Processing of Non-Metals
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Module - 3
Glass: Properties and Processing
Lecture - 4
Ceramic Powder Preparation - 1

A warm welcome to all of you, in this lecture number 4 of our module on ceramics, as your well a wear that we are discussing the course on processing of non metals. And right now we are in the middle of our module number 3 that is ceramics. Before starting the discussion on ceramic powder preparation, this is the second lecture, one we have taken on ceramic powder preparation the previous one. Before starting the discussion today, let me first revise that what we have cover till now; we have seen the basic properties of the ceramics, we have seen the comparison of the properties of ceramics metals and polymers.

We have seen that what are the distinct properties or characteristics of ceramic materials, the bounding, the type of bounding that is present in ceramics also been highlighted and the relation has been drawn between the bounding and the properties of the ceramics. Since, our course is on processing aspect of the non metallic material our focus now onwards would be on the techniques or tools or methods that are employed to convert the ceramic raw materials into the ceramic products.

Now, what are the various type of ceramics all of you know, that in our previous lectures we have seen that the ceramics can broadly be classified into two broad categories. Now what are those two classifications? Classification number is, classification number one is based on the composition or the constituats, constituents of the ceramic material. That is of the material of which the ceramic is made up of. So, on the basis of composition if you remember we have classified the ceramics into four broad categories.

Now, what are those four broad category, we have seen the ceramics may exist a silicates, oxides, non oxides. A non oxides we may have nitrites or carbides and finally, the glass ceramics. But the another important category which is relevant with today's lecture is the classification on the basis of applications. If you remember on the basis of application we have seen that there are a high performance ceramics, there are a

household ceramics, cement, concrete; number of applications are there for the ceramic materials. We have highlighted it one or two slides that what are the important application areas of ceramic material.

So, we sees ceramics all around us; we see roof tiles, floor tiles, then we see the pottery items, sometimes decorative items are there, flower vase are there. Then in the advanced category we have bioceramics we have ceramics that are used in semi conducted devices, we have ceramics which are used for electrical insulation purposes. So, we see ceramics all around us. The important point for all of us to understand is that how the ceramic products are made? Since, the topic of our course is relevant to the processing aspects of ceramics.

But before going to the processing aspects of any material, we should have knowledge about the basic of that particular material. That what is that is material made up of? What type of bonding is present in that material? What type of mechanical chemical physical properties do that material process, because once we know about the properties of the material then only, we can convert that raw material into the final product. In the most cost effective and highly efficient manner if we do not know the properties of the material we may use it, and trial methods to convert that raw material into the final product.

Thus we may not be able to achieve our final product in a very cost efficient manner and the quality may not be all that good. The whole operation may not even be effective and efficient. So in order to be effective and efficient in our operations, in order to make good quality ceramic product, in order to make cost effective ceramics product, our main objective was to understand the basic concepts related to the ceramics. For that we have already engage two or three discussions, that is - Ceramics 1 and Ceramics 2.

Then we have seen the how are raw material is prepared for making a ceramic product? If you remember in our previous lecture we have seen a number of techniques which are used for preparation of ceramics powders? To name a few we have seen ball milling, roll crushing gyratory milling or crushing, then we have seen jaw crushing. So, deferent types of techniques are there which are use for producing the ceramic powder, but these type of techniques fall under one broad category that is the mechanical type of techniques for producing the ceramic powder.

There are chemical methods also that are used for producing the ceramic powders that we are going to see in today's lecture. But towards the end of our lecture today our focus would be on the processing that how the shape can be given to the ceramic products? What are the steps involved for giving a shape to a ceramic product? What are the important types of ceramic product processing techniques or ceramic processing techniques? So, with this introduction let us now start our discussion today.

So, in our today's lecturer our main focus would be the chemical methods of ceramic powder preparation and the fundamental or the basic aspects related to the processing of ceramics powders into the final product. So, before going into the discussion of today's lecture let us first see what we have covered in the previous class and that is also relevant to today's lecture.

The characteristics of powders because powders are the raw material for giving, shape to the final ceramic product. So, ceramic products are made up of ceramic powders. Now, what type of powder we are choosing for making the ceramics product product would dictate the properties of the product itself. So, what are the important characteristics that a ceramic powder should have?

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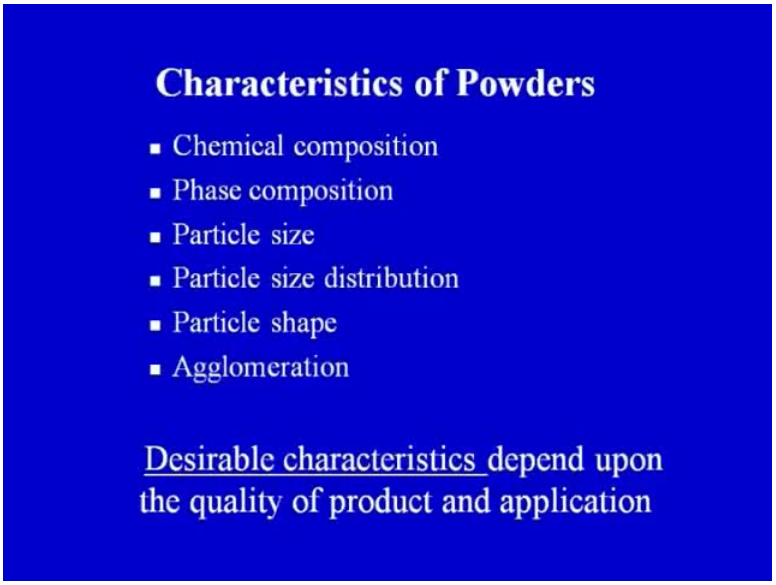

