Non - Metallic Materials
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Module – 01
Polymer materials
Lecture – 01
Classification and applications of non – metallic materials

So, let me start the Non-Metallic Materials the course and I am Subhasish Basu Majumder from IIT Kharagpur. And let us start with the classification of this non-metallic materials. And this is under the 1st module Polymeric materials, we will discuss in details and we will start with the Classification and certain applications of the non-metallic materials.

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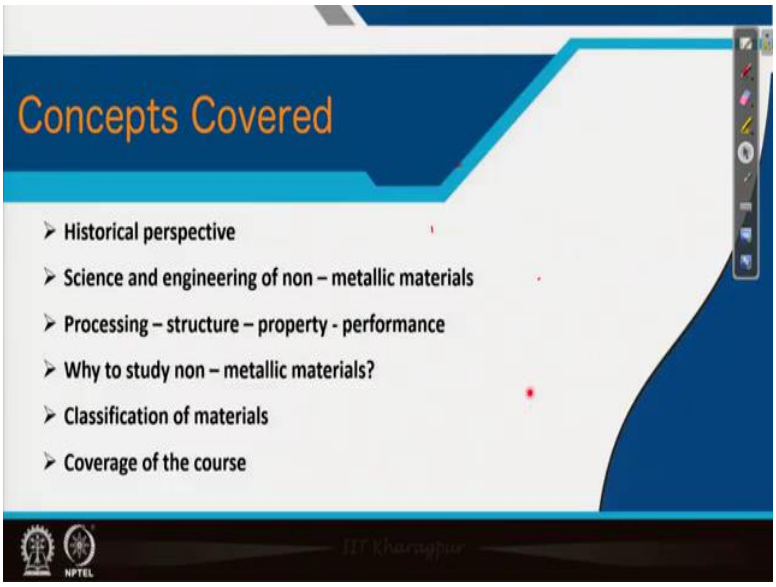

Now, here is the actual skeleton of my lecture. So, first I will start from some historical perspective and the details of the difference of material science and material engineering, particularly if you consider non metallic materials, so that will come next. And then we will show a very important aspect which is process, structure, property and performance this interrelation. So, that is important for you to understand this course content as we will proceed.

And the question that arises that, why to study this non-metallic materials? So, a brief explanation will be given that why it is important to study non materials and we will classify

the non metallic materials. And finally, I will just list the coverage of the course, the topic of the course; module wise topic of the course will be covered.

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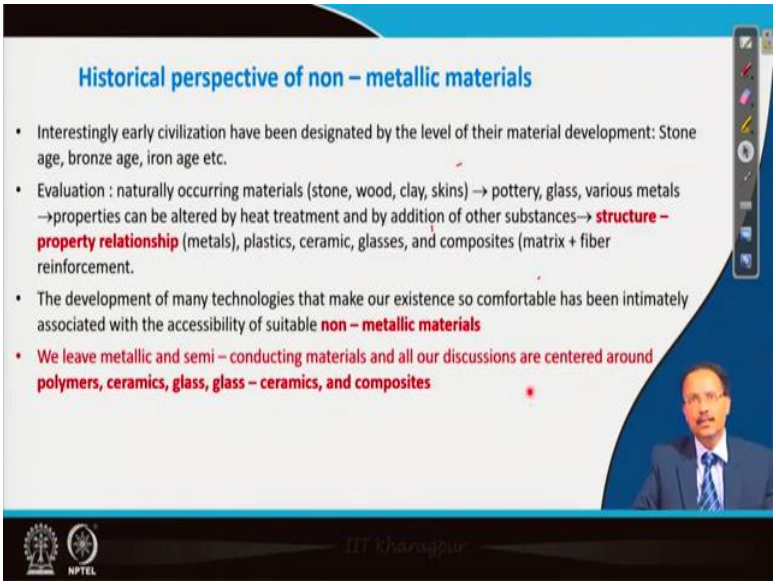

Now, if you see the historical perspective of the non metallic materials; from the ancient time, you might have noticed that we call the ages as Stone age, bronze age, iron age etcetera. So, in fact the elongated period of time that was actually defined by the ages which is named after a particular materials. So, that was in ancient time and then the evaluation of the so called material science that started with naturally occurring material like stone, wood, clay, the skins of the animals.

