Basics of Materials Engineering

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Lecture – 01
Introduction

Okay, so, this course is basically a Material Science course, aimed at giving you some basic understanding of materials because that forms the fundamental basis for several aspects of study in mechanical engineering. And, hence this course is one of the foundational courses, is extremely important for you if you want to be a good mechanical engineer.

And, so let me ask you this question. What is your first impression when you have heard of the title of this course? Whether it is going to be a boring course or an exciting course? You can be honest. First class I do not remember any of you. So, you can be brutally honest.

Student: (Refer Time: 01:12).

Lots of theory to remember. Yeah?

Student: Sir, lot of (Refer Time: 01:15).

Lot of mugging up required.

Student: Yeah.

Probably, yeah. How many of you think there is lot of mugging up required? Very good.

Student: (Refer Time: 01:26).

Why the others do not think there is lot of mugging up required?

Student: (Refer Time: 01:32).

Or others never thought anything about it? Yeah, both are possible, right? So, we will see whether there is lot of mugging up required for you in this course or not and we will comment on that in a moment, ok?

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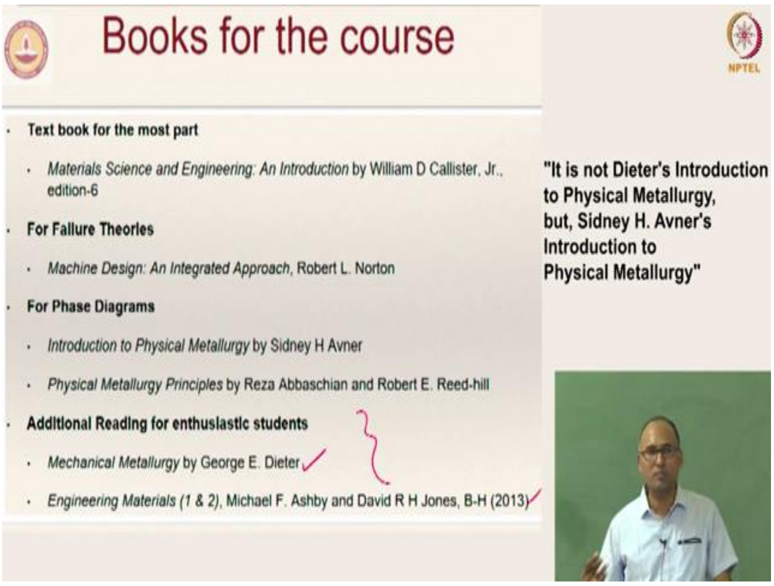

So, my name is Ratna Kumar. I sit in Machine Design Section. So, books for this course, the main textbook for this course is Callister's Materials Science and Engineering, ok? And this course has several sub-sections or several topics. The primary textbook will be Materials Science and Engineering, and we will have another section on failure theories.

For failure theories alone we will use the textbook of Machine Design by Robert L. Norton or Shigley's Mechanical Engineering Design -- one of these textbooks. For phase diagrams, which is the last topic -- for that particular section, we will use Dieter's Introduction to Physical Metallurgy or Reed-Hill's Principles of Physical Metallurgy, right? You are also encouraged to go through these additional readings -- Mechanical Metallurgy by George Dieter, and Engineering Materials 1 and 2, two volumes by Michael Ashby.

Particularly the last book is a wonderful book for you to gain some understanding of what materials can do and how they are placed in the development of engineering in general, and mechanical engineering in particular, okay? So, in your free time you can go through that textbook if you are interested, alright?

And, there are several copies of this book available in the library. This particular textbook. And, this book also is available in the library. This is available. This is available. This is also available. This -- not many textbooks, few copies are available of the last textbook.

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So, what are the contents of this course? The details are given in your course portfolio for each and every chapter, and each and every section. So, first we will start with structure-property correlations, wherein, we study how the structure of the material leads to different kinds of properties that may be needed for designing components as a mechanical engineer.

And, so, here we will study crystal structure, defects in materials, and how the crystal structure and the defects lead to different kinds of mechanical behavior of engineering materials. And we will talk about different properties: tensile behavior, compression behavior and different kinds of loading onto the materials, and we will see how to measure certain properties of the materials.

