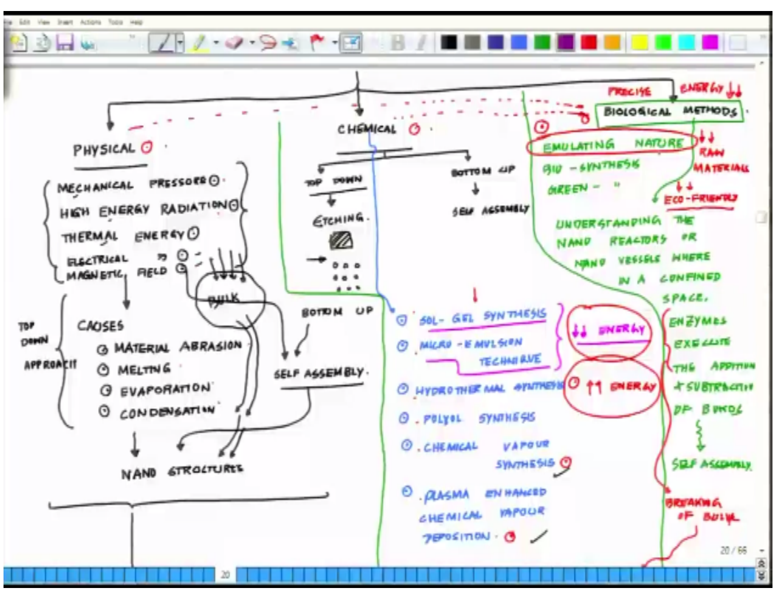
Nanotechnology in Agriculture
Prof. Mainak Das
Biological Sciences and Bioengineering and Design Programme
Indian Institute of Technology-Kanpur

Lecture-14
Detailed Biological Techniques

Welcome back we have been discussing about the basics of nanotechnology and in that context we have talked about the different type of geometry of nanomaterials followed by that we have talked about the synthesis and the synthesis we have talked about the physical synthesis followed by the chemical synthesis. And now we will proceed towards the biological synthesis, as I told you in the initial outline that biological synthesis is one of the most smartest synthesis in terms of conserving energy.

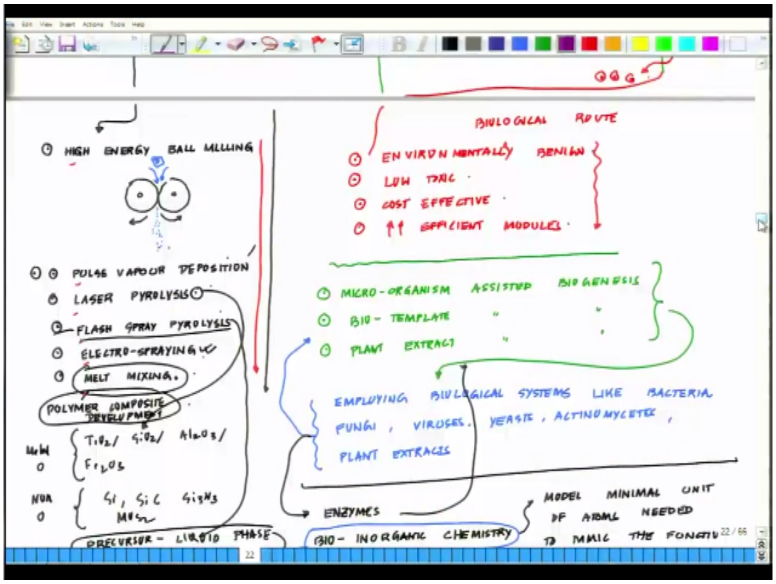
And in terms of conducting the reaction at a very low temperature or a pressure or within the physiological regime. So that is lot more to learn about the biological synthesis of nanomaterials because that is where the feature lies a very sustainable route. So, if you recollect what we talked about the biological methods.

