Thermal Processing of Foods
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Biocomposite/ Bionanocomposite Materials for Food Packing Applications

Good morning everybody. So, today we are going to discuss about biocomposite and bionanocomposite materials for food packing applications. So, as far as this lecture is concern so this is again the recent topic. And there were many polymer and filler materials combination have been tried and the literature of research is very vast.

So, here we are going to discuss about main entry cases involved in making such materials. And what are all the needs all those things we are going to discuss and whenever needed we are going to take some example bionanocomposite food packaging films or materials.

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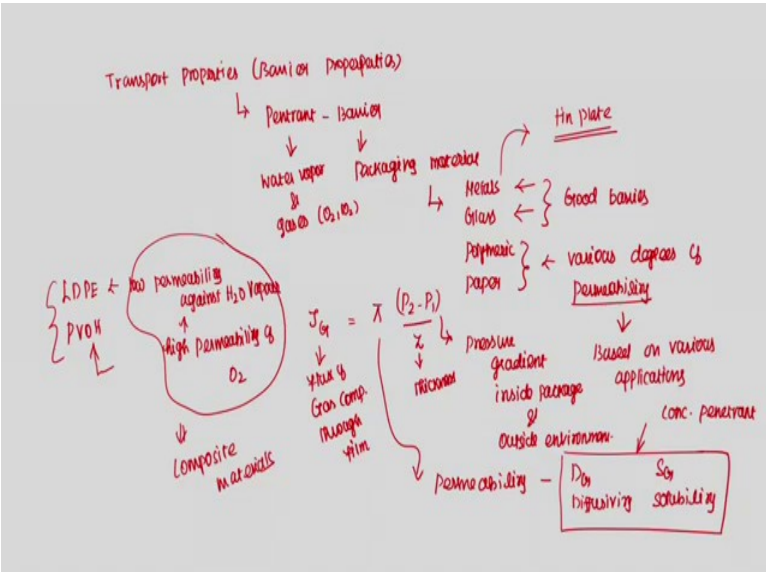

So, just a recap about previous class. So, in the previous class we have mainly discussed about transport properties or we call it as a barrier properties. So, for penetrant and barrier combination. So, we normally we say this is the packaging material. So and penetrant is most of the time it may be a water vapor and gases so example is O2 CO2 etc.

So, in this in the packaging material we have discussed main category metals, metal cans and another one is glass materials, another is polymeric materials so that is most widely used now a days and another one is paper materials.

And the transport wise they are good barriers both metals and glasses are good barriers but paper and polymeric materials where have various degrees of permeability. So, which helps us to use based on the various applications we can change the degree of permeability based on the needs as well. So, that is where this films are this polymeric films and paper materials are widely used. Where we need to have certain control over the barrier properties.

So, the moment we talk about the permeability, so we have seen one formula which JG, so this is nothing but a flux of a gas component through the film. So, which is nothing but pi into P2 minus P1 upon Z. So, this is nothing but a thickness, so this is nothing but a pressure gradient which outside and inside the packaging, pressure gradient inside the packaging and outside environment. So, this is the permeability, so which has got two component in it. So, one is DG which is nothing but diffusivity and another SG which is nothing but solubility.

So, this we derived based on simple henrys and fix law of diffusion. So, this is the properties to be looked into when we talk about the permeability and based on this DG and SG, so we already told that the concentration of penetrant is not depending upon the DG and SG. And sometimes what happens it also takes part in the changing properties of the films. Sometimes when we use condensable vapors or liquids. So, there may be a chance for the swelling of the film and also we have seen there are two things one is the LDPE, so which is nothing but low density poly ethylene and PVOH poly venial alcohol.

So, this is got low permeability or good barrier property against water. But it has got low barrier against the R may be it was the permeability of oxygen through LDPE was high permeability of oxygen. So, for PVOH it is opposite to this particular property. So, when we have certain materials one is low permeability against a water or it may be good barrier against the water and another one is high permeability against the oxygen.

So, that means it is a poor barrier against the oxygen. So and PVOH exactly got opposite to this so the concept came like. So, how do these two materials can be combined together. It is not exactly this LDPE and PVOH likewise materials, one has got good property in one particular aspect another got good properties in particular aspect. How do these two materials can be combined together to achieve the purpose of both the advantages and remove if any disadvantages.

For example, in this case I want to have good barrier against water vapor as well as oxygen. How two materials of this category can be combined together to serve the purpose. So, that is why the composite materials came into existence. So, along with this we have also seen the mechanical properties obviously metals and glasses got good mechanical properties. And metals when we see the size and shape and also thickness of the metals are important to have good mechanical property.

If we take glass one problem with that is handling and also we need specialized equipment to handle the glass packaging materials. And polymer and paper we have the problem with moisture, so it is not having a good barrier against moisture. So, because of moisture content this mechanical property of the paper may be affected. So, this are all few points we discussed about the mechanical properties and also apart from that there are chemical reactivity.

Chemical reactivity in the sense for example metals we have discuss about tin plate. Tin plate is nothing but a steel plate which is coated with the tin so, if the coating is not proper if there are any porous structure in the coating. So, there may be a chance for contamination and also when we take acid foods or when we handle acid foods in metal packaging. So, we need to be careful about again the contamination.

And also sometimes what happens the depolarizing agents such as we discussed in over nutraceuticals, the phytochemical called anthocyanin. So, that particular chemical is good depolarizing agent. So, such materials are handle with metals, so there may be chance for corrosion. And also in earlier thermal processing lectures we have also discussed about the removing oxygen inside the packaging. And also we discussed about the head space maintenance to have a vacuum.

So, this also come into the property when we discuss about the properties because the chemical reactivity is also important. So, now we are going to see so how do we combine materials which has got good properties or better properties together to enhance the performance of the packaging material.

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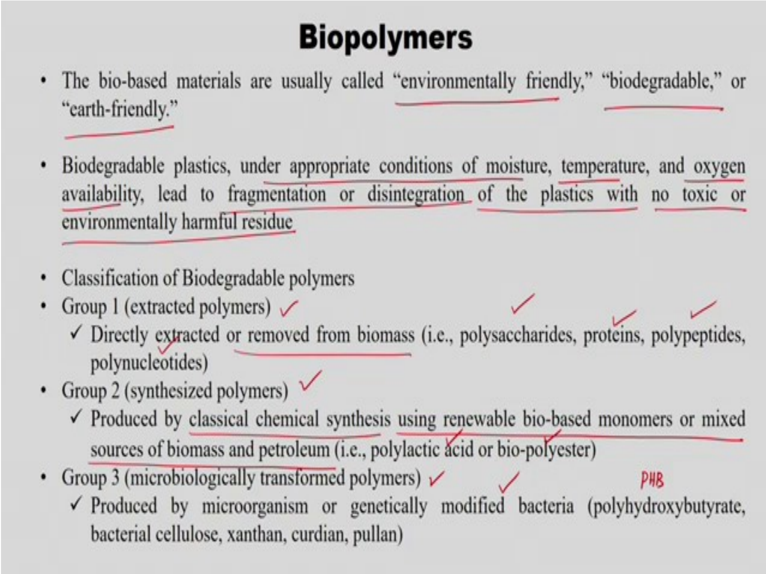

So, the first one is biopolymers. So, composite material we understood, so we are going to see nanocomposites and bionanocomposites. So, before that we start with biopolymers. The biopolymers are nothing but bio based materials usually called as environment friendly and biodegradable and earth friendly. So, that means when we throw it into the environment it should not create any further environmental problem. So, biodegradable plastics under appropriate conditions of moisture temperature and oxygen availability lead to fragmentation or disintegration of the plastics with no toxic or environmentally harmful residue.

So, one problem with normal plastic is this, first one is it takes long time to disintegrate even if it disintegrate it leaves the toxic chemicals or environmentally harmful chemicals to the environment. So, biopolymers are one so which needs appropriate conditions of moisture temperature and oxygen availability but even upon disintegration so it will not lead to any toxic or harmful residue.

So, the classification group 1, group 2, group 3. The group 1 contains extracted polymers, so which are directly extracted or removed from the biomass, examples are all polysaccharides films, charged cellulose and proteins based and polypeptides and polynucleotides all are group 1 or extracted polymers. Group 2 are synthesized polymers so they are produced by classical chemical synthesis using renewable bio based monomers or mixed source of bio based as well as petroleum. It is not pure bio polymer.