So, that is sort of the first part of this course. Having learnt the mechanical properties of the materials, now we can use these mechanical properties to actually design components, ok? So, there we will talk about failure theories, both static and dynamic failure theories, which will be used for design, and then we will talk about phase diagrams. You may have some overlap between this course and manufacturing technology or manufacturing processes. Which course are you taking? Manufacturing technology? Processes?

So, in the manufacturing processes also they will teach phase diagrams and heat treatments of steels. But here, we will spend a little bit more time on phase diagrams to understand them in detail, and of course, heat treatment of steels, ok? That is the total content that we will be trying to uncover during this course, ok?

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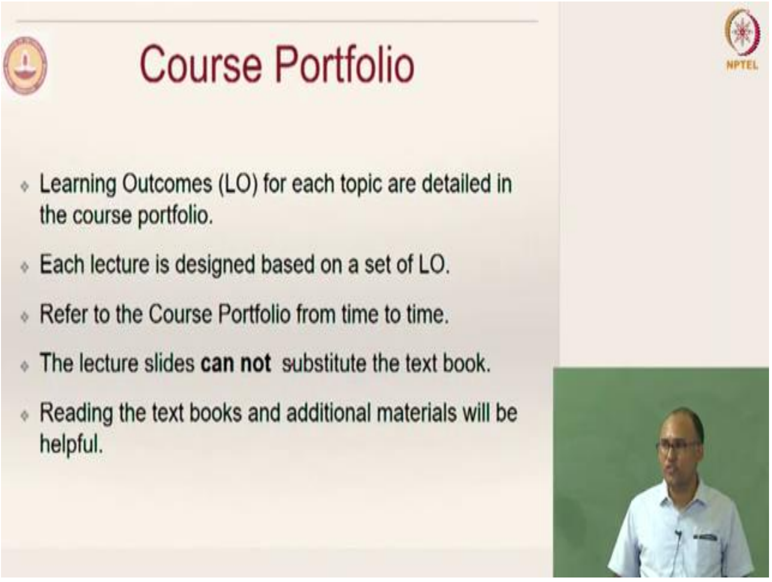

So, as I mentioned, the course portfolio has learning outcomes. We have listed the learning outcomes for each topic, each subtopic, and we have identified the chapters in the relevant textbook from which this material will be taught. So, you are required to read those textbooks and if you are at the end of reading, or at the end of the lecture you should have achieved these, or attained these learning outcomes, right?

So, each lecture that we are going to have in the subsequent classes is designed around these learning outcomes that are mentioned in the course portfolio. So, it is extremely important that you refer to this course portfolio from time to time, so that you can be sure whether you have achieved the learning outcomes or not, ok? Please note that the lecture slides cannot substitute for a textbook, you are required to read a textbook, right?

So, how many of you have the habit of reading novels? So, can you experience the difference between reading a novel, and if the same novel is filmed as a movie? When you are reading a novel, you actually participate. You actually become part of the story and you construct the scenes, right? Instead of somebody -- screenplay writer, or a director constructing scenes for you, you construct scenes. That is much more enjoyable rather than watching the scenes constructed by somebody else, right?

The same experience you will have if you read a textbook. You can listen to the lecture, but even if you do not listen to the lecture, if you read a textbook you can actually master the course, ok? There are certain concepts which may not be easy to comprehend. So, those concepts you can get clarified in the class, but otherwise listening to the lecture cannot substitute reading a textbook, ok? So, please make it a habit to read the textbook.

And, not only textbooks, you also are required to read additional materials. So, the way that we are going to design question papers and tutorials is the following: 40 percent will be recall type.

So, if you are paying attention in the class and you are listening to me properly and going back and referring to the textbook or slides after the class, you should be able to get 40 percent of the marks. That means, you should be able to pass the test, and remaining 40 percent is based on analysis and problem-solving.

So, you should be able to apply; application of the knowledge that you have gained during the class. So, that comes by practice. If you practice well, you should be able to answer those 40 percent. They are not necessarily difficult; they are just application of the concepts that you have learned in the class; but the remaining 20 percent is going to be difficult.

