Oral Biology
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Lecture - 23
Biomaterials - Polymers

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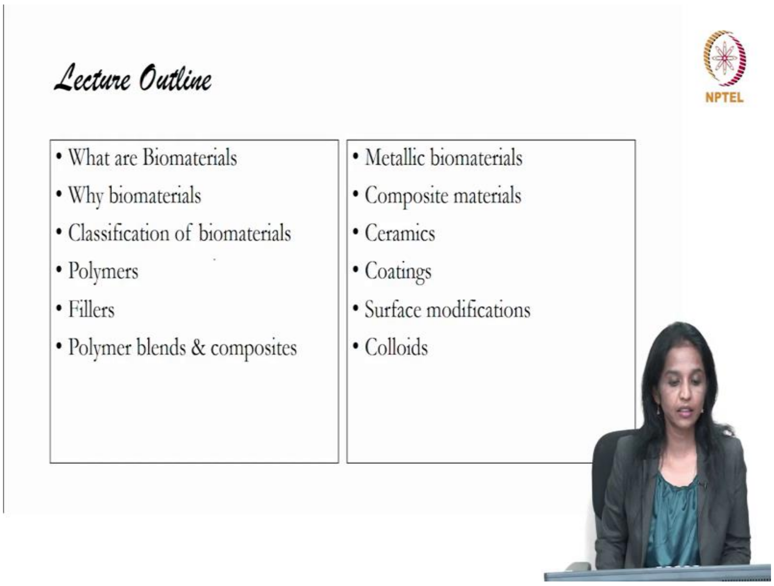

So, these are the lecture outlines.

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Biomaterial is defined as a substance that is going to become an integral part of the living system. So, it is a material which is engineered with great care so that it becomes part of the complex living system during the course of the process of the living being, be it in the form of a therapeutic event or as a diagnostic procedure.

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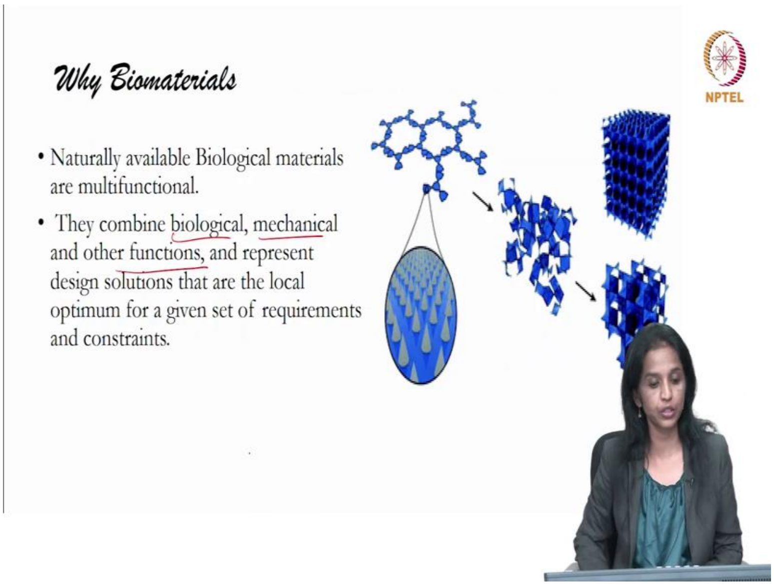

So, why do we need biomaterials or why do we use biomaterials? Because these are naturally available and they can actually execute biological, mechanical and many other functions suitable to a living environment.

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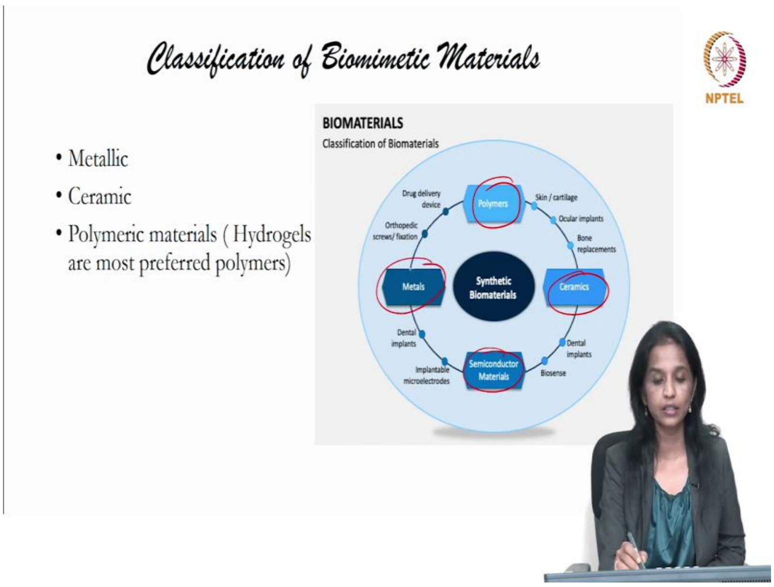

And classification of biomaterials is that we have polymers, ceramics, semiconductor materials and metals.

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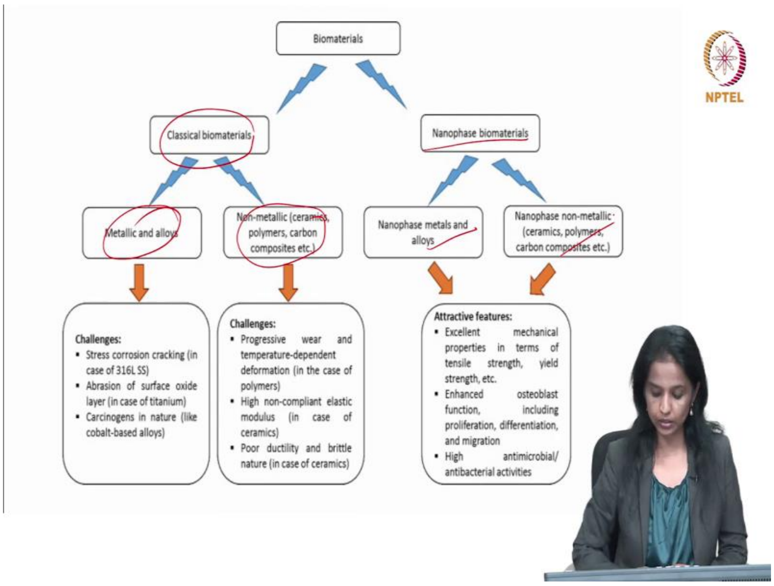

There are other classification systems of biomaterials as well, the most common ones are a wide variety of categorizing them as classical biomaterials, which actually go further goes down into subdividing into metals and alloys and non-metallic elements.

So, these are the usually used material classification system and then we have the nano phase biomaterial classification system. Here we have again metals and alloys and then non-phase metal, non-metallic alloys.

