Nanotechnology in Agriculture
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Lecture-38
Case study of Titanium Di Oxide Part-I

So welcome back to the lecture series on application of nanotechnology in agriculture. So in the previous class I was talking to you about manganese cluster, so I showed you the scheme of the photosynthesis and I told you that you now there are 2 photosystem for system A for system B and both the photosystem receives light and both the photosystem ejects out electron and while ejecting out electron for system A as well as for system B gets oxidized because you are giving an electron ok.

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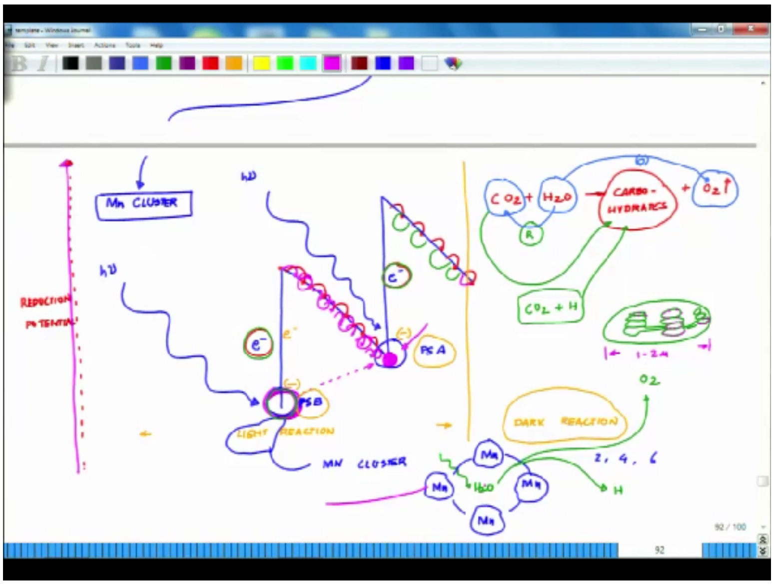

This electron passes through a cascade of proteins which are sitting in photosynthetic assembly or in the chloroplast and if you look at that nano architecture of chloroplast this is very interesting, this something like this thylakoid membrane and these are all connected structure and these are the kind of inspiration for the next generation nanotechnology ok, something like this and whatever reactions I am showing here are all happening at one dot out here.

The dots I am doing now, this is where these kind of reactions are happening and the dimensions what we are talking about if a cell is of 30 micron, this we are talking about something like want 1 to 2 micron the whole structures automatically these are nano machines, these small ones are those small, small nano machines where all these reactions re happening.

So the electron then cascade through these different proteins standing at different reduction potential if you look on your left hand side further highlighting it ok, now through this cascade of oxidation reduction finally for system A out here which was oxidised got reduced and brought back to the ground state, but still for system B is an excited state. So for system B gets back to its ground state because of electron which is donated by the manganese cluster which strips the water it photo catalytically kind of trap the water molecule to break it down.

Now in nature if you look at it all the processes which nature has been following are energy intensive processes of photo catalysis. Photo catalysis is such a powerful technique if it is successful then when these kind of desalination and if recollect all these could really change the way we are progressing.

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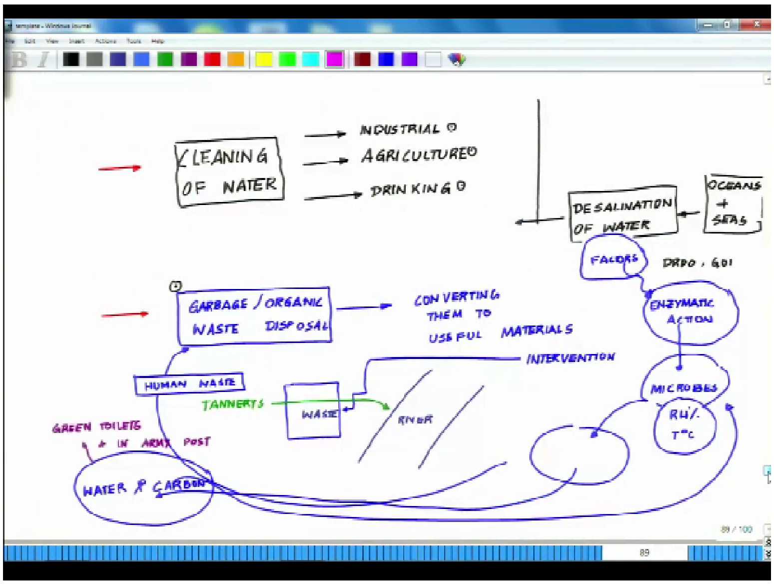

So now talking about photo catalysis here, this emulating manganese cluster.