So, either we use chemical synthesis using bio based materials or in the raw materials itself along with bio based material there may be petroleum products as well. So, example is polylactic acid and bio polyester.

The third one is microbiologically transformed polymers. So, they are produced by microorganism or genetically modified bacteria. So, examples are PHB polyhydroxybutyrate and bacterial cellulose, xanthan, curdian and pullan. So, these are microbiologically transformed polymers.

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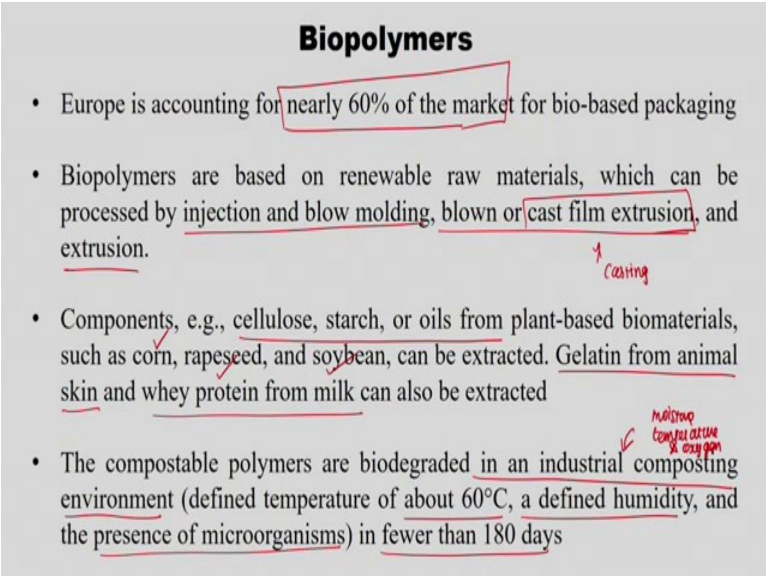

So, the next is what is the market for this bio polymers? Bio polymers are nothing but biodegradable materials. So, they account for nearly 60 percentage of the market but in Europe. So, that is the highest one among the world and biopolymers are based on renewable raw materials which can be processed by injection or blow molding or blown or cast film extrusion. So, this we know by now and extrusion pure extrusion itself. So, otherwise it can be casting technique also we can be used to produce the film or cast film extrusion or extrusion alone.

The components cellulose, starch or oils from plant based biomaterials are nothing but corn rapeseed and soybean can be extracted. So, this can be called as a extracted polymers. Gelatin can be extracted from animal skin and whey protein from milk. And the compostable polymers are biodegraded in an industrial composting environment. So, certain biopolymers we cannot say they are bio degradable. So, biodegradable in the sense when you throw in the environment it itself should be disintegrated or fragmented.

So, whatever may be the environmental conditions but here the compostable polymers are biodegraded in an industrial composting environment. So, that means we are maintaining the moisture level and temperature and oxygen. So, define the temperature of about 60 degree a defined humidity and presence of microorganism as well as oxygen level in fewer than 180 days. So, here the composting, composting means we are maintaining a industrial composting environment which is defined as about temperature of about 60 degree and with defined humidity and presence of microorganism to disintegrate fewer than 180 days.

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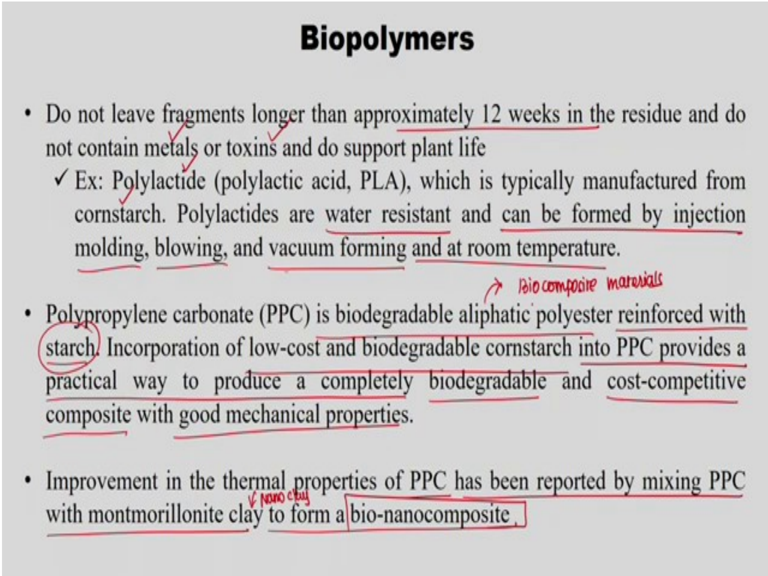

So, do not leave fragments longer than approximately 12 weeks. So, 12 weeks in the residue and do not contain any metals or toxins and do support plant life. So, even though it is biodegraded in the industrially composting environment. So, they do not contain any metals or toxins after they degraded. And also they support plant life. So, example is polylactide which is nothing but a PLA polylactic acid which is typically manufactured from cornstarch, cornstarch is the bio source from which the PLA is produced.

So, this polylactides are water resistant and can be formed by injection molding or blowing or vacuum forming at room temperature and when they have to be degraded we suppose to maintain an industrial composting environment. So, PLA cannot be degraded on its own.

Then polypropylene carbonate PPC, which is a biodegradable aliphatic polyester reinforced with starch. So, PPC is reinforced with the starch. So, this incorporation of low cost biodegradable cornstarch into PPC provides a practical way to produce a completely biodegradable and cost competitive composite with good mechanical properties.

So, now we are slowly introducing how do we combine two materials to achieve specific purpose. So, in that we PPC polypropylene carbonate is reinforced with the starch material. So, addition of starch material into PPC reduce the cost as well as the biodegradable corn starch into PPC provides a biodegradable nature for the PPC and also it gives good mechanical properties. So, this can be called as biocomposite material.

So, then next one is improvement in thermal properties of PPC has been reported by mixing PPC with montmorillonite clay to form a bio nanocomposite. So, next one we are introducing is a bionanocomposite. So, the biodegradable nature when they are introduced into the composite material by combining two materials those are called bio composite material.

So, the same PPC can be mixed with the montmorillonite clay, so which is nothing but a nano clay. So, now one dimension we got in terms of nanomaterial. So, when this nanomaterial is added into this biocomposite material it is called bio nanocomposite material.

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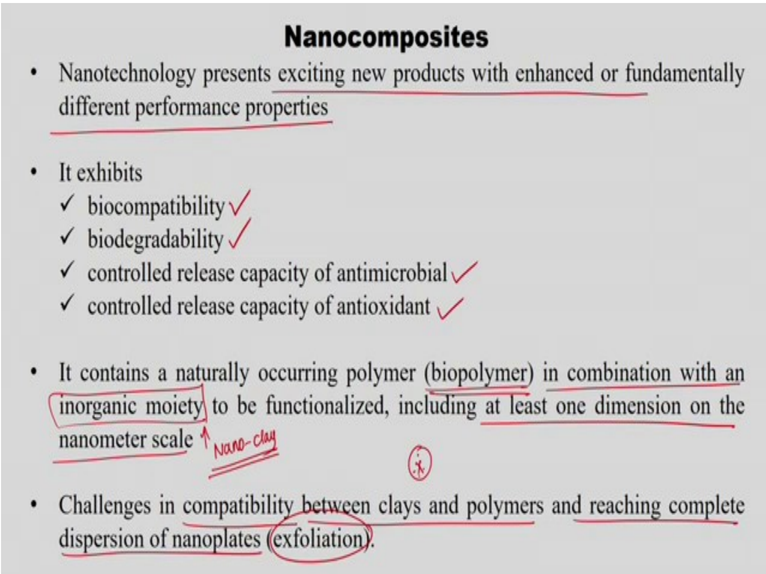

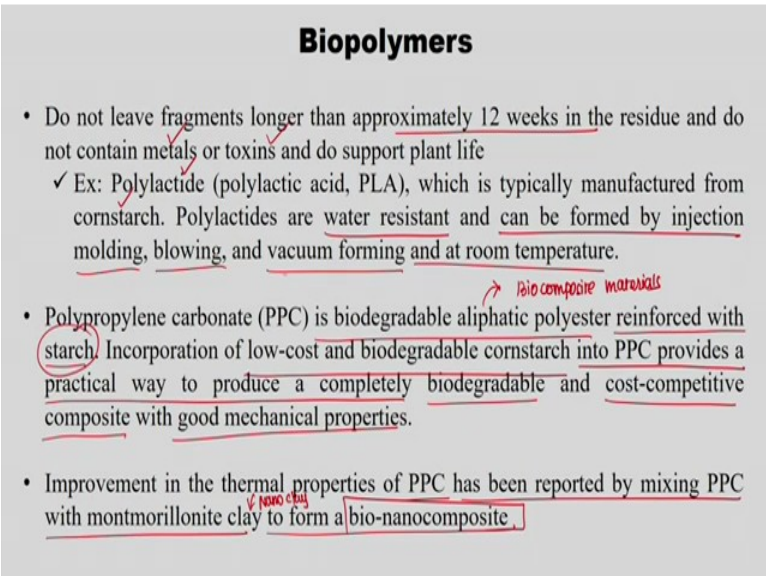

So, what is nanocomposites, nanotechnology presents exiting new products with enhanced fundamentally different performance properties, so all because it increases the surface area. So, when you go more into smaller and smaller you get good surface area more, so that is why your functional properties are improved.