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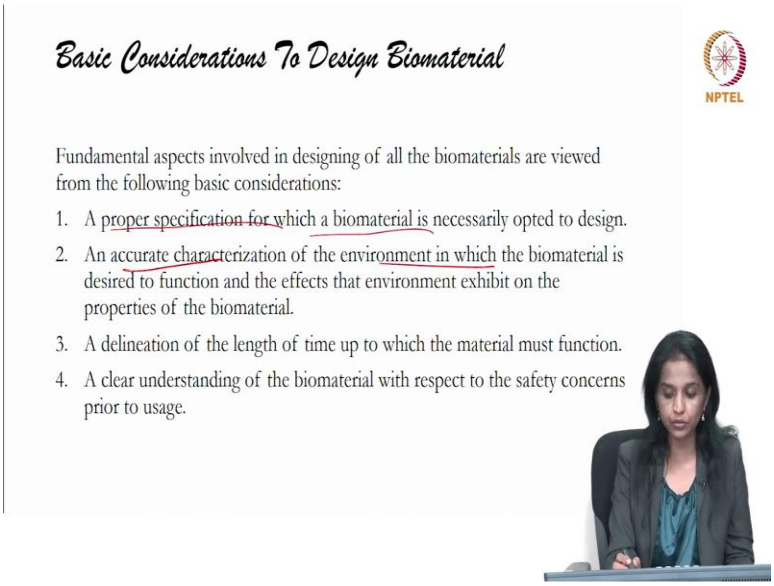

So, this is how we go into classification. So, what are the considerations which are usually taken care of or thought of during biomaterial fabrication is that why is it required and there is a proper specification for every biomaterial which is to be taken for a designing.

And an accurate characterization for that particular environment is very important for which the biomaterial is desired to function and that environment has to actually gel into, get integrated into this biomaterial and hence allow that biomaterial to carry out its function. So, this particular biomaterial has to also be very safe to the human being.

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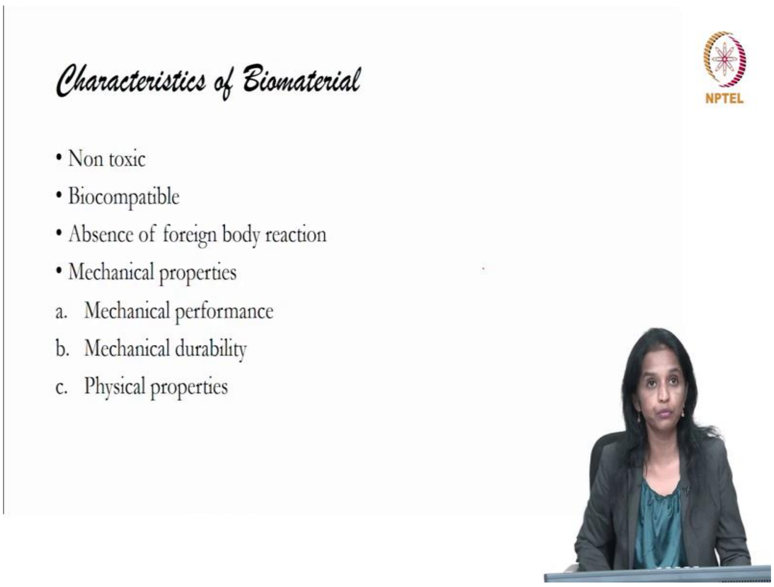

And characteristics of a biomaterial is that, it has to be non-toxic, it has to be biocompatible and there should be absence of a foreign body reaction. And it also in addition has to possess the mechanical properties with mechanical, good mechanical performance, mechanical durability and physical properties good enough to mimic the tissue which is going to be used for replacing the tissue in that particular environment.

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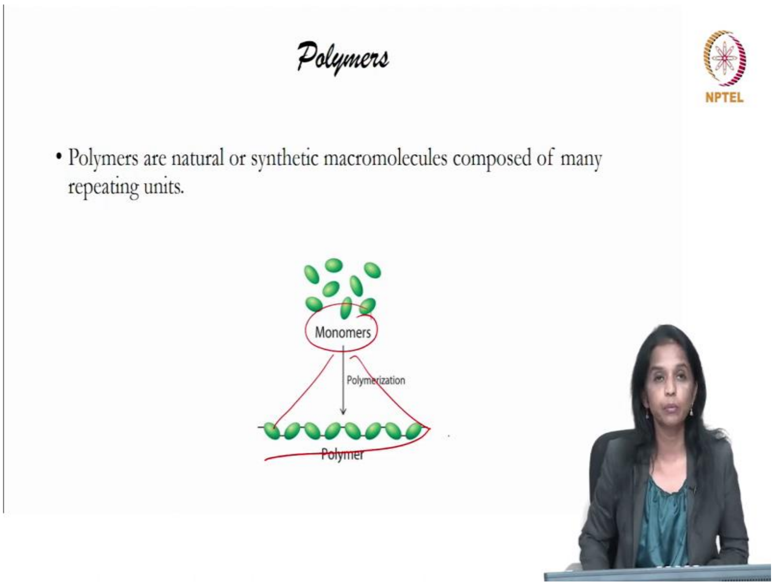

So, the first and foremost biomaterial is polymers and these polymers are actually natural or synthetic macromolecules which means that there is a bigger larger molecule made of smaller monomers.

So, we have a monomer that repeats to form a polymer. So, these are small monomers making into a larger polymer. So, finally, you have a macromolecule that is formed. So, this is a basic biomaterial which is actually used.

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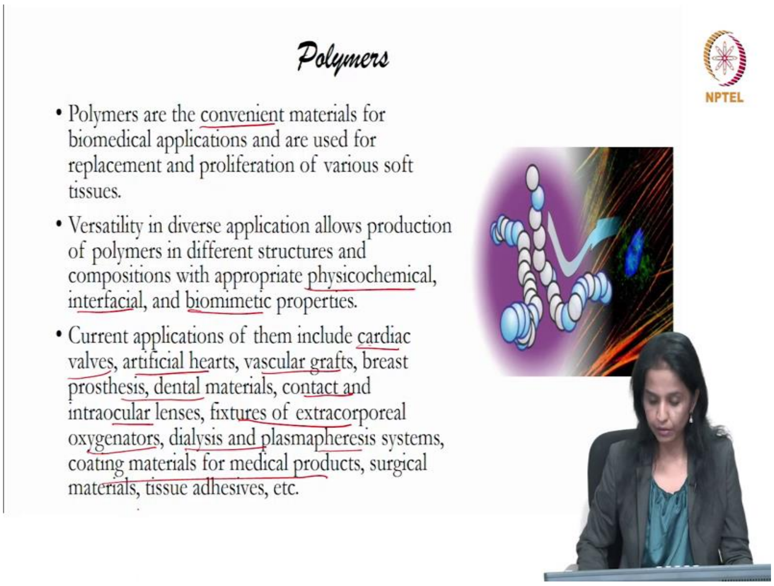

And why do we use polymers is what we need to know. So, polymers are very convenient so feasible. And why is it being feasible? Because of the versatility of the material.

So, what do you mean by versatility? The meaning of versatility is that it can be tuned into, it can be blend into many properties or it can be characterized with multiple fabrication mechanisms and it can be derived into various products, good enough to suit a organ system or it can be even for a diagnostic system whichever way it is it can be molded or tuned into various requirements that is the meaning of versatility.

So, because of its very advantageous physicochemical interfacial and biomimetic properties. So, because of this versatile nature of polymers we have a huge range of applications which the polymers can offer.

They have cardiac applications, they can be used for making cardiac valves, artificial hearts, vascular grafts, breast prosthesis, dental materials, contact and intraocular lenses, fixtures of extracorporeal oxygenators, dialysis and plasmapheresis systems, coating materials for medical products, surgical materials, and tissue adhesives.