So, people started to work on this material or use this materials for their purpose. And next human being they actually learned how to make functional material and with some specific application. So, pottery came, clay based material; then glass cames and after that various types of metals people mainly learnt how to use it in the form of making weapons to kill animals for their food, for having their foods.

So, necessity driven this growth. And only recently, we learnt how one can manage the property; the property can be altered say for example, by heat treatment or you can add other components into one material to make a composite. And once we learnt that how to make this various types of material; then the structure property relationship that was very important for us to know. So, we try to understand the structure property relationship mostly with metals.

And after that almost concurrently, we started to working on different plastic based material and ceramic was all the way there right from the ancient times ceramic and glass. And composite using either ceramics, two different ceramics or ceramic and metal those kind of composite or polymeric material and fiber to make fiber reinforce composite. So, these are all necessity driven development that took place.

So, basically most of the technology now whatever is in the forefront, that has made our life very comfortable. And actually the type of the material is very important and various types of material has been evolved over the ages, and they actually support the fabrication of those equipment's.

And mostly we will focus the non metallic materials; metal is of course part of it, it was there and semiconducting material was also there. In this particular course, I will concentrate other types of material; not really metal and semiconductors.

So, this part as you can see, we leave metal and semiconducting materials and all our discussion they will be basically centered around polymers, glass, ceramic, glass ceramic and different types of composites.

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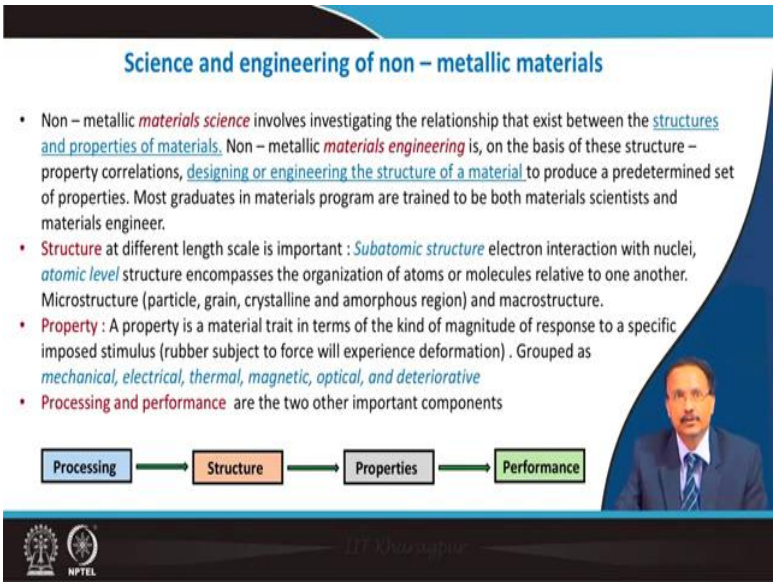

So, the important part for this non metallic material science, they basically involved in investigating the relationship between structure and property of the materials. So, non metallic

material engineering is one part and that is basically address the structure and property correlationship between the material and their properties.

And second aspect is designing or engineering the structure of the material for a particular use. So, you have a predetermined set of properties and then you will have to achieve those properties. So, we know the structure of property, structure property relationship of certain sets of material; so the engineering aspect is to take those material and use it for that purpose.

So, therefore, this terminology material science and engineering comes into picture. And a graduate students who is studying the material science; they are actually been trained for both the scientific aspect, where they know the structure property corelationship and second how to use a particular material or a set of material for a defined use, where the property that you want to have from those devices well known. So, therefore, both are important.

Now, you see this structure, actually you want to have the knowledge of structure at different length scale. So, first you can start from sub atomic structure electron, its interaction with the nuclei, so that is one set and you can predict the Venn diagram, you can predict the conductivity.

Then you go one step higher, the atomic structure or molecular structure; so the formation of a crystalline material or an amorphous material or a nano crystalline material, so that structure, identification of that structure is also important.

And then you graduate yourself to the third category of this structure, which we call microstructure. So, then the length of this length scale is in micron level, that is why the microstructure name comes.

And it is dealt with particle, then in the sintered product with the grain, crystalline and amorphous region in a particular material; particularly polymer you have a semicrystalline polymer, both amorphous and crystalline part is embedded in it and finally, macrostructure, the macro dimension the structure is important.