So, this introduction of nanotechnology in this composite materials area paved a way to new exiting products and it exhibits biocompatibility, compatibility means between two materials and biodegradability, natural degradation and controlled release capacity of antimicrobial agent if any and control release capacity of antimicrobial agent if they are added and controlled release capacity of antioxidant if they are added.

So, it contains a naturally occurring polymer which is nothing but a bio polymer in combination with an inorganic moiety, inorganic moiety is nothing but our nano clay to be functionalized including at least one dimension on the nanometer scale. So, it contains a naturally occurring polymer which is called biopolymer in combination with an inorganic moiety, so which is nothing but what we used here to improve the property of thermal property of PPC is nothing but montmorillonite clay. So, which is nothing but a nano clay.

So, the nanoclay is included in the bio polymer to as an inorganic moiety to functionalize them. So, in the inorganic moiety order here is having a nano scale dimension, so that is why it is called bio nanocomposite.

So, challenges and compatibility between clays and polymers and reaching complete dispersion of nanoplates, so that is nothing but we call it as a exfoliation. So, this is what the challenging part here. So, it is not like I mix the two materials, so we cannot always expect we mixed two different property materials but they will combine together or dispersed with high degree and give always better property. So, that may not be true in all cases.

So, challenge here is how I reliably or how the degree of mixing between these two materials can be enhanced. So, that is what we call it as a exfoliation. Exfoliation is the final target. So, exfoliation means proper mixing of this inorganic moieties with the polymers. So, how to reach that challenge or how to reach that end goal is a challenge in making bio nanocomposite material for food packaging applications.

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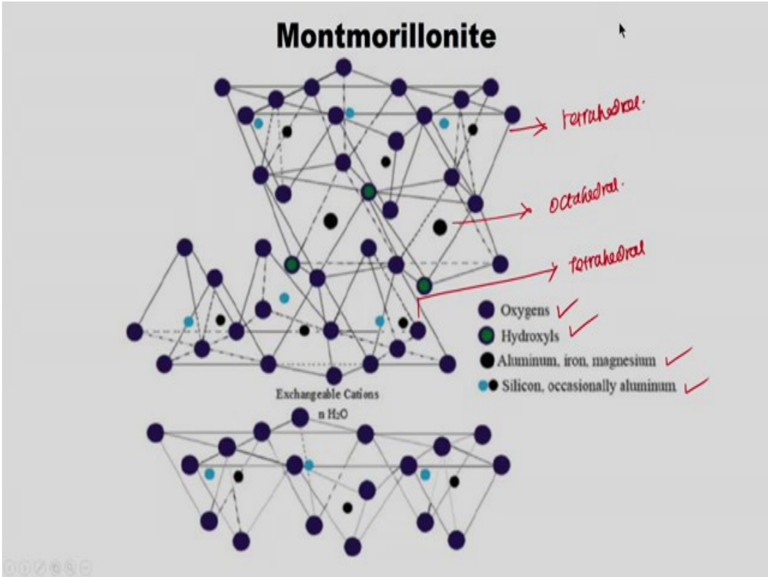

So, this is the montmorillonite structure. So, you have got oxygen, hydroxyls, aluminum iron and magnesium, silicon or occasionally aluminum. So, this silicon or aluminum which gives the tetrahedral structure. So, here also you will get tetrahedral. So and in between so you have got aluminum, so which gives octahedral. So, here in the next slide we will see in detail.

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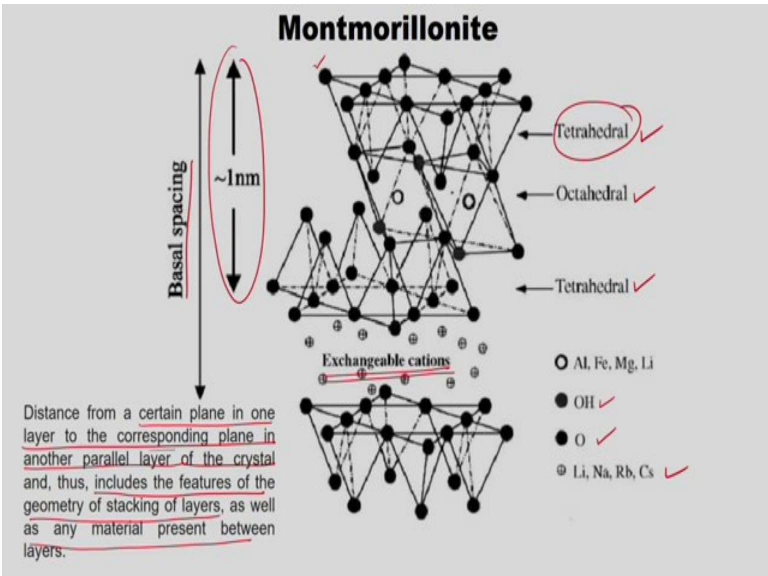

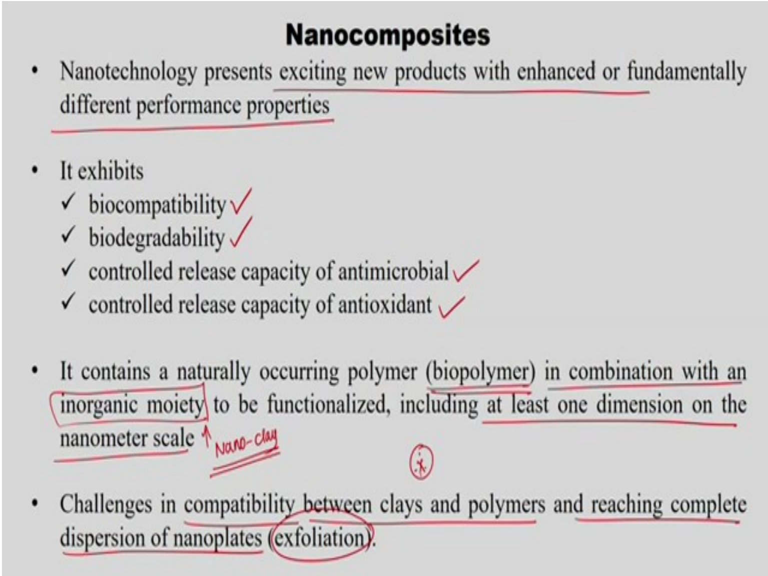

So, here you have got tetrahedral, so in between you have octahedral, so again you have tetrahedral and in between you have got exchangeable cations to have proper molecular attraction and OH I talked about O I told here, so this exchangeable cations are nothing but lithium, sodium, rubidium, cesium. And here so this dimension is about 1 nanometer. And this is something called basal spacing. So, basal spacing is nothing but distance from a certain plane in one layer to the corresponding plane in another parallel layer of the crystal.

So, this is the plane, so distance from certain plane in a one layer, so this particular layer to the corresponding plane, so this is another corresponding plan so till then. So, the distance from a certain plane in one layer to the corresponding plane in the another parallel layer of the crystal is nothing but a basal spacing, so which is includes features of the geometry of stacking of layers. So, here if you see this particular layer you got a three stacks, one is tetrahedral, octahedral as well as one more tetrahedral.

