Materials Chemistry

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Lecture - 01
Introduction to Materials Chemistry

Dear viewers, this is a new course that we are starting on materials chemistry. And this is one of the course, which has been floated by ministry of human resource. And development to highlight the recent trends in this fascinating area of materials chemistry which is coming out to be a very informative and a challenging field of science. There are several issues related to materials chemistry which has come to prominence. And therefore, it is more fitting for our government to float a separate module on materials chemistry. So, that all the viewers can be benefited by this course.

And as you see from the first slide my name is Sundar Manoharan and I teach at the department of chemistry in IIT Kanpur. And it is certainly a pleasure for me to offer this course. And I will highlight you in this introductory lecture how I plan to design this course. And what you can expect out of this course as we go through the lectures in the days to come. First of all let me highlight you why this course is being offered as a NPTEL lecture series. And per se I want to justify why materials chemistry warrens as separate course in itself. And then I will also give you some fair idea about what you can expect in this course in the next few lectures that you would be listening from me. So, to start with let me give you an idea of.

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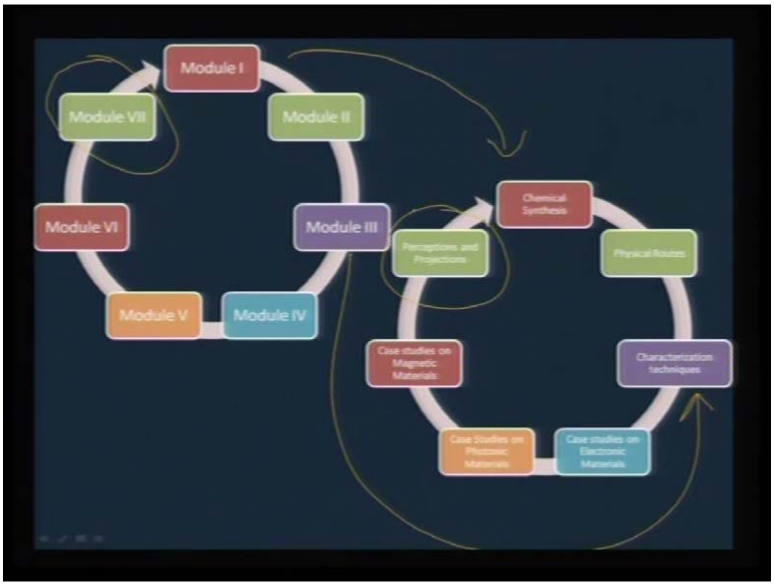

How I have a plan to develop this course for you? This particular materials chemistry course will actually have 7 modules; module 1 to module 7. And each of this module will carry a particular emphasis. And module 1 will actually have more emphasis on chemical synthesis because materials chemistry per se underlying the importance of synthesis. And how we go about with the rational synthesis for a particular molecule or material that we are desiring for? So, we will look at the chemical synthesis that is available in a greater detail in the very first module. Then it will be easy for yours to appreciate which technique that we need to use for what set of applications. So, first module will be on different aspects or different chemical methods that are available.

And that have recently emerged as important synthetic tools module 2 is physical routes to prepare materials. And we will never be able to appreciate module 1 if we do not have a comparison with the physical vapor deposition techniques that are a very nicely established in the field of material science. So, we will also look into the nitty-gritty’s of physical routes. And you would also find out that materials chemistry will again be very essential in all this 4 physical routes that we have going to look at. And once we are through with the synthetic approach in the third module I will be discussing more about characterization techniques what are all the important characterization tools that are required to characterize materials. And I would certainly like to emphasis on the state of art spectroscopic or microscopic tools that have emerged as a very clear tools for elucidating the structure or the property.

And in forth, fifth and sixth module I have collectively grouped a 3 important properties that the materials that we are looking are categorized namely electronic applications photonic applications and magnetic applications. All three are very important field of research and technology in itself. And therefore, having characterized these molecules we will look at some of the important approaches taken to study the electronic materials photonic and magnetic materials. And the how I have grouped these three modules is to pickup case studies. So, in each module I will have one case study of a particular electronic material. So, that, we can comprehensively understand the importance of such materials. And last, but not the least the module number seven is a shorter module. But it is also important, because this seems to be a ever growing field this is not a saturated field. And as you would see in the next few slides you will know that this materials chemistry is becoming more and more prominent in the last 5 years.

And therefore, I am compel to think about giving some perceptions and projections about materials chemistry. This will not only have my own perceptions in picture, but also I would bring some video clippings of some of those who have really pioneered in India in the field of solid state and materials chemistry. So, in essence we will have seven modules comprising of about 35 to 40 lectures. And we will go by it sequentially before I make further comments on this course. First of all I want to comment on the development that has happened within the branch of science materials. Chemistry seemingly has brought down all the imaginary walls that each field of chemistry has built over the years namely physical chemistry or organic chemistry. Inorganic chemistry or polymer chemistry in each of this branch of chemistry we have built our own walls mostly mental blocks where we have never been able to interface much. But materials chemistry in the last 5 to 10 years has really brought.

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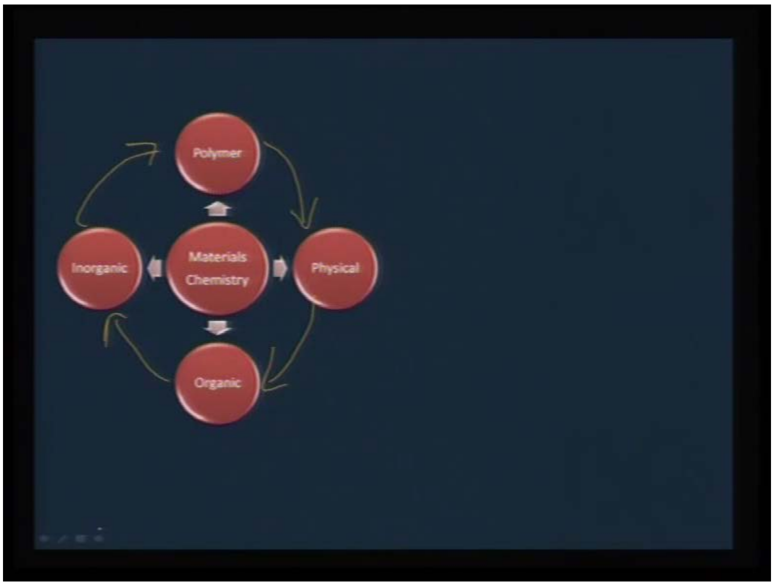

A lot of integration between all fields of chemistry so, this that way it has played more like a ambassador role in trying to integrate all this areas of chemistry in into perception. And not only materials chemistry has done a positive role or positive impact within chemistry.

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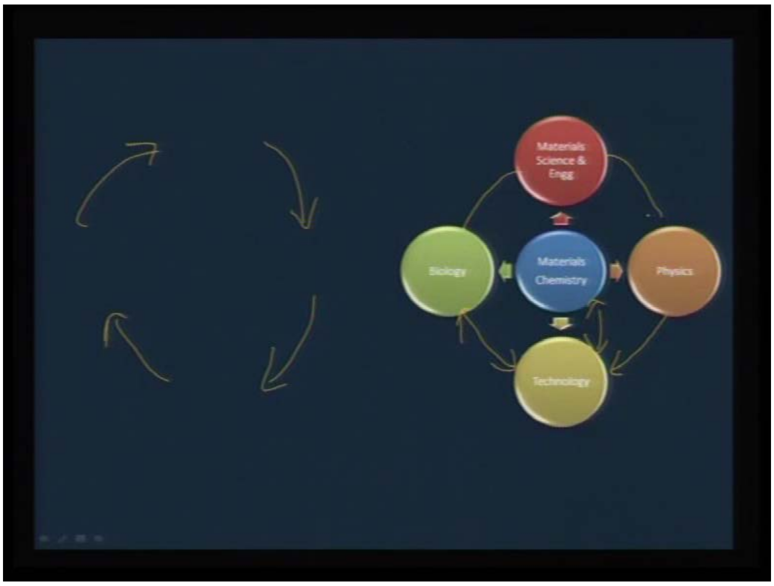

But also it has brought together many issues into picture globally for example; materials chemistry has played a very key role in integrating now physicists with technology and biologists with technology and chemistry with technology. And also material science also is integrated now with other branch of science namely physics biology and chemistry. So, materials chemistry has played 2 important roles that way one within the branch of chemistry itself. And then overall in the branch of science it has integrated all the fields together therefore, it is only more fitting that we have a course like this in this.

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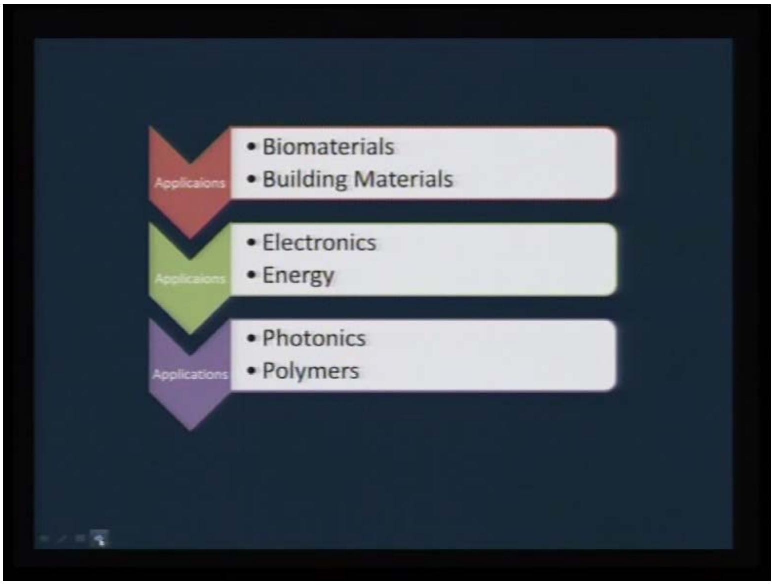

M H R D program why we are looking at materials chemistry in a greater detailed mainly because of the applications that are emerging in various fields. For example, biomaterials or building materials I am not mentioning about concrete and cement. I am talking about various building materials that are available today in present generation talk about electronics. Or talk about energy photonics and polymers in every area; you see the importance of materials chemistry coming into a greater display.

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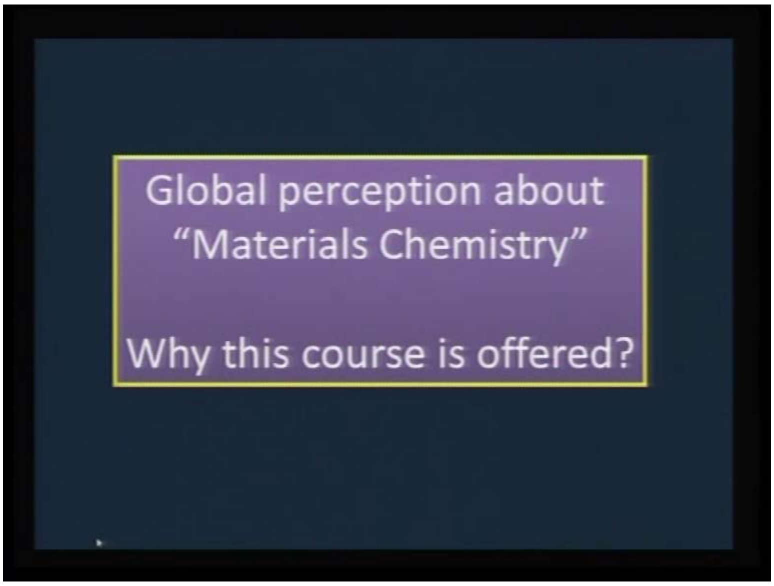

Now, I want to just take few minutes to justify why materials chemistry is a important. And why we are looking at this in a greater detail in this course 1 I want to give you an idea globally how materials chemistry is perceived and why this course is offered?

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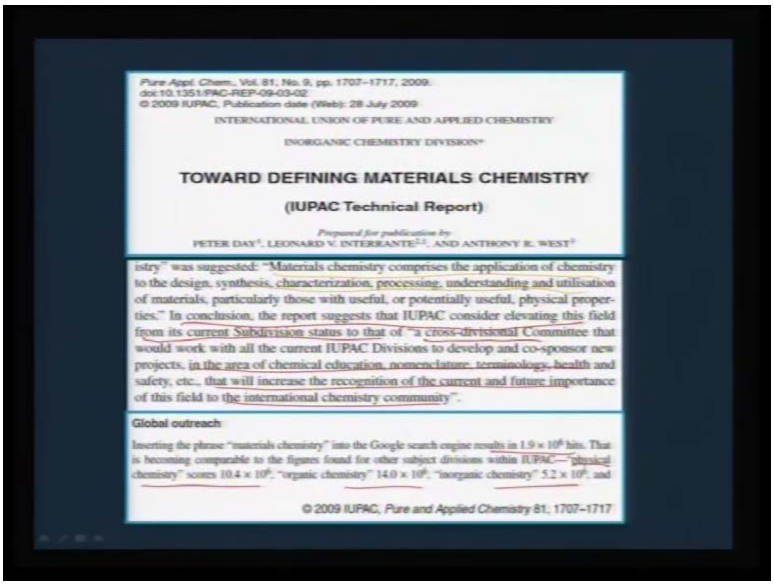

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INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

INORGANIC CHEMISTRY DIVISION*

TOWARD DEFINING MATERIALS CHEMISTRY

(IUPAC Technical Report)

Prepared for publication by
PETER DAY[1], LEONARD V. INTERRANTE[2,‡], AND ANTHONY R. WEST[3]

istry” was suggested: “Materials chemistry comprises the application of chemistry to the design, synthesis, characterization, processing, understanding and utilisation of materials, particularly those with useful, or potentially useful, physical properties.” In conclusion, the report suggests that IUPAC consider elevating this field from its current Subdivision status to that of “a cross-divisional Committee that would work with all the current IUPAC Divisions to develop and co-sponsor new projects, in the area of chemical education, nomenclature, terminology, health and safety, etc., that will increase the recognition of the current and future importance of this field to the international chemistry community”.

Global outreach

Inserting the phrase “materials chemistry” into the Google search engine results in 1.9×10^6 hits. That is becoming comparable to the figures found for other subject divisions within IUPAC—“physical chemistry” scores 10.4×10^6, “organic chemistry” 14.0×10^6, “inorganic chemistry” 5.2×10^6, and

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I was recently fascinated to come across this particular article which is applied in pure applied chemistry in 2009 which is fairly a very recent report by IUPAC that is international union of pure and applied chemistry. They had a meeting a technical meeting in defining what this materials chemistry is which means there has been confusion what it is and what it is not? Because of the greater integration that is it has brought into a various aspects of science and technology. A special meeting was convened to even understand what materials chemistry is all about? In such a case there are several issues have been discussed. And a normal definition for materials chemistry has been agreed upon which is written which is given here as materials chemistry comprises of the application of chemistry to the design, synthesis, characterization, processing, understanding and utilization of materials.

Not only that this IUPAC committee has out with the, another very interesting conclusion which is worth pondering at where they have said in conclusion. The report suggest that IUPAC consider elevating this field from its current subdivision status to that of a cross divisional status which means it is not just another field of chemistry as a subdivision. But it is actually a cross divisional one which is trying to bring many people together. Therefore a very strong emphasis now laid upon to understand the this growing field of materials chemistry. And also the recommendation involves that it be developed and cosponsored by way of new projects in the area of chemical education, nomenclature, terminology, health and safety.

And this underlines the importance that this is now coming out to be a new branch of science in itself not just a subdivision of chemistry. And one more thing, that we need to understand if you look at the global outreach of this materials chemistry. If you type materials chemistry in Google search actually you would see the number of hits that you would notice for materials chemistry is actually comparable to that of physical chemistry or organic chemistry or inorganic chemistry. So, this clearly shows that this is now emerging field. And therefore, we need to look at this aspect in greater detail. So, with this.

