An Introduction to Electronics Systems Packaging

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Lecture No. # 01

Introduction and Objectives of the course

Good day to all of you. This is an NPTEL course by video; this course is titled An Introduction to Electronics Systems Packaging or you could call it microelectronics systems packaging because it covers the entire area of macro electronics and microelectronics.

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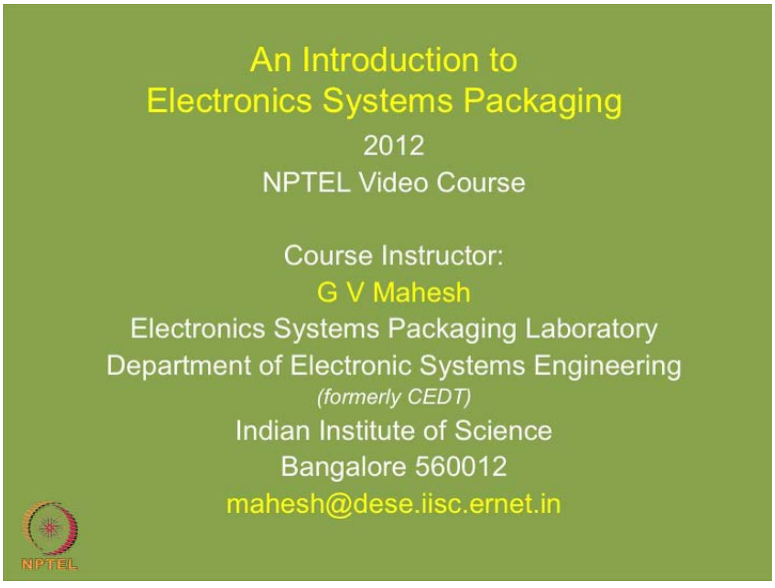

This is a NPTEL course given for the first time in this particular topic and this specifically would suit under graduate and graduate students. I am your instructor; my name is G.V Mahesh. I am a faculty member heading the electronic systems packaging

laboratory in CEDT (Center for Electronics Design and Technology) Indian Institute of Science, Bangalore.

Many of you may not be aware of this particular topic because, at the B.E level in India, you do not have this curriculum yet defined, So, many students who come to CEDT for their M.Tech program, are basically sensitized to this very interesting and multi disciplinary topic called Electronic Systems Packaging. I would like to take you through this broad spectrum of microelectronics packaging. There are several modules as you will see; each with a very definite purpose of making you understand the various levels of packaging and at any point of time if you have any necessary questions to be answered while you are going through this course in the web, you could write to my email address which is mahesh@dese.iisc.ernet.in.

We are going to talk about products; we are going to talk about electronic products which we call as systems. Now, there are various electronic products in the systems in various fields and at the outset, I want to say that the word packaging really does not mean packing an electronic product.

For example, here I have an electronic product which you all know is a mobile phone or cellular phone. Packaging does not really mean putting it into a card board and packaging it. First of all this notion should go. We are talking about electronics systems packaging; that means in some sense packaging is called miniaturization. How do you make a package perform efficiently? How do you make a product or system work efficiently at different conditions, at different environmental levels so that it can perform at the specified function and performance levels? For that we need to understand right from the basics of how a system or the product is made and how it is tested for various functionalities like reliability and so on.

Obviously, when you buy a product you want the product to function for a long time. For example, if you buy a mobile phone you ideally would like to keep the mobile phone for at least 5 years but, actually the product has a specified reliability for over 15 years. In practice, the mobile phone is often changed hands because, new models come, new technologies come and as a user, we do not wish to keep that particular model for a long

time. That is the fact. But, the technology or the product that has been made 5 years ago can still perform reliability at a specified functional level.

So, that is idea about packaging. First thing is, it is not cardboard packaging; it is relatively new in India; whereas abroad, in industries, there is a very large tie up with academic institutions to understand and research in packaging and continuously new products are put to rigorous packaging designs in various fields. It can be electrical design, it can be thermal design, it can be environmental design. Therefore, packaging should take place at the concept level; that is, from the design of an electronic product. For example, if you take a mobile phone, the packaging for this particular mobile phone would have taken place right from the design stage and I say design; electrical design as well as mechanical design because, the electronics here is now protected by a mechanical enclosure and that also aids in the performances levels of a product.

I want to specify some very general scenario because, if you are new to packaging if you take this course, you can easily pick up the basic fundamentals of all the aspects of packaging and when you go for a post graduation or for a doctoral degree you can work on specified areas or special topics in packaging.

You can be a mechanical engineer, a chemical engineer, chemist, a physicist, a material scientist, polymer engineer, bio engineer; all of these areas as has been mentioned in this particular slide.

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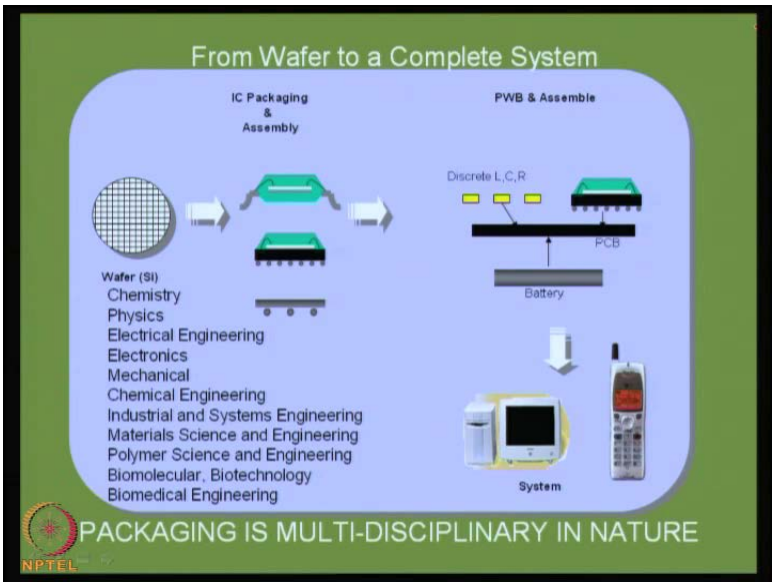

If you look at this slide where I have a depicted how the process goes from a wafer to a complete system. On the left side you see a wafer; I am showing you here a sample of a wafer, a silicon wafer.