Chemical composition, phase composition, particle size, particle size distribution, particle shape and agglomeration. So, these are the important characteristics that have to be taken into account when we are producing or preparing a ceramic powder. We have

seen that depending upon the final application of the ceramic product, we would be choosing all these parameters or characteristics accordingly.

So, if the performance is very, very we can say sophisticated or a high performance application ceramic product has to be made, which means that the product has been designed for a very sophisticated application or a very high and application or a very advanced application. In that case we would choose all these characteristics very, very carefully. For example chemical composition, we would like to have a very high purity chemical composition of our ceramic powder, which is going to be transformed or converted into the ceramic product. Phase composition we may require a single phase composition only, multiphase may be nor may not be desired.

Then particle size, we we can have a coarser particle, we can have a final particl. So, for high and application in many cases we may advocate the use of the fine ceramic particle, that is particle should be less. Next is the particle size. Distribution particle size distribution means that we can have a wide range of the size is within one sample. If we take a sample of a ceramic powder, if we find that there are many x number of particles which are having the same size, there are y number of particles which are having the same size, but deferent from the size that the particles with x have.

So, we have number of categories of sizes, then we say that the particle size distribution is very wide. On the contrary we can have narrow range of the particle sizes or all the particles in the ceramic powder may be having in the same diameter, nearly same diameter. So, particle size distribution also in many cases we would see see to it that the distribution is not very wide. Next, is the particle shape sometimes we may advocate the use of a spherical size of a particle.

Last is a agglomeration we may advocate that the agglomeration of the particle should not take place. That is the lumps of particle should not be form. So, basically all these characteristics are very very important to understand when we are going to convert a specific ceramic powder into a ceramic product. The raw material should be of good quality, then only we will get a good quality product. If there are some defects some defects or the choice of these characteristics is not proper, according to the requirements of the final product, I am again emphasizing the point that we can have two diverse applications.

Let us take an example; one of the application is a decorative item that we have to place in our display room, that is a decorative item and the another ceramic product is a bioceramic or it is a biomedical implant. Now, both these applications will have deferent requirements and the characteristics of the powders that would be used for making these two diverse products that is one is the decorative item or a flower vase and other one is the biomedical implant.

So, the type of the powders that will go into the production of or the processing of decorative item would be different and for a biomedical implant it would be different and what would be different, the difference would be the difference would be in the characteristics of the powders, that have been chosen for making those products. So, this is really important. Again I am emphasizing in the last class also we have seen this particular characteristics.

So, the last we can say highlighted portion in this particular slide is that desirable characteristics is, depend upon the quality of the product and the application. Now, whatever characteristic we are choosing for that particular powder would dictate the quality as well as would be relevant towards the application of that particular product for a specific application. Four, let us now go from this particular characteristics slide to the another slide where we would be seeing, that how the methods for preparation of ceramic powders are classified?

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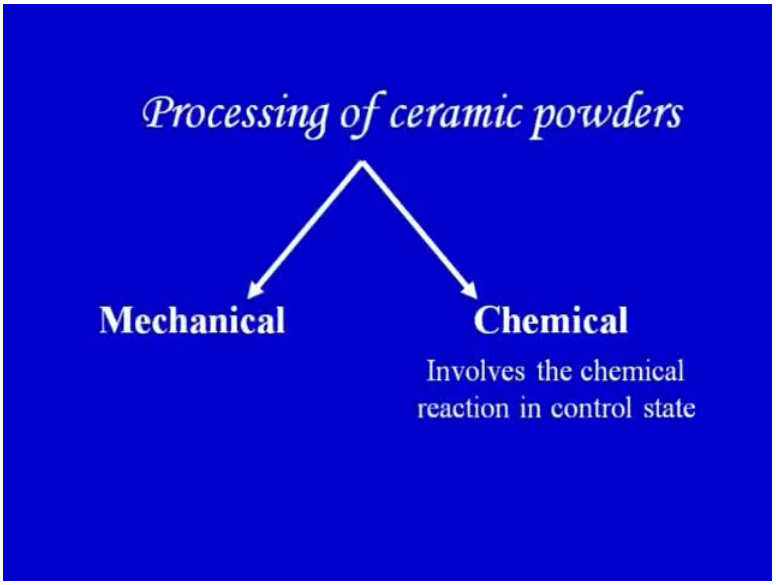

So, processing of ceramic powders can broadly be done in two important stages or two important directions. We can use the mechanical direction to convert a raw ceramic part into a ceramic powder or a ceramic raw material into a ceramic powder or we can follow the chemical direction to convert the basic, we can say ingredients into the ceramic powder or the basic ceramic ingredients into the ceramic powder.