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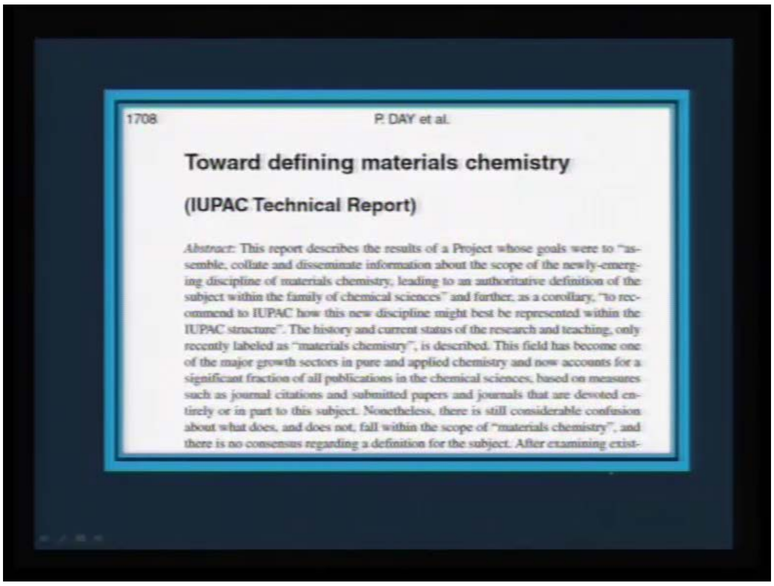
1708 P. DAY et al.

Toward defining materials chemistry

(IUPAC Technical Report)

Abstract: This report describes the results of a Project whose goals were to "assemble, collate and disseminate information about the scope of the newly-emerging discipline of materials chemistry, leading to an authoritative definition of the subject within the family of chemical sciences" and further, as a corollary, "to recommend to IUPAC how this new discipline might best be represented within the IUPAC structure". The history and current status of the research and teaching, only recently labeled as "materials chemistry", is described. This field has become one of the major growth sectors in pure and applied chemistry and now accounts for a significant fraction of all publications in the chemical sciences, based on measures such as journal citations and submitted papers and journals that are devoted entirely or in part to this subject. Nonetheless, there is still considerable confusion about what does, and does not, fall within the scope of "materials chemistry", and there is no consensus regarding a definition for the subject. After examining exist-

In prospective I just want to highlight that this certainly deserves more attention. And we need to define this materials chemistry and nurture this field in greater detailed in the days to come.

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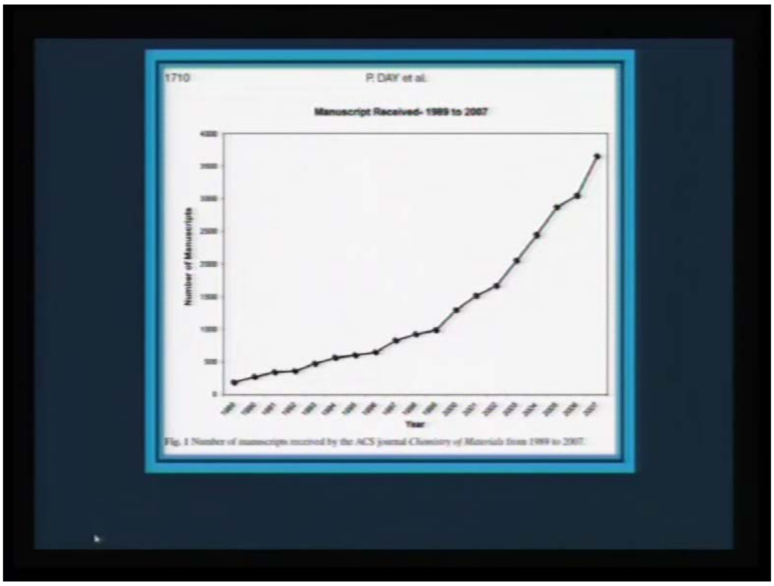

Also, if you look at the milestones that this materials chemistry has crossed in terms of number of manuscripts, that have appeared on materials from 1990. If you would take a look at this cartoon, you see that there is a exponentially increase in this field and the number of publications have crossed more than 3000 in the year 2007 itself. So, and it is fastly growing, we have almost 3 years now since this cartoon has been prepared. And I am sure, we must have crossed more than 4000 publications as if now. So, this gives us fair justification that there is.

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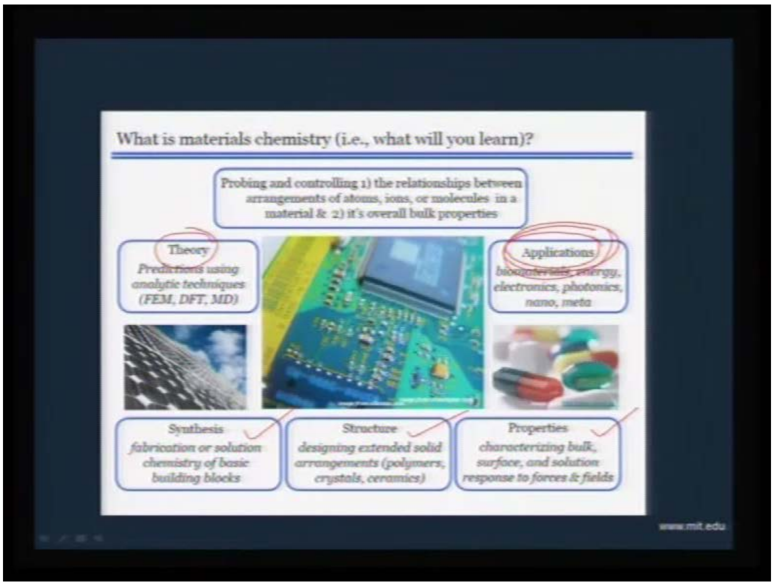

Something very special with this course and this is a nice cartoon that I found in one of the website from M I T which says what is materials chemistry? And what you will learn which is which puts in prospective, what definition of materials chemistry is all about number on we are talking about probing and controlling the relationships between arrangement of atoms ions molecules in a material. And we are also trying to look at it from the bulk properties.

And we are specially laying emphasis on synthesis which means fabrication using different approaches we are looking at the structure designing extended solid arrangements. And then we are also trying to modify the properties based on the structure. And again we try to back it up with the theory predictions using sophisticated instruments and also simulation techniques. And finally, we are actually looking at this whole development in terms of application. So, precisely we can say materials chemistry comprises of all this not only studying this in greater detail, but also transcending to the area of applications.

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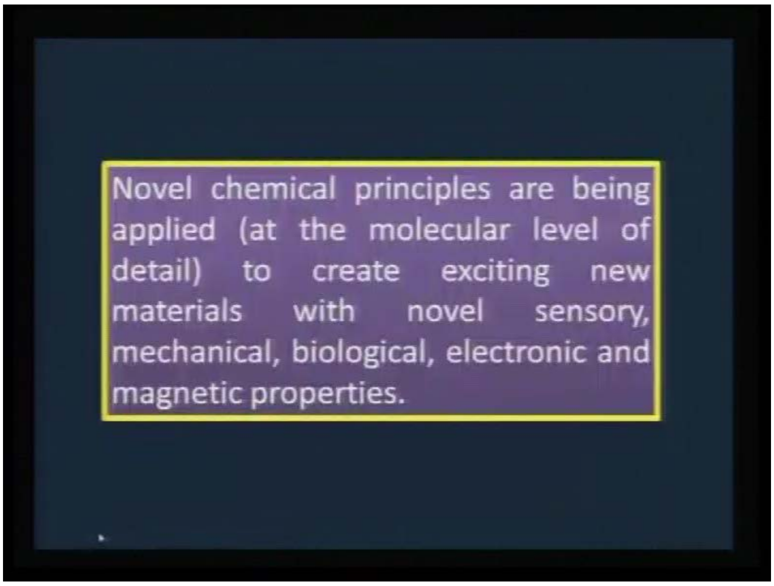

Why this is a different from conventional chemical routes? Because novel chemical principles are being applied at the molecular level of detail to create exciting new materials with novel sensory mechanical, biological, electronic and magnetic properties. So, the approach in materials chemistry is not only on the basic, but also more bent on the applied research.

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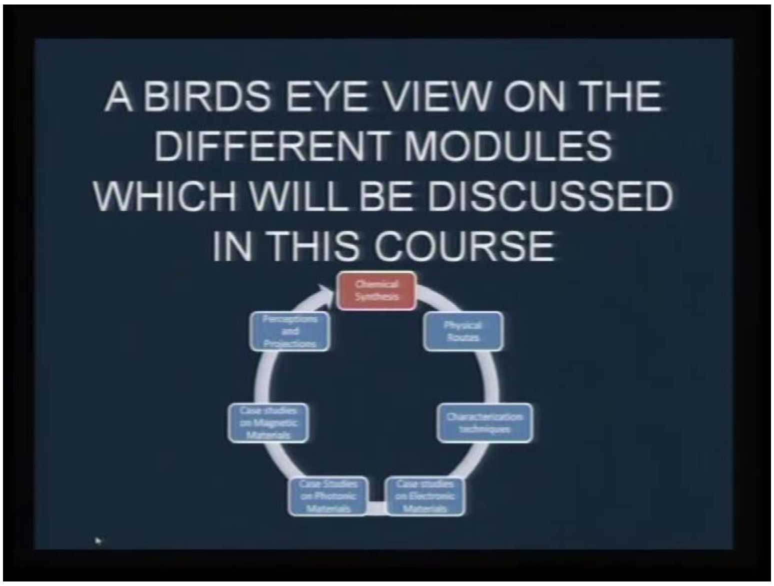

Now, again we will come back to the design of the course. And then I will liaison emphasis on each module. So, that we will know that we have something in store as we listen through this course. This is a bird's eye view on the different modules which will be discussed in this course first when we start with the chemical synthesis we will be looking at both the conventional chemical routes.

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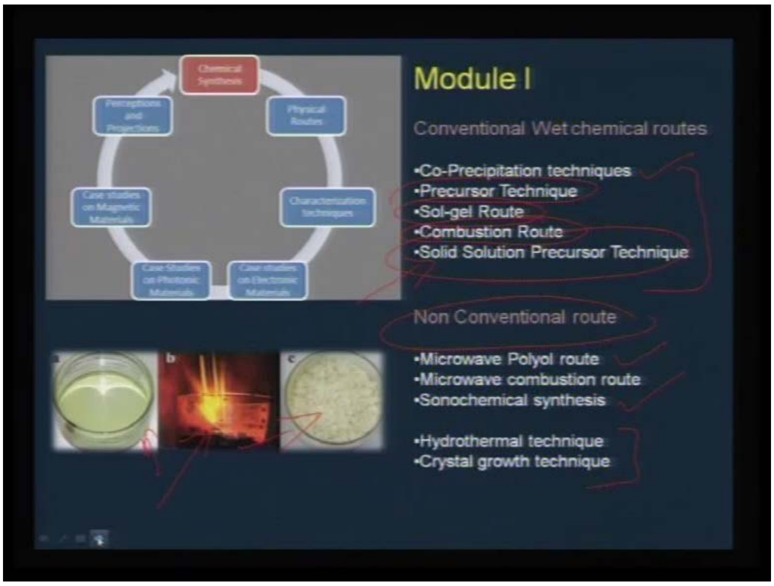

And the non-conventional chemical routes. So, under the conventional chemical route, we will see co-precipitation technique then we have precursor technique sol-gel technique or sol-gel route. And then we have this combustion technique and solid solution precursor technique which is also a very competing technique which is emerging in the recent past of all this. Not much literature is available on combustion synthesis which is a very fascinating tool where high temperature materials can easily be prepared using in situ high temperature reaction. And as you see here it is a very novel process where you just take a solution using propellant chemistry where you have both oxidation and fuel dissolve together as a homogeneous solution. And then introducing that to a furnace can generate very high temperatures which will finally, result in a solid oxide product which is the end material.

And all this can happen in a quick succession and within 5 minutes one can realize very high temperature ceramic materials or oxide materials. Therefore, this is one of the important technique that I would be highlighting other than solid solution precursor technique. And then we also have non-conventional route of which I have picked up specially the microwave and sonochemical routes which are not the normal chemical routes. But these are also wet chemical routes using electromagnetic radiation to synthesis materials with novel properties. So, I will be highlighting on that and then we have of course, 2 special techniques which has stood times. And it has always been the most effective ones from application point of view those are hydrothermal and crystal growth technique. Crystal growth technique is it is a art in itself. And then hydrothermal is one which emphasizes mostly on the use of pressure to stabilize metastable phases. So, having said this let me highlight you few examples to give you idea what this techniques.

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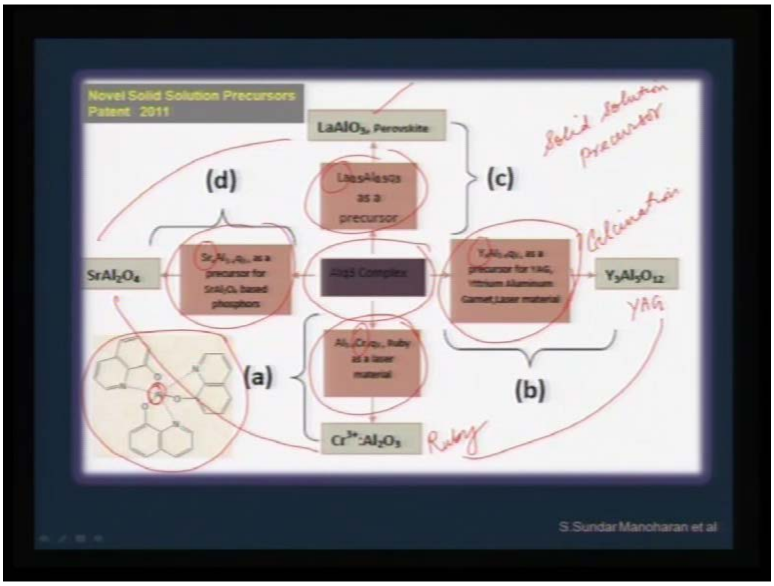

Will be discussing this is another cartoon that we would be seeing in greater detail which talks about solid solution precursors. And this particular viewgraph I will try to explain. So that we will understand how easy this chemical route can be exploited? For example, you take aluminum quinoline which is a complex. And this is a very well known complex used for organic l e d’s. But if you take this complex and then substitute in the place of aluminum core if you are going to substitute lanthanum for example, or yttrium for example, or chromium for example, or if you can replace it with strontium. Then you can actually get a corresponding precursors which is stoichiometrically doped. And the best part is all these precursors which I have circled here they all have the same x ray morphology. And therefore, we can call this as solid solution precursors, because they have the same x x ray crystal symmetry.

And once we are successful in making this on calcinations, you can find out. You can transform this into the respective oxides namely ruby which is chromium doped l 2 o 3 or a perovskite like l A l o 3 or yag compound which is a garnet called yttrium aluminum garnet or strontium aluminate which is a phosphor. If you actually look at all this n products they are all photonic materials inorganic photonic oxides used in variety of photonic applications. So, this is beauty of a solid solution approach where you just take one molecule. And you transcend to making a host of molecules simply by using the notion of solid solution precursors. So, this is.