So, which includes stacking layers as well as any material present between the layers. So, here we have lot of material present between the layers so this is called basal spacing. So, why we are talking about here, so here we said that the challenges in compatibility between the clay and polymer and reaching complete dispersion is a challenge. So, we have seen about the montmorillonite structure bit not in the detail but what are all there and what is called basal spacing what is it dimension etcetera.

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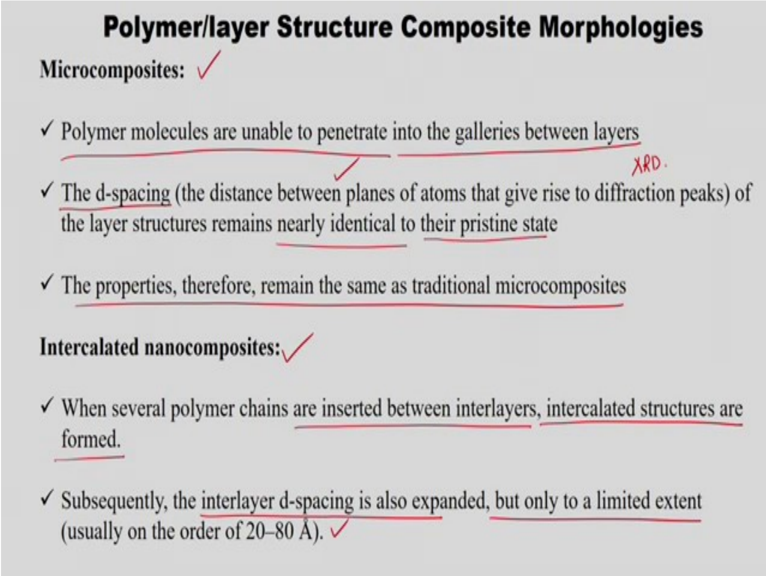

So, now we are going to see, so how this composite morphology can be. So, before reaching the state of exfoliated nano composites, so there are other composite morphology as well, one is micro composite another one is intercalated nanocomposites and final one is nothing but exfoliated nanocomposites. Micro nanocomposites they are here. The polymer molecules are unable to penetrate into the galleries between the layers. So, here the polymer molecules cannot penetrate galleries between the layers of the nanoclay.

So, the d spacing, d spacing is nothing but distance between plane atoms that give rise to diffraction peaks in XRD. So, the d spacing of the layer structure remains nearly identical so there is no change in d spacing. So, they still remain in the pristine state. So, the properties therefore remain the same as traditional micro composite. So, if you see micro composites, so you are just mixing nanoclay with the polymeric materials but you will not see any mixing between the polymer as well as nonoclay composites or nanoclay materials and the properties also same it is just that I just brought two materials together.

The second one is most of the researchers’ report which is nothing but intercalated nanocomposites. When several polymer chains are inserted between inter layers. So, that means the layers between the nanoclay material and intercalated structures are formed. So, that is the way intercalated structures are formed. So, they are the d spacing is also expended between two layers but only a limited extent usually in the order of 20 to 80 angstrom.

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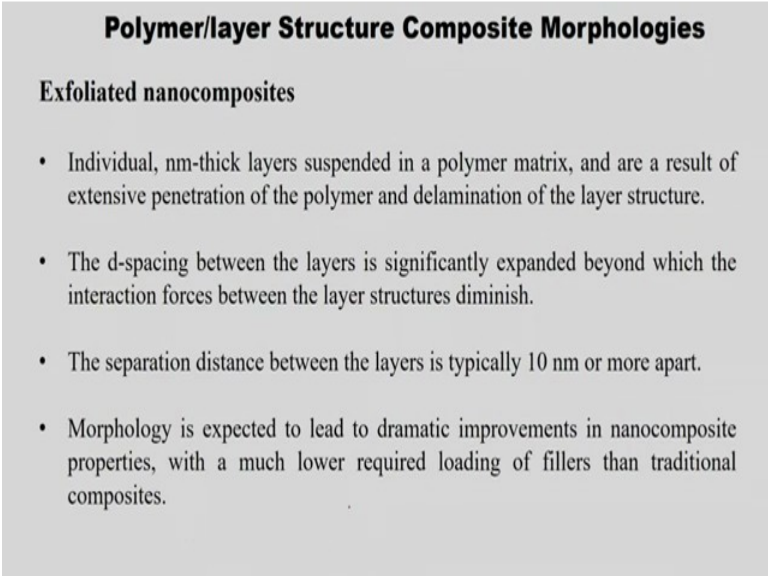

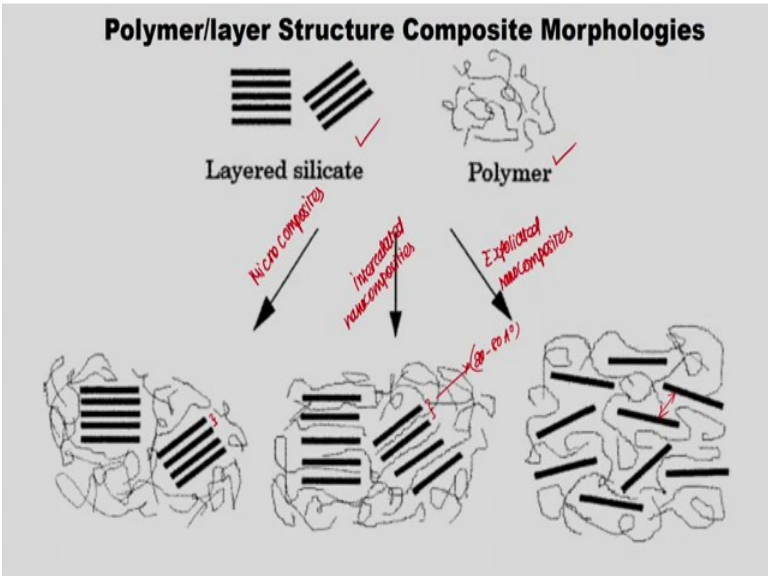

So, the last one is nothing but a exfoliated nanocomposites. So, if you see here you will better understand. So, here you have a layer silicate, so which is nothing but kind of nanoclay. So, here you have a polymer material, so this is nothing but your micro composite. So, here your polymer could not enter into the space between two layers. So, the nanoclay property whatever property it got it will be same and whatever property polymeric material have so that also will be same. There would not be any property change upon mixing.

So, the second one is nothing but intercalated composites and also remember if layer silicates are in nano range you can say them as a nanocomposite as well. So, here if you see that d spacing is bit increased so this is what we said that so 20 to 80 angstrom. level. So, this also has got in between micro composites and this one is nothing but exfoliated composites, so this is the ultimate one. So, the d spacing is increased and also your polymer could penetrate through the inter space layers.

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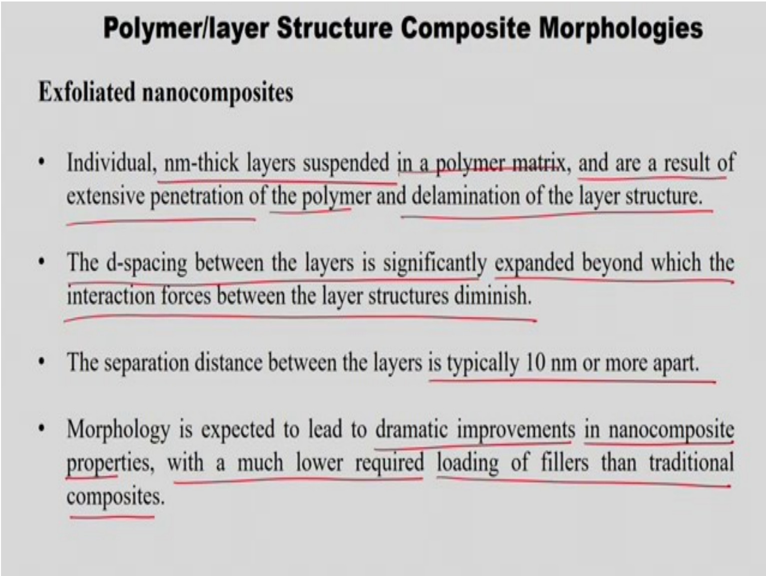