(Refer Slide Time: 01:23)



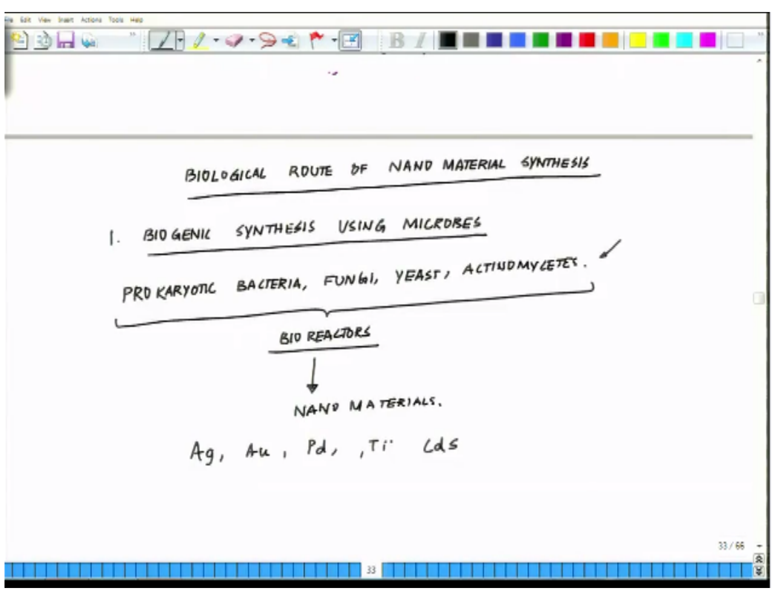
So, basic idea is will be emulating nature by synthesis which is the green root and the raw materials are in friendly and these are eco-friendly things. And understanding the nano reactors or nano vessel where in a confined space that enzymes execute addition and subtraction of bonds and leading to a self assembly okay.

(Refer Slide Time: 01:44)



And while we talk about the biological root these are mostly environmentally benign low toxic, cost effective and more efficient module. So the 3 routes what has been followed as of now pretty much well documented or microorganism assisted biogenesis, bio template assisted biogenesis and plant extract assisted biogenesis. So we will start our journey from where out here and all these techniques employ the biological systems like bacteria, fungi, virus, yeast and actinomycetes and plant extracts okay.

(Refer Slide Time: 02:23)

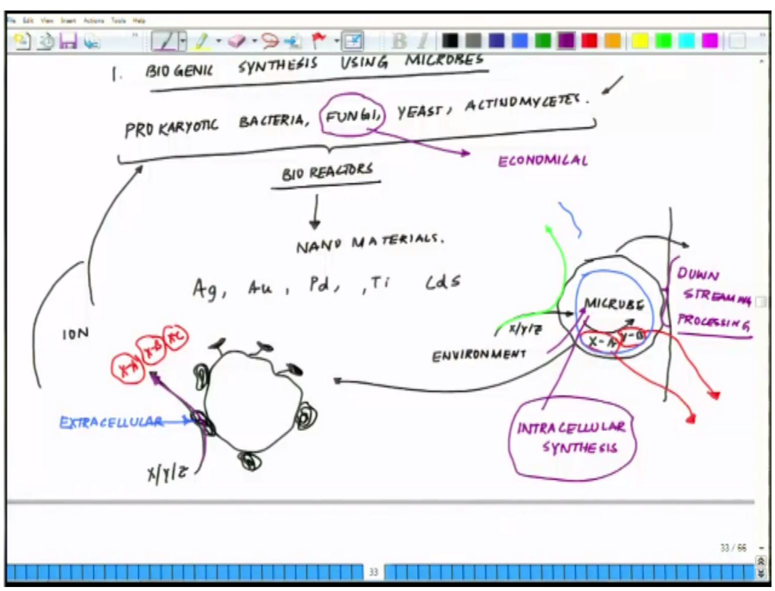


Let us resume from here, biological route of nanomaterial synthesis and biological route of nanomaterial synthesis as we have already mention. The first one will be discussing is biogenic synthesis using microorganisms, biogenic synthesis using microbes or microorganisms. So the basic idea of biogenic synthesis using microbes is prokaryotic, bacteria like actinomycetes, fungi, algae, yeast, prokaryotic, bacteria, fungi, yeast, actinomycetes, there extensively used as bioreactors.