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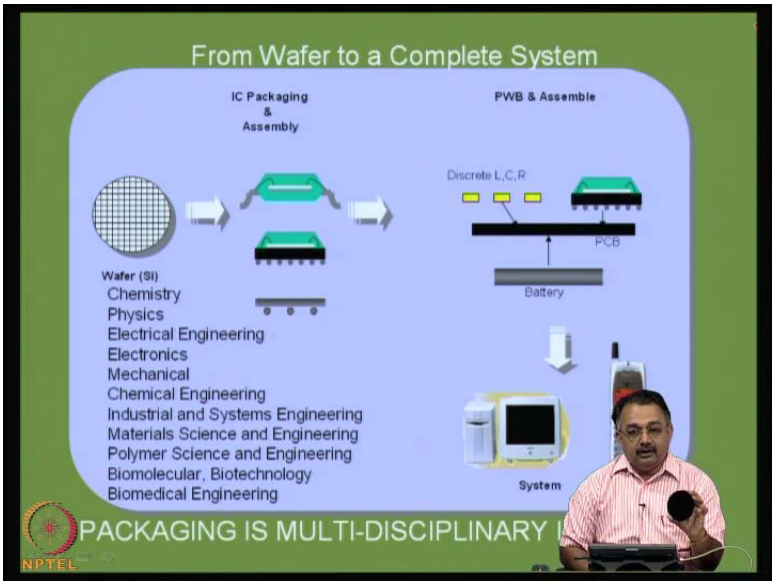

This is the starting material of all the electronics build up today for any product only the size varies and the performance levels varies. If you go back to the slide, there is the

wafer; from there you go to what is known as manufacturing or production of single chip packages; how the ICs or Integrated Circuits are manufactured in various formats and from there as you go along you will see that there is another set of activity that is called PWB (Printed Wiring Board) and assembly where a single package or group of packages are mounted together and inter connected on a single substrate called printed circuit board. There are other electro mechanical components etcetera that would be around the critical devices powered by battery and so on and then it goes to the formation of a system.

As I said before, a system can be a computer, it can be handheld product, a mobile phone for example, it can be a handset of a telephone, a washing machine in consumer electronics area, various products - audio systems, video systems and it can be very high in performance systems, commercial systems as well as specialized systems in avionics, it can be in the area of a automobiles. Today, automobiles sector is growing very fast and you can see new types of vehicles especially cars coming into the market. New models come and you can see the price tag for these automobiles increase basically because the functionalities are very high; the performances is very high which the consumer expects and there is a price tag for the performance.

In some cars for example, there can be under the hood, something like 50 to 55 microprocessors running, giving you various information; we will talk about it during the course of this talk.

So, it can be automobiles, power systems, space electronics, avionics, aerospace. Hand held products are the major contributors for the electronics market. If you look at the total electronics market, hand held products occupy very important position, very large market share. So, people who are working in the areas of electrical engineering, electronics, mechanical, chemical engineering, industrial and systems engineering, polymer science, material science, biomedical engineering, biomolecular technologies or bio technologies, all of these people can contribute in the field of packaging. That is why I mentioned here that packaging is a multi disciplinary area. The research activity globally is multi disciplinary in nature.

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If you look at various research groups globally, you find various people from these groups working in tandem to bring out a very high performance, highly reliable electronic product. We are going to discuss in this course the process from a wafer to a complete system (Refer Slide Time: 10:38). If you keep this idea in mind, you will be able to understand flow process of this course and we are going to study everything in between from the wafer to the system.

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If you look at the next slide, briefly I will talk about the electronics packaging group in CEDT Indian Institute of Science where we look at system like what is depicted here in this picture (Refer Slide Time: 10:58). It is a board, printed wiring board and it is a system because the board performs system level functions. What are system level functions? It can accommodate various packages on the surface. It is a very high density board. The activities involved in this area will be electrical design, materials engineering, manufacturing, electrical test, reliability which includes thermo mechanical reliability and environmental issues. When you define a system, you have take care of all these parameters before qualifying a system.

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In CEDT, we have a lab which caters to these requirements. We offer a M.Tech course here in CEDT; a packaging course which is probably the only packaging course in the country to offer hands-on curriculum to the students. Absolute; whatever is learnt in the class is actually dealt with in the lab and the students gain firsthand knowledge about various packaging activities. For any packaging activity anywhere, you require dust-free lab for photolithography analysis lab, chemical process lab and surface mount devices lab which we have in CEDT. We have a research focus on microvias which is basically inter connect structures between various layers of conductors in a board or a system. We also work on embedded passives. Today's hand held products and various other high end systems, tend to prefer using organic substrates because, organic substrates are very cheap compared to inorganic substrate like ceramics. During this course, I will also explain how to utilize organic substrate technologies involving sequential build up technology to produce high density interconnect substrates.

What is electronic systems packaging?

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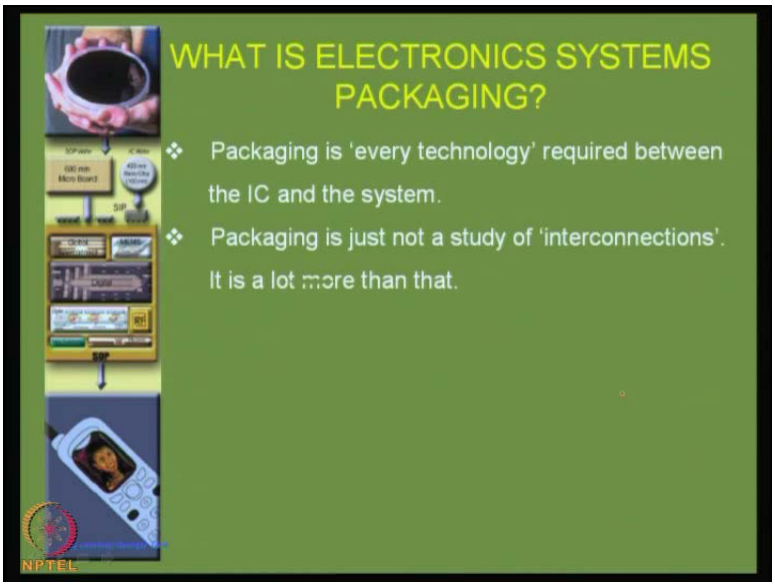

Given this background, I would like to explain some kind of definition; it is very difficult to define in it is entirety; there is no textbook definition for packaging.

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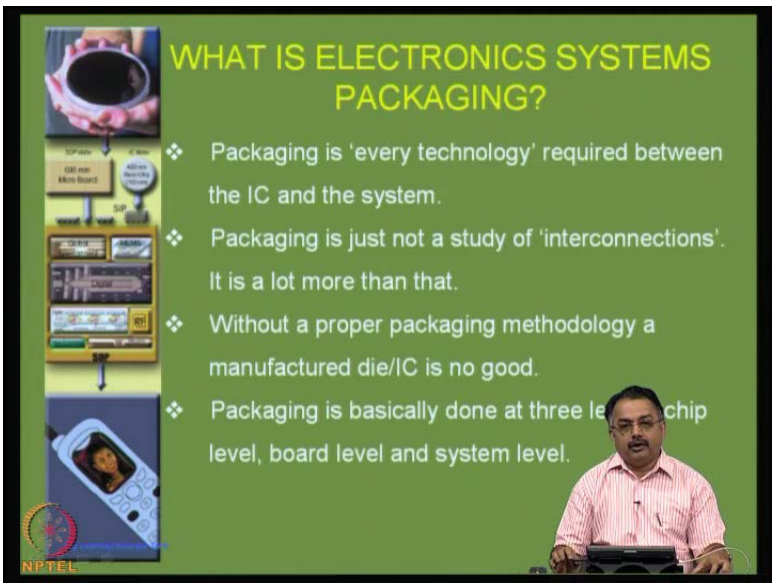

The first bullet says, packaging is every technology required between the IC and the system. Like from a wafer you go to produce integrated circuit - a chip, a device or a microchip or you can call it as an active device which is very essential in any system

whether be it a small system or a huge server or a huge satellite. So, you are going to talk about every technology required between the formation of the IC, packaging the IC and then the system.