So, they can be ranging from moderately difficult to extremely difficult. So, if you are able to answer this 20 percent, only then you will be able to get S grade, otherwise it is not possible, ok? So, you decide which grade you want, and you work towards that, alright?

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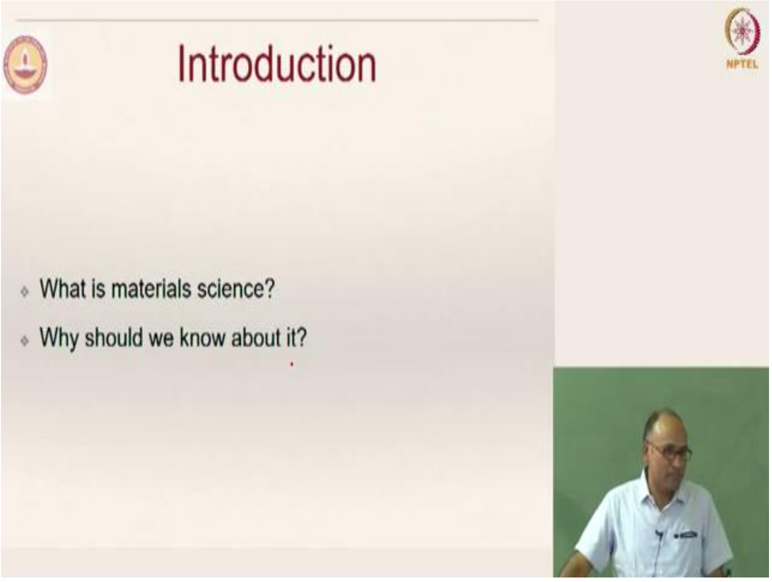

Now, what is material science, and why should we know about it? These are the two questions as a mechanical engineer. What is there in it for me? Why should I spend 9 hours per week breaking my head rather than chilling out on learning material science as a mechanical engineer? Right?

This is the question that we need to ask ourselves to see the value of this subject in the grand plan of mechanical engineering, and we will try to answer this question through the lectures that we have in this class.

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So, why should we know about it? So, almost every part of our life is directly dependent on materials, no matter whatever aspect of life that you take, it is dependent on materials right.

For instance, preparation of food. How will you make food? How will you cook? You have rice or dal or wheat, in the end you cannot eat the raw material you need to cook, right? Or you need to prepare. So, in order to prepare food, you need to have some processing, right?

How do you do this processing? So, let us say somebody else has done the processing and the rice came to your house, then what will you do with the rice? You need to cook, right? So, how will you cook? First of all, you need to have a pot. The pot should be made of a material, right? So, you should know what kind of a material I want to use, depending upon your financial situation or your liking, you decide which kind of a pot you want to buy, and then you cook the food, right?

So, the basis is even if you want to cook at all you need some material, right? Coming to shelter: housing, you need building materials, clothing, transportation, communication, entertainment. No matter what aspect of life that you take into consideration, their realization depends on the existence of appropriate materials for that particular purpose, right?

For instance, if you want to have a mobile phone, you cannot have a mobile phone unless you have an integrated circuit. You cannot have an integrated circuit unless you have the base materials such as silicon, right? So, in that sense materials forms the basis for every walk of our life, right?

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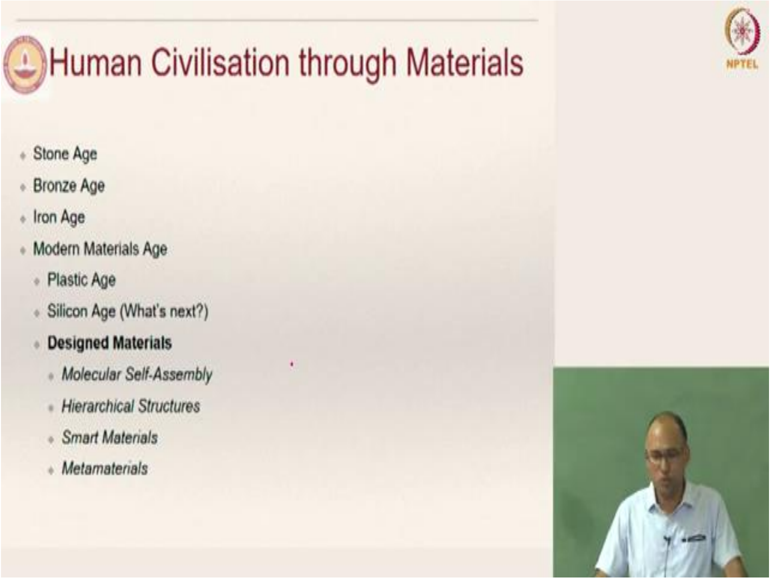