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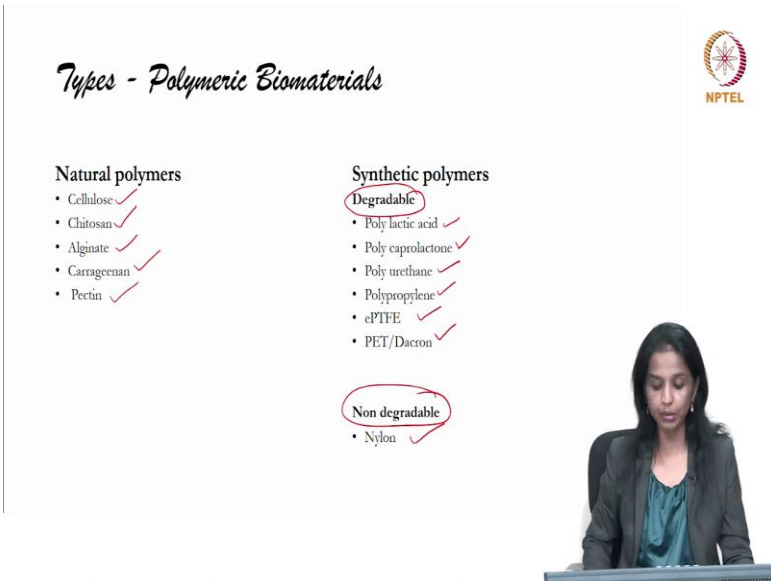

So, these are very important about polymeric biomaterials. Polymer biomaterials can be divided into natural and synthetic. So, as we say natural and synthetic, we know that they are derived from natural products and we have many times heard about the ones which are listed below. So, cellulose we know is a very important component of the living system and then we have chitosan which is a protein which are derived from insect-based coating system.

And then we have carrageenan; carrageenan is actually a sea weed derivative and then we have synthetic polymers again synthetic polymers are further divided into degradable and non degradable. As we see degradable, we can see that they are polylactic acid, polycaprolactone, polyurethane, polypropylene, PTFE and PET Dacron. And then further we have non degradable nylon.

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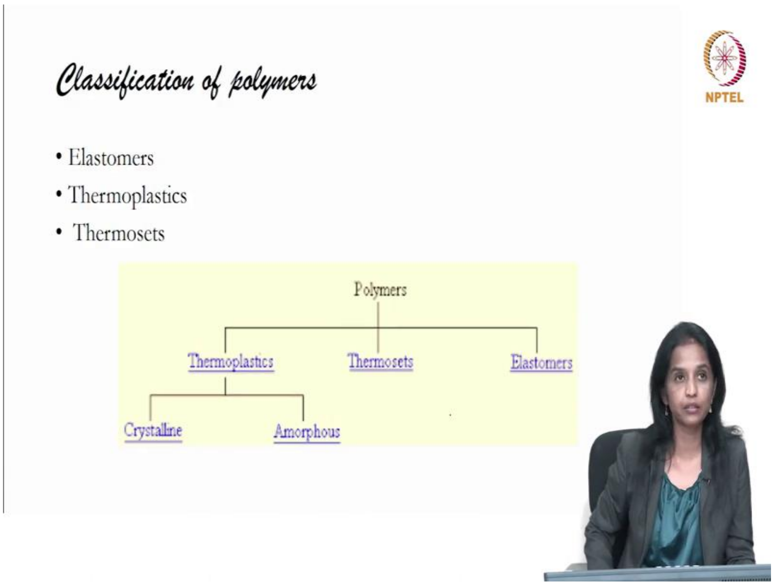

So, these are the classification system further there is another method to classify polymers. Again these are based on the characteristics of polymers or the basic properties of polymers; it is actually divided into three, the first one is elastomer, then we have thermoplastics, and thermosets polymers.

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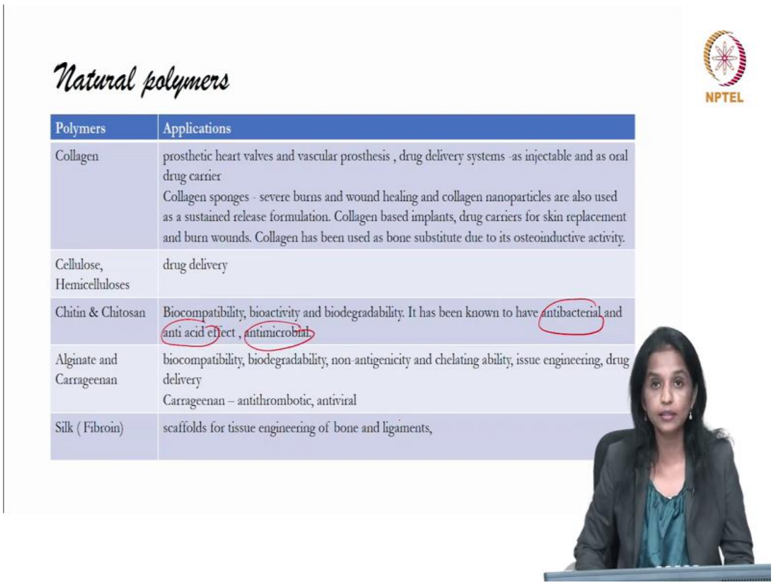

Then further the first thing which we would be doing today is the natural polymers. So, polymers as already mentioned we know that collagen, then we have cellulose, chitosan carrageenan.

And alginate again is a seaweed derivative and then silk worm, the natural silk which is derived from the silkworm has a beautiful polymer in it which is called as fibroin. This fibroin has been utilized in the recent times into multiple applications for many applications and it is found to be useful especially in tissue engineering, bone and ligaments.

The other systems like collagen are used mainly to makes collagen sponges where it is used to treat burns, wound healing. collagen nanoparticles are also used for drug release applications as well. Then we have chitosan: chitosan is actually being celebrated as a natural polymer and we have enormous amounts of research work going on in chitosan.

So, chitosan again is biocompatible, bioactive biodegradable and it also has antibacterial, anti acidic, and anti microbial effect. So, that is actually a very characteristic or most sought-after biomaterial right now.

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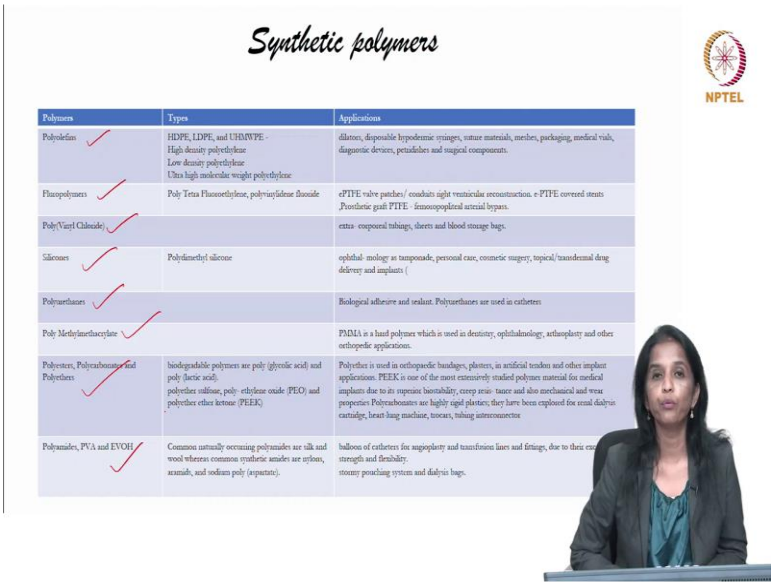

Then we have synthetic polymers, we already know that synthetic polymers are divided into degradable and non degradable. So, having that in mind a quick look at the synthetic polymers we have polyolefins, fluoropolymers, poly vinyl chloride, silicones, polyurethanes, poly methyl methacrylate, polyesters, polycarbonates and poly ethers and then we have polyamides.