So, we can follow two deferent directions, we can choose a mechanical direction and we can choose a chemical directions. So, preparation of ceramic powders or processing of ceramic powders can be done in two deferent manners. And if you remembers in our lecturers on in our third lecture of this particular course, that is processing of non metals we have seen.

Sorry, not on this particular course in this particular module. I would told that title of our course is processing of non metals and in that we are discussing module number 3 and in module number 3 we are discussing ceramics, and in module number 3 in lecture number 3 the title was ceramic powder preparation In that we have seen that there are two ways two process the ceramic powder is the mechanical ways and the ceramics ways and in that particular lecture we have seen the mechanical methods of ceramic powder preparation.

If you remember there were four to five deferent diagrams which we have seen in that lecture. We have seen the process of ball milling, we have seen the process of roll crushing, we have seen the process of hammer milling, we have seen the process of gyratory crushing, we have seen jaw crushing mechanism. So, different mechanism or different methods or techniques were seen or discuss which are use for producing the ceramic powders, but the broad summary was that those were the mechanical methods of producing the ceramic powders.

So, ceramic powders can also be synthesized with the help of reactions. So, chemical method of producing the ceramic powders involves the chemical reaction in a controlled state. So, the reactions will takes place, we can have solid state reactions. The reaction may take place in the liquid or in the solution of form. Finally, sometimes the vapour phase depositions are also used for generating the ceramic powders, now depending upon the requirements.

Now, what are the requirements basically, if you remember? The previous slide, previous slide we have seen few important points, that is the chemical composition, the phase composition, the particle size, particle size distribution, particle shape and we have also seen the agglomeration or the state of agglomeration. So, we have all these characteristics and when we are processing the powder from the raw material we have to keep in mind all points in our mind.

So, that we are able to generate the powder with the desirable characteristics because if we are able to generate the powder with the desirable characteristics, we would be able to make a good quality ceramic product. But if the powder lacks in some of the characteristics or in most of the characteristics then, the product we will out of that powder will not be a very good quality and may not also be usable for the desire application for which is it has been made.

So, basically this particular slide gives us an idea that we can follow tow different parts for preparing the ceramic powder that is the mechanical part or the mechanical direction of processing the ceramic powder. So, in today's lecture we would focus primarily on the fundamental aspects of one or two methods which fall under the chemical category of processing of ceramic powder. Otherwise there are large number of methods which can be used with large number of ceramics that can be produced.

Since our focus in this particular course is on the processing aspects of ceramic ceramics aspects of non metals. So, since then we can say the summery is the processing part, but for the last two three lectures on ceramics, our focus has been on the fundamental or the materials aspects of ceramics. So now we want to quickly shift our attentions from the material aspects of ceramics towards the processing aspect of ceramic products now we will see the chemical methods of processing the powders and quickly shift our attention towards the processing aspects of ceramics products now this is we can say the introduction towards the ceramic powder preparation by the chemical methods

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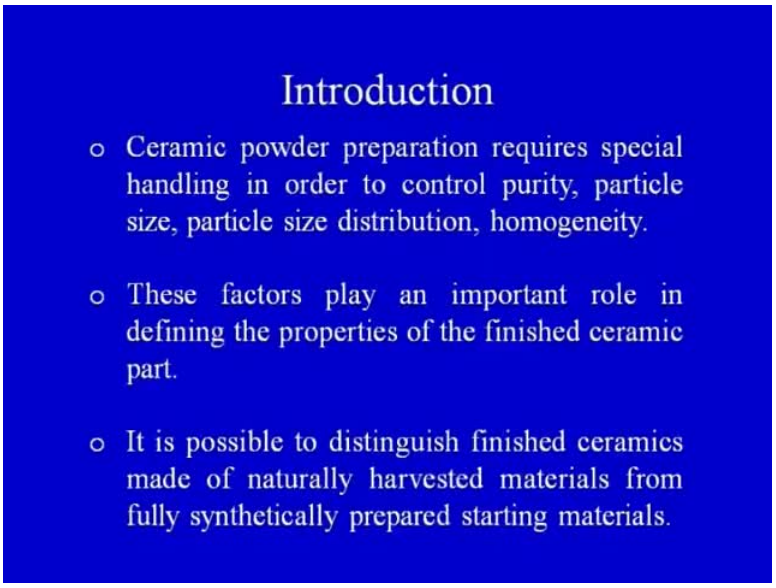

The ceramic powder preparation requires special handling in order to control the purity, particle size, particle size distribution, and homogeneity. Now, with these criteria we will use the chemical reaction to produce the ceramic powder. So, important point to note is that all these points have to be born in mind when the chemical reaction or any method from the chemical category is chosen for producing the ceramic powder. That what is our objective?

Our objective is to make a pure powder, our objective is to make a particle size fine particle size, we may required to narrow down particle size distribution, we may require the homogeneous powder without any contamination. So, these are the some of the objectives with which we set out to use a chemical methods of preparing the ceramic powders or processing the ceramic powders. These factors plays an important role in defining the properties of the finished ceramic part. So, once we have a good quality, raw material the final product that will get we will get would also be a good quality.