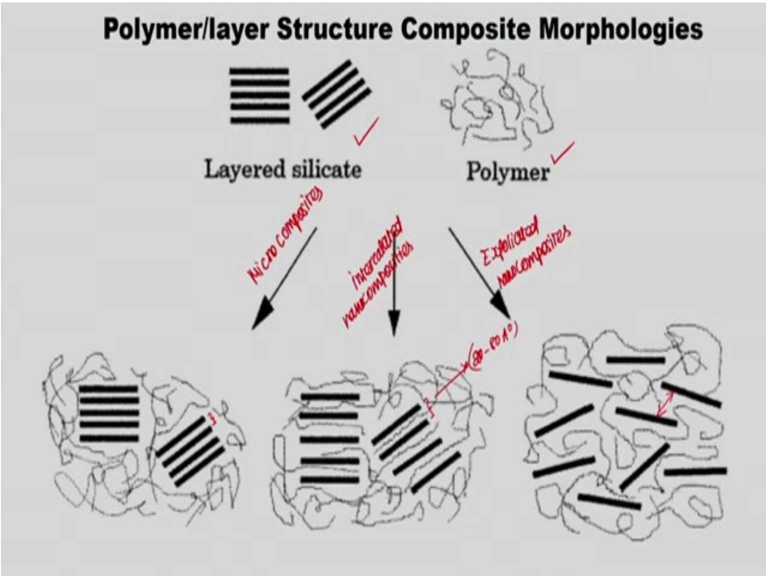

So, individual nano meter thick layers suspended in a polymeric matrix and are as a result of extensive penetration of the polymer and the delamination of the layer structure. So, if you see compare to intercalated structures, so here the d spacing is also improved and also the polymer could go inside the layered silicate. So, delamination of the layer structure also happen the d spacing between layers is significantly expanded beyond which the interaction forces between layer structures diminish.

So, here also it is expanded beyond which the interaction forces between the layer structures diminish. So, if it extend beyond this exfoliation then there would not be any interaction forces between the layer structures as well. So, it is extended to that particular level. And the separation distance between the layers is typically 10 nanometer or more apart. Morphology is expected to lead dramatic improvements in the nanocomposite properties with a much lower required loading of fillers than traditional composites.

Micro composites as we already told there is now property change. So, compare to intercalated composites, so this exfoliated nano composites have dramatic improvements in the property and also if the property improvement is very high, so then there may not be required high amount of fillers or high amount of layers silicate we may not be required to increase the property. So, this is what micro composites and intercalated nanocomposites as well as exfoliated nanocomposites.

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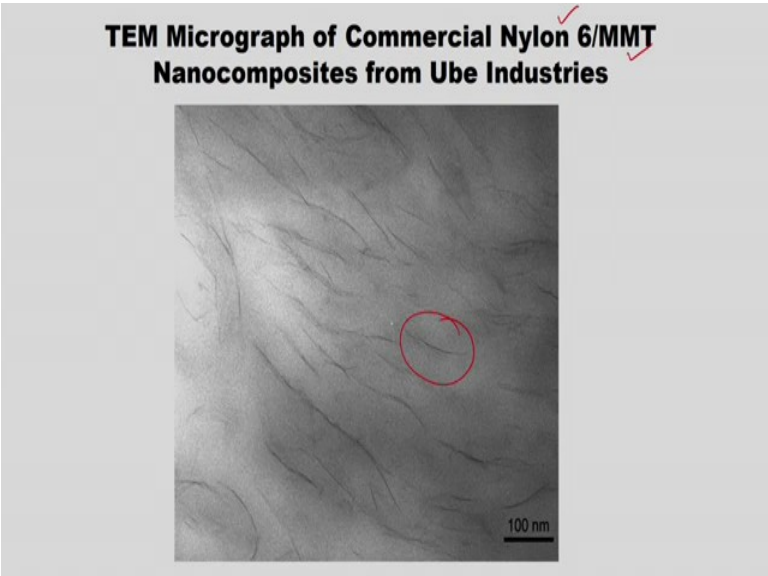

So, then this figure also taken from the same article so which shows the TEM micrograph of commercial nylon 6 and MMT, MMT is nothing but the same nanoclay. So, nanocomposites from Ube industry. So, you can clearly see about your the layered structure in the polymer. So, this figure shows better exfoliated nanocomposite structure or morphology.

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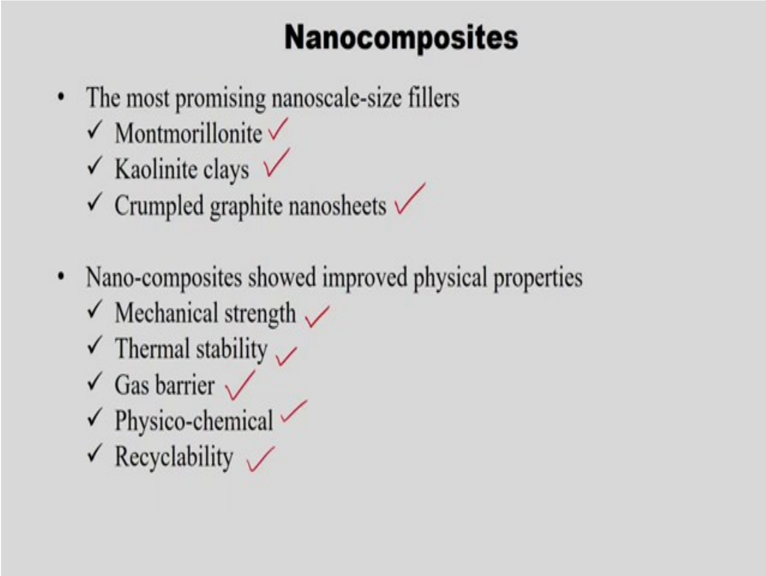

So, nanocomposites what are all those nano scale size fillers are used as montmorillonite and kaolinite clays and crumpled graphite nanosheets also can be used. So, this shows improved mechanical strength, thermal stability, gas barrier property, physico chemical properties and recyclability. And here one thing we need to also remember is so since we used a nanoclay. So, we need to be extra careful because this are going as a food packaging material. So, these nanoscale fillers what we used should not be harm to the food and also when we throw into atmosphere, so you should not create any environmental pollution.

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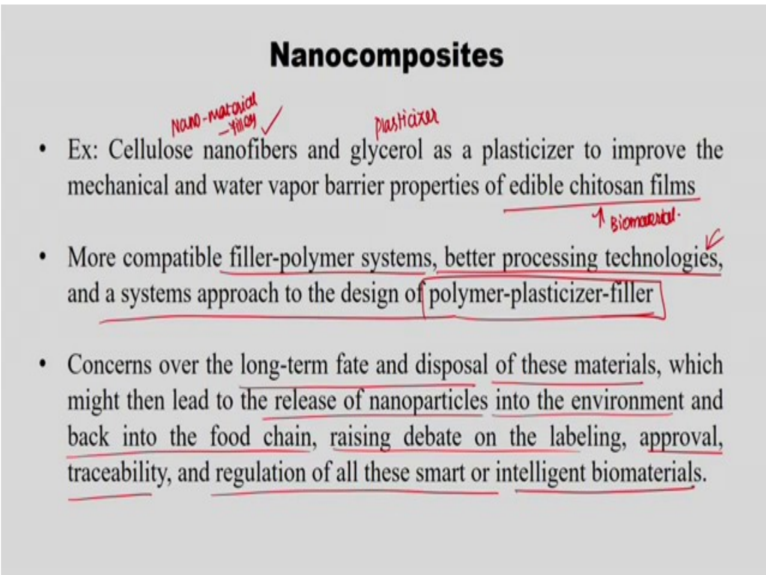

So, example is cellulose nanofibers and glycerol as a plasticizer to improve the mechanical and water vapor barrier properties of edible chitosan films. There is a research report. So, in the research report it says that so in the edible chitosan films, the cellulose nanofiber as a nanomaterial and glycerol as a plasticizer added to improve the mechanical and water barrier properties. So, here it is plasticizer and this is a nanomaterial or we call it as a filler and this is nothing but a bio material.

So, this combination, in the biomaterial the nanomaterial is added as a fillers and to improve the plasticizing effect glycerol is added as a plasticizer. So, from this research report it was reported that so it improves the mechanical and water vapor barrier properties of the chitosan film. Obliviously, when we add the fillers so it acts as a good barrier and when the crystallinity is improved your mechanical property also would improve.