So, packaging is just not a study of interconnections; it is lot more than that because, it involves study of materials (Refer Slide Time: 14:28) the relationship between material and electrical performance, relationship between materials and thermal performance or thermal management. So, the failure of a system depends on various factors which is what we have going to study.

Although, if you look at a system when it is powered up, there is an electron flow between components or devices. For that flow to be very efficient and to make sure that there is no signal propagation delay, there is no heat buildup, various factors have to be taken into account including the mechanical enclosure. For example, you should know what material you will use for packaging a board or packaging an IC. Should it be a metal or a plastic or should it be a ceramic or any other material? How does it affect the reliability hence forth if you package with that material? Without a proper packaging methodology, a manufactured IC or a die is no good.

An IC might I have been qualified as good die but then, once you integrate it with the system, a proper packaging methodology has to be defined. There are various methodologies; you cannot really say methodology a is good for handheld; methodology b is good for satellite systems which cannot be used for handheld products; so, we have to make a very proper individual design choice to make it very effective.

I hope this packaging course will give you some kind of a sensitization to these very critical questions that any packaging engineer will ask. Packaging is basically done at three levels. One is at the chip level, the second is at the board level; for example, this is a board (Refer Slide Time: 16:29) where you can see various devices are mounted - bare it the ICs and these are interconnected in between them. This is known as the board level packaging.

What are the critical issues when you have to mount an IC or an active device on a substrate? From there we go to what is known as a system level. In a system level, you can have 2, 3, 4 boards connected together by connectors wire harnessing and so on and therefore the requirements there that is the packaging requirements there at the third level or system level will also have to be taken into account. So, these are the 3 levels of packaging; a chip level, board level and system level packaging.

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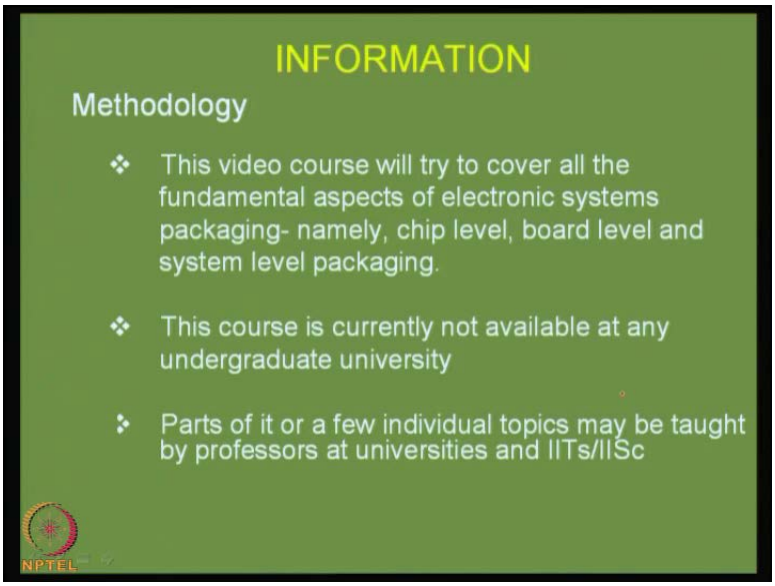

This video course will try to cover all the fundamental aspects of electronic packaging namely: I will define what is chip level; I will define board level and system level packaging and we will get into the inner aspects of all these packaging levels. This course is currently not available at any under graduate university. Part of it or certain topics from this might be available as individual topics and will be offered by professors at IITs or IIScs but here, we will see an integration. Although maybe the amount of material covered will be very less but we are trying to cover the entire spectrum of packaging, sensitize you to these individual topics, so that you can pickup from here and attend the advanced courses that are offered in your university or IIT's or IIScs. I will sensitize the students to electronics packaging at the graduate level.

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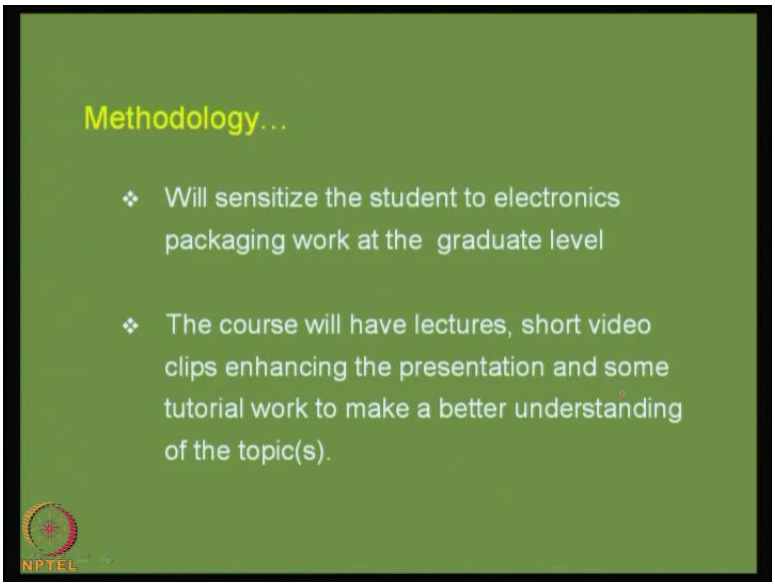

This course will have lectures basically, short video clips. I will try to present that well enhanced presentation and make you understand the process, or a design issue or an assembly issue and some kind of tutorial work in some cases in some modules that will help you understand better, the topics that we are dealing with.

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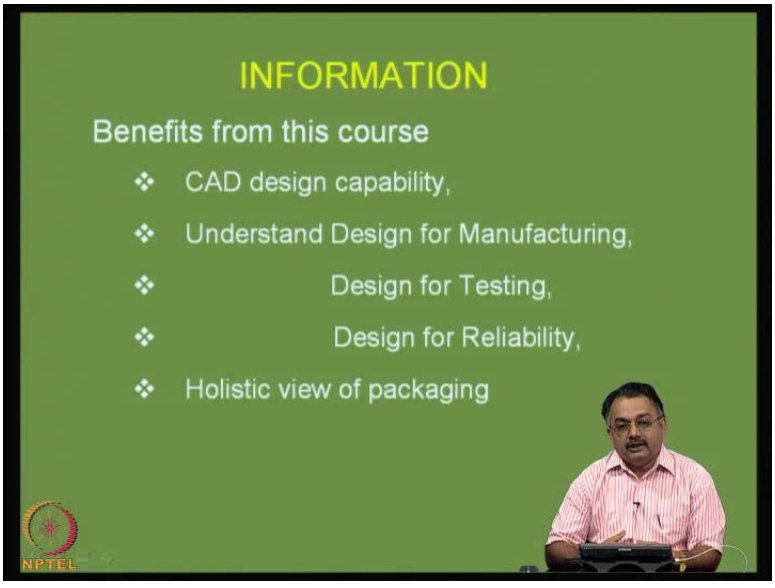

So, the question that you can ask now is, if I take this course, what are the benefits? That is a very valid question; I should be a able to answer you up front because the benefits from this course is that you will be able to understand CAD design issues or design capability that is related to packaging. And I say CAD here; we are going to talk about printed circuit CAD. We are not going to talk about VLSI Cad issues because, VLSI - Very Large Scale Integration of ICs does not really fall into the electronic systems packaging field. It is outside this field and typically IC design is not packaging. Once the IC is made and then it is subjected to packaging, then starts the packaging activity till the system is realized. I think one should be very clear about this VLSI design not coming under this particular module.