So, all these are actually comparatively are synthetically derived and there is a very very big range of applications which the synthetic polymers do offer. And because of their versatility as already said they can be used as medical devices for diagnosis and for therapeutic approaches. So, they are either used as a defect to as a filler in a defect or they can be used as a stent or they can be used as a valve or they can be used as an adhesive the applications are really very wide and multitude.

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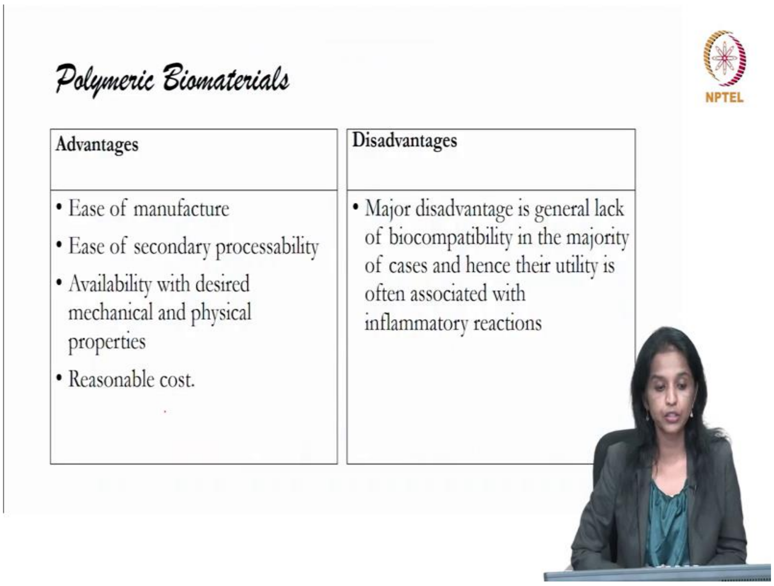

And then we have we should definitely know having said that it has got such a huge range of applications, we definitely need to know what are the advantages and what other disadvantages. The advantage being ease of manufacture as already mentioned it is very easily available and ease of secondary processability because then you can actually do a secondary processing and availability with desired mechanical and physical properties, above all it is very reasonable.

So, it is cost effective, but the major disadvantage lies in the lack of biocompatible majority of cases and hence their usage is often limited by the inflammatory reaction which is actually cast because of polymeric biomaterials. So, what happens? So, can we just ignore these polymers? Never; you can actually utilize them, but again combine them with other agents. So, that it will improve the biocompatibility and so that there will be lesser inflammatory reactions.

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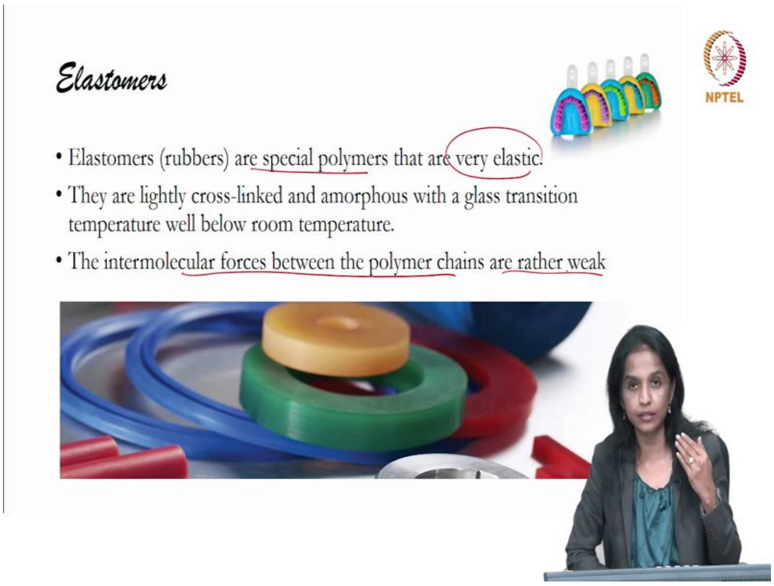

As already mentioned, polymers are classified into elastomers, thermoplastics, and thermosets. The first one is elastomer and are actually special polymers that are very elastic as the name suggests and they are tightly cross linked and amorphous with a glass transition temperature well below the room temperature. The intermolecular forces between the polymer chains are rather weak, but this weakness is what actually gives that elasticity to the elastomer.

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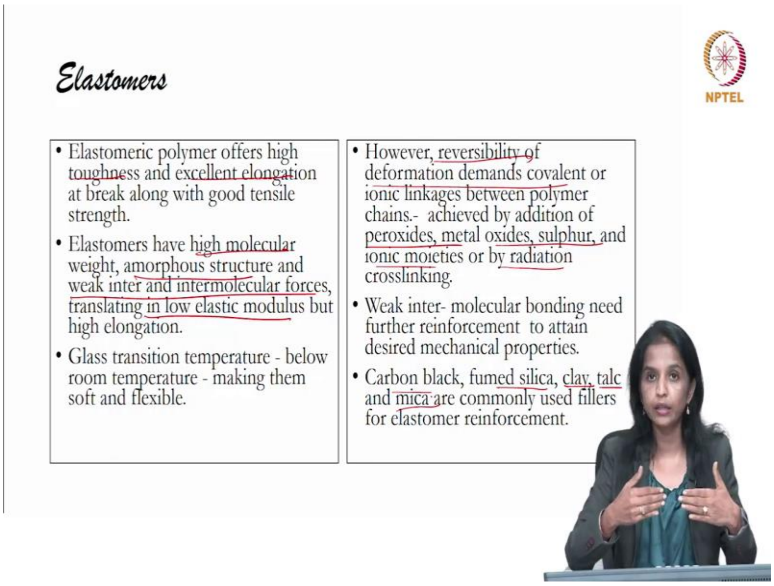

And further getting on to know further points about elastomers is that this elastomeric polymer is actually elastic in nature because of the weak intermolecular bonds and it actually offers high toughness and excellent elongation and before it could just break it can actually give up.

So, definitely it is a material which can offer lot of toughness and this elastomers have very high molecular weight and they are amorphous in structure. So, the moment we see amorphous which means that they are not crystalline and they have weak inter and intra molecular forces.

So, these are the ones which are actually translating in low elastic modulus with high elongation. The glass transition temperatures are very important as we read polymers. So, glass transition temperatures here in elastomer is below the room temperature making them soft and flexible. So, depends on the glass transition temperature you can actually understand how the material would be at room temperature.

And then then is the description of how elastic is the elastomer. So, or can we modify it by further additions or can we reverse the deformation and it can be further the molecular bonds can be strengthened or not. So, that can be done by addition of peroxides, metal oxide, sulphur, ionic moieties or by radiation cross linkage.

So, this reversibility of deformation would require some presence of cross linkage. So, how do we cross link those weak bonds? We cross link by adding peroxides, sulphides, metal oxides and radiation and these also further in addition to cross linking can be further added on with filler materials.