One of the important points to note is that the conversion process should also be of good quality because sometimes we may have a good quality, raw material but the conversion process is faulty that product we will get would not be of the desire quality. So, we will see what are these conversion processes? That is how the raw ceramic powder is converted into the final product because that is the main objective of our module on ceramics.

That we would be see, but if the raw material is not properly does not have the desirable characteristics, then it is sure that the final product that we will get would not be of would good quality. So, all these properties are our objective that whenever we are choosing a chemical method of processing a ceramic powder, we should ensure that the powder that we are getting is good in purity the particle size particle size distribution and homogeneity.

It is possible to distinguish finished ceramics made up of harvested materials from fully synthetically prepared starting materials. So, we can say it is important that too important points are there in this particular point. One important point is that it is possible to distinguish finish ceramics made of naturally harvested material. So, whatever product has been made we can very easily figure out that whether that it has been made from the naturally harvested ceramics or from the fully synthetic prepared starting material.

So, basically what we mean to say here is that we can get the ceramics from the raw materials the raw materials may be existing in nature and synthetically. Also we can process the ceramic materials that is, through the reactions. Finally, use this ceramic powders to process the ceramic parts and it is easy to distinguish between that two that these powders are coming from the naturally occurring minerals, and this powder has been synthesized through the chemical reactions.

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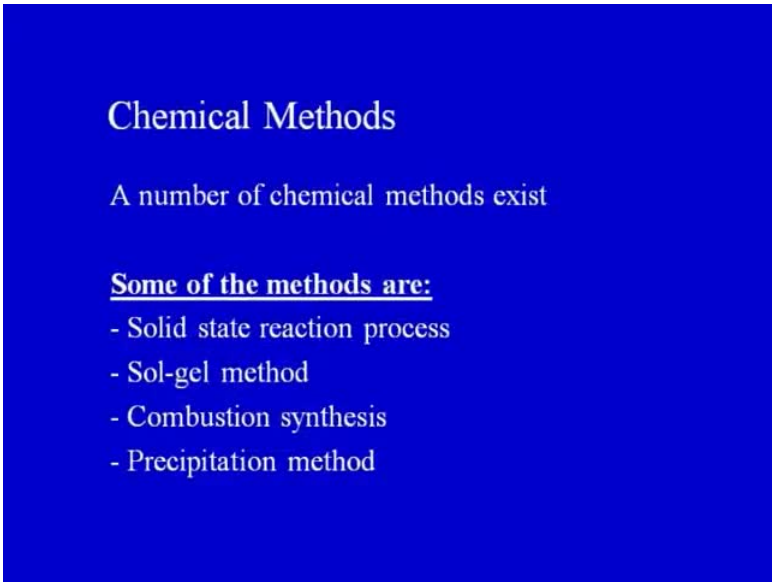

Now, chemical methods can be classified into a number of ways because we may have solid state reactions taking place, we may have liquid solution reactions taking place or we may have vapour or gas phase gas phase reactions. So, but here I have highlighted only four or five deferent methods which are commonly used for processing a ceramic powders using the chemical reactions approach. So, some of the methods are solid state reaction, sol-gel method, combustion synthesis, precipitation method and the list is endless. There are number of methods which can be used to convert the two or to synthesize the ceramic powders. So, we will see one or two methods very quickly.

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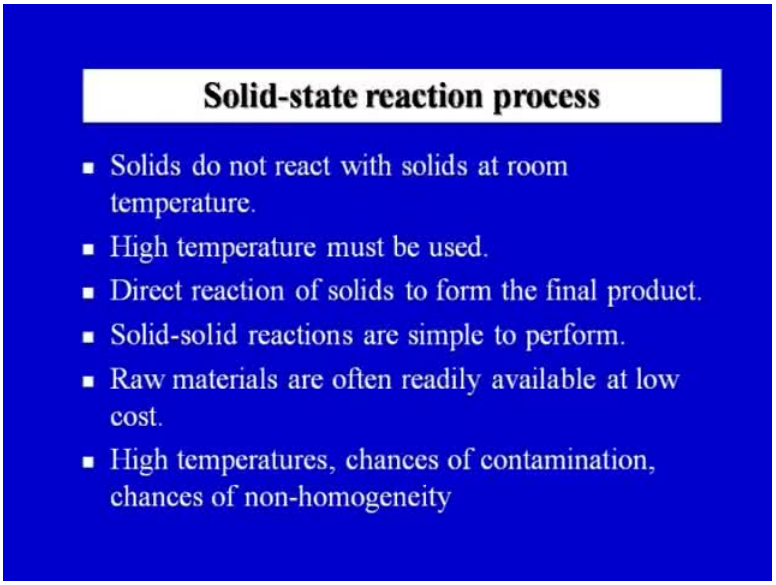

Solid state reaction process, so the solids do not react with solids at room temperature, this is very, we can say obvious statement. We see so many solids around us and they do not start reacting with one and other at room temperature which means that we require very high temperature for two solids to react among themselves. Solid state reaction means that the reaction would be taking place between two solids solid to solid reaction. So, solids do not reacts with solid at room temperature that is first important point to note, but in order to process the ceramic powders.