This design that I am talking about will be basically printed circuit board design or second level packaging design. Then you will be able to understand the terms like design for manufacturing, design for testing and design for reliability. these are not only buzz words in the industry today, these are essential components of packaging activity. Because, a very simple point is, if you are designing a particular system and if it is not manufacture-able, then your entire design cost is a waste and the time that you have spent or your company has spent, is going to be accounted for.

First you should know what is the consumer requirements. Whether this product can be manufactured and it is not only manufacturing, you should be able to sell it at an affordable cost. Suppose I sell this mobile phone at 500 dollars, nobody is going to buy it. It has to be affordable with high performance and high reliability.

You can understand that packaging involves a lot of responsibility from design engineers and manufacturing engineers to reduce the size, miniaturize it, lower the cost, increase the performance and provide higher reliability so that the consumer or customer is satisfied globally. The other issue that is you will see in the slide is design for testing. If you design a product which you cannot test it later then you are at a problem to answer because, you need to define systems that can be tested repaired and reworked. Obviously, all systems are not 100 percent reliable. There can be some few parts per million that will

undergo failure; but then our engineers should be able to understand what is the problem, test it and probably repair and rework, to extend the life of the system.

The next point in the slide that will see is design for reliability. In today's world reliability is something that goes when you do the design aspect itself. If you think of reliability at a much later stage, then this not accepted in the industry today. So, when you do a design for example, you choose a material, let us a plastic for this particular product and if it is going to be subjected by heat and if it is going to warp or bend or creates some kind of bubble at the surface that means, there is a reliability problem on the material itself; which means, you have not taken care of it when you selected or designed this product.

Similarly, when you talk of a board or an IC here (Refer Slide Time: 23:20), during its operation if there is a crack on this silicon die or if there is some copper interconnect that is breaking up during the process that means there is some problem at the design level when you have manufactured this subsystem. You have to build in reliability at the design stage itself so that, your throughput is large, yield is large and time spent for repair and rework is very minimum.

Today, these industries are looking for very low failures; failure rate should be very low. So today's products are trying to achieve this you can experience this over the last 10 years, even our consumer systems or not failing much because, the reliability has been built in because of the understanding of various packaging levels including materials and so on. The benefits from this course finally will be, you will get a holistic view of packaging including electrical, thermal, materials and so on.

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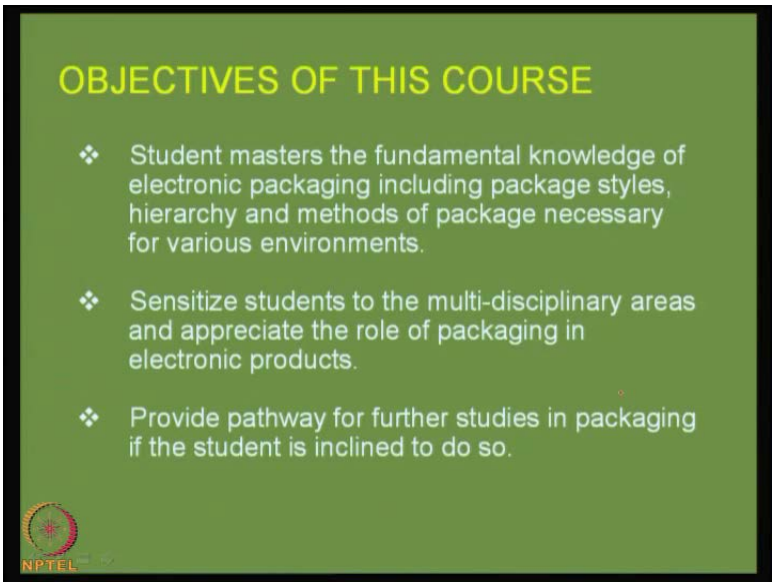

The objectives of this course as we will see now, is the viewer or the student will master the fundamental knowledge of electronics packaging including package styles.

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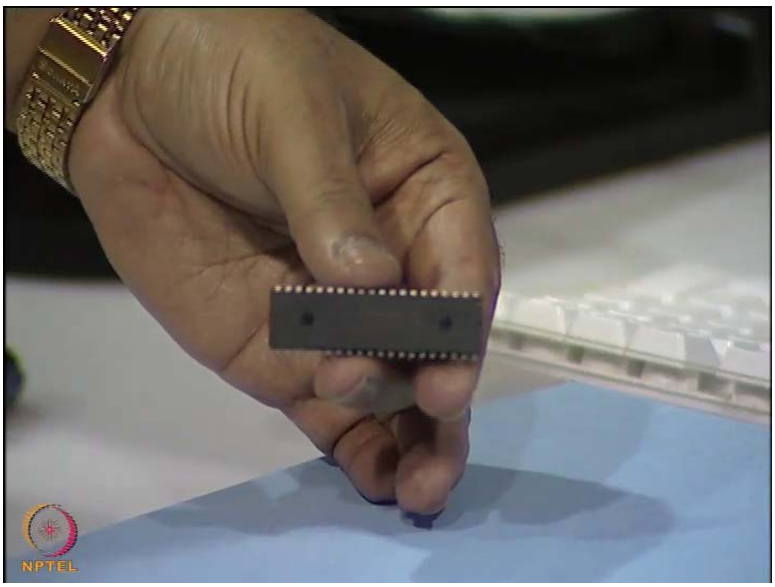

For example, this is an IC you can see here; the very old device this is known as a DIP package (dual in line package) and from here (Refer Slide Time: 25:08) we have moved

on to various form factors and what I can show here is very small device which probably houses 20 times this IC functionally and with high reliability.

this is very large DIP package where as this is small package this is called chip size package (Refer Slide Time: 25:23) which is equal to 20 times this particular package. How is it achieved? Because there is a lot of miniaturaization from the design stage; new technologies at the silicon level has been built into it and there is very minimum packaging and it occupies very less area when it is mounted on a substrate like this (Refer Slide Time: 25:44). Yet it will perform 10 times, 20 times more than the earlier device which I showed you so you will get a fundamental knowledge of various packages styles, the hierarchy of packages over the years and the methods of package necessary for various environments.

So if you are going to work or use a product that is going to be used in the desert for example, where the temperatures can vary from plus 50 degree centigrade to in the winter it can even go up to minus 25 let us say; so how is a product going to perform and what kind of package materials are required for various environments? Space for example, what kind of package you have to use? Mobile phones, should you have expensive materials or you can do with very cost effective packaging requirements? That will be covered in this course. Students will be sensitized to the multi disciplinary area and you have to appreciate the role of packaging because of this multi disciplinary area are activity in these electronics products.