So, you can see the impact of materials on our civilization just by looking at the way that we have classified civilization, right? How did we classify civilization?

Student: (Refer Time: 12:26).

We talk about different ages, right? What ages are we talking about? What is the first age?

Louder.

Student: Stone age.

Stone age. Why did we call it as stone age?

Student: (Refer Time: 12:43).

Because all the instruments during that time, all the weapons that they use to hunting all are made of stones, stone is a material, right? So, the material that is dominating that particular era has become the name of the era, right? So, that is why you have stone age, then bronze age, iron age and then you have modern materials age, right? What are those modern materials? Plastics? We have seen the development of plastic, right?

Student: (Refer Time: 13:18).

So, maybe most of you were not born when the plastic revolution has started, right? All of you are 1990s guys? 90s? Late 90s, right?

Student: (Refer Time: 13:32).

Yeah.

Student: (Refer Time: 13:34).

2000s right not even 90s, yeah? So, you have not seen the plastic revolution shaping up, right? So, there were no water bottles, pet bottles when I was a kid. We used to carry water bottle with us, and in each and every train station, we used to get down and fill in the bottle. Now, we do not do that, right? We sit in our seat and we buy the water bottle in pet cans.

So, you cannot imagine the amount of change that brought to the comfort of human beings from the day when we did not have access to such materials to the days that we have access to such materials. So, I am only giving you a simple example that we are familiar with. But take into account the medical industry: surgical instruments. So, when plastic was not prominent -- how many of you have taken injection with a glass syringe?

Have you ever taken an injection with a glass syringe? You do not remember, right? So, when the plastic syringes were not there, syringes were made of glass, and every time you give any shot what you do is you actually boil the syringe. So that means, you are sterilizing the syringe for the next shot. And now, you do not do that, right? What do we do? You buy for 10 rupees one plastic syringe, and then give a shot and throw it away, right?

So, the comfort levels have increased significantly. And then, of course, silicon age and plastic age; they are not one after the other and that is not the meaning that I have here. It is also the modern materials age; you can see what silicon did to us, right?

Student: (Refer Time: 15:31).

So, silicon did so much that we stopped talking to each other, we start talking through phones to each other, right? And then, now we are going beyond silicon age, and then we are moving towards design materials age.

So, we are now talking about: Can we design materials the way that we want, and then get the output the way that we want, right? So, there are several examples. So, I would encourage you to go back and Google these terms, and then you will see excellent articles and videos on these particular topics. For instance, molecular self-assembly, hierarchical structures, smart materials, meta materials.

These are all the new age materials that we need to focus on, and there is lot of R and D money spent on these aspects, which is going to revolutionize the way that we see the world today, right?

So, may be when you become a professor, if at all you want to, and 20 years later you may say that we only were thinking of these devices that can be made of molecular self-assembly. They are in their infancy and today they are everywhere, right? You may say something like that to your students, like I am telling you about the plastic to you guys.