We need to make this reaction possible and how this is made possible? it is made possible at the elevated temperature. So, the high temperature must be used to facilitate the solid state reaction. So, basically we will have two solids raw materials. These would be reacted in the solid state only. So, this material would be heated to a high temperature.

The temperature would certainly be less than the melting point of these individuals solid raw materials. So, first important point here is that the solids do not react among themselves at room temperature. High temperatures are required than the direct reaction of solids to form the final product.

So, in solid state reaction the direct reaction between the two solid raw materials takes place to form the reaction product, which is our ceramic powder to the direct reaction of solids to form the final product take place and we get our reaction product in the reaction product that is our ceramic powder. Solid solid are simple to perform, so one of the, we can say advantages of this particular process is that these reactions are easy to perform, but there are few limitations also, of solid state reaction processes, that we would be seeing, in the subsequent slides.

Raw materials are often readily available at low cost, so the cost involvement is also not that high in this particular method. But we can say that it is easier said than done there would be certain important operating conditions that have to be kept in mind. So, that we are able to generate good quality powders, because we have seen that the process chosen for converting the ceramic raw material into the ceramic powder should take into account the desirable powder characteristics.

That is powder characteristics are the chemical composition of the powder the phase composition of the powder the particle size of the powder, the particle size distribution of the powder, the agglomeration of the ceramic powder particle. So, whatever method is chosen all these desirable characteristics are the final objective with these objective the methods has to operate. And here we will see, but there are chances but some of these desirable characteristics may not be achieved.

So, the raw materials often readily available which is one of the advantages, it is easier to perform the reaction is easier to perform it is also we can say one of the advantages. But there are few limitations also. I have been highlighting that we have we can say we have the ceramic raw materials this material. I want to convert into ceramic powder and for converting this raw material into the ceramic powder, I have a plenty of choices. I have number of process is which can be used to convert the ceramic raw material; it can be a naturally occurring mineral or it can be we can say any other form of ceramic raw material, it has to be converted into the ceramic powder.

Number of process is exist if you remember in the previous lecture also we have seen that there are mechanical methods of like role crushing or gyratory crushing or jaw crushing, number of methods to convert the ceramic raw material into the final ceramic powder. What are the objectives, with what objectives? How we will we can say judge that this process is good? So, the judgment basically on the basis of the powder characteristics that what type of powder we have been able to generate?

On your screen, why I have emphasize this point again on your screen, you can see the last point that is one of the limitations of solid state reaction process is, that it requires high temperatures very high temperatures are required. Then chances of contamination are also there. So, the purity may not be achieved. Then chances of non contamination are also there, so these are the some of the important limitations. We can say of the solid state reaction process. So, we have to choose the process in such a way that whatever desirable characteristics are there for the powders that those are achieved or the maximum desirable characteristics are achieved.

So, in solid state reaction process, we can see that there are advantages it is easy to do or there solid state reaction easy to perform and the raw materials are also available at a low cost, but the important points that are there are that we require very high temperature, contamination is a problem and non homogeneity may exist in the ceramic powders which have been made by the solid state reaction process. So, this process has got advantages also, but it has got certain limitations also.

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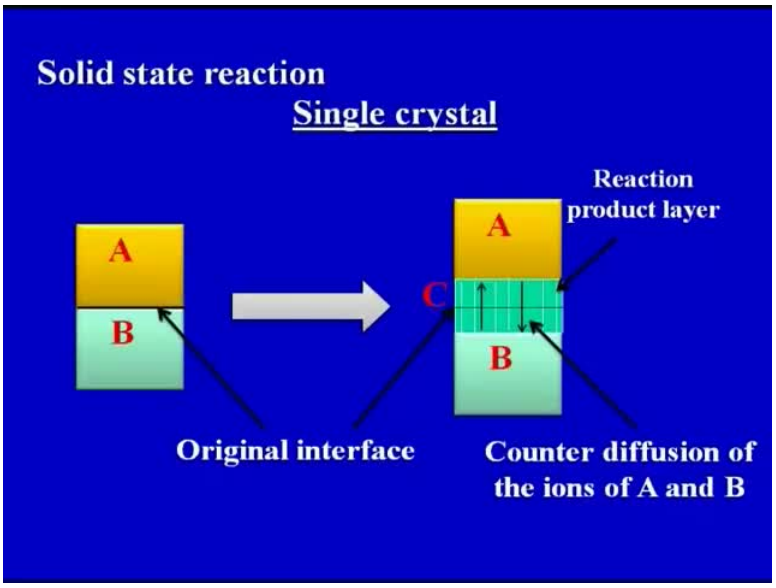

Now, let us see with the help of a diagram how we can represent the solid state reaction process? On your screen you can see A and B, these are the two we can say solids. Solid solid A and solid B and there is the original interface that is present in the two solids. Then it has been converted into a bigger interface or a reaction product layer. This green portion that I am highlighting with the help of the curser, this is the reaction product layer. So, this is A again that is solid A, this is again solid B and this is the reaction product layer. That is a solid state reaction or a solid solid reaction has taken place and here we are getting a reaction product because of this is our ceramic which has been form.