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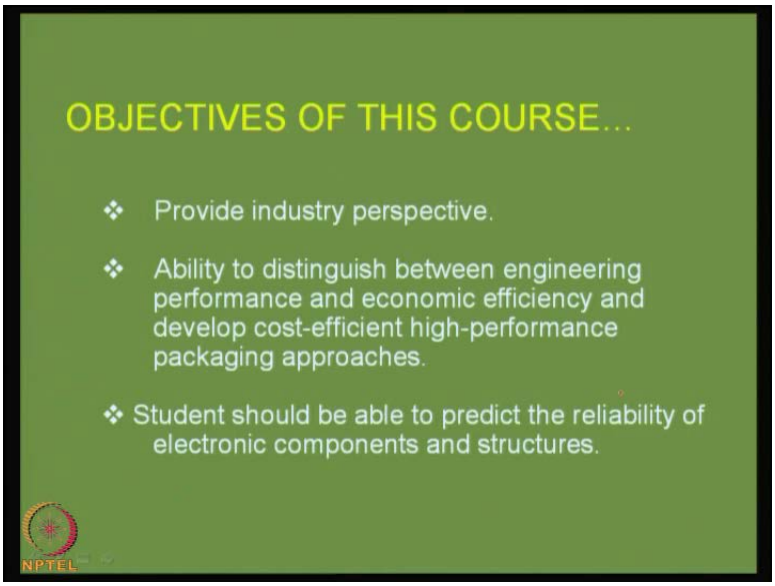

This course will provide a path way for you for further studies in packaging if you are further inclined to do advanced training or academic activity in electronics packaging. It will provide an industry perspective. It will also give you an ability to understand a distinguish between engineering performance, economic efficiency and to develop cost efficient high performance packaging approaches. The one important thing which I want to highlight here is, if you are designer, the important thing is cost efficiency and high performance; these are very much related. At the outset it is going to be very difficult to build high performance at low cost; but, a good packaging engineer will strive to achieve these very two extremities in packaging.

I think this part is very important for all of you to achieve. Even if you are going to be an expert let us say in electrical, you can contribute to these two aspects from the electrical stand point or a thermal stand point or a material stand point. The student should be able to predict the reliability of electronic components and structures; that should come very automatically once you become well versed with various topics.

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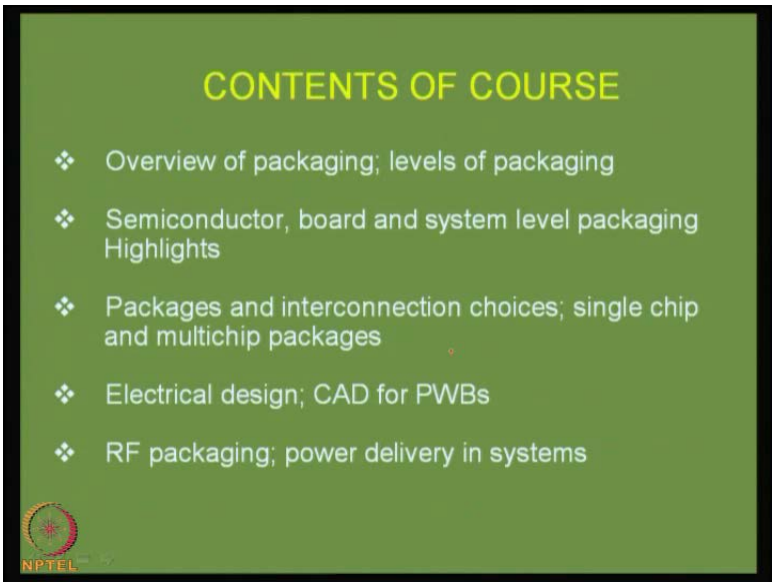

The contents of this course, we have now discussed the objectives. I will list the contents of the course which you can expect: overview of packaging: levels of packaging. We will talk about semiconductor manufacturing briefly, semiconductor packaging; board level packaging and system level packaging highlights. We will also look at road maps; technology road maps that each of the these contribute today because, road maps are very important if you want to work with the industry.

The industry is going very far ahead because of large contribution from the academia; very good consultation established between academics and industry. If the industry has to grow they put new targets every year and that is called road map which we will see about. We will talk about packages and interconnections choices; single chip modules and multichip modules, electrical design aspects; basically, we look at parasitic in electrical issues or a good electrical design will be understood; computer aided design for printed wiring boards is a very important method to implement here electrical design activity; so that will be taken care of in this course.

We will try to talk about RF packaging and power delivery in systems because, many products today are using RF and we will talk about various printed wiring board

technology because if you talk about printed wiring board, this is something like a heart of an electronic product (Refer Slide Time: 30:12).

You are going to realize this is something like a system (Refer Slide Time: 30:17); it can perform system functions but you have if you have a huge product it will be called a subsystem because it will be connected to various boards and we are going to see how these second level packages are manufactured because there are various choices today in the industry.

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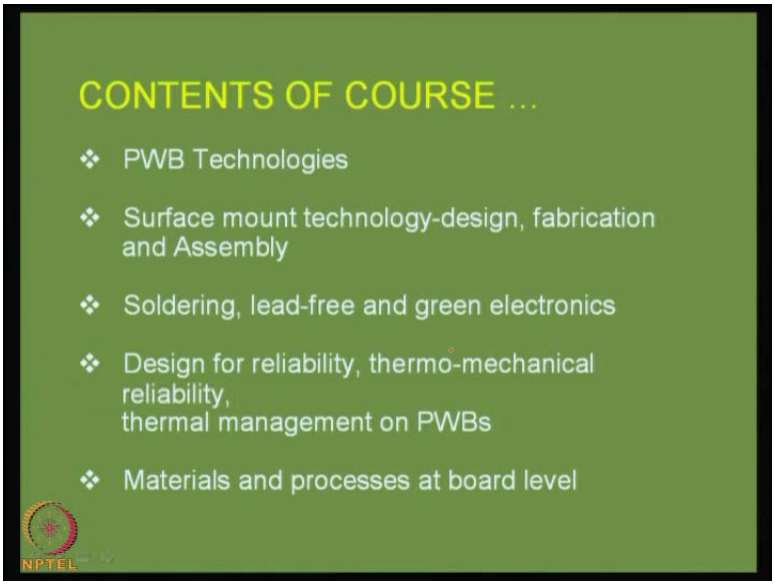

We will look at cost issues in these technologies also and we will also look at the status in India today in these technologies. We will talk about surface mount devices or surface mount technology the design fabrication and assembly issues in surface mount technology because surface mount technology is very current state of the art technology for miniaturizing an electronic product. Components need to be interconnected or joint by a process called soldering; so we will study soldering process. We will also look at how soldering has taken place over the years and what is current technology and very importantly, current packages or current electronic systems, packaging methodologies will need to be lead free and we have to implement green electronics everywhere. So I am going to devote a very substantial part of the time on evolving a green product. When

I say green, it is environmental friendly and lead-free. Why should it be lead-free? Lead is a metal and till now it was used as one of the elements for attaching components on to a substrate. Because of the health hazard posed by lead it has come into legislation, lead has to be removed. We are now trying to see how to use lead-free materials for attaching components on to substrates. Then we will discuss issues like design for a reliability thermo mechanical reliability thermal management on printed wiring boards because, when you take a device or a group of devices and when you power up on a board obviously the first thing you will notice is heat is built up on the surface. Heat is dissipated from the device. How are you going to tackle this heat effectively so that your system can survive? Accordingly, if there is a chance of heat buildup what kind of materials and processes you need to use? so we will spend some time on materials and processes at the board level. You are also going to look at materials at the chip level.