More compatible filler polymer system, so that means the nano material as a filler and bio polymer as a polymer system better processing technology and better processing in the sense how effectively we mixed both of them to get the exfoliated structure. And system approach to design of polymer plasticizer and filler. So, this is what we call it as a bio nanocomposite material for food packaging application.

Polymer, plasticizer and filler system. So, how effectively we design such a polymer plasticizer and filler system depends upon the compatibility between the filler and polymer system and how do we process that, so all together contribute to better polymer plasticizer fillers bio nanocomposite material.

Concerns over the long term fate and disposal of these material, this I expressed already which might then lead to the release of nanoparticles into the environment and back into the food chain raising debate on the labeling approval traceability and regulation of these smart and intelligent biomaterials. So, this is another concern we need to be careful about.

So, how it is going to be impacting the environment and also it is going back to the food chain. So, which raises the debate how good it is to use this smart and intelligent biomaterials.

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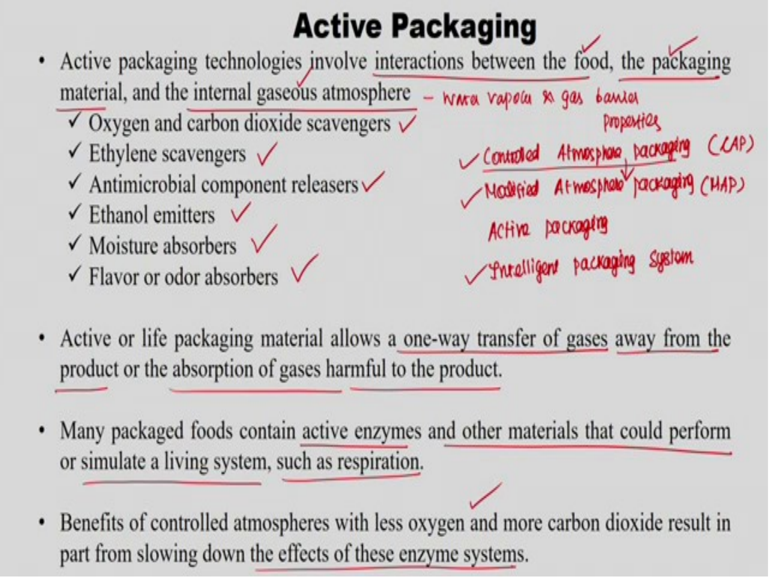

So, then the next one is so these polymer filler and plasticizing composites or nanocomposites can be used as a food packaging material. So, this is called active packaging so which solves the following purpose because it interacts between the food and the packaging material and also internal gaseous atmosphere. So, that we talked about in water vapor and gas barrier properties.

So, this active packaging technologies involve interactions between the food and the packaging material and internal gaseous atmosphere, so it interact with all of them. So, this has got one of these functions, one is oxygen or carbon dioxide scavengers and sometimes as an ethylene scavengers and antimicrobial component releases and ethanol emitters, moisture absorbers, flavor or odor absorbers.

So, this all together, if these functions are incorporated in the packaging material, so it serves as the active packing material. So, apart from this active packaging material. So, we have also got certain things discussed in the last class itself but still I would like to remind you.

So, there are something called controlled atmosphere packaging and modified atmosphere packaging. So, this we call it as a CAP so this is MAP and active packaging system so that is what we are discussing now and there are something called intelligent packaging system. So, this controlled atmosphere packaging system which involves the controlled atmosphere inside the packaging itself.

So, this is most of the time will create a problem for example if the packaging material has got certain permeability to the water vapor or any condensable vapors or liquid or gasses, so then your controlled atmosphere inside the packaging material whatever we have designed may get change and also if there are any respiration activity so that also this controlled atmosphere packaging can be altered during the packaging or during storage and distribution.

During storage and distribution the package atmosphere the controlled atmosphere may get change when there is any respiration or there may be a permeation of water vapor or other gasses through the packaging material. So, after realizing that fact then it put under modified atmosphere packaging itself.

So, the modified atmosphere packaging is nothing but so based on the packaging permeability and based on the food packaging or food material respiration activity, so the atmosphere inside the package can be modified based on the rate what we wanted and also for example if we wanted to store it for 30 days. So, accordingly the atmosphere inside the packaging can be or inside the packaging for the food material can be adjusted.

So, active packing anyway we are going to see intelligent packaging, I already told there is a sensor system also comes along with packaging. So, this sensor system tells the consumer that so there is some contamination happened inside the food material. So, that is nothing but intelligent packaging system.

So, what we are doing is active packaging, active packaging in the sense I add the active components in the packaging material itself, so that can serve as a function of oxygen or carbon dioxide scavengers, ethylene scavengers, anti-microbial component releases, ethanol emitters, moistures absorbers and flavor or order absorbers.

So, active or live packaging material allows one way transfer of gases away from the product. So, it is nothing like the normal packaging, so the normal packaging has got degree of permeability. So, based on the needs but here in the active packaging only one way transfer of gases away from the product is allowed or it can allow the one way transfer or it can itself absorb the gases which are harmful to the product. So, basically it should transfer the gases which are harmful to the product or it should be able to absorb within itself.

Many packaged foods contain active enzyme and other materials that could perform or simulate a living system such as respiration. So, this we just discussed and benefits of the controlled atmosphere with less oxygen and more carbon dioxide result in part from slowing down the effects of these enzyme systems. So, if we maintain the controlled atmosphere with less oxygen and more carbon dioxide so which slows downs the respiration because we do not have enough oxygen for this activity.

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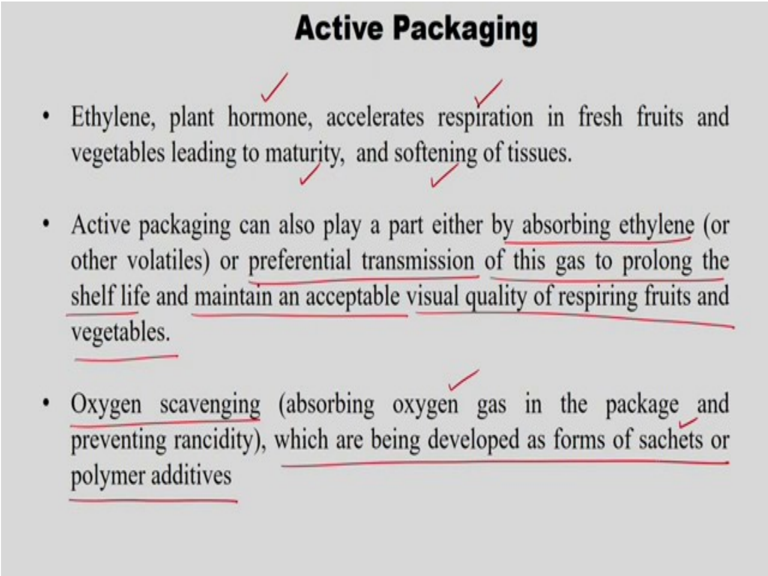

So, the ethylene which is nothing but a plant hormone, so which accelerates this respiration in fresh fruits and vegetables which leads to maturity and softening of tissues. Sometimes that yellowish color also it creates the ethylene. So, active packaging system also play a part either by absorbing ethylene or preferential transmission of this gas to prolong the shelf life and maintain an acceptable visual quality of the respiring fruits and vegetables.

So, if there are any respiring fruits and vegetables to be packed so we can use the active packaging system which has got absorbing capacity of ethylene or it should preferentially transmit ethylene inside the packaging material to outside environment. So, oxygen scavenging also got same function which either absorb the oxygen in the packaging or it can transmit the oxygen, so which prevents the rancidity which are being developed as a forms of sachets or polymer additives.

So, sachets also we can put as an oxygen scavengers but active packaging role is nothing but so we can add some additive in the packaging film itself to serve as an oxygen scavengers.

