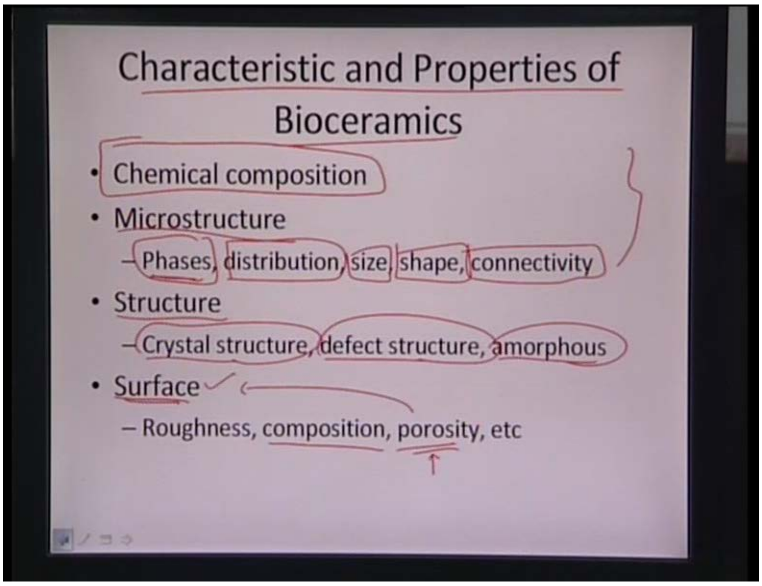


And again, so, depending on them we can have, we can classify the characteristic and properties of bioceramics. So, first of all is, which is very essential component is the chemical composition, so, whether it is really compatible with the material, if had there been any releases of ions into the body, so, we need to consider that, if a implant material which can have a tendency to release its ion into the body, then probably we do not want to utilize them as a bio-implant material. So, chemical composition of a particular material is also one of the very important aspects, if it is a degradable material, then also it constituents should also be much more compatible in nature. So, the chemical composition is one of the very essential features of deciding upon a bio ceramic material.

Again coming onto the microstructure part, the way the phases are distributed, so, what kind, what is the overall distribution of microstructure in terms of whether they have any degradable phase or not, whether it is totally stable or not, and how the phases are basically being distributed within the structure. So, we have a ideal distribution in terms of their size, the overall grain size, what is the shape of the secondary phases, or do we also need some sort of a connectivity. And microstructure also involves porosity, whether we need to have particular kind of porosity into the material, what size of porosity, what is the distribution, whether we need a connectivity of the pores or not. So, these are certain aspects of microstructure as well.

And the overall structure, it can be a crystal structure, it can be a defect structure, or the amorphous nature of the particular phase. So, these are all the different things which are also talked about like, that it can be crystal structure, or defects which are present in the structure, or the amorphous structure.

And again, the most essential component of bioceramic is as well the surface because surface is the one which comes in direct contact with the surrounding cells. So, surface has to be ideally defined in terms of its roughness, if surface is much more rough, it can provide much more surface for the cells to come on to itself and get adhered to it. Even the porosity will also tend to induce much more surface area, so the higher surface area higher will be the response of the, kind of, it will be basically, the whole response will get magnified by the surface area. So, if it has porosity, it can have much higher surface and that can affect the biocompatibility as such.

Again, what is the surface composition? If surface itself is not only compatible, then it would not lead to any killing of the cells, or it would not show a good response with the surrounding cells. So, compositeon of surface also one of the very critical aspects like, if you have hydroxyapatite, which is much more bioactive in nature, it will have much stronger bonding with the surrounding cell, if the surface itself has a composition of very inert nature, it may not basically guide, allow the cells to get clung to it biologically in a very nice manner, or depending on porosity it may not be biological. So, chemical bonding can also happen if the material itself is very active in nature.

Again, the porosity also holds one of the keys in terms of deciding the overall compatibility. So, porosity is also related to the surface in terms of providing higher surface area and getting acquainted with the cell in growth into the material.

So, in this particular case we did realized the various classes of ceramics and glasses. And glasses basically tend to be much more inert in nature, so they can handle much more of ph or temperature variance, or they cannot get corroded so easily. And again, with the ceramics and bioglasses, we realized there are certain classes of materials, of first being (( )) total toxic in nature, which is not really acceptable, because if it is toxic, the surrounding cells will die very soon, and it basically, it would not suffice, suffice in improving the quality of life.

The implant metal can also be highly inert in nature and in that particular case we do not see a good bonding, only morphological bonding can form when the metal is becoming little porous, it can even become much more compatible, it can be biologically fixed in case once it has much more porosity. So, it can be morphologically fixed, in case once we have only very dense material and it can just morphologically fixed, in case once we have porous material then ideally cells can grow into the pores and they can get much more biologically fixed, once we have bioactive material it can basically get chemically and biologically both, it can get really adhered to the surface and form a interfacial bonding.

An interfacial bond is the one which is highly responsible for deciding the overall life of an implant in terms of its functionality and that it can also allow the restricted movement between the cells and the implant material. Because a drastic movement between them can rupture the cells and it can rupture the blood flow along there, it can (( )) the nourishment to the cells and overall cells can get destroyed or they can die out. So, it can also cause some inflammation and toxicity via basically the interaction between the implant surface and the surrounding environment. So, for that we need to also have some sort of a coating, which can sustain the corrosion resistance, which can provide a cytocompatible surface. And at the same time, it should also allow some kind of activity to the cells from which cells can get adhered to it. So, there are certain characteristics and properties which are associated with the biological materials. So, that is what we discussed in this particular case. So, this, I end my lecture here. Thanks.