So, that is about the structure. And property, basically the property is to identify something, some response for a specific stimuli. So, that property it could be anything, it could be mechanical property, electrical property; in fact we have grouped it into six different properties

starting from mechanical, electrical, thermal, magnetic, optical and of course the corrosion or degradation property of the material.

So, for example, you take a piece of rubber and then you apply a stress and it will undergo deformation. So, you can measure the deformation. So, that is the result and the causes the application of the stress in it.

So, this property is important and more important thing is that, you will have to correlate the structure with the property, and the science of this non metallic material is based on the structure and property correlationship. Now, two additional thing are intermingled. So, that is one is processing and performance.

So, these are the other two components that you need to understand; apart from structure and property, you need to understand the processing of the material to achieve a certain specific structure, you need to understand that how the performance is influenced by structure at different level. So, this four component is processing, structure, property and performance this forms a chain and in order to understand any non metallic materials, you need to understand the interrelation among this parameters.

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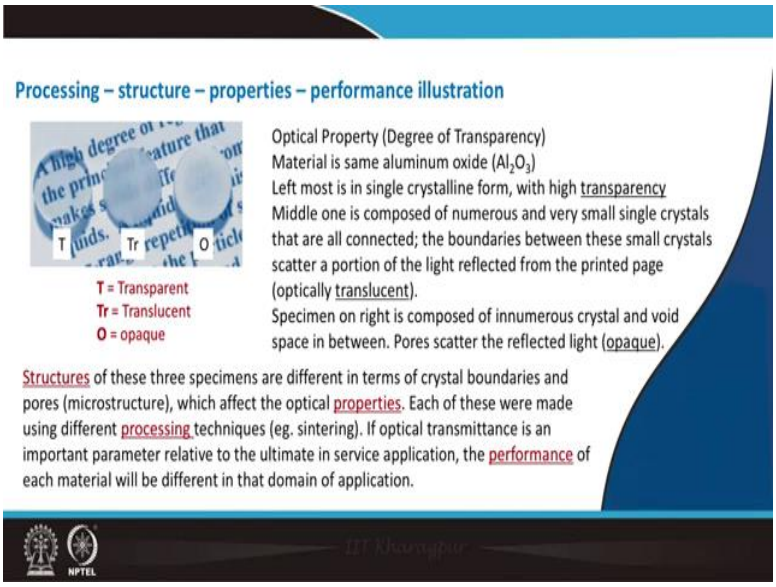

So, I will cite one example where whatever I told, I can illustrate that. So, illustration can be given in terms of as you can see, there are three disk here; this disks are made by alumina Al 2 O 3. So, the composition wise all these three they are same material. But if you are considering

the optical property, as you can see that the underlying write up, you can easily see; you can see that the first component you have transparent, you have transparency, you can very well read whatever is written at the bottom.

Then the second one is translucent. So, here you can somehow manage to read; but the third one is completely opaque. So, you cannot read anything. So, the leftmost thing is a single crystalline alumina and the middle one is composed of and as you know the single crystalline aluminum means, there is a single grain, there is no grain boundary. So, there is no scattering of the light wave and these are wide band gap material.

So, light is not absorbed. So, light passes, it transmits; so you can see through it. Second one is translucent; so single crystal is in very small region, we call them as grain, very small single crystalline region which are separated by grain boundary and also to some extent porosity is also there unless they are properly sintered. So, the some percentage of porosity maybe 2 percent or 1 percent porosity is still there.

So, these grain boundary and the porosity, they will scattered light. So, it will not be completely transparent; but it will be translucent as you can see. And third one is similar to the second one, except here the porosity is higher, relatively higher maybe 5 percent 10 percent porosity is there after sintering. So, light is completely scattered and you cannot see it. So, it is completely opaque. So, pore scattered there is reflected light.

So, if you see in terms of structure, they are different in terms of their crystalline boundary; we call it grain boundary or pores. So, that is related to microstructure and this microstructure is eventually affecting the transmittance property, that optical property it is getting affected by this. So, this correlation you will have to understand; in order to make it transparent, I will have to sinter in such a way or do some kind of processing, so that can give me a totally transparent material.

If I do not do that, then I will not get a transparent material. So, processing is important. Performance is related to that, if I want to make really a transparent material; then I will have to have a single crystal in nature of alumina, otherwise I will not get this transparency.