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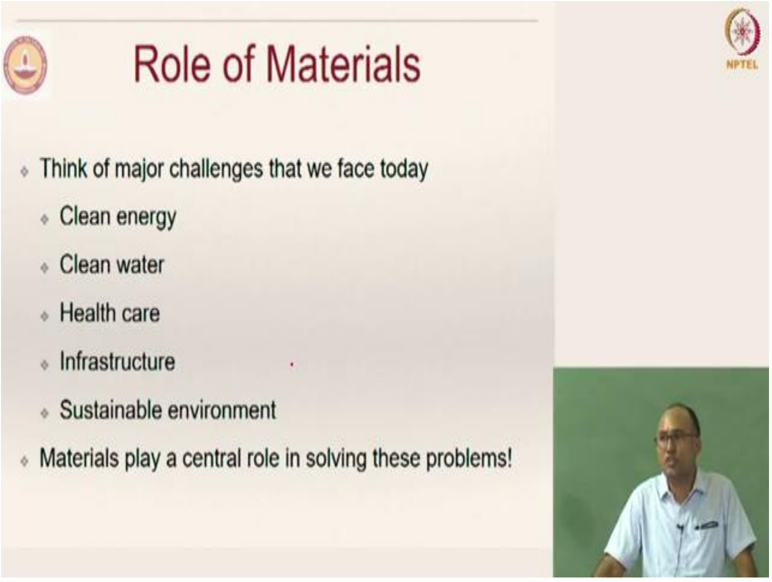

Okay, so, what is the role of materials in our human life? In order to talk about it, just think of major challenges that we face today. What are the major challenges that we are facing today? What are the problems that we have? Are you aware of any problems that we have today?

Student: (Refer Time: 17:20).

Louder.

Student: Water.

Water, ok. He has problems with water ok, is that all?

Student: (Refer Time: 17:30).

This helps you wake up if you are sleeping.

Student: (Refer Time: 17:41).

Global warming, very good.

Student: Clean form of energy.

Clean form of energy, very good. So, clean energy is one of the important aspects. Everybody talks about clean energy, right? Clean water, portable water, healthcare access to everybody; not everyone has equal access to good healthcare, right? If you have money, you can have access to good healthcare, but if you do not have money, you probably do not have access to good healthcare, right? And infrastructure, and sustainable environment. So, these are the challenges that we need to address.

And, materials play a central role in solving these challenges or solving these problems or addressing these problems. The development of new materials, new kinds of materials, new kinds of material processes is going to help you address several of these problems, and many of you may be in the forefront of solving these problems in future, right?

And, you will realize that somebody elsewhere developing a new class of material, is going to change the way that you are probably designing a product or conceiving a product and so on, right? So, you can actually think of the computers, right? So, the way the computers have been miniaturized, from the first-generation computers to the mobile phones you have today, because of the development of new technologies and new materials that we have today.

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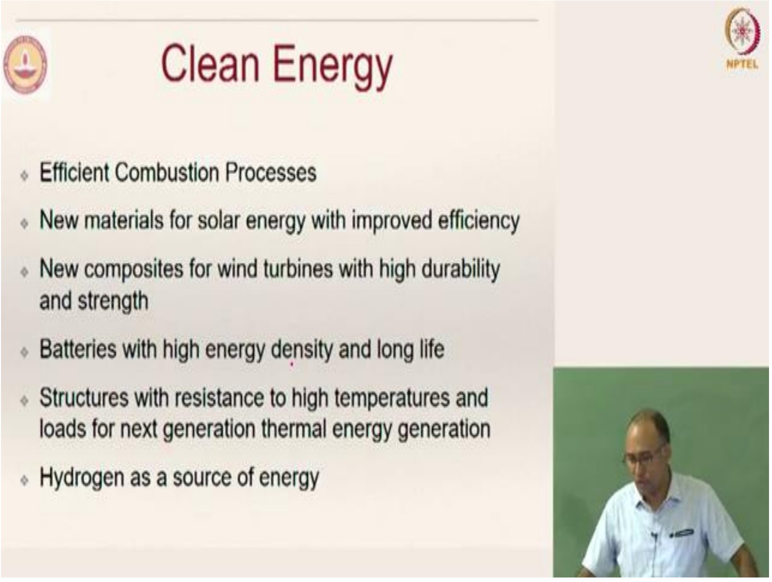

Alright. So, how about clean energy? What are the issues with the clean energy? Main problem is you have a lot of thermal coal-based energy, right? What is the problem with coal-based energy?

Student: (Refer Time: 19:47).