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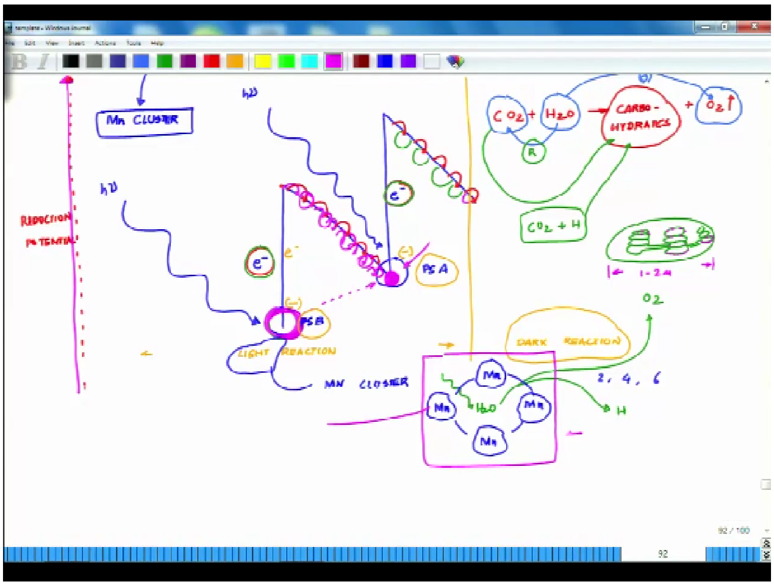

This is a dream the day mankind will be emulating the manganese cluster, this will be the D day for energy and environment and possibly from this day on mankind will learn one of the cheapest or cheap on the right word say one of the most elegant ways by which nature does its own catalysis. Now where we are currently, the lot of research happening on understanding the manganese cluster at atomic level it will trying to crystalize this whole assembly.

But nano world currently is using one of the molecule which they are using which triodes inspiration from here is titanium oxide, we have talked about this titanium oxide, today I will talk little bit more about titanium oxide.

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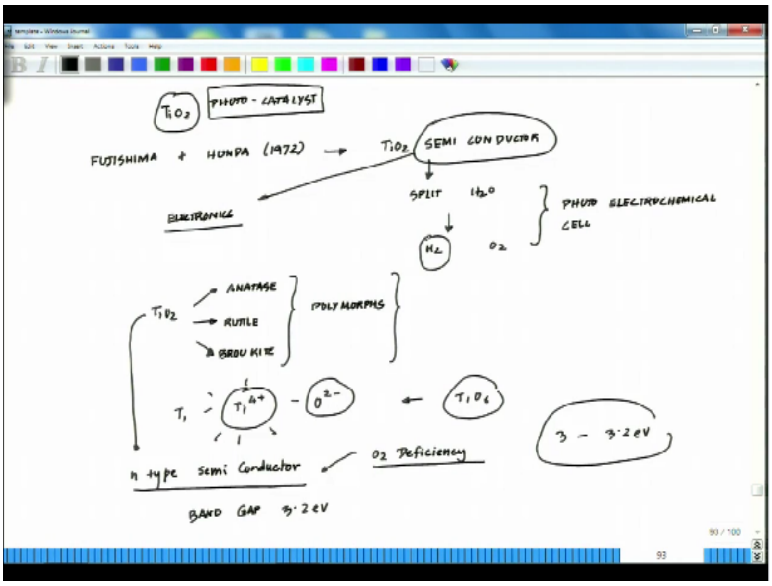

TiO2, so titanium oxide is a photo catalyst and if I go back in the historical perspective of titanium oxide then Fujishima that 2 guys Fujishima and Honda in 1972 demonstrated that the first one to demonstrate that titanium oxide which is semiconductor TiO2 semiconductor could split water into hydrogen and oxygen in a photo electrochemical cell or in a yeah photo electrochemical cell.