So these functions as the bioreactors if you consider these single cell organisms as bioreactor. And these bioreactors are use to synthesize the nanomaterials. And if you look at it the enormous scientific effort where may to develop the strategy of producing nanoparticles of silver, gold, palladium, titanium, cadmium mostly cadmium sulphide okay, microorganism grab the ion targets, the way they do it very straight forward.

So, these microbes basically they grab the target ions from their environment and they turned the metal ions into element metal through enzyme generated by cellular activities okay. The synthesis can be classified into intracellular and extracellular.

(Refer Slide Time: 05:15)



So, for example they are pulling the ions, so this is the environment outside if this is the microbes and this is the surrounding environment. They are pulling the raw material from the environment it could be x, y, z whatever and out here by enzymatic reaction at a very low temperature and pressure they are converting them into some of the intermediate whatever we are asking for.

And then this is the time where we are intervening into this system to extract out these desired products out of it. So, purification and different kind of routes okay and this is what is about the basic outline of the process. And the synthesis could be classified into 2 level, this could happen either for example for addition route strategy it happen at this level also at the surface okay.

So in that situation what we are having is the microbe is say decorated with a series of enzyme on top. So these what I am drawing now at the decorated enzymes sitting on top of the microbes. And these are helping in transforming some x, y, z whatever into some desired product by the enzyme activity to say XA, XB, XC or likewise depending on what is the desired product we are asking about.

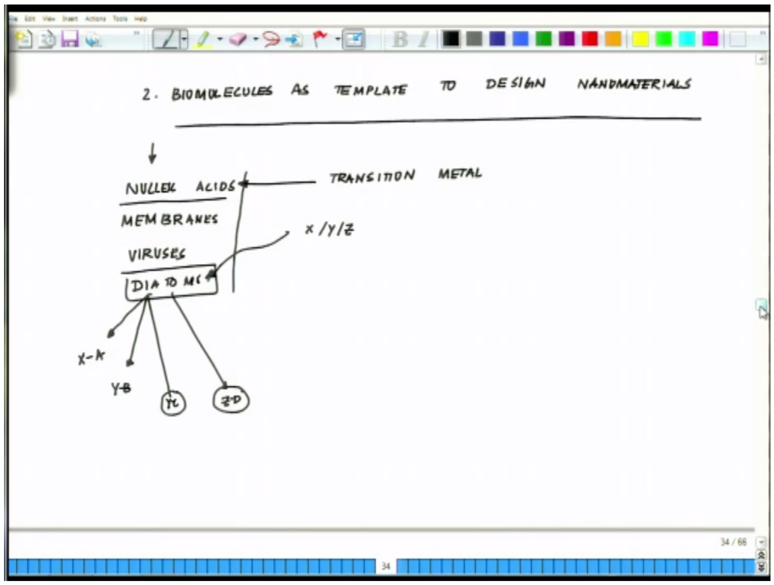
But depending on where it is happening you have either these are extracellular or these are intracellular. If it is happening outside like this we call this kind of synthesis as extracellular synthesis and if it is happening inside the cell here we call them intracellular synthesis. These are the 2 modes of synthesis following the microbes. The intracellular method involves transporting the metal into the microbial cell to form nanomaterial in the presence of enzyme as if it could see if the transport has to happen.

So which is slightly more energy intensive. The extracellular synthesis of nanomaterial involve cracking the metal ion on the surface as you could see on the surface of the cell and reducing the ion in the presence of enzyme. So bacteria utilize number of anionic functional groups proteins and enzyme reducing sugar in bacterial biomass to reduce interacting metal ions okay.

So, this is the basic, basic approach and this could be done by fungus where fungus mediated green chemist approach for synthesis of nanomaterial as several advantage in terms of bio-chem accumulation, economic viabilities, scaling up synthesis due to simple downstream processing and biomass handling okay. That suppose you are using fungus most of these processes are fairly economical.