Lot of pollution, right? So, you cannot get rid of coal-based energy at all. You cannot say that ok today I am going to shut down all my thermal power plants. I am only going to rely on renewable sources of energy. Then you probably should stop using, or you probably start accepting huge power cuts, once an hour per day availability of power, right? Because the fraction of thermal power is significant in our economy, right?

We cannot simply stop them. Rather what we should do is, we should try to make that energy a clean energy. That means, you we need to reduce the pollution that is coming from these energy sources. So, efficient combustion processes; you need to burn coal in a better manner, so that you reduce the pollutants.

So, even today solar energy has several issues. What are those issues? Particularly the efficiency, the kind of materials that you have. The efficiency values are not really encouraging today, but if you have new kind of materials which can enhance the photovoltaic efficiency for solar panels, that can reduce the energy production costs significantly. If you reduce the energy production costs, then probably one day you will be able to get rid of thermal power.

But then it comes with some problems, right? So, you now if you want to create a solar power plant you need to have lot of land area, right? And it should be depending on the sunlight.

So, these are the issues that you need to work around. But the main issue is if you are able to come up with new kind of materials, you can actually enhance their efficiency, and hence probably increase the fraction of solar energy that we have in our economy, right?

And, wind turbines: again, the materials that are used for making these wind turbine blades needs significant improvement. So, there are different kinds of composites that are used which reduces the weight of these things, and at the same time increases the strength of the blades. This is another area.

So, that means, there is a need for new kind of material design there. And, you must have heard about lithium ion batteries, right? All of you have at least one lithium ion battery with you, right?

Student: (Refer Time: 22:29).

At least one, if not more. The problem again is the energy density, right? How much energy that you can store per unit volume of this lithium. So, if you can increase the energy density of these materials, and efficiency of these materials (lithium ion batteries), then you can actually use these batteries for longer time, and you can reduce the losses.

So, that means, you need to invent new materials, and understand the behavior of these materials, or you need to minimize the failures in lithium ion batteries. Sometime back you probably heard of batteries exploding, right? (overheating). So, as an engineer you need to understand what is the cause for this overheating, and how can you circumvent these problems, right?

So, it involves lot of money, right? If you are designing a battery and which produces a lot of heat and your customers are not going to be happy and they are going to return the product and causes lot of money. So, you need to understand as an engineer what are the causes and see if we can fix these issues, right?

And, even if you are going to live with your thermal power for instance -- today people are talking about super-critical boilers, wherein you increase the temperature at which you are running your turbines, right? If you are increasing the temperature at which you are running your turbine, what happens? What is the advantage? How many of you have taken thermodynamics course? Right? How can you increase the Carnot efficiency?

There is a source temperature and sink temperature, right. What are the different ways that you can increase the Carnot efficiency?

Student: (Refer Time: 24:17).

Either increase the source temperature or decrease the?

Student: Sink temperature.

Sink temperature, right? So, analogously for a steam turbine, if you increase the temperature at which your turbine can operate, you are sort of increasing the distance between source and sink. That means, you are going to increase your thermal efficiency.

But the problem is the materials cannot withstand such high temperatures, right? The current materials that we have, are not able to withstand such high temperatures, they will fail quickly. So, now, you need to develop new kind of materials, new alloys which can withstand these high temperatures, so that you can increase your thermal efficiency. Why do you need to increase thermal efficiency? So that you can burn less coal for getting same amount of energy, right?

Another important area of study for clean energy is hydrogen as the source of energy, because it is a carbon zero source of energy, right?

Recently you probably have seen LinkedIn posts or Facebook posts from IIT Madras, that one lab has developed a better way to extract hydrogen, right? So, people are working on extracting hydrogen at minimal cost because that is going to change the way that we are going to work with energy. You can completely get rid of carbon-based pollutants, right? It is cleanest form of energy that we can think of. Alright.