So, those are again can be carbon, silica, clay, talc, mica are used as fillers for reinforcing elastomer. So, first what we need to understand is elastomers are preferred because of its elasticity, but situation demands where we might want the toughness to increase at that time, we can add a cross linking agent in addition for if the further there is a reinforcement required, then further there can be fillers which can be added to elastomers.

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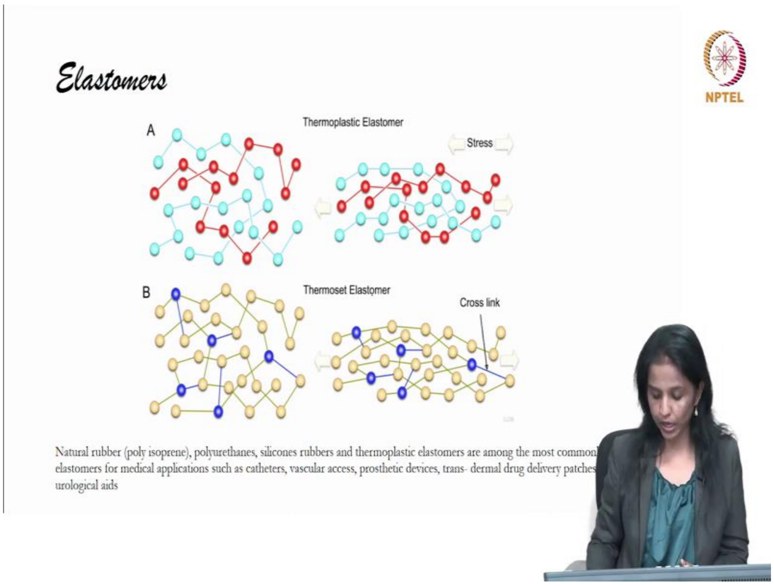

So, this is a schematic diagram which actually represents the thermoplastic elastomer, the thermoset elastomer.

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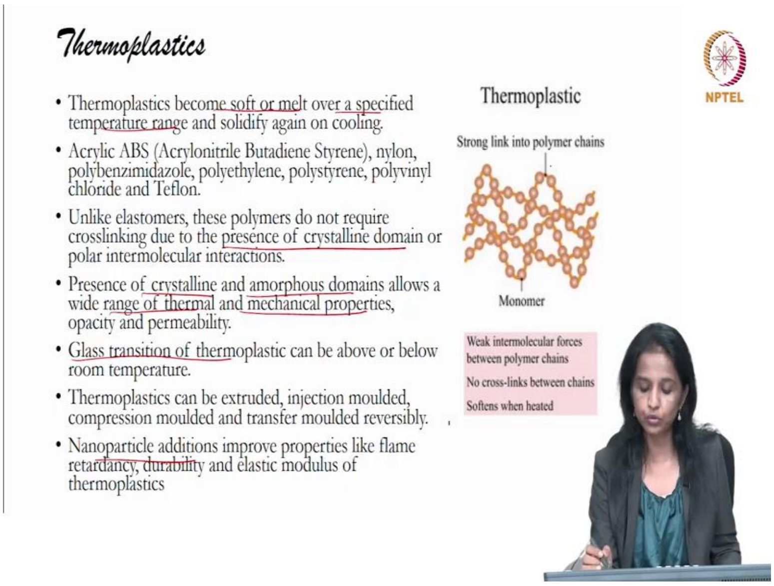

So, we would go into the details of thermoplastics we would understand that best. So, thermoplastic as the name indicates has a meaning which suggests that there is a plasticity to that material which reacts with increase in temperature. So, what exactly does thermoplastics mean?

So, it is a soft, it becomes soft over a specified temperature range. So, it becomes plastic at a specific temperature or it becomes soft at a particular temperature and becomes a solid again on cooling. So, the examples of thermoplastics are your acrylonitrile butadiene styrene, nylon polybenzimidazole, polyethylene, polystyrene, polyvinyl, chloride and Teflon.

And again, unlike elastomers these polymers that is your thermoplastics do not require cross linking because they have a presence of crystalline domain. At this particular juncture we should please recollect elastomers were amorphous in nature and next comes slightly more harder your thermoplastics.

So, this thermoplastics does not require cross linking because it actually has a crystalline domain making it more tougher. So, what happens, as it becomes crystalline the intermolecular bonding becomes more stronger and presence of crystalline and amorphous domain together allows a wide range of thermal and mechanical properties opacity and permeability.

So, there is a merger of two characteristics that is it is amorphous at the same time it is crystalline as well. So, the advantages of both the materials can be used up here and please do note that the glass transition temperature of thermoplastic can be above or below the room temperature that is because there is again a, element of amorphous structures within. So, there is always the glass transition temperature is almost similar to your elastomer.

So, thermoplastics can be actually extruded or injection molded or compression molded or transfer molded whichever way we want to fabricate it. So, any, if in case if there is I said cross linkage is not required, but in case if you want to reinforce the material you can actually add nanoparticles to improve the properties like flame, retardancy, durability and elastic modulus of thermoplastics. So, this picture over here actually shows that the link between the intermolecular link is slightly more stronger than what you see in elastomer.

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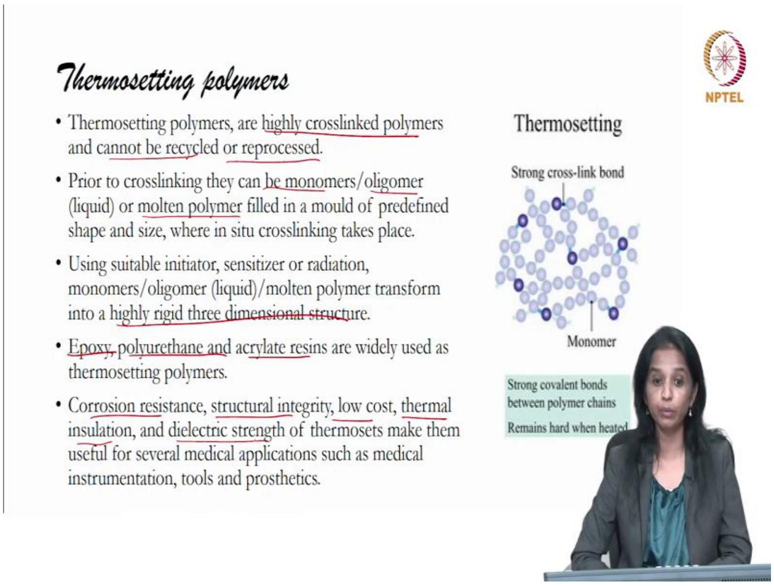

Now, we move on to the other end of the spectra of polymers. The first was elastomer, then we read about thermoplastics and the next one is thermosetting polymers. So, in thermosetting polymers the highly cross linked polymers cannot be recycled or reprocessed and they would be really solid, they cannot be reversed there is no reverse reversibility in thermosetting polymers.

So, prior to cross linking they can be monomers or oligomers or even molten polymers, but then once cross linking takes place it becomes solid. So, with a suitable initiator, a sensitizer or a radiation agent this can become a highly rigid three dimensional structure making a thermosetting polymer. So, the examples of thermosetting polymers are your epoxy resins, polyurethane resins, acrylic resins which are widely used thermosetting polymers.