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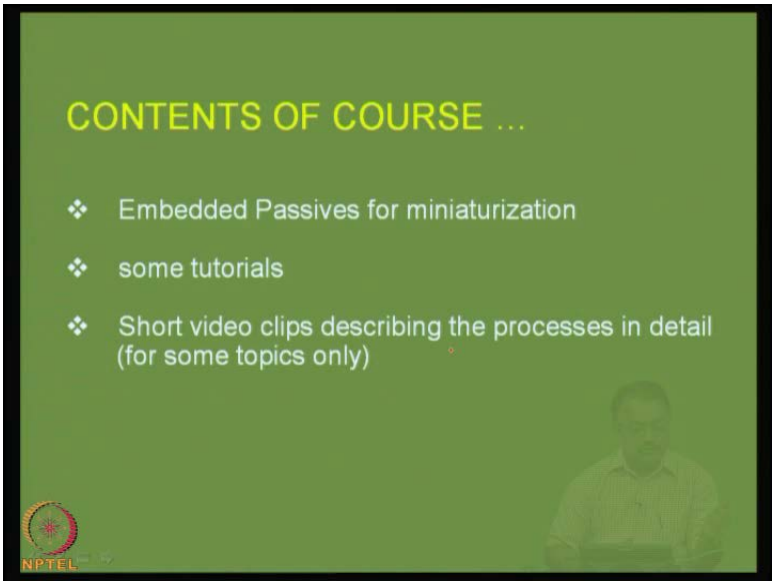

Continuing, we will finally look at embedded passives for miniaturization because today we are talking about very bulky components like capacitors and resistors (Refer Slide Time: 33:14). Are there new technologies to dispense of with these kind of bulky components because, these occupies space, large amount of space? Yes, there are

technologies and we are going to see what is the role of embedded passives in electronic system packaging.

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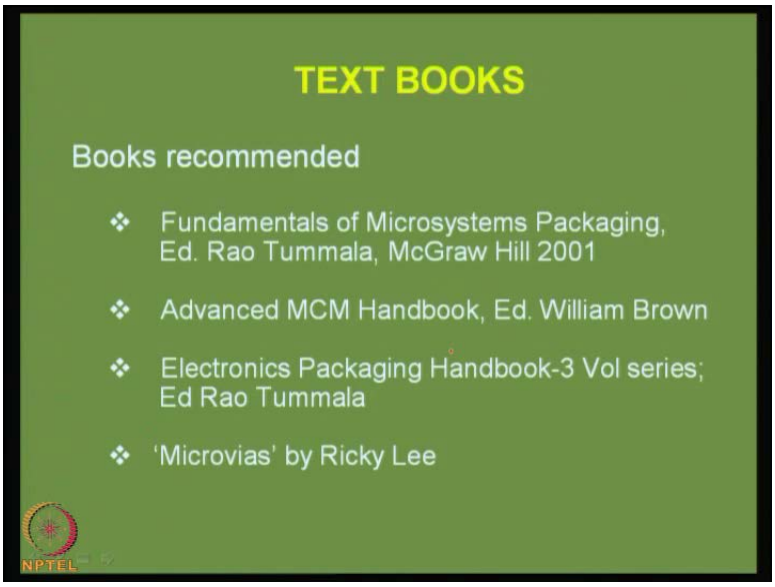

There will be some tutorials and short video clips describing processes in detail for some selected topics. Now the textbooks that are recommended for this course: the first one I would recommend is Fundamentals of Microsystems Packaging. This is a book which I show here the cover page (Refer Slide Time: 33:57). This is a 2001 edition and the editor is Rao Tummala. This is considered a Bible and this is being used by over 60 universities globally. I am very glad to be part of this book; I am one of the authors in this book. I recommend everybody to go through this book and we will follow this book in this particular course.

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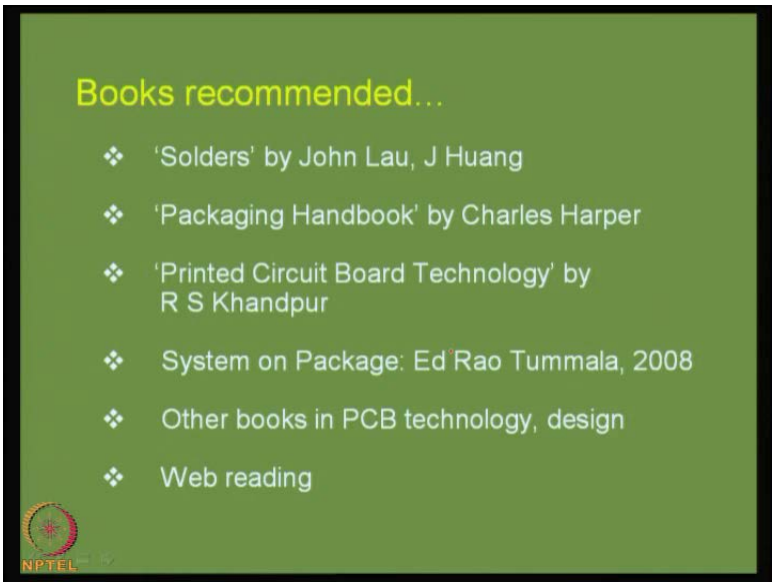

There are other books which you can go through; Advanced Multichip Module handbook by William Brown; Packaging handbook series by Rao Tummala; 3 volume series which many libraries will have; Microvias technologies by Ricky Lee; if your interested in board level packaging issues you can look at these topics. Solders by John Lau, J Huang; if you want to study further on soldering technologies, Handbook on Packaging by Charles Harper. We have an Indian book, Printed Circuit Board Technology by R S Khandpur; that is also available and it is a highly recommended book for this course. More advanced topics are available on system on package by Rao Tummala. It is a more recent 2008 handbook; but it describes more research aspects in packaging from global centers. So there are other books in PCB technology, board design materials, semiconductor fabrication, so on which is very difficult to list the entire series here.