So, this is original interface, here also we have this is original interface, but because of the diffusion process counter diffusion of ions A and B, counter diffusion is shown with the help of this arrow. This is arrow one number one, this is arrow number two. So, counter diffusions of ions A and B at this interface generates a reaction product layer which is we can say our solid solid reaction product or a ceramic powder that we want to generate. So, this is, we can say very basic fundamental schematic representation of the solid state reaction.

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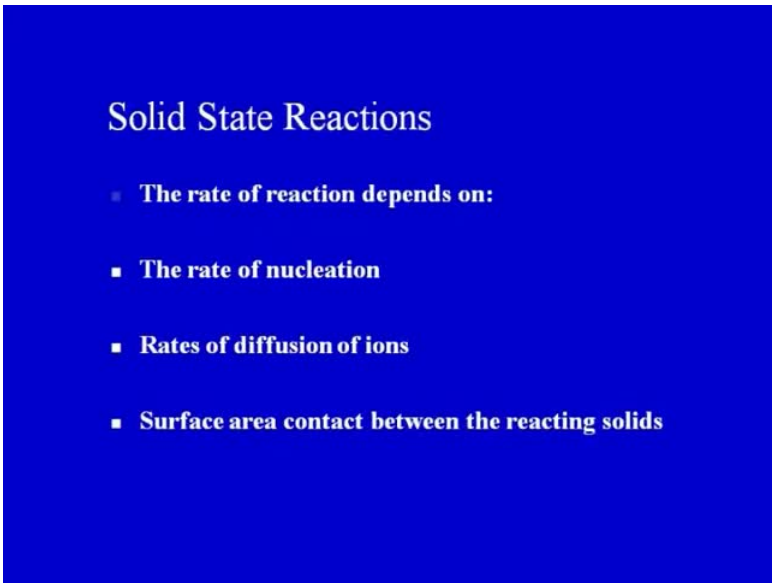

Now, solid state reaction is basically the rate of reaction, because the rate at which the the layer would form or the reaction products would be forming, that depends upon the rate of nucleation. Always nucleation will start the process or the reaction. The rates of diffusion of the ions as we have seen that the ions are diffusing from A A to B and B to A. So, the rates of diffusion of ions as well as the surface area contact between the reacting solid. So, this is a solid state reaction two solids are reacting among themselves, but not at the melting point the temperature is always high, but it is lower than the melting point of the individual, we can say solids.

So, surface area of contact between the reacting solids is also very very important. Now, in order to we can say improve the solid state reactions, what should be our objective? Surface area is an important point, so the surface area contact between the reacting solids dictates the rate of reaction. So, in order to improve the rate of reaction, what we can do? We can try to improve the surface not improve sorry, to increase the surface area that can be done by grinding, then we can say solid into very fine particles.

So, that the reaction takes place, so the surface area contact between the reacting solvent we want to improve the surface area. So, that the contact is increased we can like to increase the rate of nucleation we would like to increase the rate of diffusion of ions. So, that we are able to generate the ceramic powder product. So, basically the rate of reaction depends upon the rate of nucleation the rates of diffusion of ions and the surface area

contact between the reacting solid and our objective is to how to increase the rate of nucleation, how to improve the surface area contact between the two reacting solid and how to increase the rate of diffusion of the ions from the two reactive solid?

So, if we are able to control this process properly we will be able to get a ceramic powder of a very high purity and we would be able to get a uniform size of particles or the particle size distribution may also not be very, very wide. So, if the process is can properly control, we would be able to achieve the desirable characteristics of the powder. Once we are able to get the desirable characteristics of the powder the final product that we will be making out of these powders would also be of very high quality.

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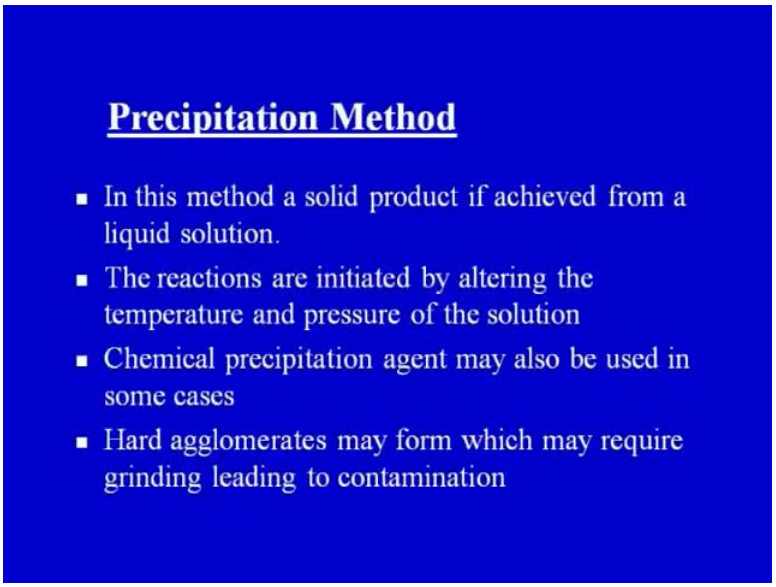

So, now coming on to the next method, that is the precipitation method of preparing or processing or synthesizing the ceramic powders. So, in this method a solid product is achieved from a liquid solution. So, in our previous example that we have seen or the previous previous method that we have seen that is solid state reaction, the reaction was taking place between two solids. But here the raw material or we can say the starting material is a liquid solution. So, in this method solid product is achieved from a liquid solution.