We have been hearing about all these resins quite in many many applications, and what are the advantages of thermal setting polymers is that there is definite corrosion resistance, structural integrity because of its rigidity, low cost thermal insulation and dielectric strength of the thermosets. Which makes them useful for many many medical applications not only for any filler materials, it is also used for medical instrumentation tools and prosthesis.

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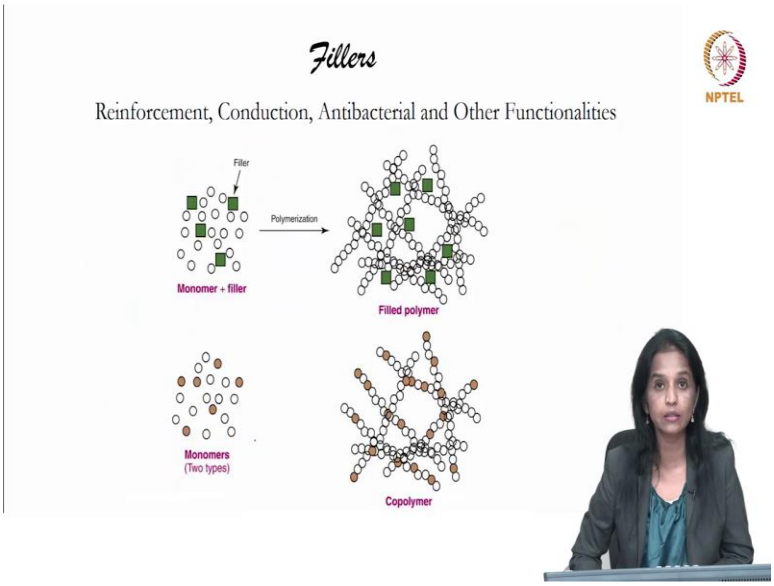

And now then we go on to reading about fillers. We have just completed polymers and now we in between read those elastomers and thermoplastics require the presence of fillers. And what are these fillers? So, biomaterial fillers what are these. So, as we add a biomaterial filler to a biomaterial it makes the material more stronger, that is it reinforces makes it more stronger. And then it allows the material, it gives more conductive ability, it also renders antibacterial effect to the material and other functionalities as well.

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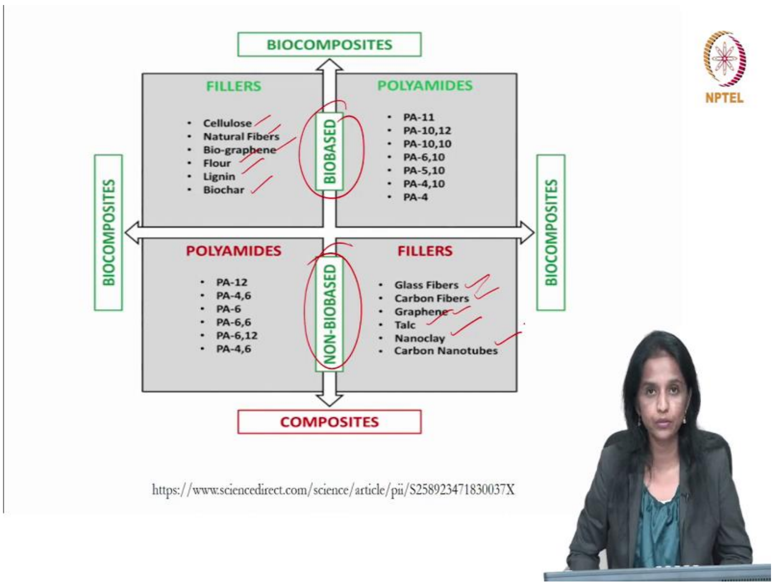

So, a quick look at what are the fillers which are actually present, we have biobased fillers and non-biobased fillers. So, these are the broad category by which the fillers are classified. So, if you see the bio based, again we have cellulose, natural fibers, graphene flour. lignin and biochar. Here we have glass fibers, carbon fibers, graphene, talc, nano clay and carbon nanotube. So, these are the filler materials which are non bio based. So, natural and artificial.

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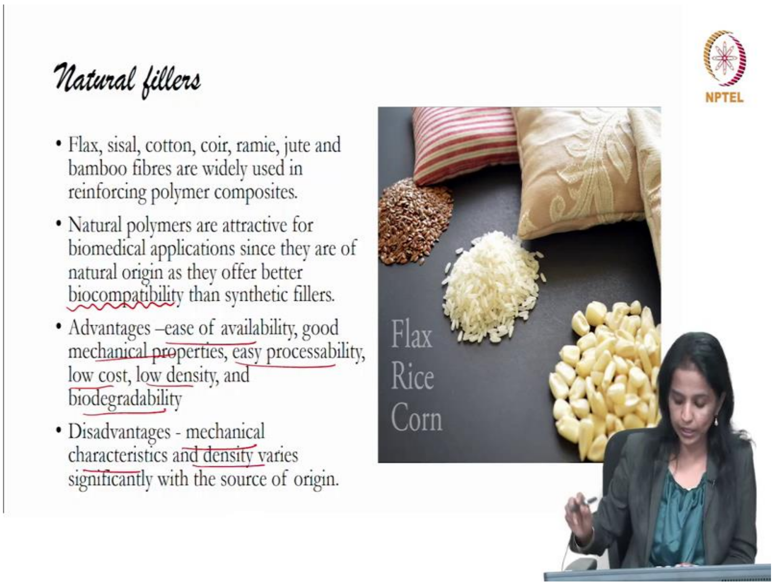

So, natural as the picture mentions over there. So, these are the commonly used fillers the raw materials from which the natural fillers are derived from. So, all these are very useful in biomedical application mainly because the single one term which is very important as far as biomaterial is concerned that is bio compatibility.

So, natural fillers; obviously, would definitely be bio compatible. The advantage of natural fillers is that that is its ease, it you can get it easily, it is easily available there is good mechanical properties, ease of processability, low cost, low density and biodegradable. That again is a very important characteristic which one looks for when selecting a biomaterial. And then the disadvantage its mechanical characteristics density again varies with this source of origin.

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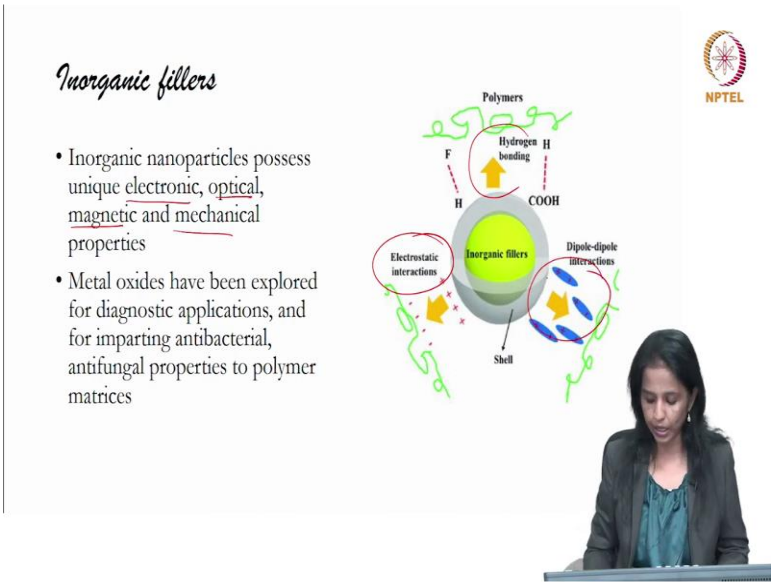

The other inorganic filler materials are that they are synthetic and they are actually more unique and they can exhibit electronic, optical, magnetic and mechanical properties. So, usually metal oxides are used as inorganic fillers and these inorganic fillers are actually capable of giving out an electrostatic interaction, it can be also giving out a hydrogen bonding and then it can also create a dipole interaction making it very very interesting and; obviously, giving in much more applications.