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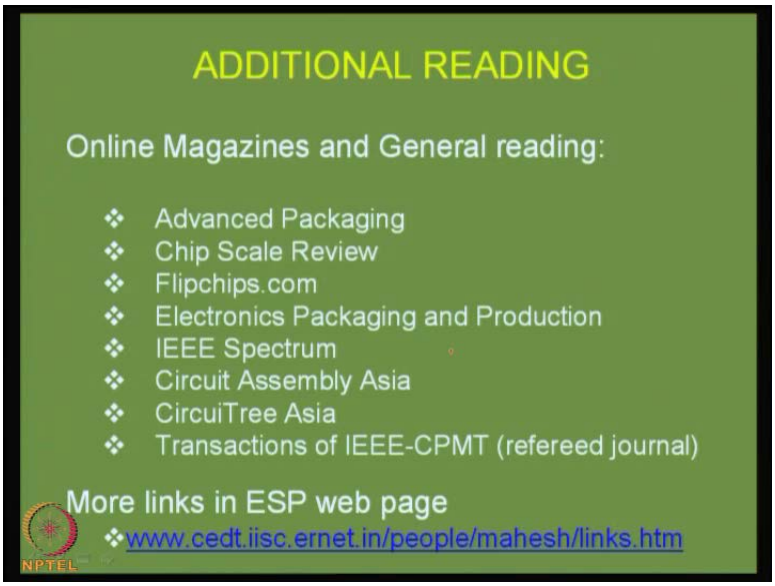

There is also web reading that you can do. But, this course will try to bring various materials from various sources and this will be collated and shown to you here so that you can look at the entire spectrum of packaging and benefits from these. Online magazines are recommended to read because, very excellent packaging journals are available today like transactions of IEEE CPMT journal is a refereed journal for researches in packaging magazines like advanced packaging chips scale review which are monthly magazines which give you current state of the art technology issues globally. Both academy and industry are presented; electronics packaging and production a website called flipchips.com is very useful if you wish to read about bare die or flip chips. IEEE spectrum will give you very often interesting packaging activity presentations, Circuit Assembly Asia, Circuit Tree Asia, are magazines from southeast Asia which focuses on Asian industry activities. You can visit CEDT electronic systems packaging web page at www.cedt.iiscernet.in where, I have listed many links and we have also listed current research activities that you can look for globally.

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I was talking about road maps. I think for any packaging engineer one much understand road maps at regular intervals; every industry will have road maps and there are some institutions like IPC - Institute for Inter Connection and Printed Circuits, Semiconductor Industry Association, ITRS - International Technology Roadmap for Semiconductor and inemi - International Electronics Manufacturing Initiative; all of these bring roadmaps.

The road maps as I said earlier are guidelines for the industry and that is how the industry can grow fast if there are no road maps the industry would have been stagnant. So it is good once in a way to go and check, download these road maps and understand and get some useful numbers. For example, you must know what is the wafer size that is being used today in the industry, wafer dia (Refer Slide Time: 38:23) and what is the thickness and what is the technology that is the line which that is the generated on these wafers currently and for the next 10 years what is the industry plan or progress that is anticipated.

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You can also visit IEEE-CPMT; probably this is the only society that gets us to packaging and manufacturing technologies. So please visit IEEE-CPMT website for conferences and various seminars, web based seminars or webinars as you call it and some workshops that are being held even in India. So CMPT is a very important society. I think for people who are interested in becoming packaging engineers, it is better to become member of IEEE CPMT. ITRI - Industrial Technology Research Institute, works with various academic institutions on one side and industry on the other side. It is like a consortium and they bring out various details and new processes are published in their website. They also publish road maps. There are various associations in packaging, Surface Mount Technology Association, SMTA IMAPS USA and IMAPS India. These are all important societies professional societies for the benefit of students, for the benefit of faculty members, academics and industry. In India, we have Indian Printed Circuits Association and also the Surface Mount Technology Association chapter in India that is also available.

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Now I will briefly give a glimpse of various academic centers worldwide which is focused on packaging research. The first that I can remember is Packaging Research Center, Georgia Tech Atlanta, one of the leading centers of the last 12 to 13 years; CALCE, university of Maryland that is Computer Aided Life Cycle Engineering of systems, part of the university of Maryland; Cornell University Packaging lab; MIT and Stanford packaging labs; Institute of Micro Electronics and National University of Singapore, in Singapore.

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Institute from Micro Electronics, Belgium, Chalmers university in Sweden, Arkansas University in U.S.A, University of Colorado at Boulder and few others. The reason why I give this is, you can appreciate the spread and growth of packaging research even at the Masters' level and Bachelors' level in various universities abroad.

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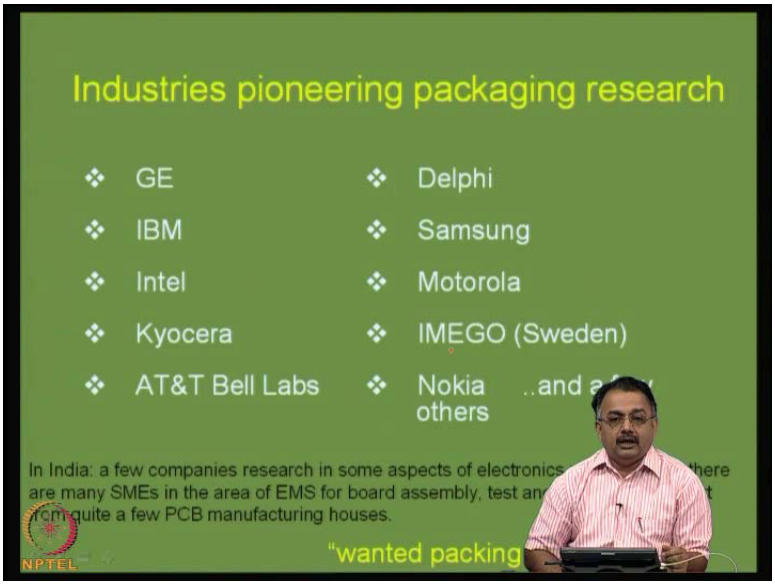

Now, industries pioneering packaging research globally would be General Electric, IBM, Intel, Kyocera, AT&T Bell labs, Delphi automobiles, Samsung electronics, Motorola, Nokia, IMEGO is a consortium in Sweden and so many. The reason why I put few of these players is, most of these are spending a lot of money in tie up with academic institutions for research in packaging in various fields electrical thermal materials processes and so on.

In India, a few companies are there which research in aspects of electronics packaging. But in India you will find there are all lot of small and medium scale enterprises working in the area of EMS that is, Electronics Manufacturing Services which means, assembly of such devices (Refer Slide Time: 42:17). For example, if you prepare a substrate they will assemble the entire packaging devices here, test it and give it you at a price. Obviously, the price for these things depend on volume. If you have more assembly devices to be assembled then the cost will obviously be less. When we talk about cost versus performance, the cost will always come down if the manufacturing volumes are very high. This is true even in the wafer level, board level or the system level.

I have a written a quote here or important point (Refer Slide Time: 42:58) mentioning packaging engineers are required globally they are in great demand and the experience abroad is that students working in packaging area for their internships are quickly absorbed in the industry; that is the kind of trend. Globally, packaging has become very attractive because, the area is very vast. As always, because we are talking about packaging and implementation in the lab, safety issues are very important. So if you are working in any packaging lab at your university or elsewhere, I think it is very important that the institute offers a safety training inquest so that the student is familiar with the equipments, the processes and the effect it has on the human life. It is very important to have safety training in the lab and it is always advisable to follow certain basic principles when working in the lab.