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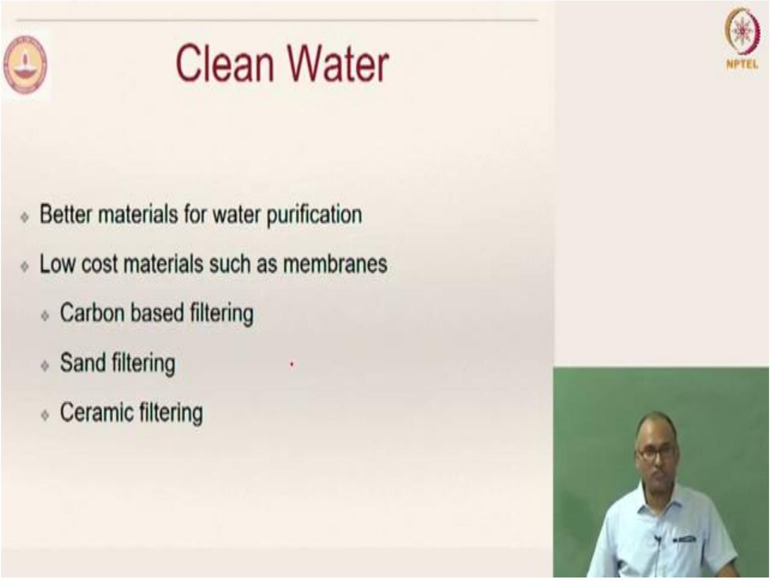

Then clean water, of course, you need to have better materials for water purification, right? All of you must have had a water purifier at home or at least you have one in your hostels, or you have purified water in your hostel, right? So, you need to have better materials which can reduce the cost of purification, right? If you can reduce the cost of purification, then it saves lot of energy again.

So, in some sense energy is going to influence every other technological invention that we are going to make, ok?

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And, health care: biodegradable materials for implants, disposable materials for surgeries, and how can we minimize hazardous healthcare waste, right? So, just now we have discussed that we use the syringes for taking shot and we just dispose them. And do you know how much time does it take for one plastic syringe that you are we are disposing off to decompose? Do you know how much time does it take for a banana peel to decompose? The banana skin you peel off and throw away, right?

Student: Right.

And, it decomposes or not? It does decompose, right? How many days does it take? Couple of weeks? Yeah? How many days does it take, for instance a cigarette bud to decompose? Have you thought about it??

Student: (Refer Time: 28:02).

Please go back and Google the time for decomposition of different materials, ok? And then you will see why we have problem with plastic today, ok? And you will understand the reason why the government has banned usage of one time use plastics, right?

So, next time when you go to a restaurant, ask them to give you steel cutlery, rather than giving you a plastic cutlery. Do not request plastic cutlery from Zomato and Swiggy. Say I do not want cutlery, after Googling, and you will realize what we are doing by saying do not want plastic cutlery, ok? Alright.

So, we also need to develop new methodologies to deal with new epidemics, and develop new medical devices, right?

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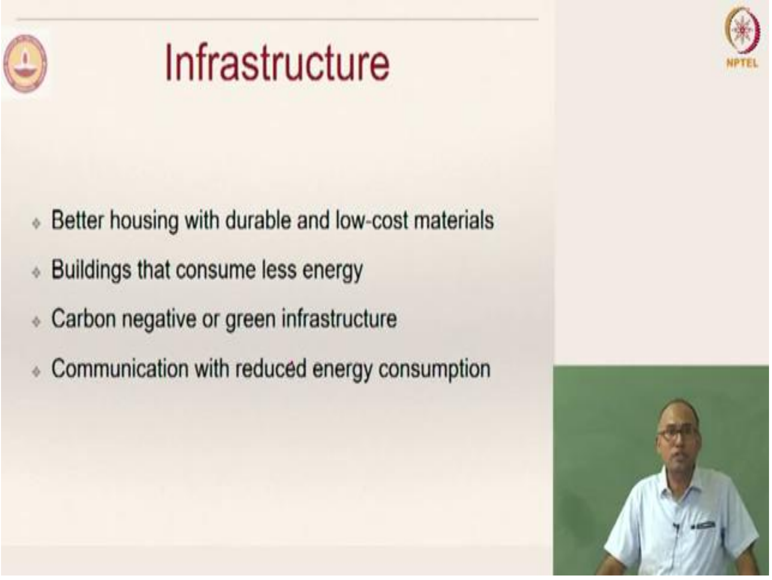

And, for infrastructure, you need have better housing. So, you need to have better material. So, for instance, if you are in a cold country, you need to ensure that your housing material is good enough for safeguarding you from extreme cold.