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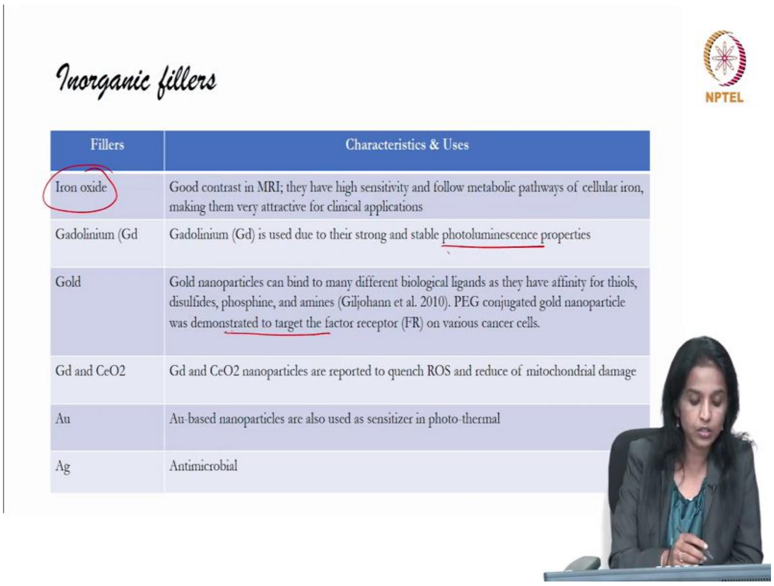

So, the examples of inorganic fillers are your iron oxide. The moment we see iron oxide iron oxides are of great use in diagnostic imaging, especially in magnetic resonance imaging where it is most sought after metal oxide. And then we have gadolinium that is used as because of that is photoluminescence properties and then we have gold, gold has a very important characteristic that it can be used as a, at a target agent, as a drug delivery system and it also has affinity for many biological tissues.

And then we have serum and these serum and gadolinium nanoparticles are actually very importantly used as an antioxidant agents and also they reduce mitochondrial damage which is of great importance in metabolomic studies and then further we have gold. Gold based nanoparticles are also used as a sensitizer in photothermal agents and silver well known for its antimicrobial agents.

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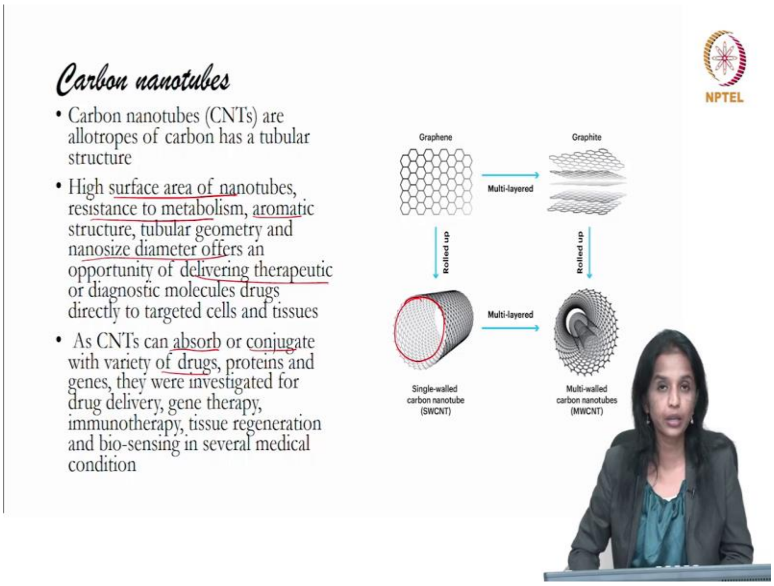

A quick look at the fillers, the synthetic fillers. The most commonly used ones are your carbon nanotubes as the name suggest it is a tubular structure and this is actually made of or its an allotrope of carbon and it has a very high area, resistant to metabolism, aromatic structure, it has a tubular geometry, the shape is of a tube and the nanosize of diameter offers opportunity to deliver therapeutic or diagnostic molecules at the targeted site.

So, it is very small at the same time very highly durable and they can also absorb and conjugate variety of drugs. So, that increases its efficacy and serves as a very effective drug delivery system. So, this is of great biomedical importance.

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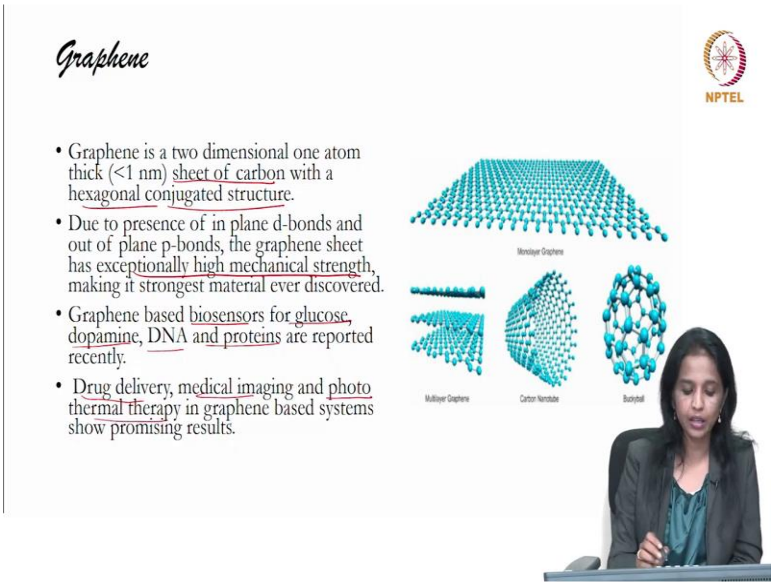

And then we move on to graphene; graphene again is a carbon allotrope and it is actually a two dimensional one atom thick sheet of carbon with a hexagonal conjugated structure.

So, we can see that with this picture here. So, it has a plane d bond and plane p bond and this graphene sheet has a exceptionally high mechanical strength making it the most strongest material discovered. So, the most strongest material which is actually synthesized is actually graphene.

So, because of these characteristics and because of the inherent properties which thin sheets of carbon can provide, they are used as biosensors for glucose, dopamine, DNA and proteins and then we also have use it as a drug delivery system medical imaging photothermal therapy just look at how much of a variety of applications it can offer to us.