And this is the part what we are talking about the downstream processing where you are isolating the desired product at a particular point and much of these downstream processing are well within the economical limits of producing such nanomaterial. So, this is one of the basic methods in biological synthesis.

(Refer Slide Time: 09:51)



The next one is in this line will be coming to template assisted which is bio-molecules as template to design nanomaterials okay. Now when we talk about template assisted synthesis, so there are various bio-molecules like you know you can use nucleic acids, they can use bi-lipid membranes, you can use different viruses, you can use diatoms might what in wonder what it diatoms.

These are algae, these are single cell algae and these are really one of the most populated algae in the algae family. And they have silicate cell membrane and those are really beautiful silicate cell membranes, if you just give a search in Google images then you go for diatoms silicate covering you will see amazing part on sentence. So these diatoms could be used as a very interesting template for any kind of lithographical applications and some artifact.

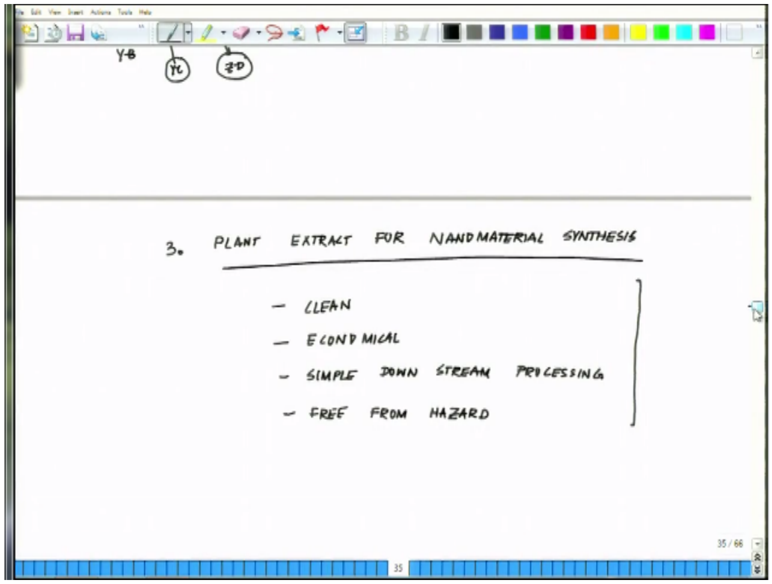
There are groups in the world we are trying to use those kind of pattern templates for bioelectronics application for developing transistors, developing electronic using the mass electronic substrate okay coming back where we were. So your nucleic acids, membranes, viruses and the diatoms these are used as template to synthesize nanomaterial DNA is widely known as an excellent biomolecular template.

That has the strong attraction with transition middle ions for any transition metal ion nanomaterial synthesis DNA could be used as a template. And that shown that the DNA hydrogel could be made and crosslink before incorporating transition metal ions like gold to DNA macromolecules that eventually lead to the formation of gold nanomaterial. The process involve reduction of gold from it is 3 stabling the formation of gold atom and metal cluster that develop into gold nanomaterial on the chain of DNA.

So, this is one way you can use DNA and DNA mediated synthesis or strategy to synthesize highly stable wire like clusters or silver nanomaterial is also a very common new observed area of research okay. So, one such area, so basically the whole idea is you are using a template in this case the template is nucleic acid. Similarly you can use diatom as a template, so on this template you are attracting your material which you are going to convert on this template to you know something like this.

As I was showing in the previous example something like this okay, so these are template assisted synthesis.

(Refer Slide Time: 14:04)