So, performance is related to your processing, performance is related to the structure of the material. So, in terms the property is also related to the structure of the material and processing. So, that defines the terminology that I used that, this four verticals processing, structure,

properties and performance these are very well related to each other. And at each step of understanding this non-metallic material, we will have to have a clear idea about these things.

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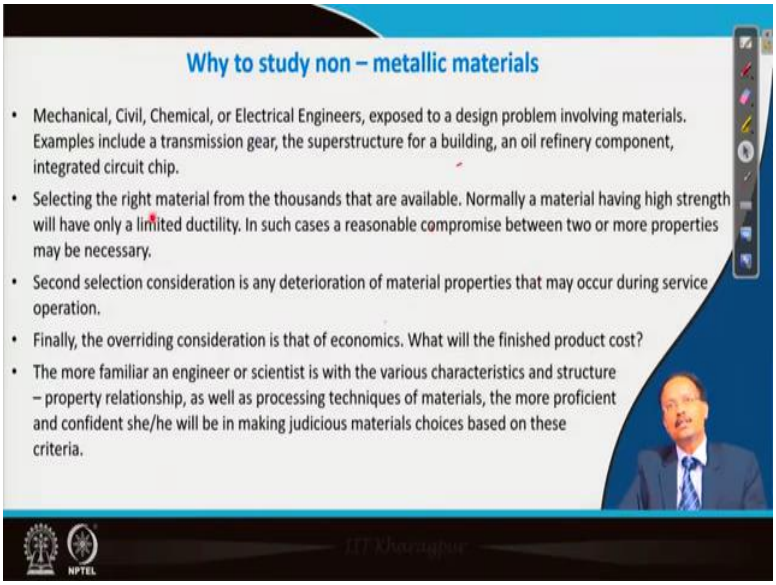

Now, the question is that, why should I study this non metallic materials, what is so special about it? Being a material scientist, it comes to my mind that why at all I will study the non metallic materials? The first reason is that, you are playing a supportive role which is a very major supportive role; particularly to the core engineers, mechanical, civil, chemical or electrical engineers who are exposed to design problems that, they will have to make something.

So, some kind of transmission gear or a superstructure for the building in case of civil engineers or some component for the oil refinery or integrated circuit chip, they will have to develop and the material support is required. So, they need to know about the materials, either themselves; but in details if they get a material scientist, they will ask to comment on it from a host lot of a material what to pick it up for their specific purpose. So, that is a supportive role that one must understand.

Now, selecting the right material that is important, because many of the materials are available, their properties are available processing is also well known; but one should be trained to make a well processed material and also they should have control, for example, if you want to manipulate the strength with reasonable amount of ductility, this two does not go along.

So, high strength and ductility is a bit difficult; but there are certain non metallic materials that is possible. In fact, you know that cementitious concrete, this is a brittle material; it may be hard, having highest compressive strength, but ductility is not there. So, a material science scientists they may attempt to make a ductile concrete for example. So, there are lot of scope of innovation, you can make lot of novel materials and their material scientist they play a major role.

Now, third aspect what is important is the deterioration aspect and say someone is laying a metal pipe and then it corrodes; it corrodes and the sewage or the water which is flowing in it lake since that create lot of nuisance. So, how to actually control this, this kind of corrosion of the metallic part or what material I can use, instead of metal maybe I can use concrete which is which will serve the purpose?

So, selection of the right material for the right kind of application that is very important and you should study the science of the material and as engineering of the material to attempt to use it is more efficiently for a particular purpose. And other aspect which is also very important is the cost effectiveness; I may have a fantastic material, but once I try to use it for a practical application, I will find that the cost is it is too much expensive. So, I cannot use it.

So, how to make a cheaper material which serves the same purpose as compared to the relatively expensive materials? So that is also another aspect that you will have to contribute after learning the non metallic materials and in that way the materials, most of the materials you will have to learn that, and how to address a cheaper material, cheaper novel material for a particular use.

So, the structure property relationship is very important and throughout the course, you should understand the structure property relationship of and understand the science of the materials. So, you can have a better choice of a particular material for a particular typical application.