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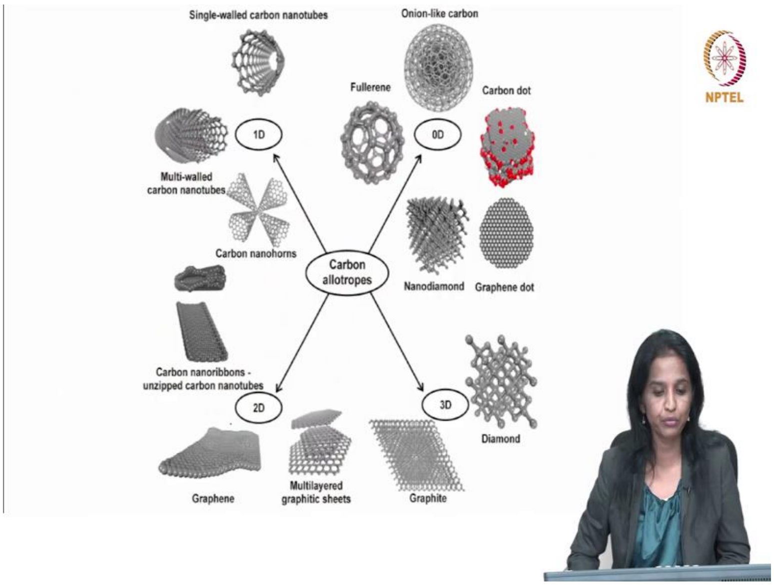

So, these are again a wide variety of the carbon allotropes, which can be used as fillers, the ones which we saw are the carbon nanotubes and the graphenes. In addition to that we have numerous other carbon allotropes of great interest in biomaterial science.

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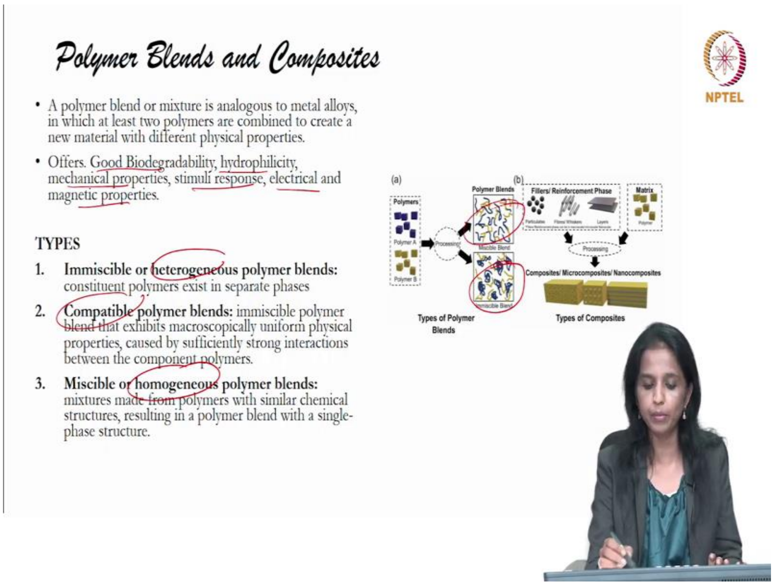

And then we go on to polymer blends and composite as the name indicates, a composite means a mixture of two elements. Again polymer blends as the name indicates there is some other material which is blend into polymer to derive a new material so that there is an advantage by mixing two material we derive a synergistic advantage.

So, a polymer blend or mixture is similar to a metallic alloy in which two polymers are combined to create a new material. The advantage being good biodegradability, hydrophilicity, mechanical properties, stimuli response, electric and magnetic properties. So, there are various types of polymer blends, we have heterogeneous compatible polymer blends and homogeneous polymer blends.

So, as a name indicates we can see that the heterogeneous things are immiscible and there is a heterogeneous tendency to it does not gel with each other. They stay together, but they do not gel and then we have the polymer blends which are miscible.

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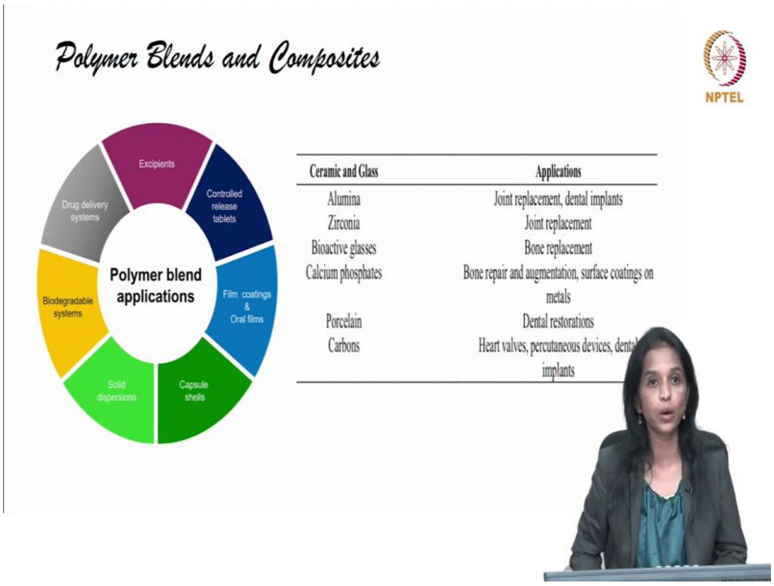

So, these two are important and then further to understand the applications of polymer blends and composites again like how we saw for other biomaterials till now, these are also got numerous applications.

So, like for example, you have your alumina which is a blend of alumina and glass and then we have it to be used for implants. Zirconia again implants and replacements calcium phosphates and bone repair and augmentation, porcelain and dental restorations and carbon in heart valves, percutaneous devices and dental implants.

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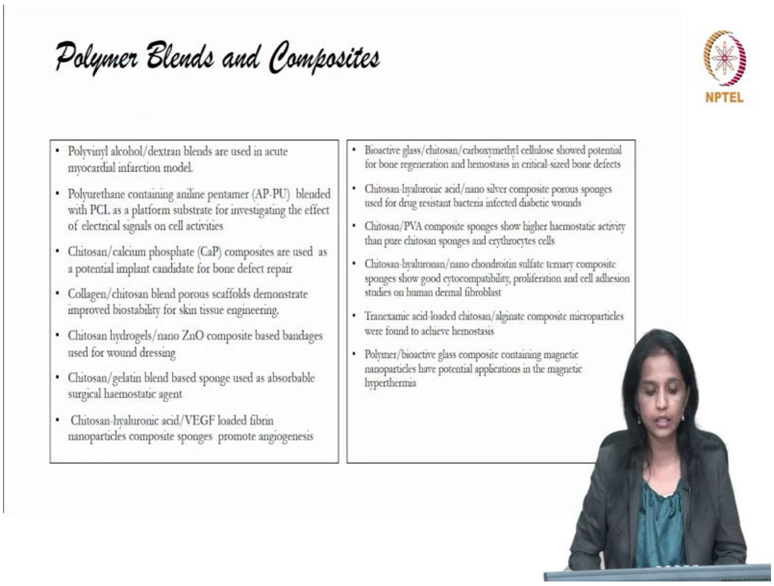

And this is a very big interesting list about polymer blends these were so tempting that it had to be included in the list of polymer blends over there. This is just to give you an overview about how much of polymer blends are available and to give you an idea of how much of applications it has to offer and looking at the scope in this particular list it was so tempting that though there was lot of text, it was so tempting that every learner of this course should benefit into the intricacies of this particular material.

So, a quick look or a quick glance in these polymer blends and composites is that we have beautiful combinations being applied into multitude of a range of applications. So, it starts from being a filler material, it starts from being a graph material, it starts from being a drug delivery system as a biosensor, as a cardiovascular tent as a valve material and then it is used as an antibacterial agent and so on. So, there is never ending opportunities, hemostats and so on.