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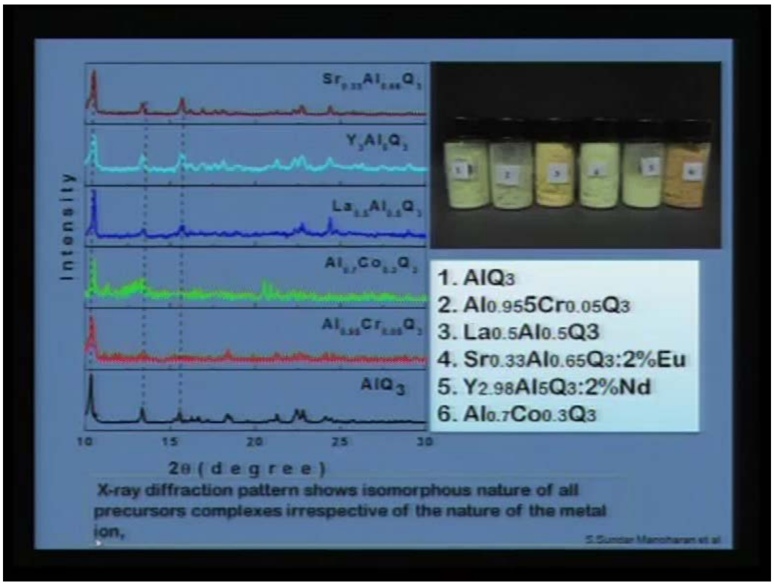

Will be studied in greater detail just to give you a flair for what I talk about as you see here this is A l Q 3 molecule which has a x ray symmetry like this. And even if you dope chromium or cobalt or aluminum or strontium yttrium you can see in all cases the x ray remains the same. And these are also flourishing once and in this cartoon what you see here the, all this compounds are actually glowing in the dark under UV radiation and once we try to heat this.

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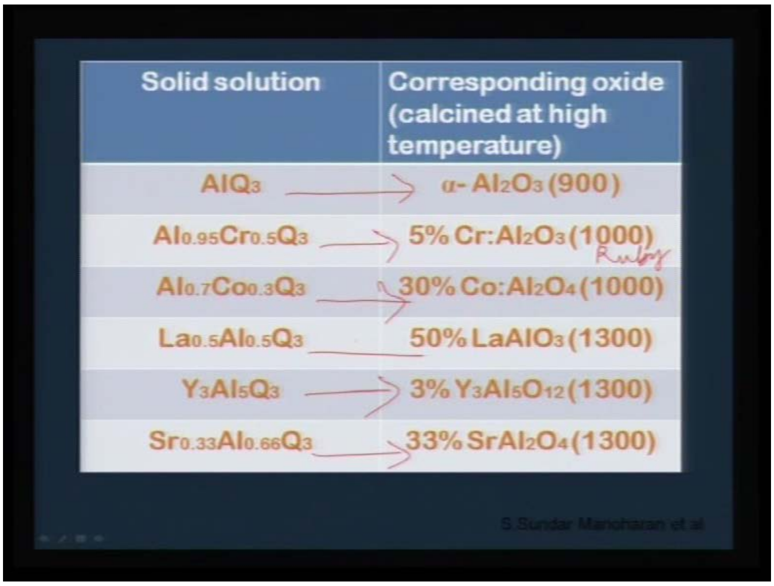

Solid solution	Corresponding oxide (calcined at high temperature)
AlQ_3	α- Al_2O_3 (900)
$Al_{0.95}Cr_{0.5}Q_3$	5% Cr:Al_2O_3 (1000)
$Al_{0.7}Co_{0.3}Q_3$	30% Co:Al_2O_4 (1000)
$La_{0.5}Al_{0.5}Q_3$	50% $LaAlO_3$ (1300)
$Y_3Al_5Q_3$	3% $Y_3Al_5O_{12}$ (1300)
$Sr_{0.33}Al_{0.66}Q_3$	33% $SrAl_2O_4$ (1300)

Molecules you can see A L Q 3 transforms into a high temperature alpha aluminum phase. Then you get the ruby powder at 1000 degrees you can also get pigmented a cobalt aluminum oxide or perovskite or yag compound or a phosphorus. So, corresponding oxides can be synthesized in a highly chemical stoichiometric way and therefore, the solid solution precursors.

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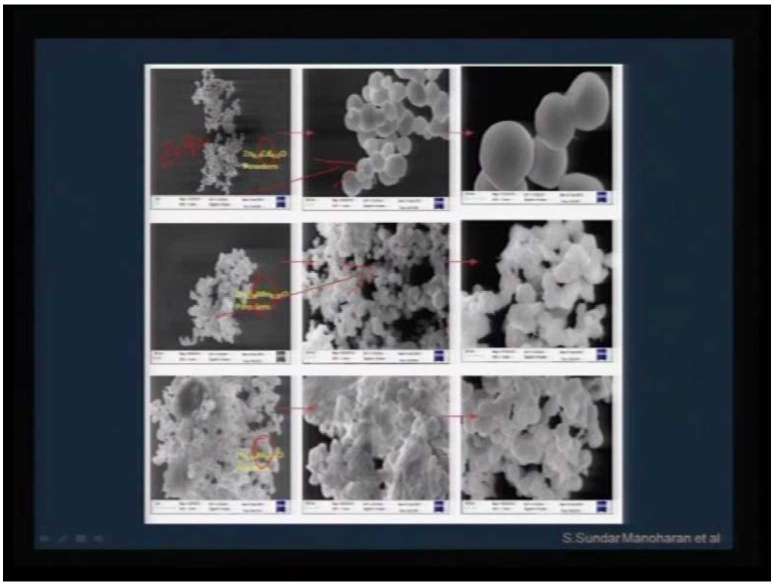

Do comment lot of respect and attention; this is another viewgraph just to show how we can extrapolate this for a variety of zinc oxide based materials. In this case you can see cadmium is doped to z n q 2 precursors. And we can also selectively dope cadmium or we can dope manganese or we can dope nickel. And depending on that you can see there is a clear transformation in the morphology of the corresponding oxides. This is also prepared using a simple solid state.

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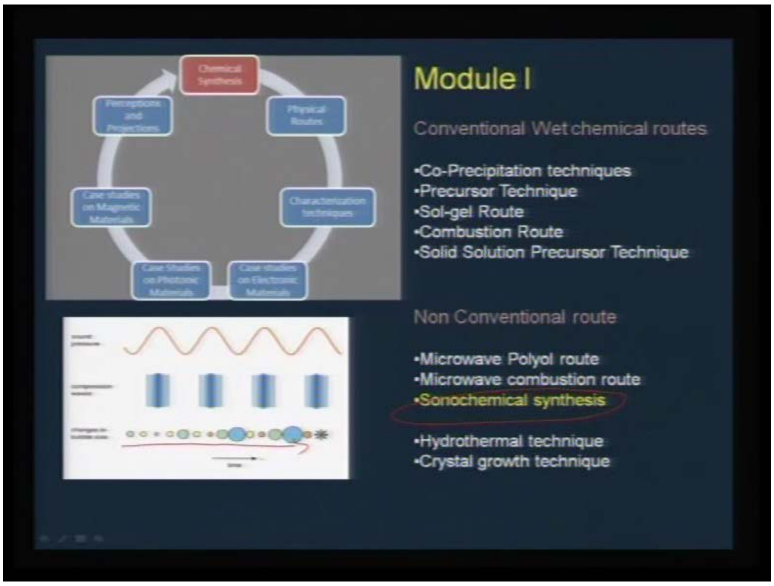

Solid solution approach in the next module, in module 1, we also we will be looking at the non-conventional route where we have sonochemical synthesis which is turning out to be a very very fascinating area of research. Because this particular sonochemical wave is able to bring about a fast and effective way of preparing materials using a indirect effect of interaction of sound wave with matter it is not a direct interaction of sound waves. But the secondary effect of ultra sound is actually used for making materials through a process called cavitation where cavity grows and implodes. And the result result of it we are able to stabilize high temperature phases and the best part of sonochemical synthesis is that.

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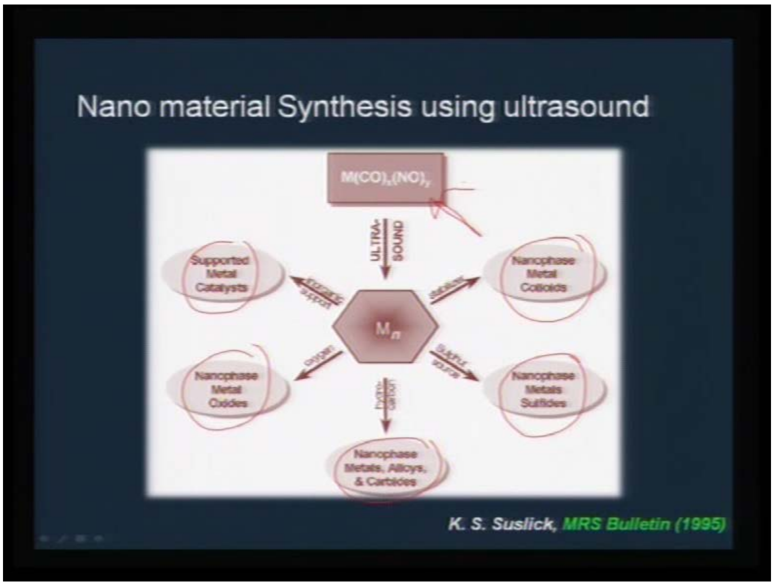

We can make a variety of compounds in nanoform for example, nanophase metal colloids, nanophase metal sulfides, nanophase metal or alloys a metal oxides or supported catalysts, all this can be prepared using ultrasound, But with very very simple starting materials like carbonyls or nitrosyls and this is fascinating area because most of the compounds that we prepare using. So, ultra sound they are all nano in size not only that they also through a very a different or anomalous behavior compared to the bulk oxides or alloys.

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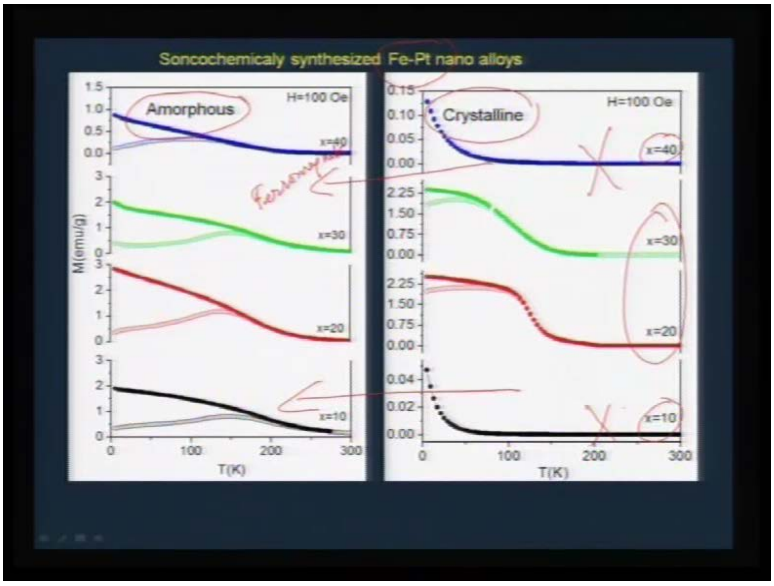

For example you take the case of F e P t nanoalloy as prepared nanoalloys are all amorphous. And you can see here M versus T curve clearly shows that all the compositions are ferromagnetic in nature, because they show a typical ferromagnetic transition. Whereas, when you sinter these alloys when they turn out to be crystalline you can clearly see only these 2 compositions retain magnetism whereas, the 40 and 10 percent they do not show magnetism. Therefore, if you try if you try to compare with the as prepared compounds even those compositions which are suppose to be showing a order disorder parameter where it is not suppose to be magnetic turns out to be magnetic in nanophase and this is possible through sonochemical approach.

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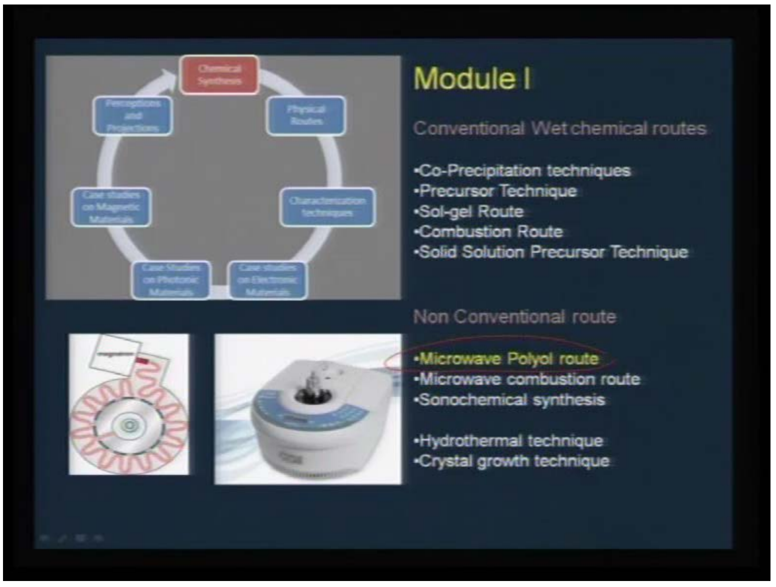

And also we can take other examples. Let us take the case of microwave is another electromagnetic radiation which can be used not only for our kitchen applications, but also in a greater detail for engineering applications including synthesis of materials. For example, we can have simple microwave reactor like this a bench top equipment which will give a single microwave mode cavity. Like this where you can do a variety of chemical reactions and for example.

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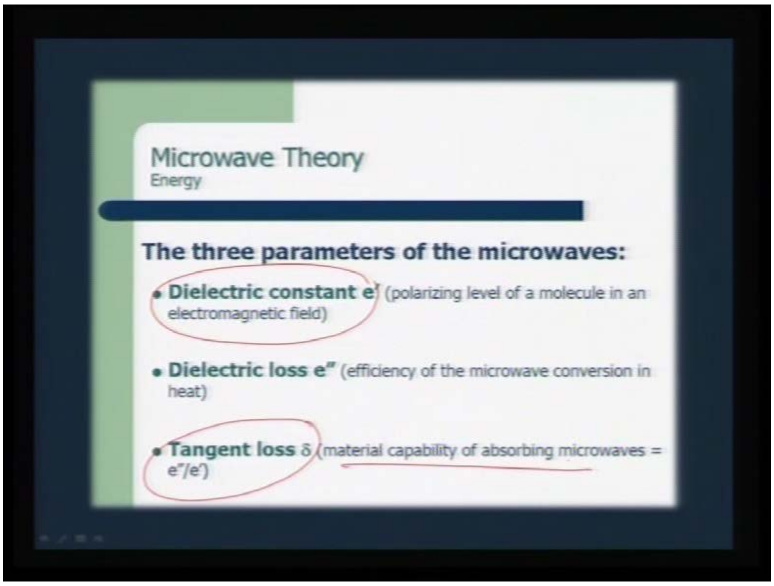

I will show you, what are the 3 undermining parameters of using this microwave? One is if you have the material which is having a substantial dielectric constant. Then based on the tangential loss the material capability of absorbing microwaves, it is possible to make a variety of novel materials.

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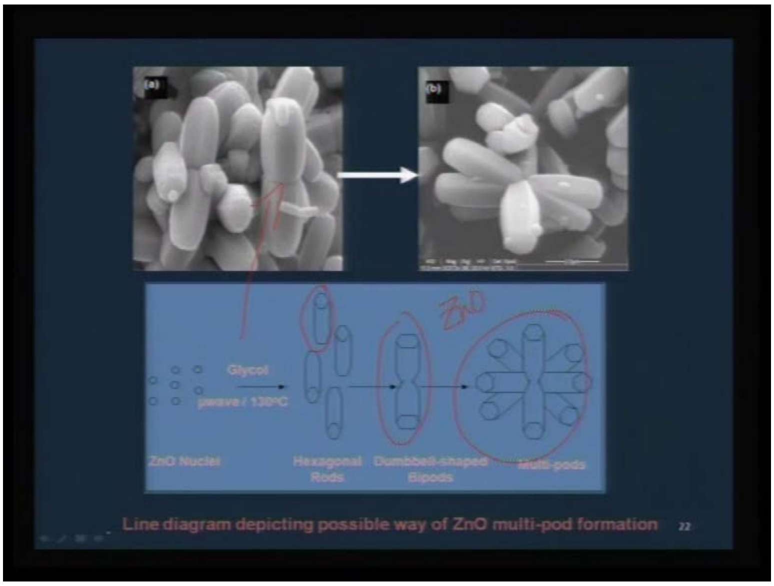

Shown in this cartoon is the preparation of zinc oxide nanoparticles using microwave polyol route where you take a corresponding metal nitrate salts. And then add it with ethylene glycol which is good hydrolyzing agent as well as it is a solvent. And if you expose this to microwave then you can see beautiful nano rods of zinc oxide can be prepared. And this comes out to be initially as monopods then as bipods. And then multipods of this zinc oxide nano rods can be formed. And not only making this materials with preferred orientation and morphology you can also see from here.