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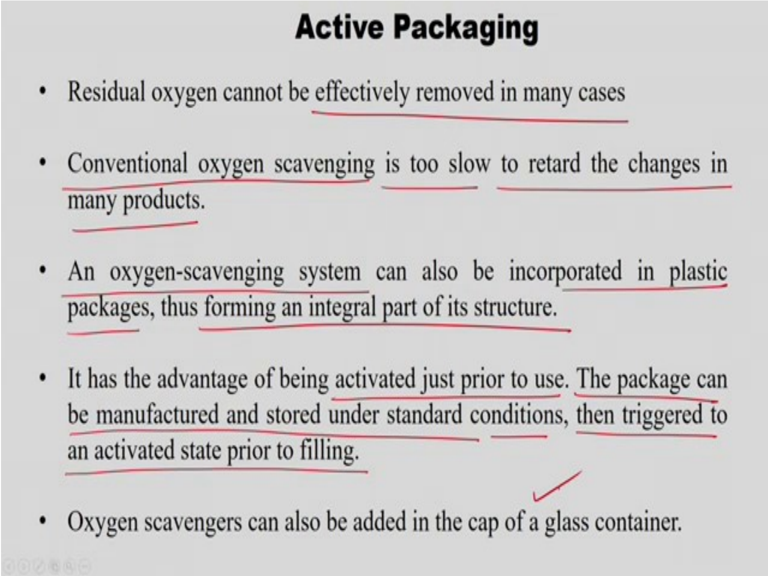

So, the residual oxygen cannot be effectively removed, so the question is here. So, we discussed in the earlier classes, so we take care of the head space and we remove the oxygen inside the thermal processing. During thermal processing we ensure that there is no oxygen and also we maintain the head space vacuum. So, not to have any have oxygen inside the cans.

But here it will be very difficult to say even though we said, we maintain a head space vacuum and we ensure that there is no oxygen inside the packaging or inside the cans during thermal processing. There may be residual oxygen which cannot be effectively removed. So, this conventional oxygen scavenging is too low to retard the changes in the many products. So, there are conventional oxygen scavenging technics as well so as we said like we can put any sachets or kind of scavengers but that is very low to retard the changes in the many product.

So, an active oxygen scavenging system it is that the plastic packages or designed in such a way that they also take part in the oxygen scavenging activity. Thus forming an integral part of structure itself. There is no extra oxygen scavengers to be added in the food or there will not be any extra sachets which is added inside the packaging. It has the advantage of being activated just prior to use.

The package can be manufactured and stored under standard conditions, then triggered to an activated state prior to filling. So, this kind of active packaging system the oxygen scavengers are added in the film formation or the packaging material formation itself and the packaging can be manufactured and stored under normal conditions whenever the packaging is used for filling at that time the oxygen scavenger activity can be triggered. So, these oxygen scavengers are also added in the cap of a glass container, so this is also another active packaging system.

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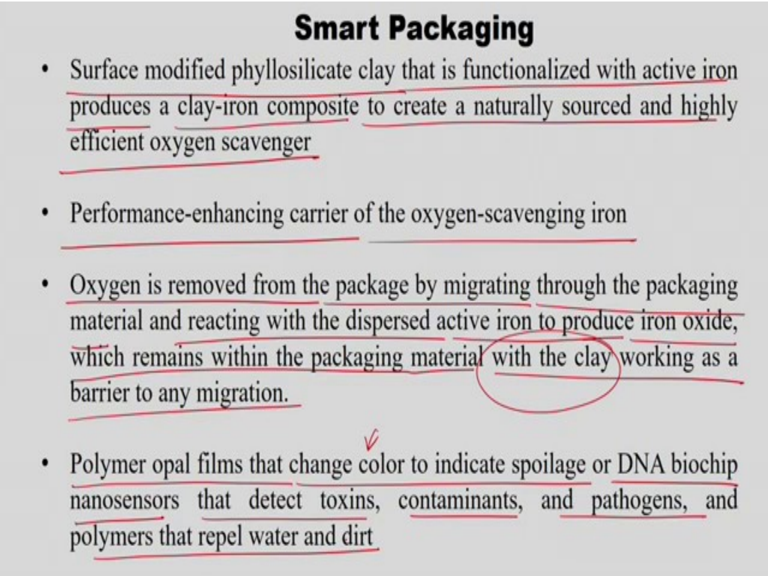

So, then what is called smart packaging, so we can also call it as an intelligent packaging. So, here what we are doing is the surface modified phyllosilicate clay that is functionalized with active iron produces an clay-iron composite to create a naturally sourced and highly efficient oxygen scavenger. So, here the surface modified phyllosilicate clay which is functionalized with the active iron. So, instead of directly using the active agent so here we are doing in the phyllosilicate clay.

So, we already talk about polymer filler and plasticizer unit. So, here the filler is nothing but phyllosilicate clay. In the clay itself we functionalized with a active iron content. So, this clay-iron composite creates a naturally sourced highly efficient oxygen scavenger. You know iron is nothing but a good oxygen scavenger, the performance is enhanced. So, this is the performances increased due to carrier oxygen scavenging iron.

So, what happens exactly is oxygen is removed from the package by migrating through the packaging material and reacting with the dispersed active iron to produce iron oxide. So, which remains within the packaging material with the clay working as a barrier to any migration. So, what we are telling here is, so here in the packaging material itself where we have a phyllosilicate clay, so the phyllosilicate clay is here functionalized with the active iron component, so which interacts with the oxygen and forms an iron oxide and the clay present in it act as a barrier not to migrate further.

So, it basically absorbs the iron oxide because if it goes to food then it may be a problem again. So, what happens here the oxygen is removed from the packaging by migrating through the packaging material and reacting with the dispersed active iron which is there in the phyllosilicate clay itself and forms the iron oxide. So, the formed iron oxide remains within the packaging material itself. So, with the clay working as a barrier to any migration. So, here the clay takes care of absorbing the iron oxide which is produced during oxygen scavenging action.

And some polymer opal films so that change color to indicate the spoilage or DNA biochip nanosensors that detect toxins, contaminants and pathogens and polymer repel water and dirt. So, some of the polymer opal films also can be used so which has got changed in color property based on the contamination level. And certain cases DNA biochip nanosensors also use to detect the toxins, contaminants and pathogens.

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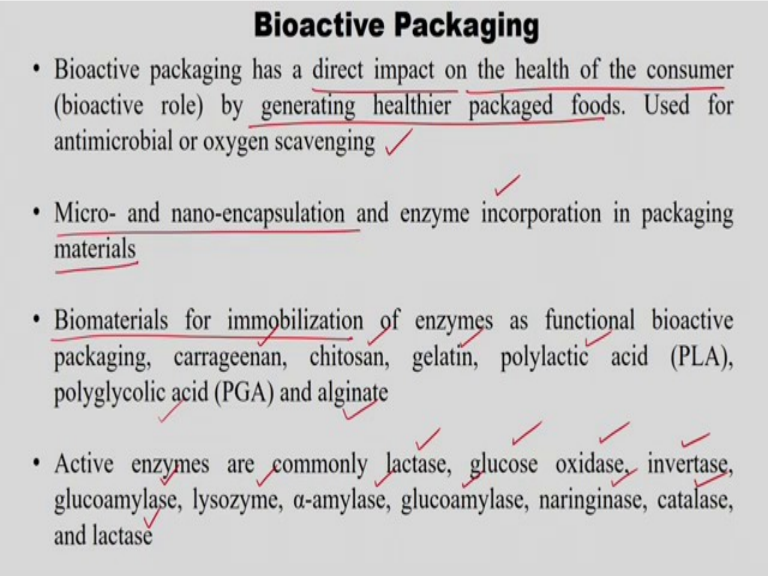

Then the next one is bioactive packaging. So, what is the difference between the active packaging what we have seen and bioactive package? So, active packaging we are adding the active materials, in smart packaging we also check the contamination level. So, without using any extra active materials either we do it with the normal packaging whatever we use in the filler itself the active scavenging agent is added and that is the way oxygen scavenging is done. And also we told about the polymer films changing its color upon contamination.

So, here in the bioactive packaging it is not only playing an active role but in bioactive packaging so it has got great impact on the health of the consumer. So, it also play a role in the health of the consumer by generating healthier packaged food. So, this is used for antimicrobial or oxygen scavenging purpose. So, the example is micro nano encapsulation and enzyme incorporation in the packaging material. So, here we do micro or nano encapsulation or enzyme incorporation in the packaging material.

So, biomaterials for immobilization of enzymes, so here we said that so enzyme incorporation. So, how do we incorporate the enzyme in the packaging material? So, that we do using immobilization. So, for this the functional bioactive packaging used or carrageenan, chitosan, gelatin and polylactic acid and polyglycolic acid and alginate. So, this are used as a bio material to immobilize the enzyme.