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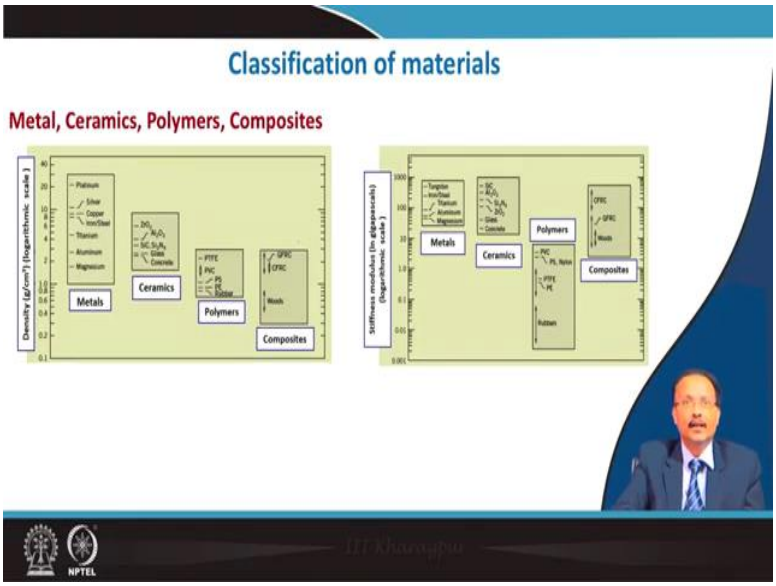

So, broadly we can classify the material into four parts; one is of course metal and metallic alloys and this thing I will not touch in the course. Mostly I will be concentrating on a brittle material like ceramics and also we will introduce polymeric material and various types of composites. So, these are the four things that we will touch in this course.

And property wise if you see this material, you can categorize it in terms of its density. So, metal is more denser, it is a close packed material; if you take polymer, it is not that much dense. You can also categorize it in terms of its property say, fracture toughness; metal is having very high fracture toughness, a very large wobble coefficient you get out of this most of the metallic material.

And ceramic is worst, it is hard; but it is brittle and its fracture toughness is also not that good. You can categorize it in terms of its conductivity, magnetic property and several other properties you can categorize it. I am not going into the details, but two view slides I have shown that, if you compare say platinum with zirconium oxide and with glass fiber reinforced composite the where the density lies.

So, metal is having high density. So, specific strength is relatively low; but this same glass fiber reinforced composite, they are having little relatively lower density higher specific strength.

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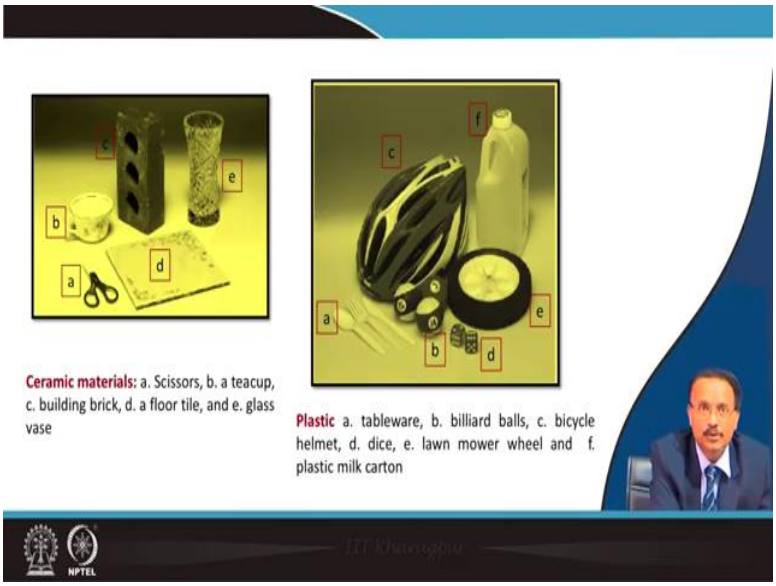

So, this interrelation we will understand throughout this course and here are the typical examples and day to day you see non metallic materials; I have cited certain examples. For example, ceramic scissor nowadays that is there and you are familiar with cup saucer, then floor tiles, then glass vase and clay based brick; now it has been replaced with fly ash based brick. So, ceramic part we will be talking about in this course.

And second one is polymer, another magic material; in fact I will just start the polymeric material in my next lecture. So, you can see the helmet for the bicycle, then the rubber, elastomer, tires, billiard balls, then these dices, then pet p e t bottles for carrying the milk and also the cartularies, plastic cutleries; they are day to day use, we all use it and they are all different types of polymer materials. So, you should need to know about the basic of this polymeric material to start with, we will do that.