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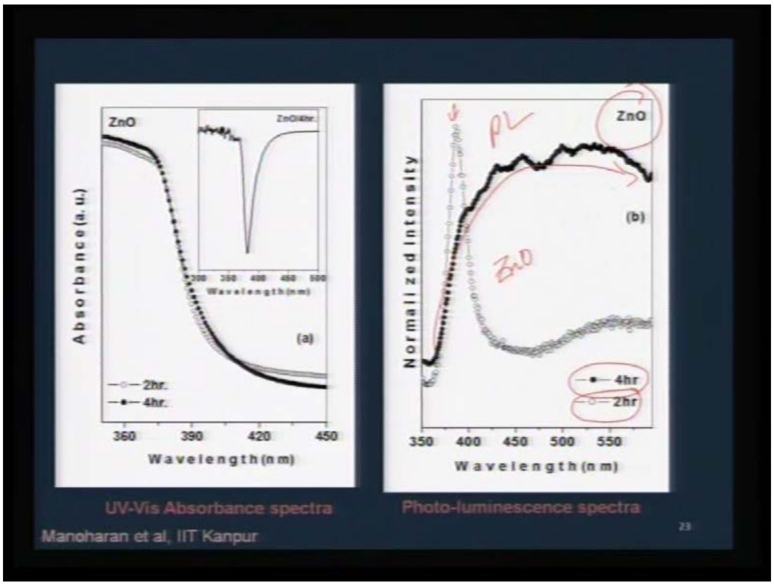

This same zinc oxide when it is actually prepared using sonochemistry exposing this to microwave for 2 hours or for 4 hours can explicitly change the p l properties of this zinc oxide. As you would see here 2 hour microwave exposed zinc oxide can show this 380 nano meter band to band emission. Whereas, if you expose it for 4 hours then you see that there is lot of defect induced p l is seen. So, you can very clearly see that not only we try to make a make a approach which is suitable for particular morphology we can also fine tune the physical properties based on the structure and morphology of this materials. So, microwave certainly plays a very important role in today's materials chemistry approach.

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Lastly in this in this module 1, we will also emphasize on hydrothermal synthesis which is a wet chemical route, but totally done under high pressure And you as you can see this; this can be a very small setup where you have a oven and a Teflon bond which can take you to very high temperatures. Then you can try to prepare oxides with unusual oxidation states or crystals with the very large dimensions can be prepared using hydrothermal conditions which is another very strong effective tool for a materials chemistry person.

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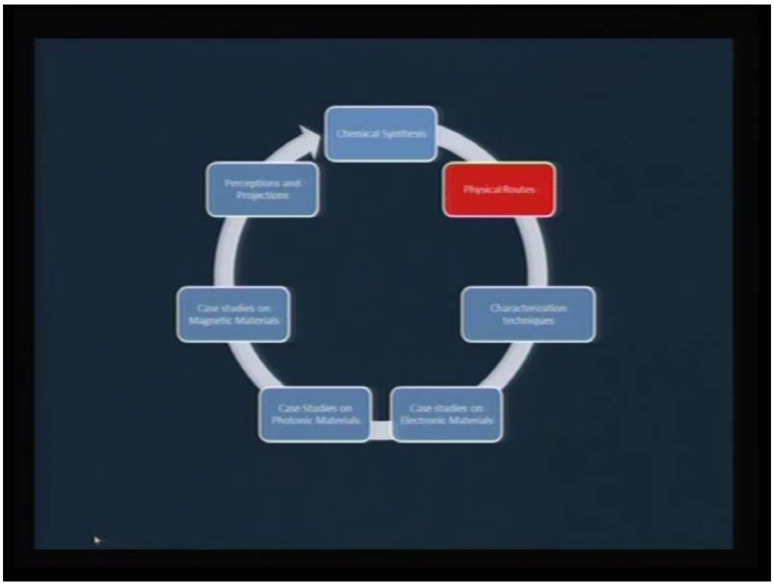

In the next module, we will make comparison with physical wafer deposition techniques the notion that we try to bring between module 1 and module 2 is not to see which one is better than the other. But to highlight that there is also a way to prepare materials with preferred dimensions. But using a physical wafer deposition technique nevertheless the starting materials have to be made using one of the routes that I have highlighted in module 1. Therefore, I would not make a comparison to put module 1 or 2 in bad light, but rather you would see module 1 will play a very effective role in controlling the parameters for the routes that are mentioned in module 2.

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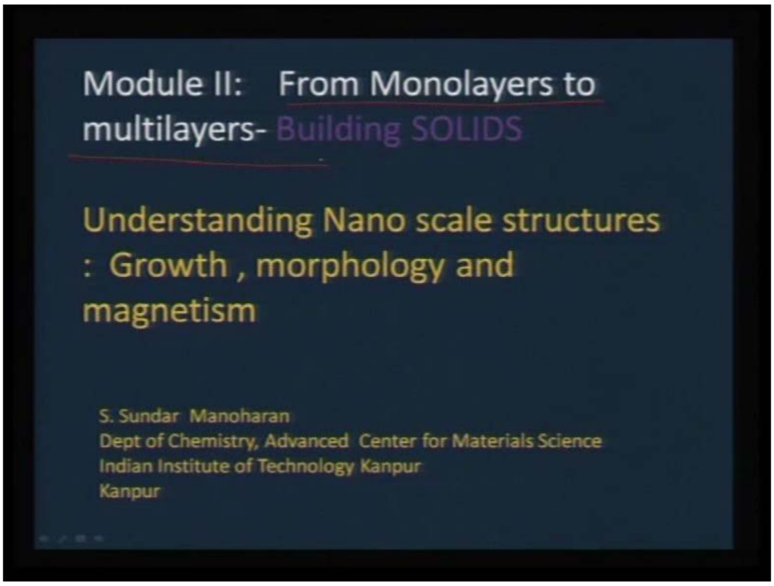

So, in module 2, we will actually be looking at the physical wafer depositions. For example, how we can construct monolayer's and how we can transform to multilayer's building solids starting from atomic level? We can try to progress to bulk and how this can be done understanding nanoscale structures you growth morphology? And how the magnetism also evolves with the growth mode?

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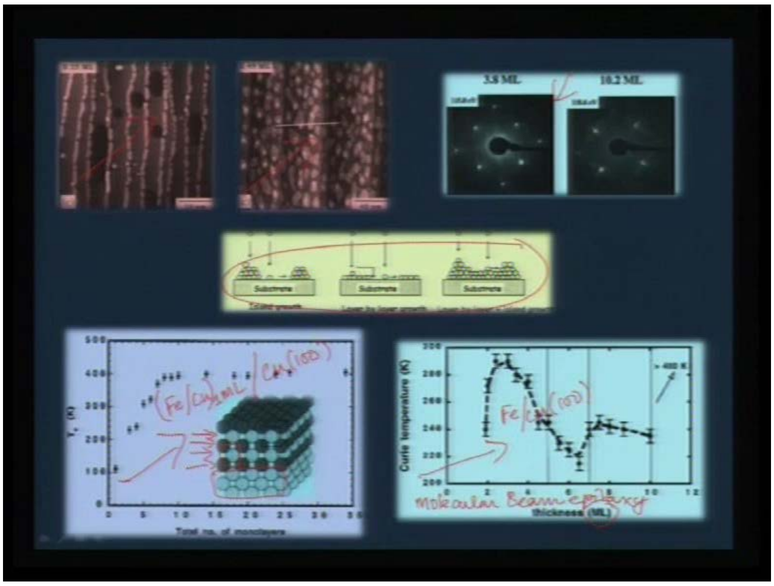

So, this is another important approach that we would be looking at specially using molecular beam epitaxy molecular. Beam epitaxy is a very well known and most costliest route for preparing multilayer’s. And as you see here we will be looking at the basic growth modes how in atomic level atoms arrange themself to go progressively into a multilayer or into a bulk material. So, we will look at the fundamentals of how the growth mode happens. And here is a cartoon which talks about how one dimensional stripes can be made and with the different technique how we can make for the same material a two dimensional stripe. And as you can see here even with 10 atomic planes you can control on the epitaxy of these layers. And here is a cartoon which talks about iron copper atomic layers these are repeats of iron copper one monolayer by 1 monolayer.

And in this we can actually try to grow on a single crystal like copper 1 0 0 which is nothing but this and you can put your iron layer and then copper and then iron and copper so on. And as you see here if you try to grow it from inception; you can clearly evolve at a unit lattice which is actually a 50 50 composition of iron copper. So, the molecular beam epitaxy brings out very fascinating approach to even realize materials which are not known in nature. So, we called this as artificial alloys and here is another cartoon of understanding how the magnetism grows on iron and copper 1 0 0 just iron layers. And you can see with the monolayers with this atomic layers how the magnetism swings. So, this can really give us perception about how to control the magnetism in very thin layer specially in device applications.

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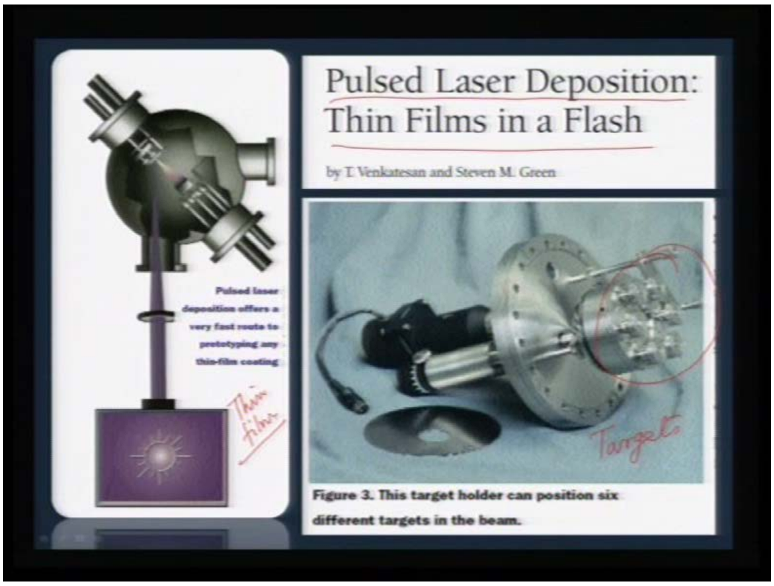

Another fascinating tool in physical process method is pulsed laser deposition thin films in a flash that is the way it is nick name. Because it involves a less complicated approach not much sophisticated like molecular premium beam epitaxy. But still using laser we can try to get a variety of compounds using a pulsed laser beam. And therefore, this is another important tool which we need to understand in the materials chemistry field. So, that we can go for a range of compounds again as you see here this is a target holder. And targets have to be made which is extremely pure again materials chemistry plays a very important role in making targets. So, that P L D technique can be used to prepare thin films. So, thin film coating is a big challenge, but again materials chemistry per se holds key in controlling.

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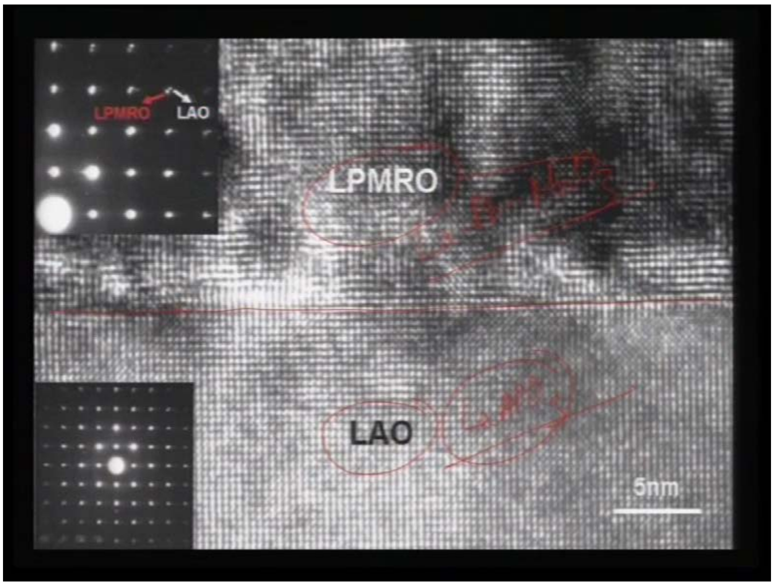

This area and this is one viewgraph I just want to show you how using P L D, you can grow highly oriented epitaxial films this is l a o which is nothing but l A L O 3. And this is L A P b M N O 3; this is a perovskite. And when we grow as you can see here this is the interface of the substrate and the material. And you can see that you know as each of these dots are atoms you can see how nicely you can grow this epitaxial films.

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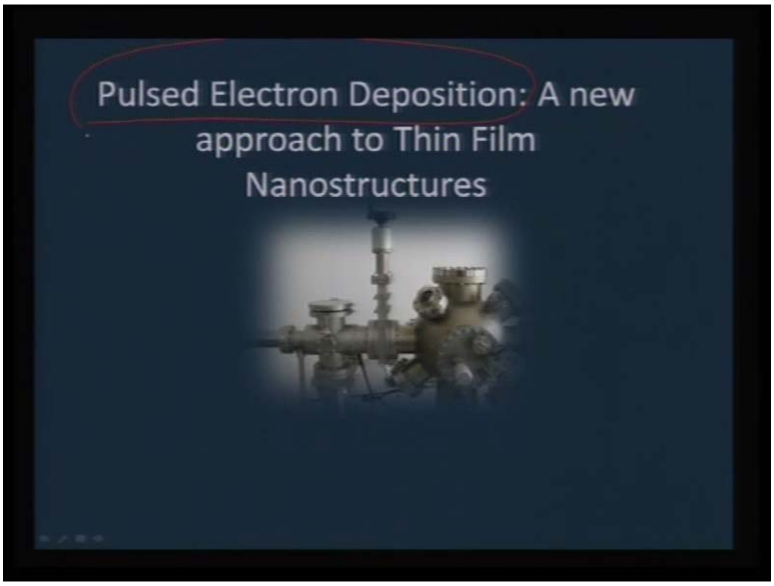

Using p l d approach. There is another complimentary technique close to P L D which is called as pulsed electron deposition technique. And this is fairly a newer approach even compared to P L D approach where instead of laser we are going to use pulsed electron beam to prepare a variety of materials. Again you would see a blend of many techniques including materials chemistry coming into perception.

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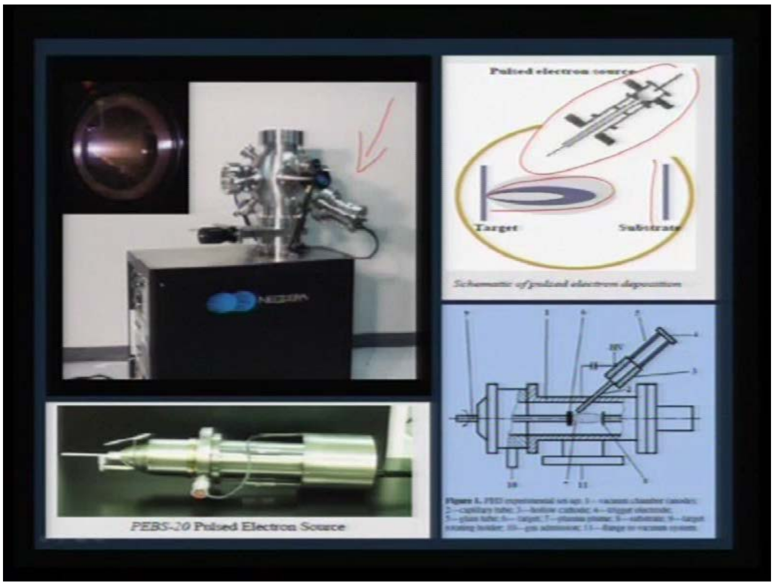

This is another viewgraph of the pulsed electrode deposition unit it can be as simple as this in a lab scale. And this is the electron source which is used to upgrade the material and you can deposit here.