And active enzymes are commonly lactase, glucose, oxidase, invertase, glucoamylase, lysozyme, alpha amylase, glucoamylase, naringinase and catalase and lactase. So, this are active enzymes. So, the active materials, packaging material which used as this enzyme immobilized biomaterials are this materials.

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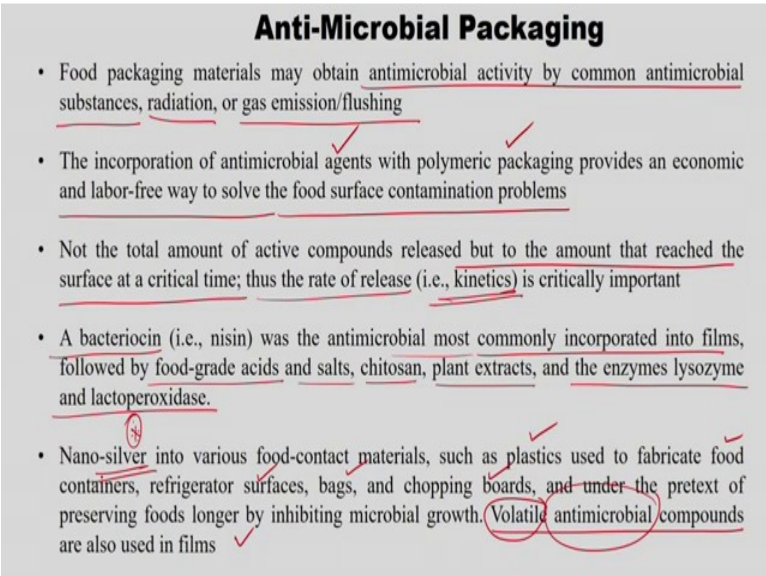

The next one is the antimicrobial packaging. So, food packaging materials may obtain antibacterial activity by common antibacterial substances by radiation or gas emission or flushing. So, either one of the way the antimicrobial packaging system can be done. So, here the food packaging materials itself got antibacterial activity. So, by radiation or by gas emission or flushing.

So, the incorporation of antimicrobial agents with the polymeric packaging provides an economical labor-free way to solve the food surface contamination problems. So, here so instead of adding a separate substance in the food material or radiation means for example laser or IR radiation so that is again harmful to food and gas submission and flushing as well.

So, instead of doing we try to think how the antimicrobial agents can be directly added in the polymeric packaging system itself to provide the purpose of antimicrobial packaging. So, not the total amount of active components released but the amount that reached the surface at critical time that is important. This we call it as a rate of release which is a critically important parameter.

So, if you see antimicrobial packaging there are lot of research and development happened in this particular area. So, if you see there are lot of research article above to a maybe 500 also you may find when you search for. So, all this things says that the such kind of antimicrobial packaging system are common and it can be done. But the critical issue to be solved is so it is not like how much active components are released, how we can have at a critical time, so how much released to be there at the food surface, so that is what we call it as a kinetic.

So, that is what critically important because controlled release, you cannot release it everything at together. So, controlled release to prolong the shelf life. So, till it goes for consumption so during the storage and distribution so how this antimicrobial materials can be released at a controlled rate. That is what the critical issue to be addressed. Otherwise, the antimicrobial packaging system are now a days very much common.

So, a bacteriocin are which is called nisin was the antimicrobial most commonly incorporated into the films followed by food-grade acids and salts, chitosan, plant extracts and the enzymes lysozyme and lactoperoxidase. So, this all got antimicrobial activity. So, the bacteriocin is the common antimicrobial agent which is included in the packaging material. And also along with that foodgrade acid, salts, chitosan and plant extracts and lysozyme and lactoperoxidase also added as an antimicrobial agent.

And another important is this particular material which is nano silver so which are added into various food contact materials such as plastics used to fabricate food containers, refrigerator surfaces, bags and chopping boards and under the pretext of preserving foods for longer by inhibiting the microbial growth. So, silver has got very good anti microbial property and also we just said when you make it a nano material so it has got its own advantages the property also improves. So, it can also contribute to that.

So, this nano silver now a days got attracted in the antimicrobial packaging system. So, this is added in most of the plastic food containers, refrigerator surfaces, bags and chopping boards. And there are certain volatile antimicrobial components also used in the films. So, in such case this antimicrobial compounds need not interact with the food. So, this are volatile so it volatilize. So, we need not have this materials in the food surface to do the antimicrobial activity.

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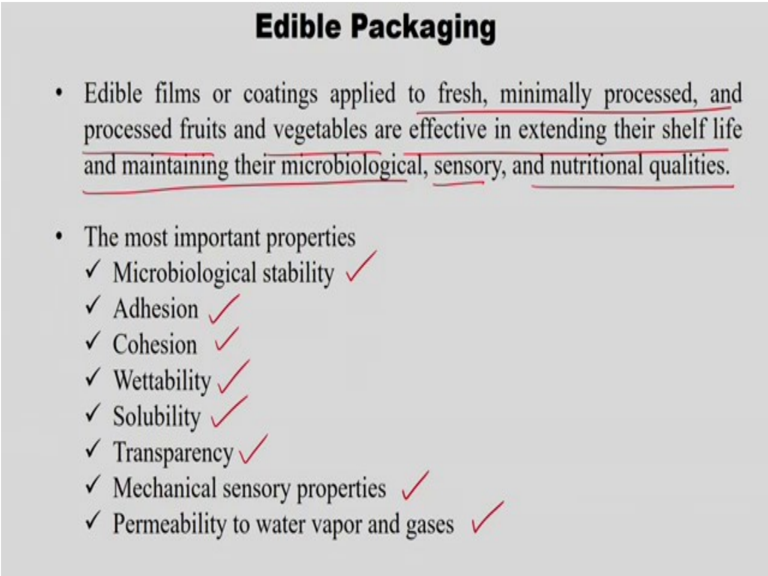

So, the next one is edible packaging. So, the edible films and coatings applied to fresh minimally processed and processed foods and vegetables are effective in extending their shelf life and maintaining their microbiological sensory and nutritional qualities. So, instead of active packaging, active packaging in the sense active materials are directly included in the films. So, instead of that so we can coat those material bioactive materials in the surface of the films as well. So, it gives the good microbiological sensory and nutritional quality.

So, that means the edible packaging can be done to fresh also minimally processed and processed foods and vegetables and which are effective in extending the shelf life of food by maintaining the required microbiological characteristics and sensory properties and nutritional qualities.

So, the most important properties we need to consider while doing the edible coating or microbiological stability of the coating material and adhesion on the film surface or any packaging material surface and cohesion and wettability, solubility, transparency, mechanical sensory properties and permeability to water vapor and gases. So, this are all the properties we need to check before coating any edible coating material on the packaging.

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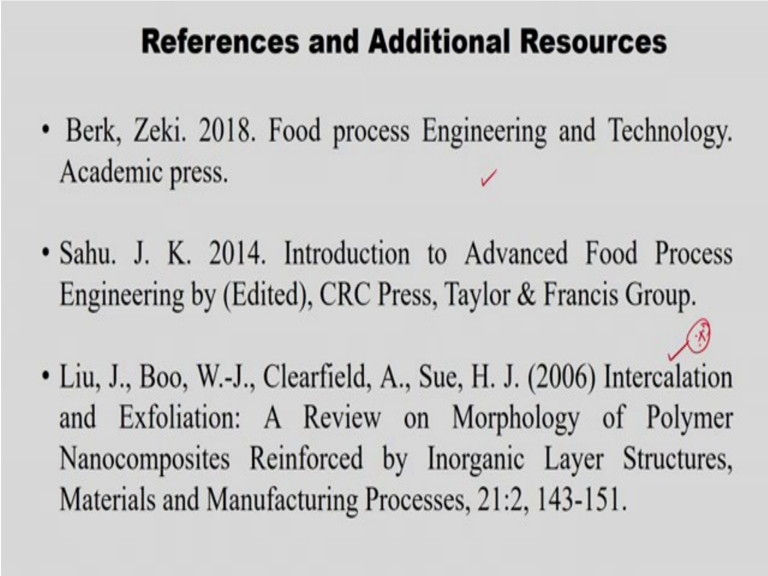

So, here I stop. So, the next class we talk about the regulations and food processing industry. So, here in this particular research article I have taken the whatever the polymer layer silicate interaction as well as the TEM image and these two literatures were used in this lecture. So, these are extra references and additional resources, so we will meet for next class thank you.