So, the reactions are initiated by altering the temperature and pressure of the solution. So, in this particular we can say that this particular method falls under the liquid stage or liquid state processing of ceramic powders. Why because in this, the starting, our starting

material is the solution. So, in this method a solid product is a cheap from a liquid solution, so first and foremost we should have a liquid solution. The liquid solution the precipitation would take place there that reactions are initiated. Now, how the reaction would take place? How the reactions are initiated?

Two important guidelines are there that is to control the temperature and the pressure of the solution. So, the reactions are initiated by controlling and changing the temperature and pressure of the solution. So, the chemical precipitation agents may also be used in some cases so we have to encourage the precipitation and for that chemical precipitation agents may sometimes also be used. So, we can alter the temperature we can alter the pressure or we can use the chemical precipitation precipitation agent, so we will be able to get a solid material from the liquid solution. In many cases hard agglomerates have the tendency to form during this process of precipitation.

There are step by step procedure for this precipitation method, but we will not going to the detail, but the basic summery of the method is that we have a liquid solution. In order to we can say a reaction to take place, we alter the temperature and pressure sometimes. We may add some chemical precipitation agents also, but there are tendency that sometimes hard agglomerates may form. Now what can be done if hard agglomerates are form we have to go for the grinding process in order to decrease the size of the particles or the ceramic particles that have been form?

Grinding would certainly add up to another step in the processing of ceramic powder which would subsequently add up to the cost of the whole conversion process from the liquid solution to the ceramic powder. So, summery of precipitation method has only been highlighted here, again I would like to summarize the whole precipitation method as that we have a liquid solution. Temperature reactions are initiated by controlling the or by altering the temperature and pressure sometimes in order to we can say facilitate the reaction chemical precipitation, as agents may also be add and if the hard agglomerates are formed grinding process can be done, in order to achieve the ceramic powder with the desirable characteristics.

So, we have seen till now that there are deferent methods which can be used for processing the ceramic powders. Now, the question may be there that why we have emphasized so much on production of ceramic powders? The characteristics of ceramic

powders again and again I am emphasizing this point that the quality of the raw material would define the quality of the final product? What is the raw material that is going into, then we can say final final product or the conversion process that is basically a ceramic powder specifically in case of ceramics. So, ceramic powder preparation is an important step in the production of ceramic products or the processing of ceramic product.

So, we have devoted adequate time in trying to understand, that how a ceramic powder can be produced? What are the objectives or the desirable characteristics or what are the important criterion on the basis of which we should choose our methods of getting the ceramic powder. So, we have seen two types of methods are there for getting the ceramic powders; that is the mechanical method and the chemical method. In mechanical method we have try to understand with the help of diagram some of the methods such as ball milling, roll crushing, gyratory crushing, jaw crushing and hammer milling. Numbers of method we have seen I have drawn few diagram and try to explain the basic working mechanism of these method.

So, all these methods fall under the mechanical method of producing a ceramic powder. Then towards the chemical method I have highlighted four to five deferent method, we have seen the summery two methods that can be use that is solid state reaction method and the precipitation method. There can be other methods also like sol-gel method, we can have the CVD process also for producing the ceramic powders, but we will not going to the details of all those methods.

But with this we come to the end of one of the important aspects of this particular module, that is this particular module, that is module number 3 is focusing on ceramics as the material. So, we have discuss the materials aspects of ceramics. We have seen the raw material aspects of the total process development of ceramic products. That is the there are deferent stages in which the ceramic products would be form, we have focused on the first stage of the total cycle that is the preparation of the raw material. That is ceramic powders in this case.

So our focus till now has been on the first stage of the total product development or product we can say product in our case is the ceramic part or the ceramic product so for producing that ceramic product we have highlighted first stage that is how to get the raw material which can be converted to get us a desired ceramic product now from now

onward our focus would be on the tools and techniques or methods that are used for converting this raw material into the final product So, now let us see the second stage of this particular module on ceramics that is processing of ceramic parts .

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So, generally it involves three basic steps, step number one is the ceramic powder preparation which we have already covered in our previous lecture also. Today also we have seen two important methods of processing powders using the chemical root. So, ceramic powder preparation here we have mentioned three important we can say, which are name, with the names are used interchangeably. That is crushing, milling and grinding, and all this we can say methods fall under the mechanical methods of getting a ceramic powders.

Today, we have seen two important methods, that is solid state reaction and the precipitation method of producing the ceramic powder. So, those methods can also be used for producing a ceramic powder. So, the first step basically is the ceramic powder preparation, which we have already covered. I think all those who have heard the lecture number, lecture number 3 of this module and today's lecture, have have an idea that, what are the methods that can be used for producing the ceramic powders?