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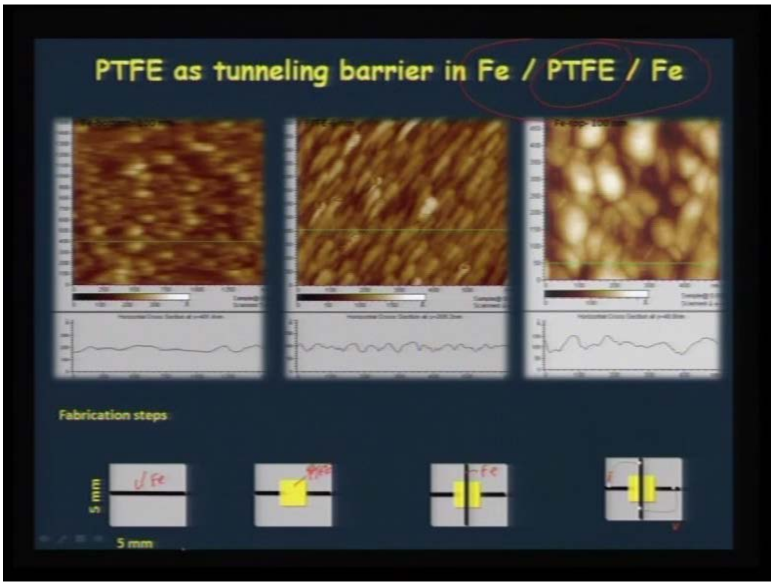

And using this technique one of the most fascinating thing is you can actually make a very thin films of organic layers here in this case it is P T F E which is nothing but Teflon layer in very small dimensions. And how small it can be we can control a device A T M R device of this nature iron P T F E iron where you put this first layer which is iron. And then this is your P T F E layer and then the top iron layer. Then you can make a device which is called tunneling magneto resistance device it is possible to make such devices with very thin thickness.

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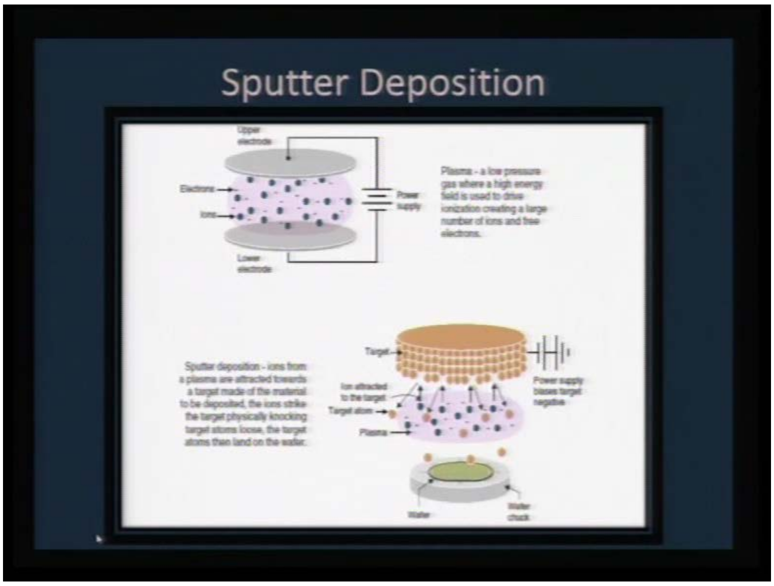

Using P L D and lastly I would like to discuss in module 2 on the sputter deposition which is a grand old technique used almost in every lab not only for making materials, but for making conductive layers a specially in studying microscopic. So, we were also revisit this issue of a sputter deposition how materials can be made out of this. And we will now see in the next few slides what is the emphasis on module 3 and module 4, 5 and 6. In module 3, we will be looking at the characterization techniques and as you would know that in any field of a science characterization of materials is a very very important component and.

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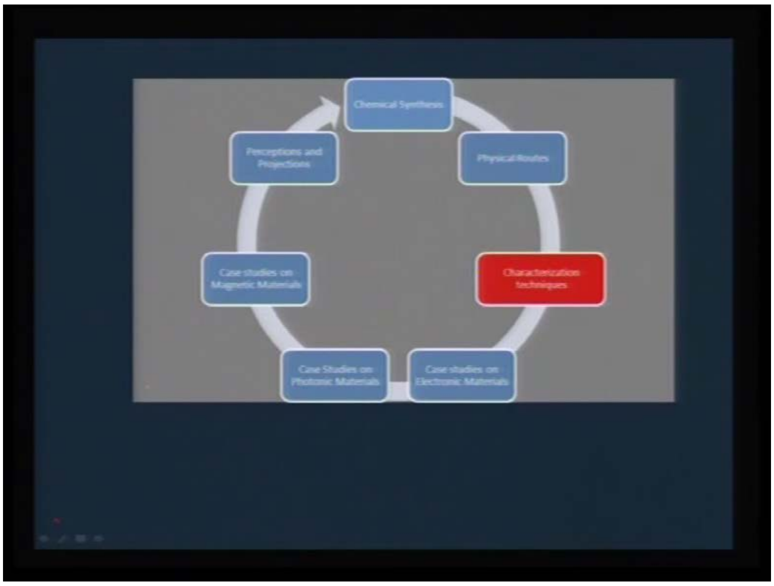

The moment we look at characterization tools all that comes to our mind is microscopy and then spectroscopy and diffraction techniques and other mechanical testing techniques. So, in this module I am going to specially cover that which is not covered usually. And also highlight how this simple techniques can also play a vital role as much as the sophisticated techniques.

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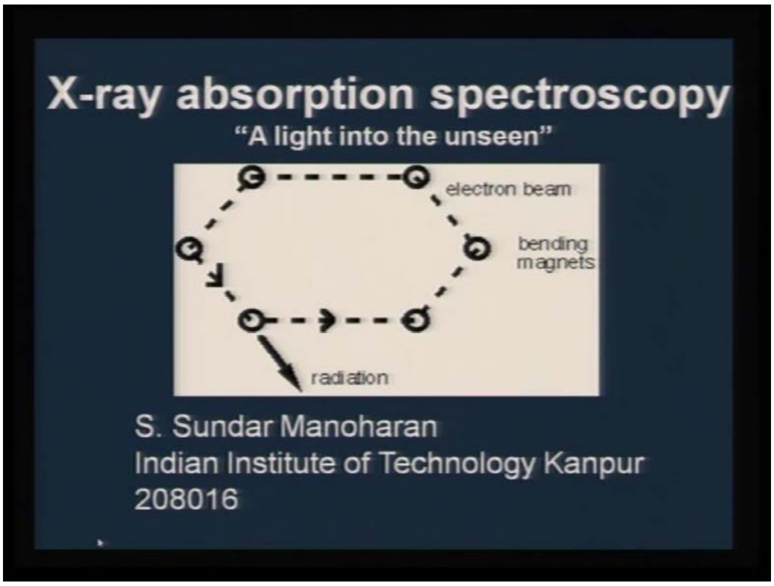

One of the highlight of this module will be to discuss about x ray absorption spectroscopy where we are actually using light which is generated by synchrotron radiation. And the effect of synchrotron radiation source on, say understanding the material.

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Chemistry will be highlighted in this particular module and this is a picture of a synchrotron radiation where we have a booster here. And through the booster we can actually try to get this fast x rays. And these are several substations where you can try to use this synchrotron radiation to study molecules. And specially XAS is a very important tool which required synchrotron radiation. So, we will be looking at this in greater detail.

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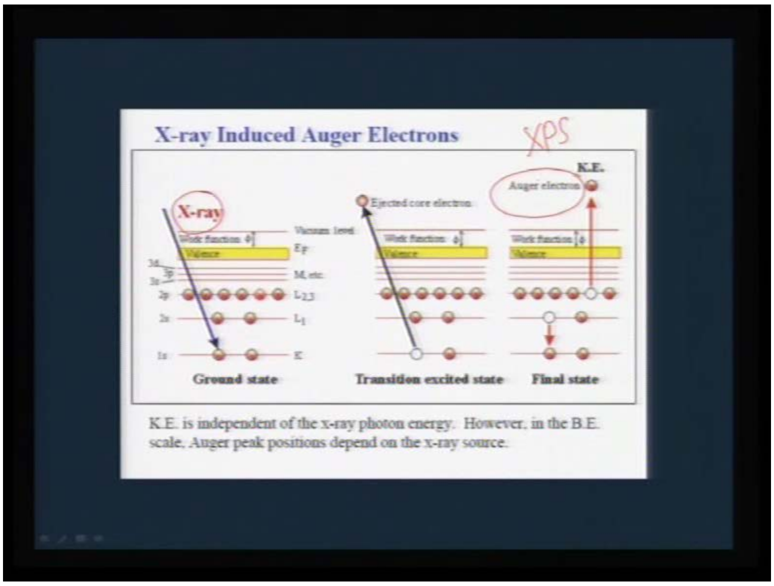

In our lecture and this is an another viewgraph that tells that we will be also looking at another very important tool for materials chemistry which is x ray photoelectron spectroscopy. The reason for studying this with some examples specially what the occurrence is and what are all the secondary influence of x ray photoelectron spectroscopy and how we can use this as a tool to elucidate oxidation states of transition metals.

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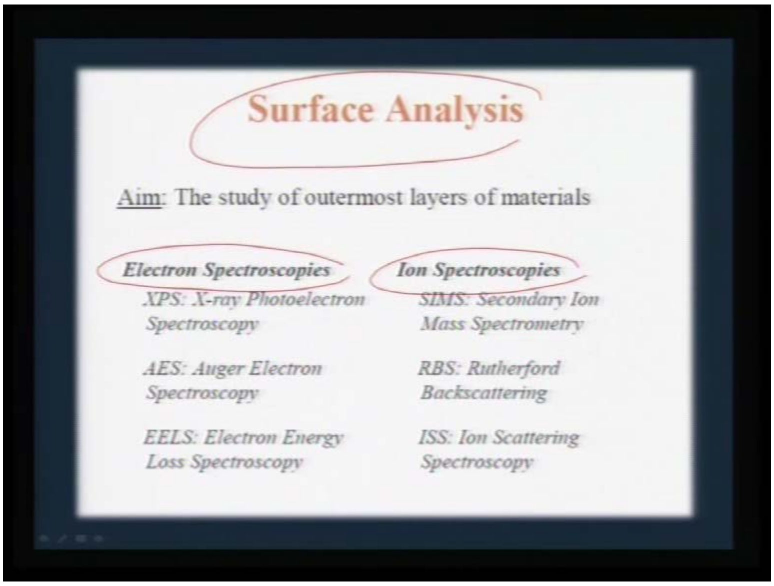

So, the therefore, in terms of surface analysis we will be looking at both the electron spectroscopies and some of the ion spectroscopies in perception and.

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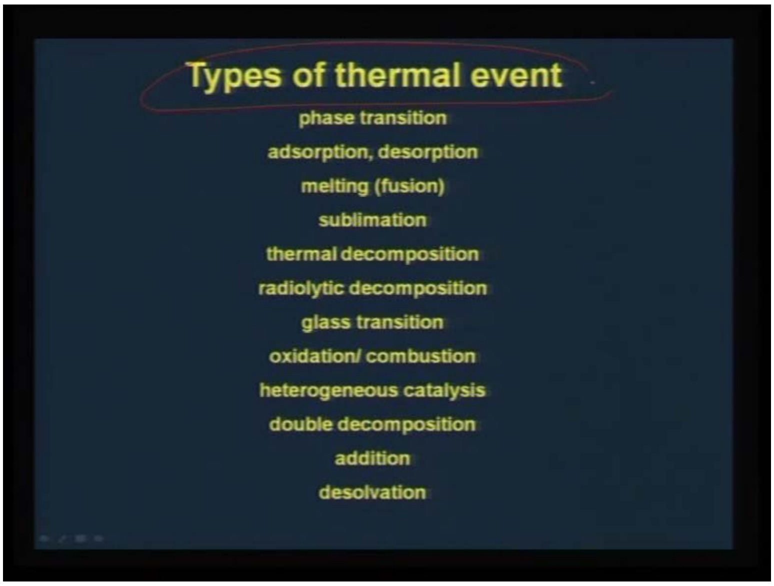

We will also look at another technique which is usually not taken seriously. But then I will do well at greater length to say that such a simple technique can give a very rich information in terms of the physics and chemistry of those materials. This is nothing but thermal analysis and any compound which is heated actually go through goes through a variety of changes including sublimation, melting, glass, transition, oxidation, double decomposition and so on. And when all this things happens what do we understand about the materials chemistry is the question. And therefore, we will have some idea about thermal analysis how this can be a very decisive tool to understand materials.

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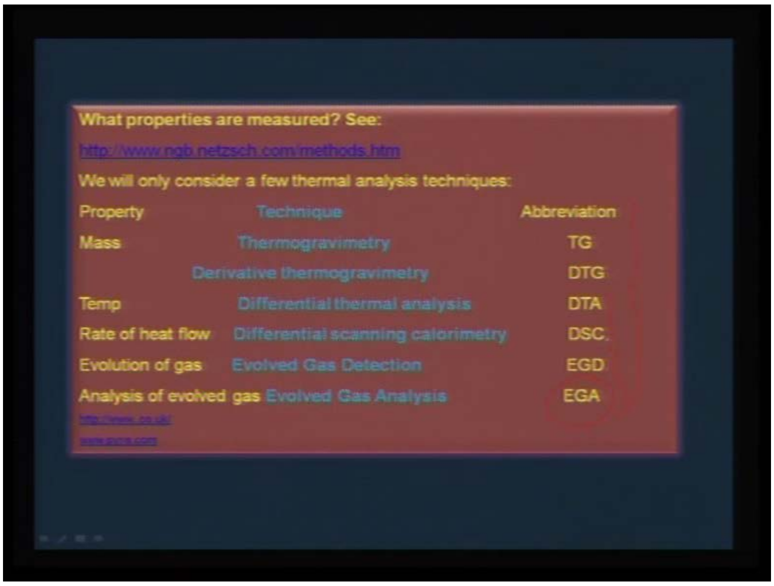

Some of the techniques that are listed under thermal analysis is TG or d TG DTA that is differential thermal analysis and the DSC that is differential scanning calorimeter. And then we have evolved gas detection evolved gas analysis. All these techniques will be discussed in module 3.