So, that means, the thermal conductivity; it should be a good insulator, so that you can minimize the heating costs. You will have a heater in the house, but if you do not have a good insulating building material your heating cost will go up, right?

So, your building material should be reasonably good enough, right? And you need to think about developing buildings which actually produce energy rather than consume energy, right? So, people are now talking about green buildings. So, carbon negative buildings; that means, they actually would not consume energy, they will have a net negative consumption of energy. The building itself generates energy by using solar panels and so on, right?

The new kind of materials that one needs to develop, and then that leads to a significant reduction in energy costs. And of course, communication: how can you reduce the energy costs through communication? Have you ever thought about posting an image in FB, Facebook? Does it cost energy? How?

Student: (Refer Time: 30:38).

Which generates the?

Student: (Refer Time: 30:43).

Yeah. For every image that you are posting on FB, they are not storing actually on one server, but they are storing on several data servers, ok? So, if you keep on increasing the number of posts, then you are actually increasing the overhead on the servers, and you are actually causing global warming. So, posting a message can also cause global warming, right. So, you should be responsible then.

Student: (Refer Time: 31:13).

Right.

(Refer Slide Time: 31:14)

So, can you think of materials that changed history? Can you name?

Student: (Refer Time: 31:20).

Louder.

Student: Plastics.

Plastics. Plastic is the only thing that changed history?

Student: (Refer Time: 31:27) iron.

Iron.

Student: (Refer Time: 31:33).

Quick quicker.

Student: (Refer Time: 31:36).

Concrete.

Student: (Refer Time: 31:38).

Aluminum; so, metals. So, then one person said iron, another person said aluminum, then you will start reading all the elements in periodic table.

Student: (Refer Time: 31:48).

Silicon, very good.

Student: Bronze.

Bronze.

Student: Carbon.

Carbon.

Student: (Refer Time: 31:56).

Go ahead.

Student: Carbon (Refer Time: 31:59).

Carbon fiber ok, very good, go ahead.

Student: Glass.

Glass. You are sitting on?

Student: Wood.

Wood, ceramics. You never bothered about talking about this.

Student: (Refer Time: 32:26).

And, none of you said.

Student: (Refer Time: 32:32).

Yeah, we have spent almost 15 - 16 years of your life with that and you forgot; and semiconductors, right? These have changed the way that world operates, and new materials are going to change the way the world is going to operate, alright? So, we cannot imagine how the future is going to be, because we do not know what kind of new materials that are going to come out, right?

Student: Yes.

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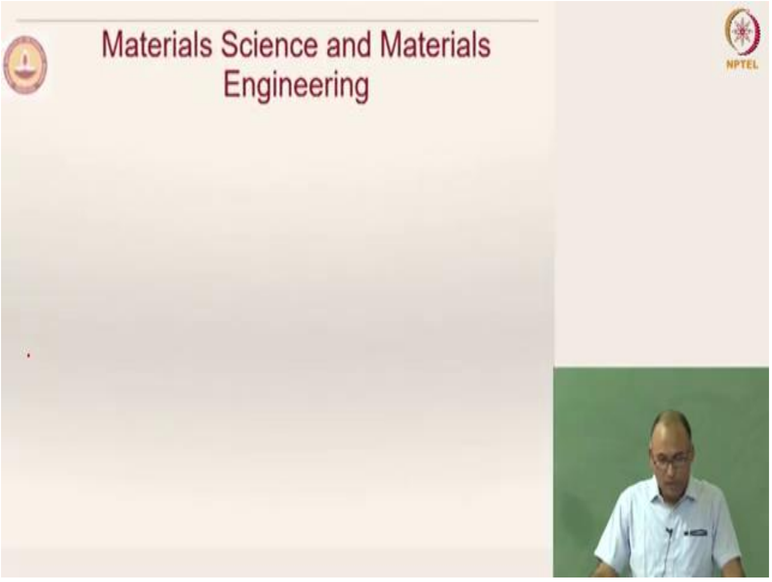

Okay, so, with that I will stop.