And if you essentially this work has triggered the development of semiconductor based photo catalysis for a wide range of environmental and energy application. So if you look at it, so semiconductor which whenever we talk about semiconductor we talk about electronics right and this is what I was trying to highlight in last few lectures if you guys go back if you see this, this was what was I was trying to highlight multifunction, so it has electronics applications titanium oxide.

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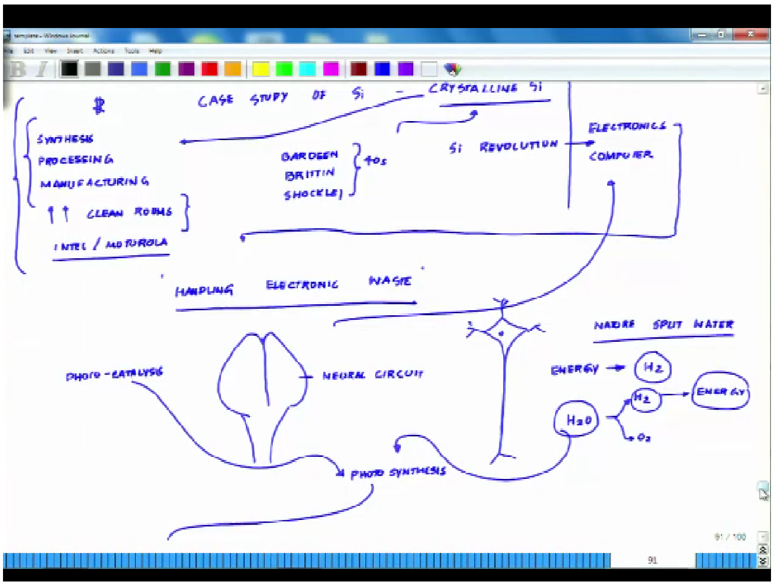

It has to be used for water purification and maybe it can be used for waste management, use for energy.

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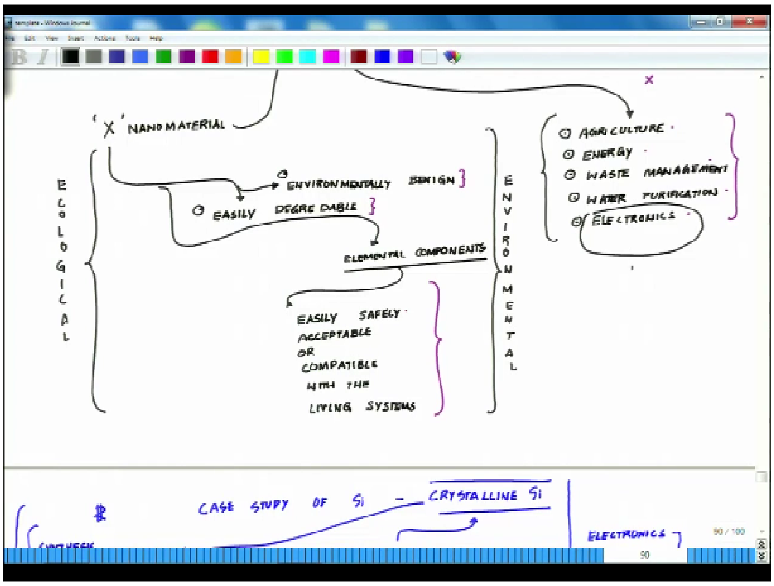

So this is when I say a material should have multifunctionality this is exactly what I meant, that this is how multifunctionality of material could be decided. Now if I look at titanium oxide how it does and what are the challenges which have been made. So I gave you this example of visible light doing this water splitting ok.

And this is all visible light of the spectrum, now titanium oxide has a band gap of approximately 3.2 will come to that ok. So one of the aspects what titanium oxide what I wish to highlight is that titanium oxide in nature remains in 3 polymorphs ok.