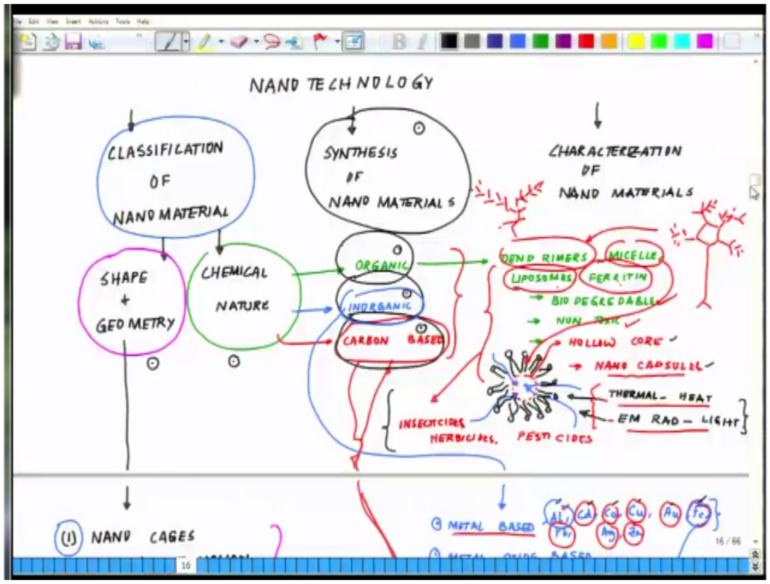
And in the third in that series is the next one which is plant extract for nanomaterial synthesis okay. So the biosynthesis of nanomaterial using plant extract or plant biomass is one of the very effective, rapid, clean and non-toxic and eco friendly method. This method has been utilized predominantly is to synthesize nanomaterials of double metals, metal oxide, bio metallic alloys.

And they have been adequately demarcated various plant bio metabolites that could help in preparation of nanomaterial based on their valuable role as reducing agent and as capping agent. One of very common logic what is being followed in this kind of a plant extract based nanomaterial synthesis is you are utilizing the specific enzyme needed for forming some specific bond which otherwise in an inorganic setup could consume significant amount of energy and power.

So, you are in a way where manipulating the milieu of the reaction by introducing an enzyme. And this is these are some of the very very very clean methods and these are economical and they have a simple downstream processing and they are free from much hazards. Because you are not now dealing with living microbes, you are just using a plant extract.

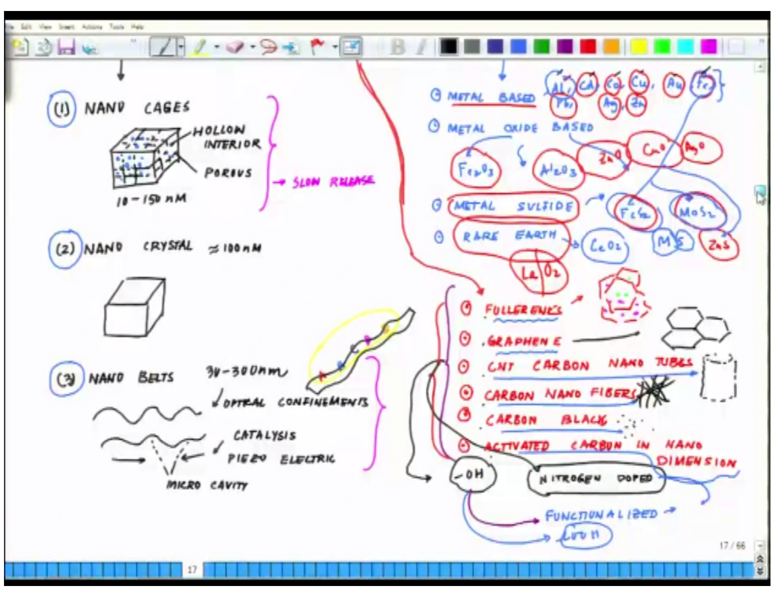
So the core idea is very straightforward as I mention for making or breaking any kind of bonds the nature uses series of enzymes as a matter of fact our story of life is could also be called as story of enzymes. So here we are exploiting those gifts of nature to us was wonderful enzymes to make or break bonds to synthesize the desired product or desired nanomaterial what we wish to obtain.