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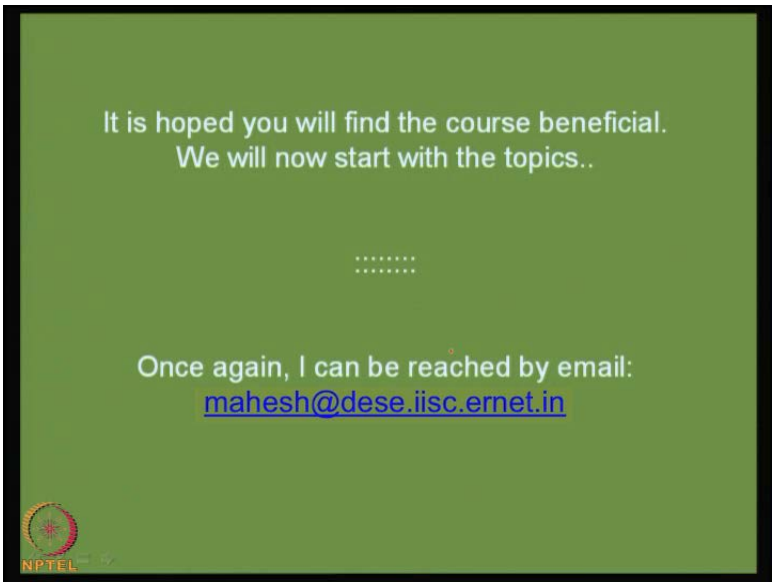

I hope you will find this course beneficial. I have given the objectives of this course, have given a complete gist of what you can expect from this course. We are not talking too much advance topics here although all the topics will be covered, we will sensitize you appropriately and that is required at this level and further reading can enhance your understanding of various topics that is going to be presented in this course. At any point of time as I said, if you have any questions you can mail at mahesh@dese.iisc.ernet.in and we will now start with the topics.

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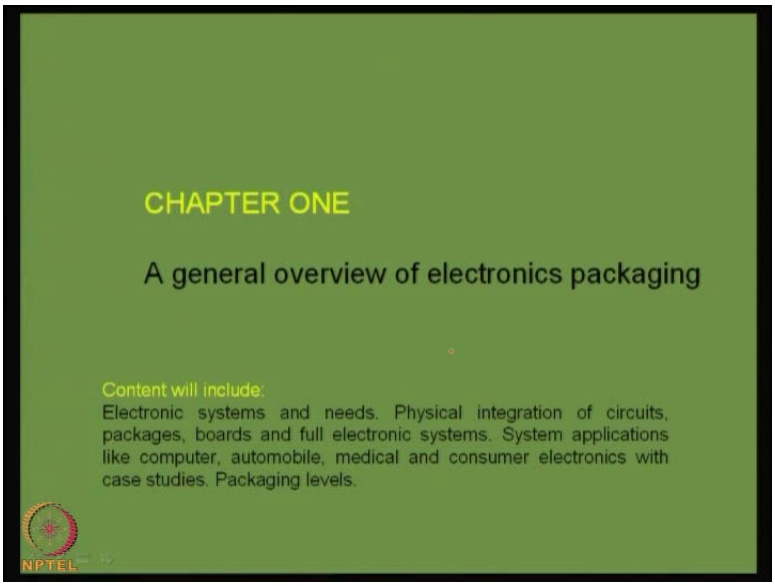

Chapter one will talk about a general overview of electronics packaging. Under this, the contents will be electronics systems and needs, physical integration of circuits, packages, boards and full or complete electronic systems, system application like computer, automobile, medical and consumer electronics with case studies will be presented and you will understand what are the packaging levels in detail.

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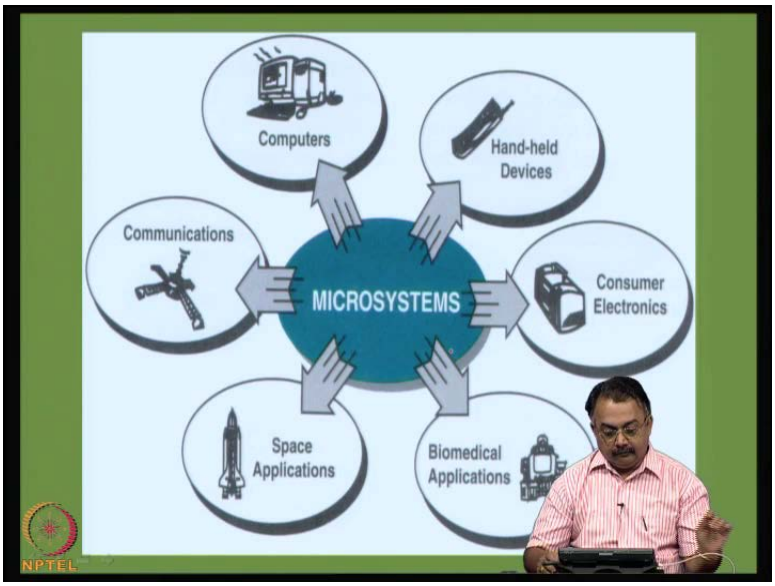

Now, if you look at this slide at the center, you see micro systems. Today we are looking at nano systems but, we will first look at what is the micro system. In micro systems you have various aspects; computers are very common today. Many people are using computers and we are in the realm of computers as it is and there are various specifications, various standard bodies in the field of computers while manufacturing a computer. Then you have handheld devices as I told you earlier this is very major segment occupying a large market share in electronics today globally. When you talk about handheld devices, it is not only mobile phones; there are various other equipments

that is used in the medical industry that requires miniaturization that should fit in your palm. That should have very good ergonomics that is, human to machine interaction; it should be very smooth and easy. So we are talking about efficient systems that can be held in your hand. There can be systems like your wrist watch today which can perform not only just giving you the time, it can act as a BP monitor for yourself. It can look at or give indications about the temperature and various others. It can also act as email inbox.

People are on the move today; people require everything it their hand; they want miniaturization. You will not be surprised in the next 5 to 10 years you will see more growth in the handheld devices area. Consumer electronics will look at various things like your printer, washing machine, audio devices, videos devices, video systems, all that is used and required for the house, where the percentage of electronics is very small. There will be lot of mechanical or electro mechanical components in this and the reliability conditions for each of these computers or the hand held devices or consumer electronics, is going to be different. You cannot give this same reliability fixation or calculation for each of these. Then, the major area today is communications because, we are seeing growth globally because of the excellent communications both wired and wireless communications.

Today, I do not have to emphasis the various technologies that have come up in communications; it includes satellite communications and then there will be some key areas like space applications and military (Refer Slide Time: 49:36) which is also very important today because, these sectors have different conditions. They do not mind cost;

they would rather work at higher cost to achieve higher performance. Whereas, if you take the case of consumer electronics, we want low cost but a large reliability and a lifetime that a consumer can be satisfied with.

So, you can see that there are extremities here. On one side you have space and military where you will have to very carefully look at the different set of materials and properties and biomedical is another crucial sector. Whereas, space and military you can call it as strategic sectors; very much defining with a very rigid target specifications in biomedical which is very miniaturized component for example, if you take a pacemaker are something that is going to monitor your heart condition and which will be inside the body very close to your heart. It will be implanted such an implanted device and that will remain there for a long time and then you have to monitor this continuously from the outside using wireless devices. This is another important area because we are talking about various fluids in the body that are going interact with your electronic device and the electronic device are package should not fail under these circumstances (Refer Slide Time: 50:53). What I am trying to explain from this slide here is, you can say Microsystems encompasses or includes various sectors and these various sectors have various target specifications and requirements; all of them are not uniform.

So, the packaging designer will have to take care of requirements of design issues, manufacturing issues, testing issues and reliability calculation issues, based on the application area.