So first stage is known to all of us stage number two, that is mixing powder particles with additives now powder has been produce. Now, we require certain additives. Now, the question is, why we need to add certain additives into the ceramic powders in order

to convert them into the final ceramic products or ceramic parts? The additives are added in order to give or imparts certain special characteristics to the final product, so that particular purpose the additives are added into the powders.

So, this we will see in detail in our subsequent lectures when we will see some of the important methods of processing the ceramic parts. So, the second stage is we can say blending of the ceramic powders in which we will be adding some additives. The third stage is the shaping drying and firing the material. The third step stage mean that we have to give the desired shape to the product or the ceramic part. So, suppose we want to make a dental implant, now depending upon the shape of the dental implant we would give the desired shape to our ceramic raw material.

Once the shape has been given it would be dried down because sometimes we may not be requiring certain binder. So, during that drying a process those binders may be eliminated from the process and finally the firing the material. So, firing the material may be centering process can be done. So, shaping drying and firing the material is done, in order to get the final product. So, there are number of processes that are used for processing a ceramic parts, but these are the three may may be basic steps which are done in order to get the ceramic part. Finally, we will see what are the important ceramic processing techniques?

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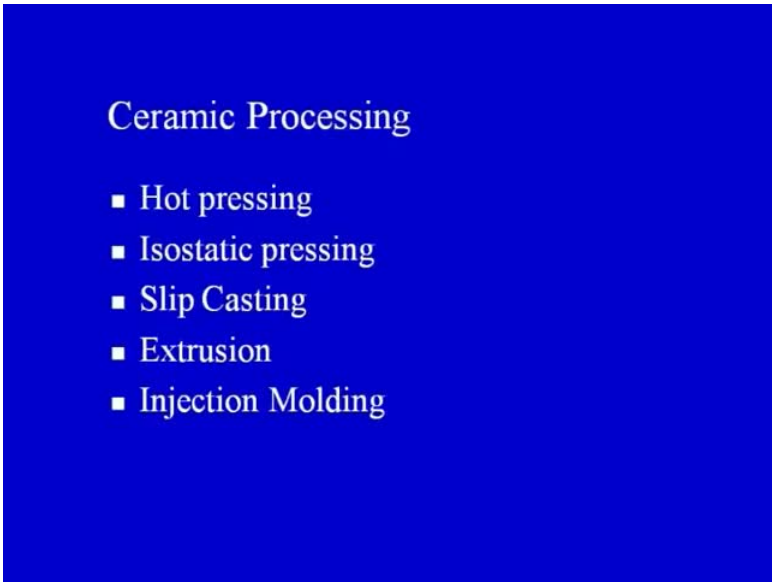

We can see we have hot pressing, isostatic pressing, slip casting, extrusion, injection molding. So, all these processes are the techniques which are used for processing the ceramic parts or ceramic products. So, we would be discussing the basic details or the working principles, as well as the application areas of these processes along with the advantages and limitations of these processes. As your well a wear that injection molding and extrusion are two of the very important and commercially available processes used for processing of plastics.

These processes we would also be covering in our discussions on the processing of polymers as well as the processing of polymer matrix composites. So, these are very versatile processes which again also be used for processing of ceramic parts. So, basically we our focus now onwards would be on the processing aspects of ceramic materials. So, let us now see that what we have covered till now and what we are going to cover in future. So, we have covered till now the basic aspect of ceramic materials, we have seen that how thus ceramics compare with the metals what are the distinct characteristics of ceramics which make them a deferent material, as from metals as well as from polymers.

So, that is one important that we have highlighted, then we have highlighted the important mechanical physical and chemical properties of the ceramics. Then we have highlighted the type of bonding that is present in the ceramics. We have try to correlate the bonding with the properties of the ceramics. Then we have seen that in order to convert a raw ceramic into the final product or a usable product we require to process the ceramic into powder form.

For that we have seen the processes that can be used for preparation of ceramic powders can be broadly classified into two categories, that is the mechanical type of processes and the chemical methods. Within mechanical we have seen, there are deferent mechanisms for crushing the powder or milling the powder or grinding the powder. Similarly, the process is also called ball milling, we can say jaw crushing, gyratory crushing, roll crushing and there are chemical also, there are a wide verity of chemical methods, that exist but we have just highlighted or summarized two important methods. That is in today's class we have seen solid state we can say solid solid state reaction as well as the precipitation method.

Then finally, we have seen that what are the important step involved in making a ceramic product. Once we have the powder available with us. So, we have a ceramic powder available with us, that is the first stage number one, ceramic powder preparation. Second is blending of the ceramic powder with the additives and the final is the shaping firing and drawing or shaping drawing and firing of the ceramic part to get the final ceramic product.

In this particular slide we are seeing some of the processes like hot pressing, we can a wet pressing also, high isostatic pressing, slip casting, extrusion, injection molding, these are the processes which are use for converting a ceramic powder into the final ceramic products. In our subsequent lecture we would be focusing our attention on the process details of these processes with with the, with emphasizing on the advantages limitations and applications of the various ceramic products.

Thank you.