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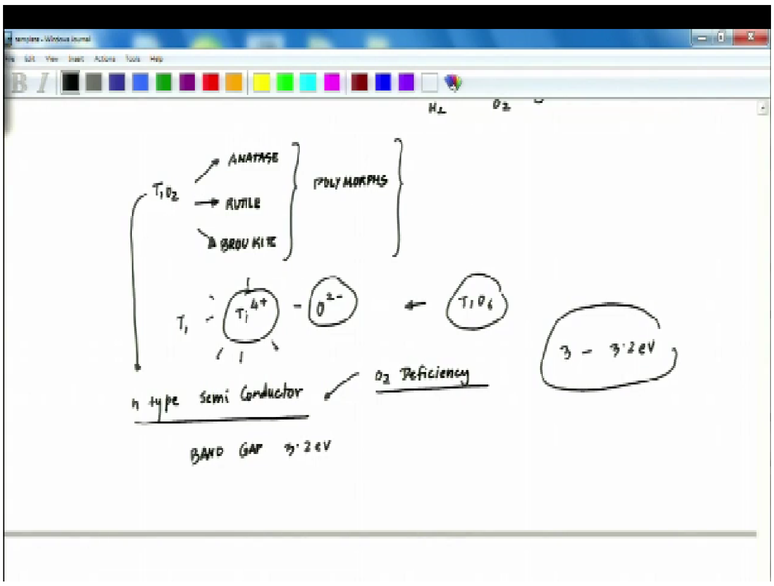

It has a anatase, retile and broukite phases, anatase form so these are called the polymorphs of titanium oxide anatase, retile, and broukite. And all 3 polymorphs can be readily synthesized in laboratory and typically the metastable anatase and broukite will transform to the thermodynamically stable retile upon calcination at temperature exceeding 600 degree centigrade ok.

So you realise that much of these when you are synthesizing they all go for a pretty high-temperature, similarly if you look at it in all the 3 form titanium is existing in Ti4+ form ok, so the valence is 4+ atoms and are coordinated to 6 oxygen atom 4, 5, 6 and oxygen atoms are sitting this. So essentially what we have is TiO6, it is an octahedral geometry it follows whereas anatase is made up of converters sharing octahedral which forms 001 planes.

You do not have to go to the plains and it gets the tetragonal structure and titanium oxide is typically is an n type semiconductor ok and this n type semiconductor due to its oxygen deficiency, locks in deficiency gives hit a entire features and it is a band gap of (()) (10:11) of 3.2 electron volt, for anatase it is, for anatase and for retile it is 3 and 3.24 broukite.

So it is around they can 3 to 3.2 electron volt, all the 3 polymers are standing at that and all of them are as I mention all of them are n type semiconductors ok and Tio2 is most widely used investigated photo catalyse due to its photo toxicity, low cost, low toxicity and good chemical and thermal stability. So this is another aspect which I was highlighting Tio2 for photo catalysis ok. So these are the features which are important.

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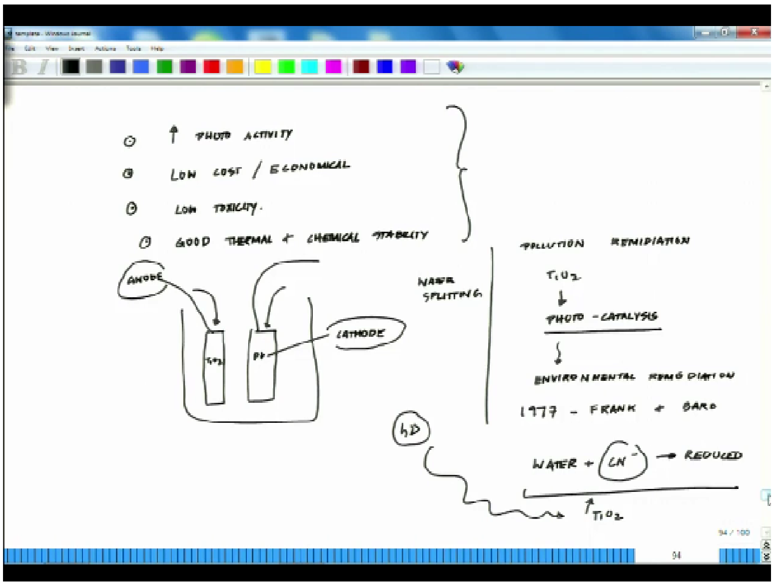

It is pretty high photo activity one aspect, the second aspect it is pretty low cost, so in another word it is economical you have something easily manufacturable, it has low toxicity, so handle able and good thermal and chemical stability. These are the 4 features which made this a very popular material for all sorts of photo catalysis and water splitting and water purification.