(Refer Slide Time: 17:39)



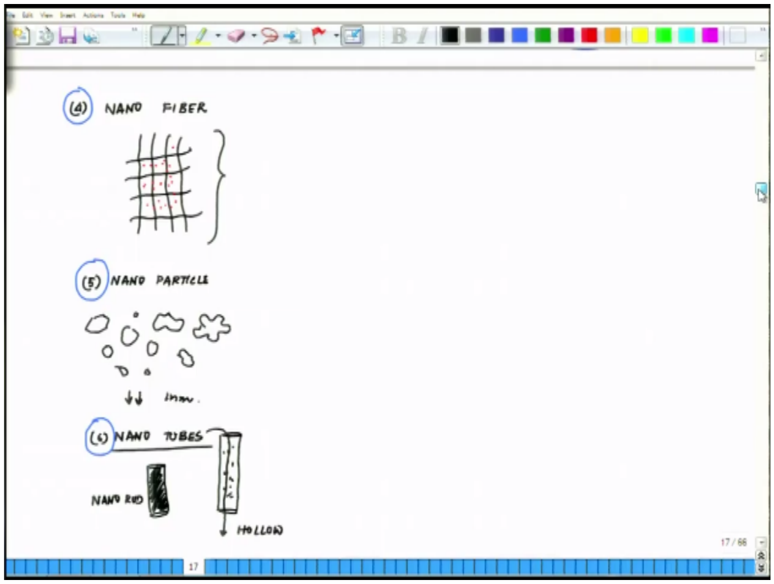
So, let us summarize what all we have covered in this section as of now, to start off with. So, this is where we started on the module of nanotechnology. We talked about the classification of nanomaterial in terms of shape and geometry and the chemical nature.

(Refer Slide Time: 17:57)



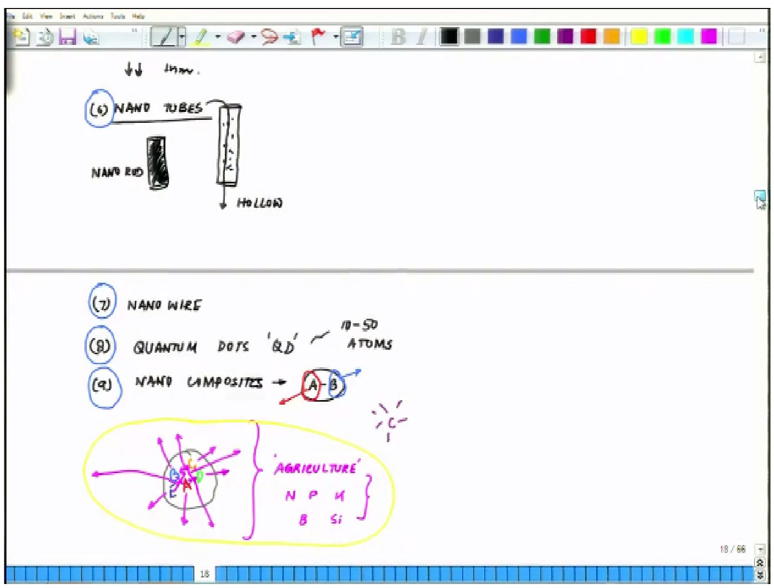
There we talked nano cages, nano crystals, nano barrels, nano fibers, nano particles, nano tubes.

(Refer Slide Time: 18:02)



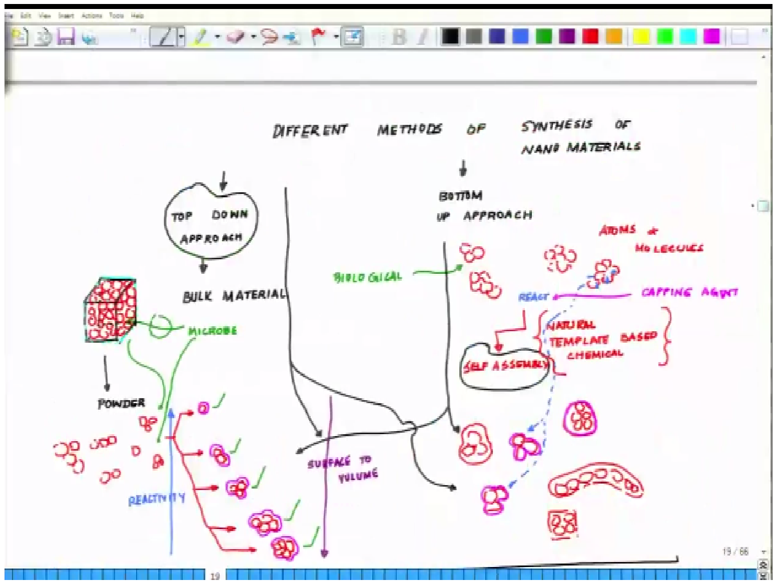
Both hallow and solid.