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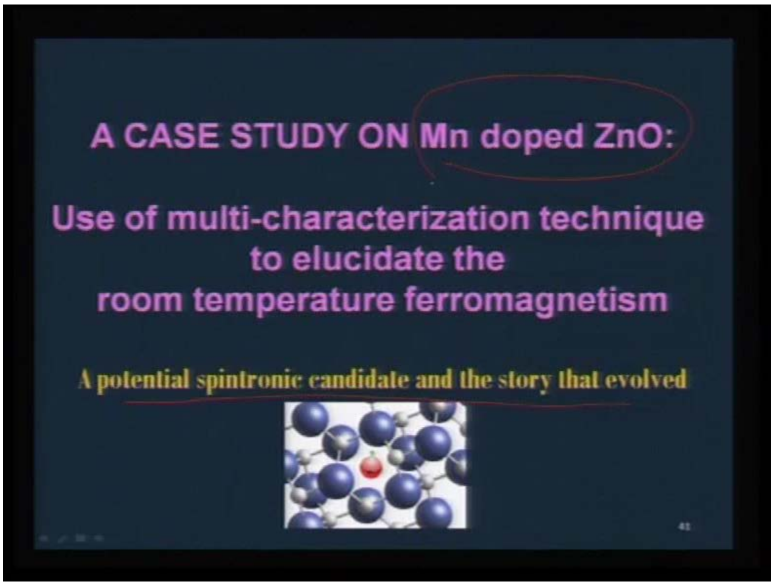

Also I would like to take few examples or case studies where we will be using a multi-characterization technique meaning drawing informations from several technique and trying to go beyond out to elucidate a particular mechanism. That is of importance for example, a potential spintronic candidate like manganese doped zinc oxide has created lot of curiosity and where this origin for magnetism come from. But we will take this as a case study using several techniques how we can be careful in interpreting the magnetic origin. So, we will look at some of these issues and.

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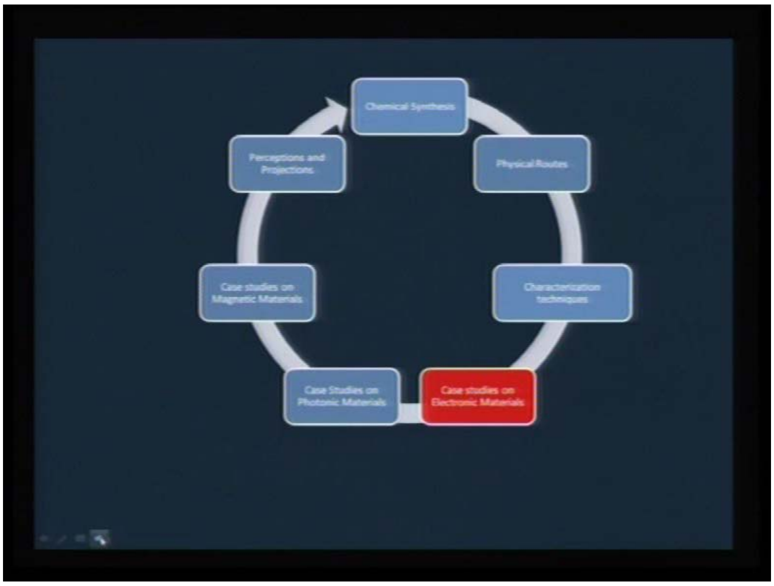

Next we will go into module 5 6 4 5 and 6 where we will be looking at specific case studies of electronic materials photonic and magnetic. In module 4, we will be looking at this electronic.

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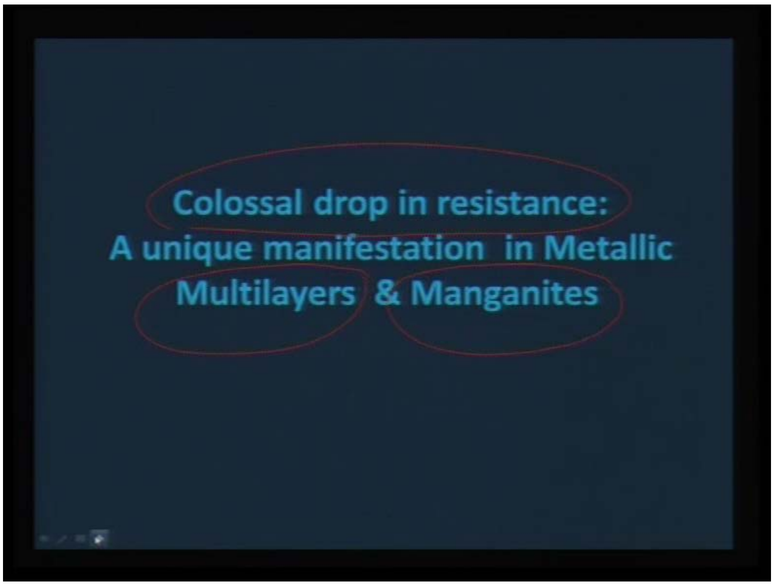

Materials for example, a very well known a perovskite which shows at huge fall in resistance when it is actually placed in a magnetic field which is called as magneto resistance. So, this colossal drop in resistance not only occurs in a perovskite compound like manganite, but also happens in multilayer's. So, we will be studying.

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Both these compounds in greater detail and as I told you this perovskite manganite is nothing but a simple lattice in which a genie is actually inside the lattice. So, its, brings out several manifestations of the magnetic phenomena that is occurring there. And correspondingly how it affects the electronic property all this can be seen. And therefore, I have just titled this as a genie inside the lattice. And 3specific points I would like to bring out very easy to remember XRD factor which means x factor which talks about the double exchange there r factor. And d factor to do with the charge the chemical pressure effect that you introduced and also how dimensionalities will modify the magnetic phenomena.

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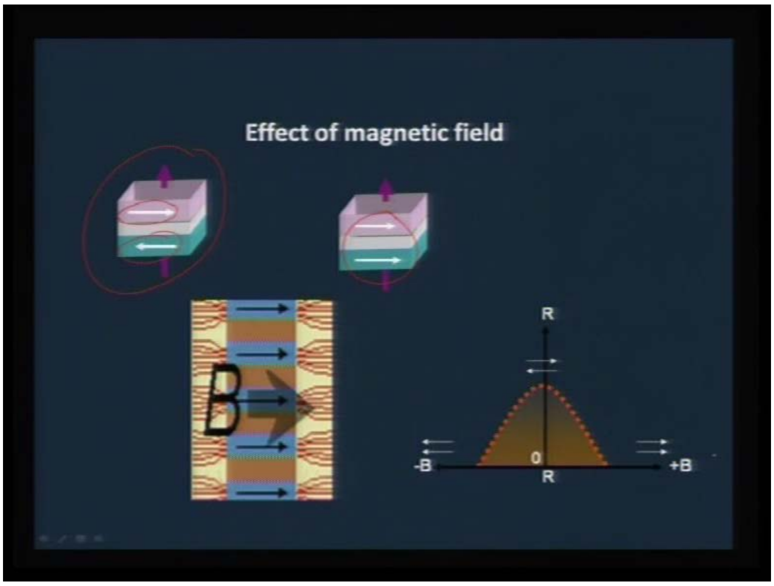

And also in a multilayer situational like this without the magnetic field And with magnetic field you can see how the alignment of this ferromagnetic layers are aligned in the absence. They are antiferro magnetically coupled in the presence of field; they are ferromagnetically coupled as the result you can see that there resistance changes in a very marked way. So, we will be looking at this multilayers also.

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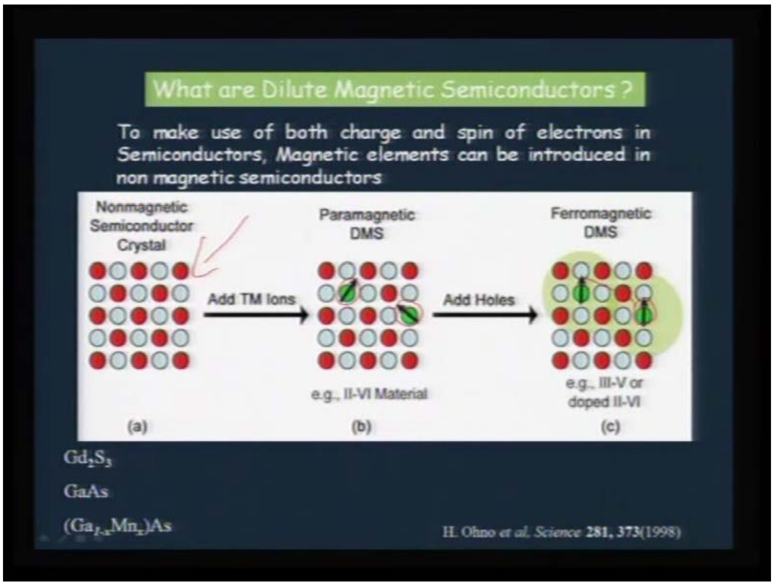

And another important area is dilute magnetic semiconductors this is a nonmagnetic semiconductor crystal. And if we actually put this paramagnetic ions in DMS and if you can add holes then these are getting ferromagnitically ordered. Because they are in a proximity which can engineer or which can actually stabilize ferromagnetism. So, we will be looking at some examples of this dilute magnetic semiconductors

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As well and will also in module 4, we will be talking about materials for superconductivity as you see here this is a magnetically levitated train which is actually running not on wheels. But it is actually floating and this is a clear manifestation of superconductivity where you can operate maglev trains. So, I will be talking about a variety of superconducting materials that are available. And those which have which have come in the last 30 years have made a phenomenal change in the applications as per as superconductivity based materials are concerned. So, those things will be discussed.

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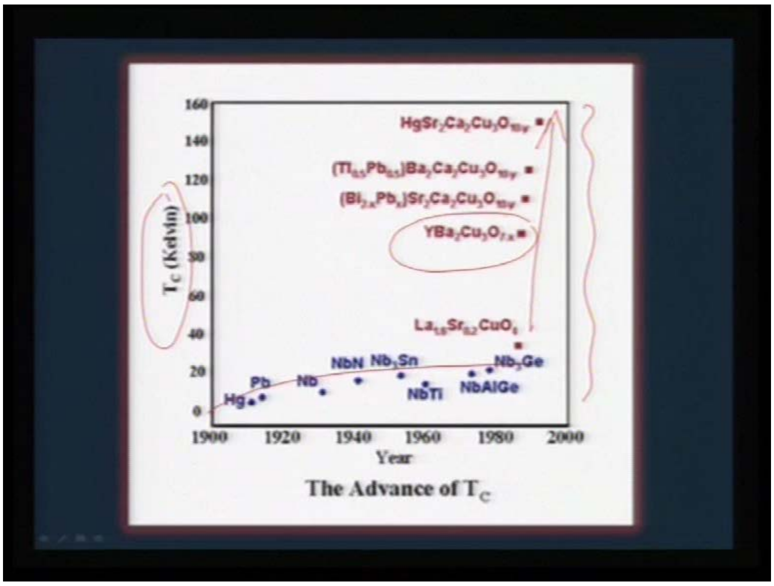

In module 4, and here are some of the materials which I have been mentioning as you can see these are all alloy or element based superconductivity. And these are the oxide based superconductors which have given a quantum jump in the super conducting transition that we have achieved so far. So, today this lot of work going on using this materials prominent of which is yttrium barium copper which is a very good perovskite compound which has been explored for device applications in greater detail.

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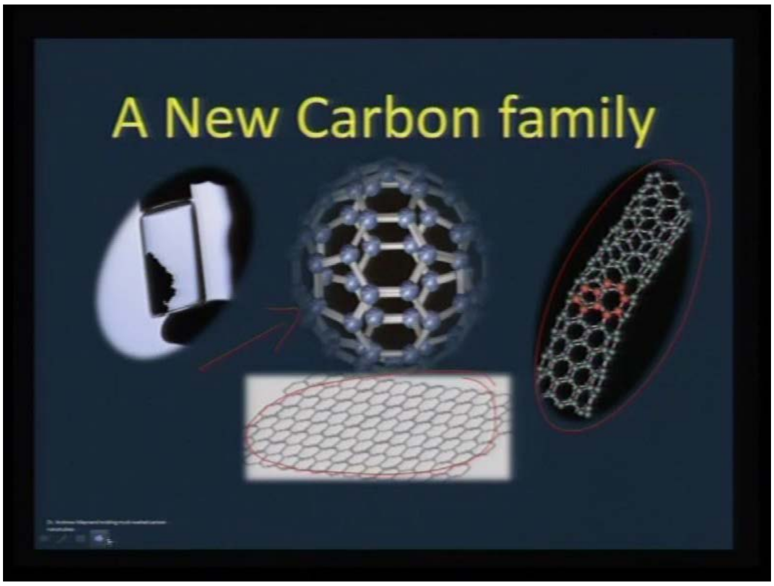

And also in module 4, I will be touching on another interesting aspect of a new carbon family which has really shaken our believes on or our understanding on the nature of carbon. And its existence you can see here we can make not only fullerenes which has come out as a discovery in the late nineties. And then we also have carbon nanotubes and recent past, we have also stumbled at another new discovery on graphene which is a two dimensional carbon. So, it has totally changed the landscape of all the allotropes of carbon in the recent past. And these are to be studied in greater detail. So, in module 4, we will also study.

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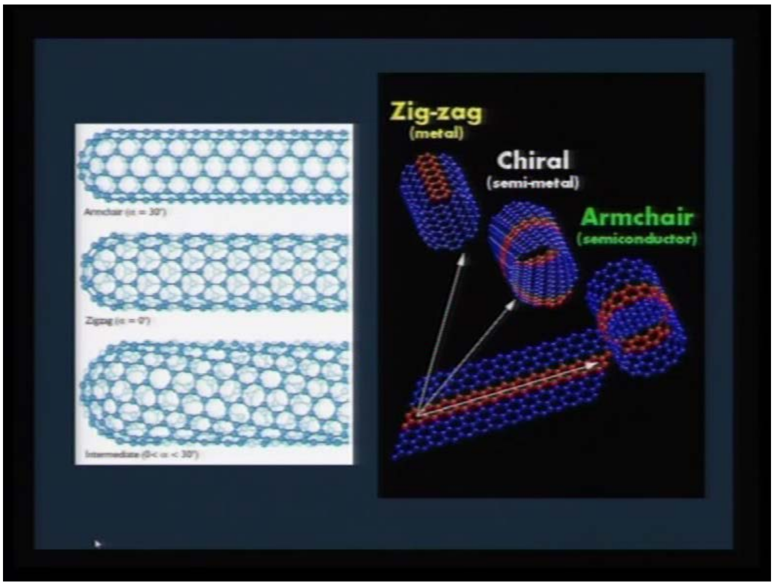

About different class of carbons that are available now and how and what is controlling a open chain or a closed end carbon nanotubes we look at the chemistry of it.

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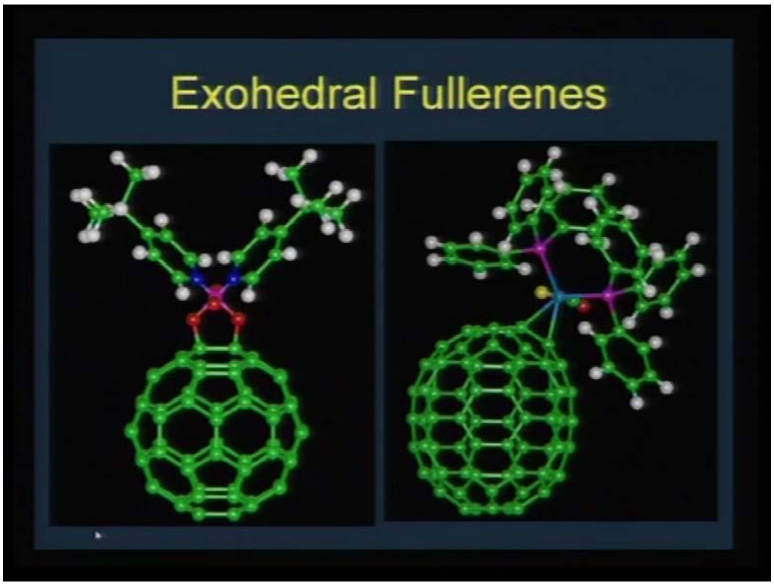

And we will also look at the possibilities of extending this c 60 molecule by substitutions either with the, with osmium or iridium base complexes and these are called as exohedral fullerenes. So, we will look at all these aspects in greater detail.