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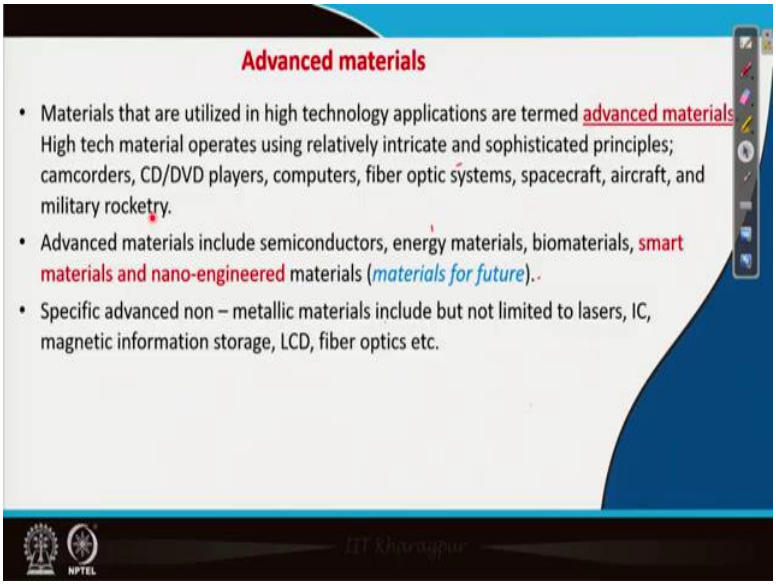

Now, then it comes the materials for the future. So, we call it is the advanced material and what is this advanced material? This advanced materials are the heart of various types of so called high tech devices. Now, what is this high tech devices? So, these devices are relatively integrate and sophisticated principle behind it.

So, this mechanism is a bit sophisticated and intricacies are there for this type of devices; for example, camcorder, the technology is quite complicated, CD, DVD players, computer, then fiber optic system and starting from this you go to spacecraft, aircraft, military rocket. So, all these things are high tech materials and you will finally, see that lot of this non-metallic materials, they are used in this high tech devices. So, these are all advanced material.

And advanced material is something the raw material you will have to prepare in the laboratory; you cannot use it, you cannot take it from outside like you make a clay based brick, you take the clay from the field and then add some water to make it plastic, then you mold it and fire it and your thing is ready. It is not that simple, you need to have a very precise control of the material, preparation in terms of, its purity in terms of, its particle size in terms of, its face fraction that is related to purity of course.

So, that are artificially made a non metallic materials and then you can use it for this purposes. So, this also includes semiconducting material and nowadays energy material is also very important.

So, lithium ion battery, sodium ion battery, super capacitors, fuel cells all uses this electro ceramic materials; biomaterial is coming in a big way, but more important is a smart material.

So, material is smart when it can behave according to the situation; you are smart when you can behave according to the situation, then you are called smart.

So, the material behaves according to its, according to a particular situation. And once the dimension change from micron to nano level, then the property is dramatically different. So, it is a new section of a material science that is coming up in terms of the nano engineered material, nano engineered non metallic materials.

So, those are the materials for the future. And carbonaceous material also I will cover in this course, although not very extensively; but the exotic materials that are there, we will cover in this course. And specific application that you are having is laser, then IC integrated circuit, magnetic information storage and fiber optics cable. So, this advanced application also will be covered in this course.

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So, if I now summarize, basically I have 12 different modules; we start with polymeric material in the first module and each of this module has five lectures I have designed in that way. Then second we will consider the defect and reaction kinetics of this non-metallic materials, including carbonaceous material which is important for you to understand as far as the processing is concerned you need to understand that.

Then I will be talking about diffusion, phase transformation in nonmetallic materials and introduce glass and glass ceramics. Then progressively we will go to different material

properties, starting from mechanical properties, electrical, magnetic, thermal properties, then optical and electrochemical properties; then we will talk about the processing of this non-metallic materials.

And then shift flexibility thin film, form fibrous form; fabrication of the device actually you need to form material in different shapes, we will be talking about it. Then brief account of the characterization of this material in terms of their respective properties and also measurement of specific properties all six properties how you can measure; once you prepare the material how you can measure it.

Then we will talk about corrosion and degradation aspect of this non metallic material and finally, the economic environmental and societal issue that is also will be covered. So, we will continue. So, let me stop here and let us go to the next part of the lecture for this module.

Thank you so much.