In the last few decades there have been several exciting breakthroughs with respect to titanium dioxide, the major advance was in 1972 which I mentioned when Fujishima and Honda reported the photo electrochemical splitting of water using titanium oxide anode and a platinum counter cathode. So basically Fujishima and Honda story was something like this where you have this anode and you have cathode.

So what essential you had titanium dioxide electrochemical cell has titanium dioxide as anode and platinum as cathode. This is your anode ok, this is your cathode, so followed by that titanium dioxide photo electrolysis was first used for remediation of environmental pollution. So see look at it for the same material in 1976 by Frank and Bard. This was another major breakthrough, so water splitting is one of the aspect titanium dioxide does.

The second thing is pollution remediation, so basically titanium oxides photo catalysis was utilised for remediation of environmental pollution in 1977. So if you look at they are not very old ok 1977 by 2 guys called Frank and Bard, they reported that the reduction of cyanide Cn- in water ok, Frank and Bard so water+Cn-, so this Cn- is getting reduced in the presence of this whole things happening.

Tio2 and TiO2 is getting activated by flight, so that lead to a dramatic increase in the research in this area because of the potential for water and air purification through utilisation of free solar energy. So your major source of solar energy is free, other significant breakthrough included Wang in 1997 who reported that titanium oxide surfaces with excellent anti fogging and self-cleaning abilities.

So this was another breakthrough, so when we talk about the again I will highlight this aspect multifunctional, sustainable green material multifunctional. This is the word which is very important for you guys to understand that this is where the future lies something which has multiple application. So similarly when we talk about the next breakthrough, the next breakthrough was 1997 where this was shown potential water and air purification followed by Wang Etal who showed that titanium oxide surface has anti fogging.

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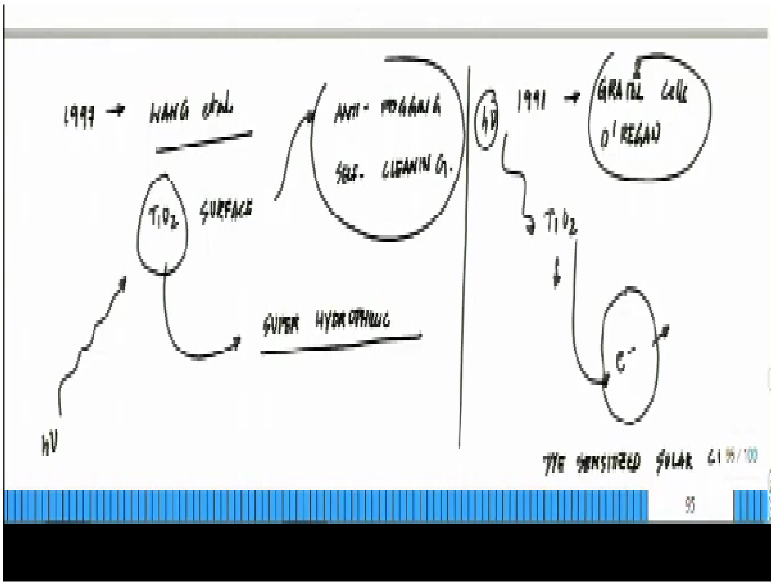

So it means you can use it in the car anti fogging properties, self-cleaning abilities, next thing what it has an attributed to the super hydrophilic properties of photo excited TiO_2 surfaces. So titanium oxide when it is photo excited that is super hydrophilic ok. Now photo excited TiO_2 surfaces and use of nano titanium dioxide is an efficient dye sensitized solar cell. In 1991 there was another report and this came from Grätzel he is in Switzerland.

Grätzel cell whose name this is the dye sensitized cell call Grätzel cells or this is reported by Grätzel and O’ Regan that TiO_2 is because when light is falling it is generating an electron and this electron could be now incorporated into a dye sensitized solar cell, will talk about this will get more about dye-sensitized solar cell and what these are. So these are the areas where lot of research is happening all over the world ok.

So if you look at it same titanium dioxide it is being used for photo electrochemical cell to split water, so technically we can use this for hydrogen energy, this could be used as semiconductor material of course there are issues which will come very soon while we will talk about mechanism of action for pollution remediation, for Grätzel cell and for anti-fogging and self-cleaning.

So the same material having multiple function, this is where the future lies, this is where much of these work are happening. So in the next class we will talk about brief mechanism of titanium dioxide and how it execute this process ok, thank you.