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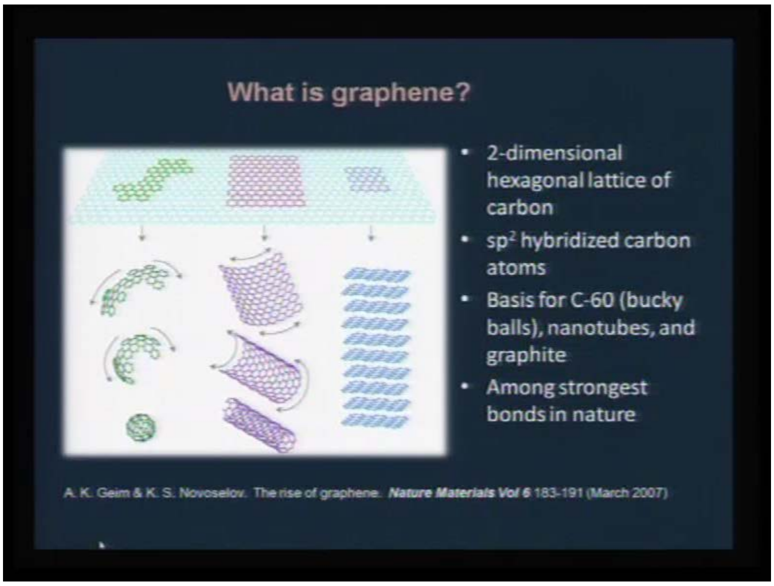

And we will also understand in prospective what this graphene is and how graphene can be made and what are all the applications? And how this graphene can change the conductivity of a of many device applications? We will look at the.

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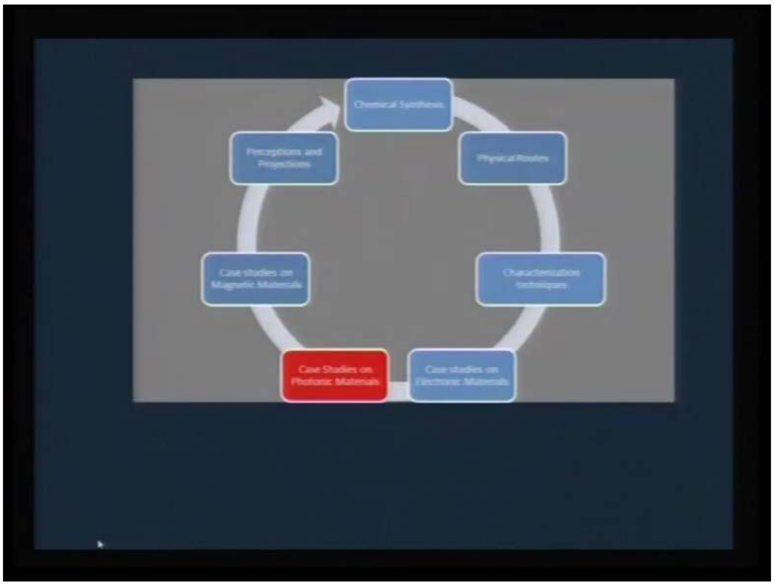

Graphene chemistry also in greater detail and then we will also look at some of the case studies on photonic materials from module 5.

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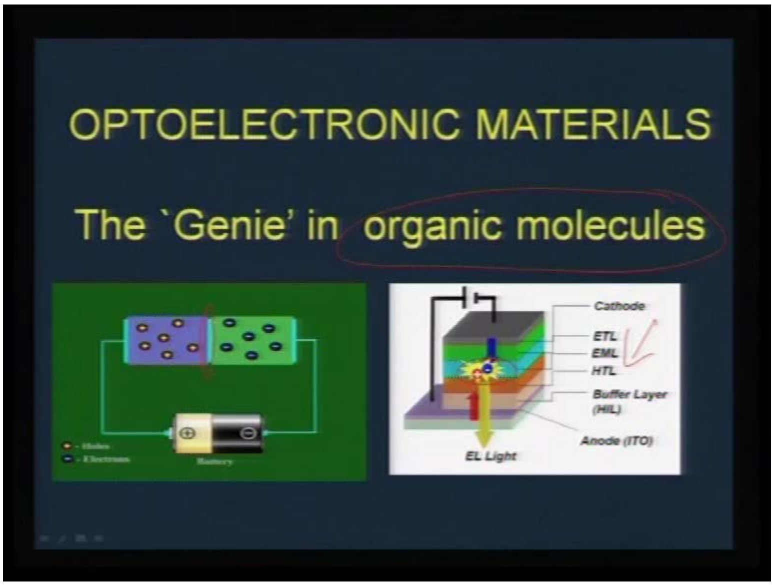

And to name a few I would be picking out mostly on organic molecules as I told you about lanthanum manganite where a genie is inside a lattice. Here is another situations of organic l e d's where there is a genie in organic molecules which is really transform the whole scenario of the applications of organic molecules. Here is a cartoon that shows where organic molecules are playing a fundamental role specially in the emissive layer a variety of organic molecules can be substituted to tune the color. And not only that the whole device application of l e d is transformed because you can make a large area applications using organic l e d molecules. And the here is where we will be actually worrying about replacing organic molecule so, that the color emission can be tuned. So, we will be looking at specific examples.

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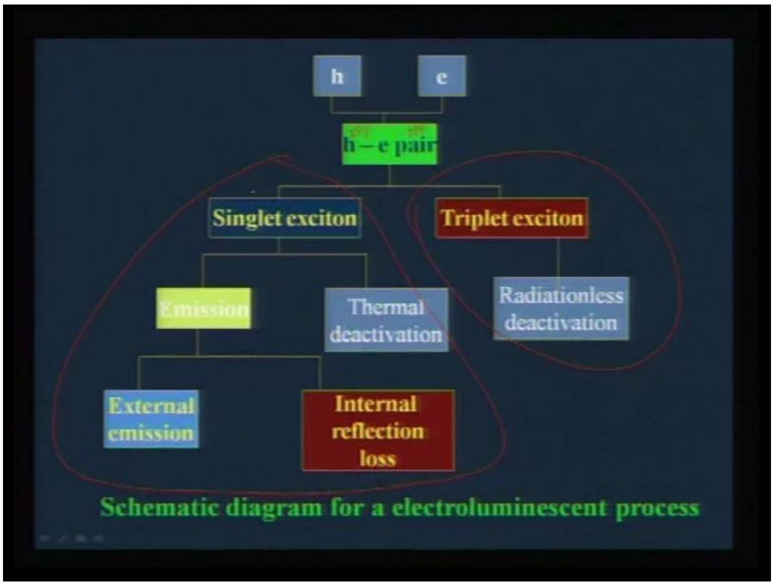

And we will also try to see in prospective what are the limiting cases because if you look at the spins statistics there will be nearly 75 percent of triplet formation and 25 percent of singlet formation. As you know singlet; singlet is what is responsible for fluorescence. And we are actually looking at light emission in this organic l e d's only which is giving you 25 percent of efficiency and what are all the processes that control this 25 percent of color emission against the 75 percent of triplet exciton. So, there are lot of examples which can give us some idea about how to harvest this 25 percent light output from this organic molecules.

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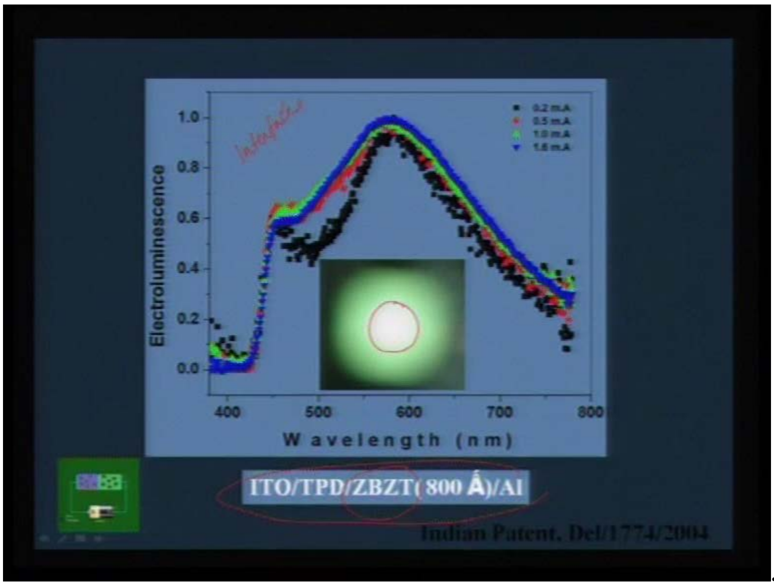

Also there is a interesting physics that we learn from these molecules when you try to put this molecules in solid state that is in devices the interface really plays a important role. For example this is a molecule zinc benzothiazole which is showing a very sharp photoluminescent emission around 500, but once you make a device like this in the device its shows a strong white light. And that is because of the inter interface chemistry that is acting between a inorganic material and organic material we will try to understand.

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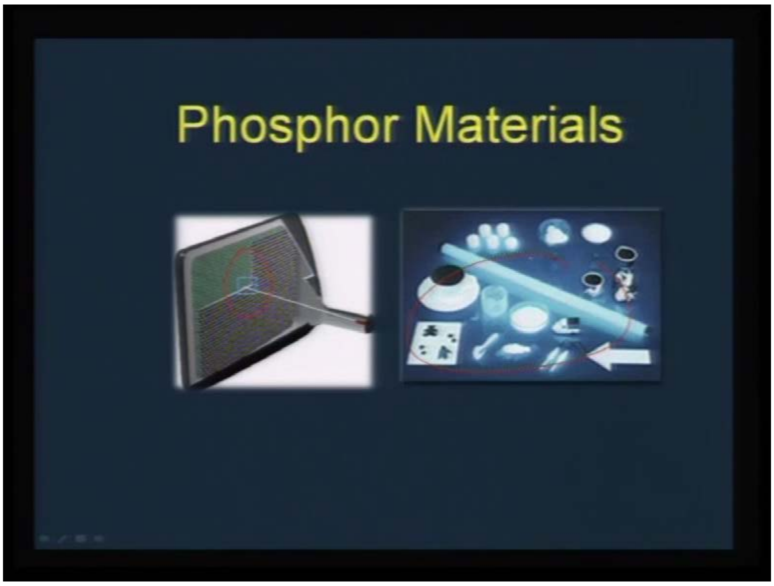

All this in greater detail I will also emphasize on some of the classic phosphor materials which are used specially in the cathode ray tube. And also in several lighting applications how materials chemistry play can play a very decisive role.

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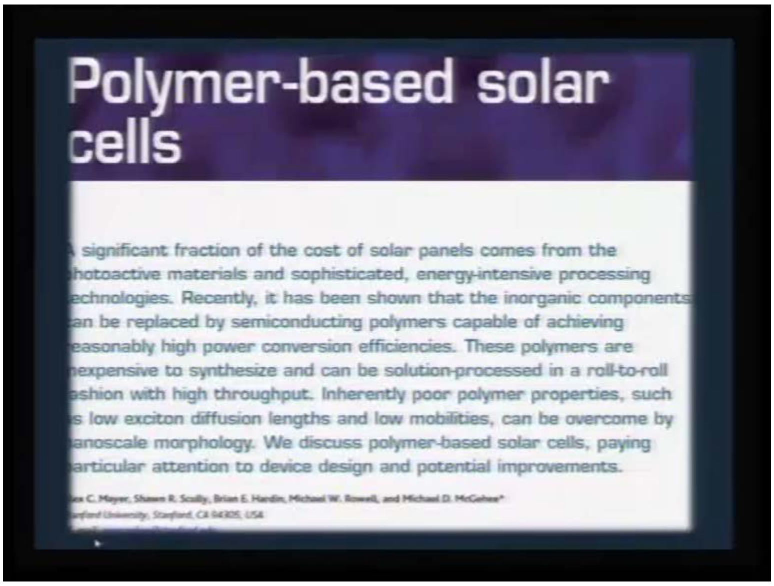

We will look at it and we I will also touch up on solar cells and how materials chemistry is transforming this area. And specially, I would like to talk about polymer based solar cells, because that is the one which is going to give us flexible substrates. And we can actually go over a printable solar cells which can revolutionize all our energy application procedures.

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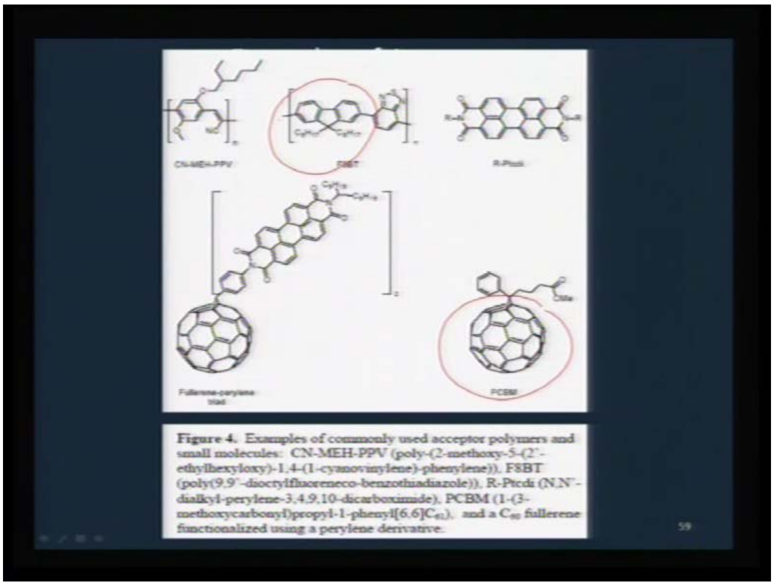

These are some of the molecules or candidates which have been very nicely used in the recent past those are fullerene based and also fluorine based molecules has blend they bring about a heterojunctions.

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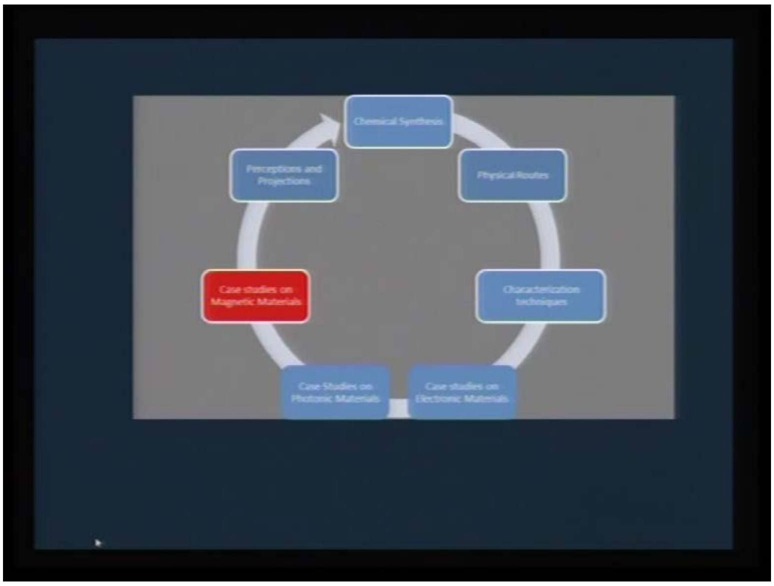

We will also look at some of the case studies of magnetic materials.

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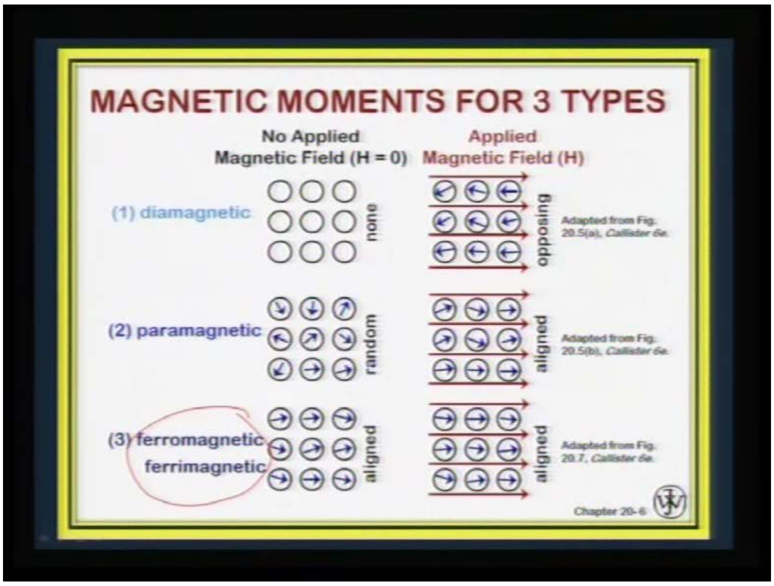

For example, we will understand the different classification of magnetic materials laying more emphasis on ferromagnetic, ferrimagnetic materials how they are controlling today's market and specially in.