(Refer Slide Time: 18:05)



Nano wires, quantum dots and nano composites okay. Then in terms of synthesis of nanomaterials oh in terms of the chemical nature there could be either organic, inorganic or carbon based.

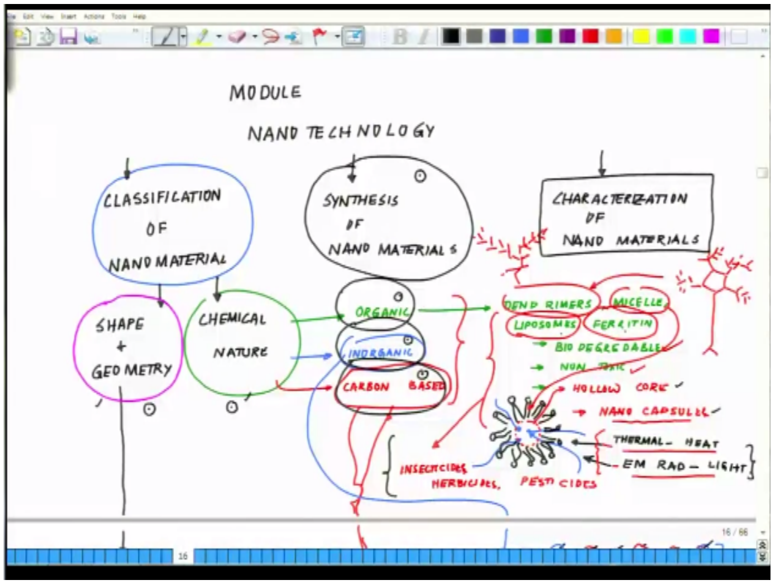
(Refer Slide Time: 18:22)



And in terms of the synthesis you could have either top down approach or bottom up approach. And these are further classified based on the route we are following, there could be physical, chemical or biological. Physical we have talked about all the techniques high energy ball milling, pulse vapor deposition, laser pyrolysis, plash spray pyrolysis, electro spraying, melt mixing and polymer composite development whereas in the chemical section we talked about SOL-gel synthesis.

Micro-emulsion technique, hydrothermal synthesis, polyol synthesis using poly ethylene glycol, chemical vapor synthesis, plasma enhanced chemical vapor deposition. And now in the biological segment we talked about microorganism assisted biogenesis, bio-template assisted biogenesis and plant extract assisted biogenesis.

(Refer Slide Time: 19:29)



So, in this segment now you are left with the characterization of nanomaterials, so this is in the module of nanotechnology. This is where we will be concluding once we talked about the characterization. So, we will close in here and in the next class we will talk about the characterization of these different nanomaterials characterizing them based on their geometry, characterizing their chemical nature, characterizing their specific functional groups which are available.

And that way we will be concluding this section and the way we are moving, so your first week we have devoted about the role agrochemicals in agriculture and the need of nanotechnology in terms precision farming, in terms of reducing the usage of optimizing rather the right word will be optimizing the use of fertilizers and pesticides from there in the week 2 we move into the nanotechnology.

The basics of nanotechnology and there is a slight spillover of the second week into the third week and after characterization. So we talked about the classification nanomaterial, we talked about the synthesis and now will be talking about the characterization after characterization we will move on to specific nanomaterials which have been tried out in the laboratory in the field for agricultural application okay.

So, let us catch up in the next class with the characterization of the nanomaterial before we proceeding to the application of nanomaterials in agriculture which includes plant, annual production, food packaging or post harvest technology and cleaning of water, thank you.