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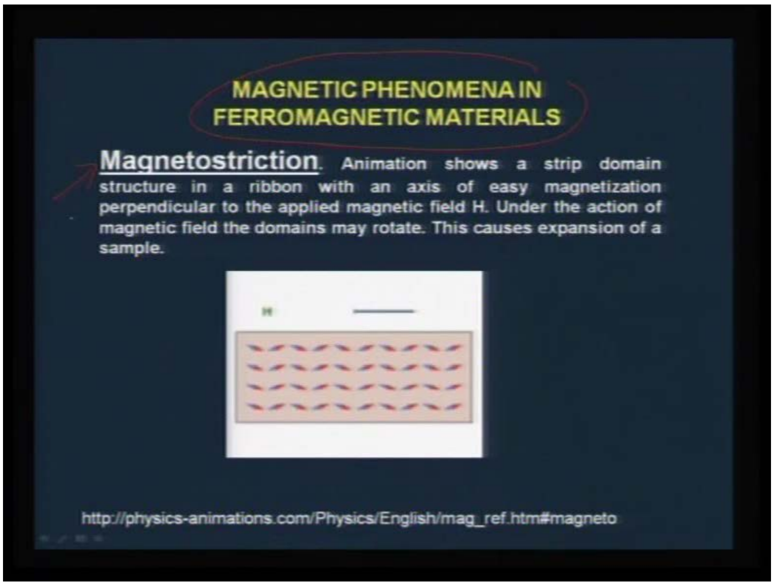

Magnetic storage I will also talk to you about a magnetic phenomena in ferromagnetic materials. For example issue of magnetostriction which will dilate the molecule, because of the rotation of the magnetic dipole in the presence of magnetic field. Therefore, we will talk about several magnetic phenomena that occur in materials in the presence of a.

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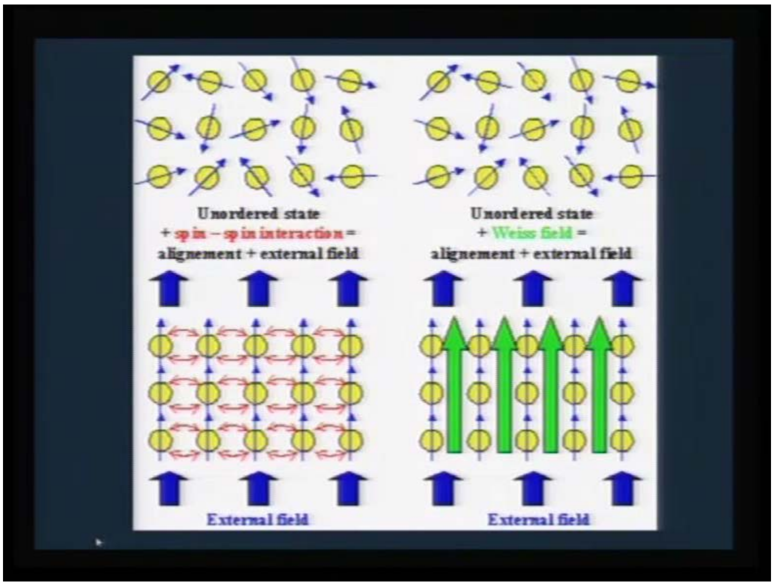

Magnetic field I will also discuss with you about some of the issues related to what is contributing to this ferromagnetism and the phenomena that governs ferromagnetism against paramagnetism. We will look at into all those issues.

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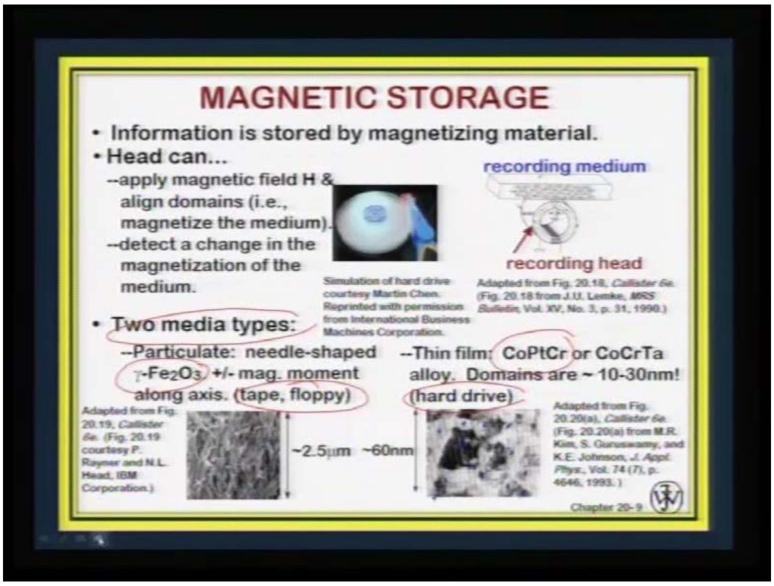

In the later modules and I will also emphasize some of the materials which are used for magnetic storage. For example, for media we have gamma F e 2 O 3 which is actually used in tape and in floppies whatever we see here is nothing but a gamma F e 2 O 3 based material. And also in hard drives we are using cobalt platinum chromium alloys and how these are actually affecting the magnetic storage devices.

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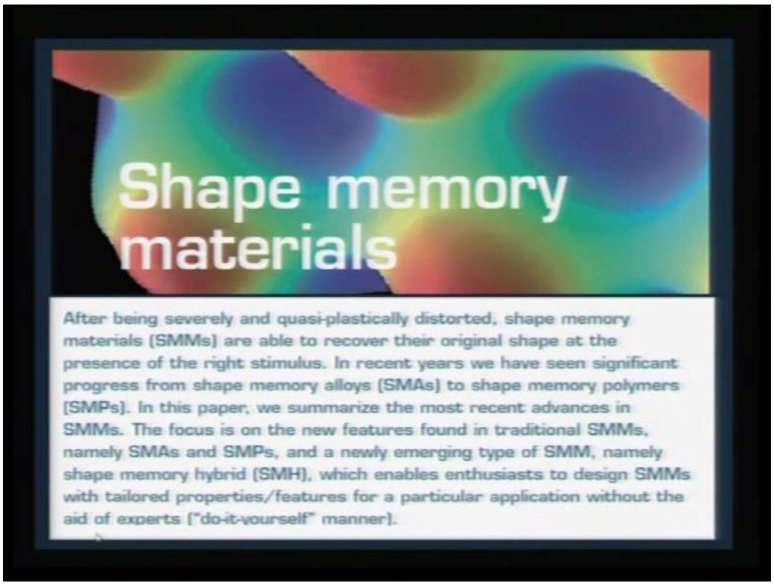

Lastly, I will also emphasis on shape memory materials which are able to remember their shape even if you transform it.

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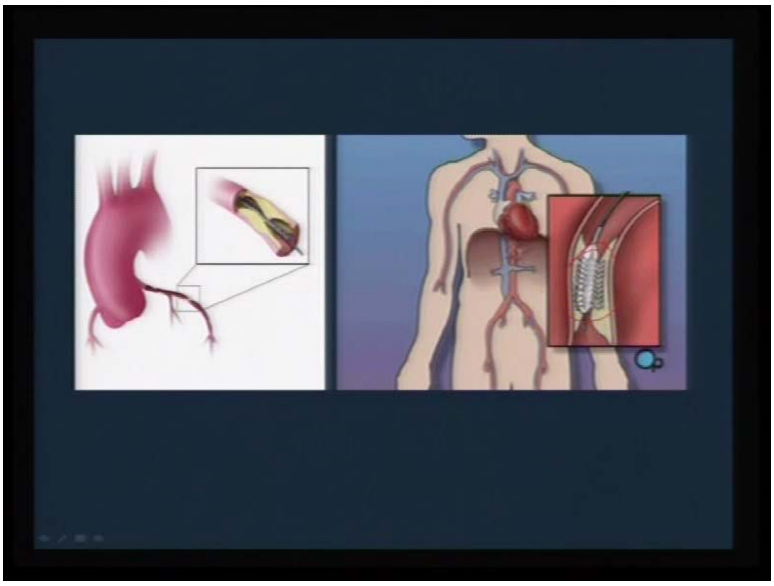

One of the shape memory alloy which is actually used is in the cardiovascular devices which is a cobalt chromium alloy. And you can see here this is the metallic tube which is made of such a shape memory alloy.

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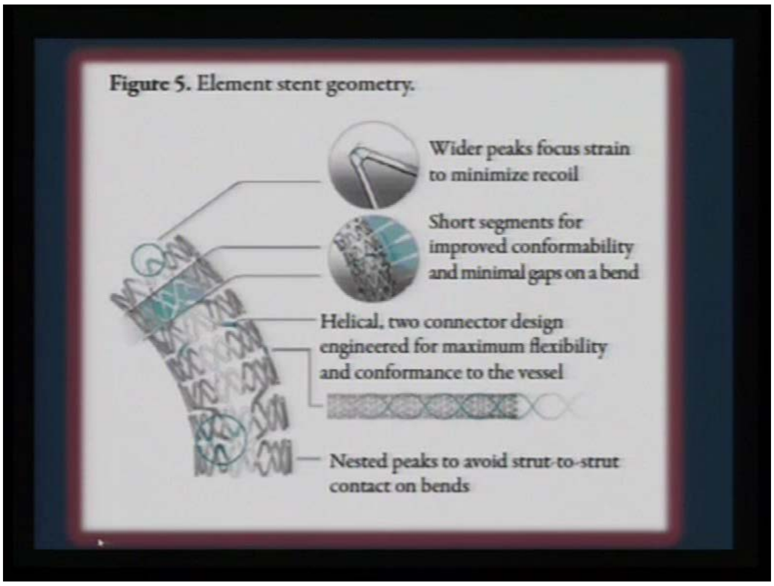

And we can see the fundamentals of it the details that control the properties of the shape memory alloys.

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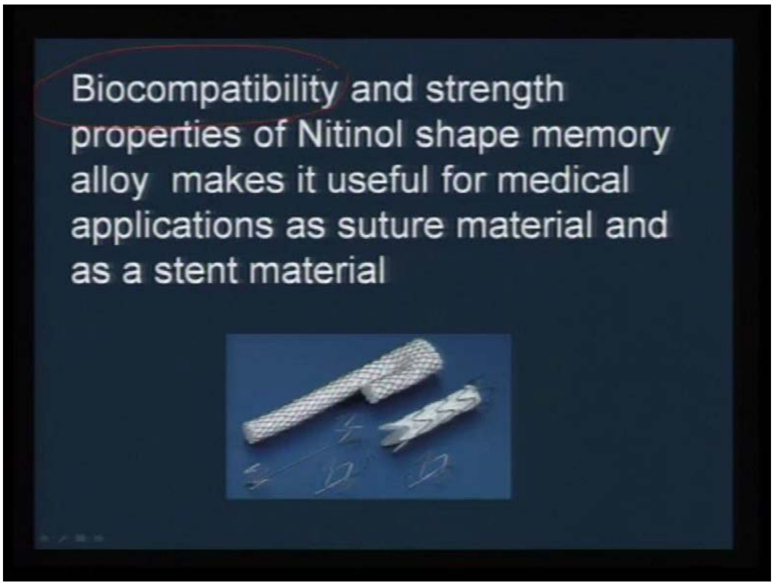

And, we will also look at how biocompatible these alloys are when it is actually placed in cardiovascular applications.

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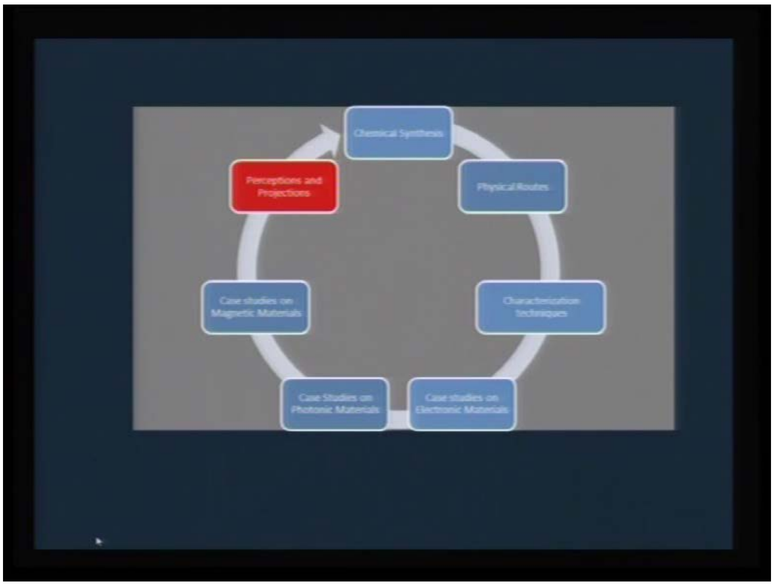

Lastly I will also bring to your notice some of the perceptions, because this is not a established field this is a emerging field. And therefore, there are lot of overtone to this emerging field where people have lot of ambition they have greater vision to take this integrating field to a a larger extent. Therefore, in the last module although it is going to be a short one I am going to actually.

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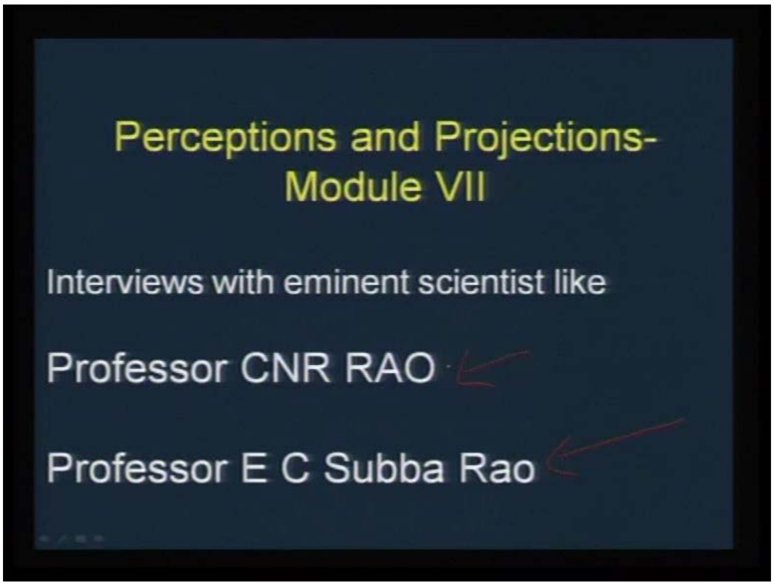

Show you some of the clippings of my interviews with the some eminent people like professor E C Subba Rao who has been a very very important person in anchoring materials research in India who has also been a teacher at IIT Kanpur. And I will also have a interview with professor C N R Rao who also started a his long innings with IIT Kanpur. And later he was responsible in bringing solid state chemistry in materials chemistry into focus not only in our country in countries abroad. So, I will be talking about some of my own perceptions about this emerging field. And tell you, what are all that things that we need to have in mind. And what are the forecast based on this modules, how we can look at materials chemistry? And how we can nurture this emerging field? So, that lot of device applications can be harvested using this. So, in a sense I will be teaching you lectures on chemical approaches from module 1.