Nanotechnology in Agriculture
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Lecture-40
The future_evolving nano world

Welcome back to the lecture series in application of nanotechnology in agriculture. So in this section we have been talking about multifunction nanomaterials and we are talking about the case study of titanium dioxide. So just recollect back, so this is what titanium dioxide can do, if we have talked about it the multiple application of titanium dioxide.

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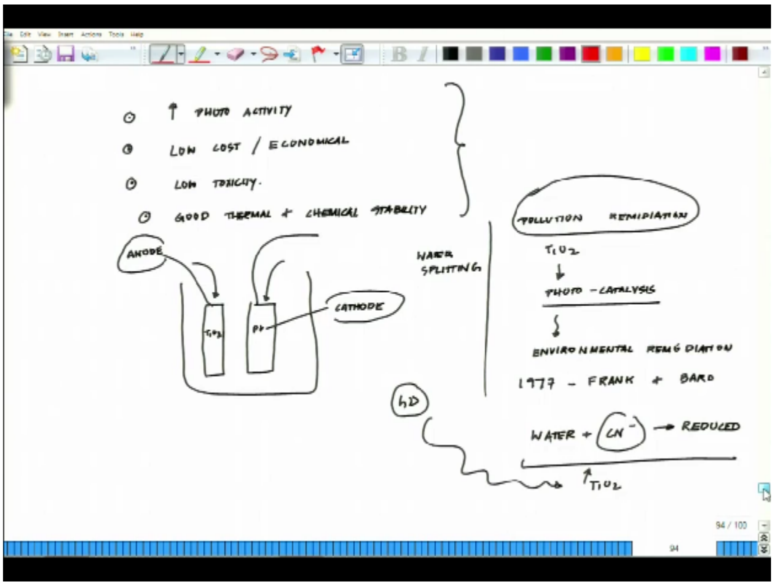

We talked about its pollution remediation, water splitting, dye sensitized solar cells, anti-fogging self-cleaning.

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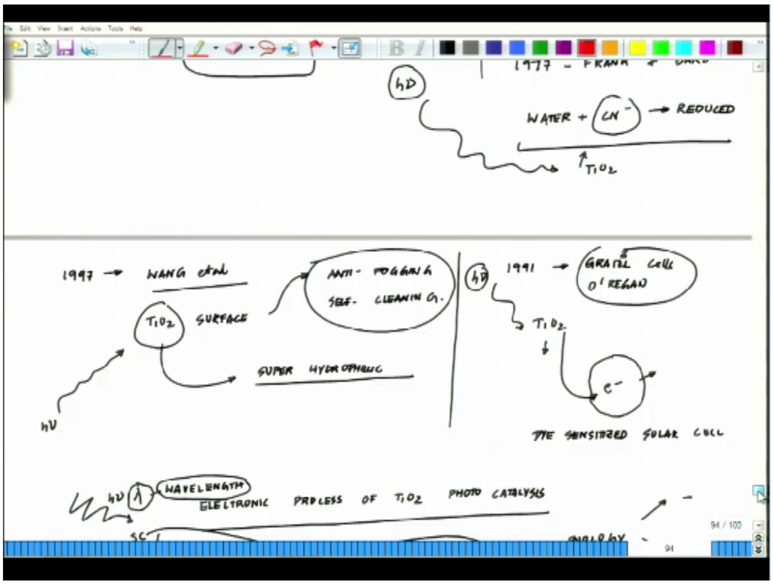

So and we talk in depth about the mechanism of action of generation of free radicles.

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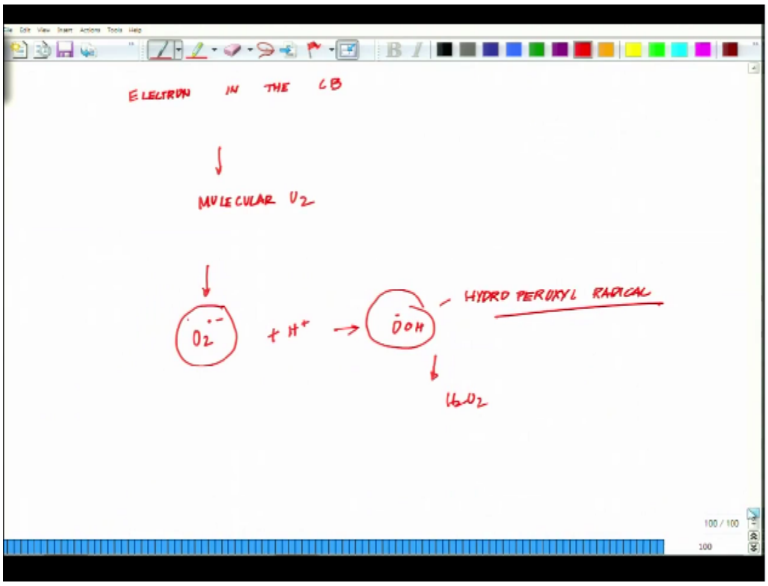

So one of the challenging problems in these kind of material is the problem of recombination, what really that means is recombination of photo generated charge carrier is a major limitation in semiconductor photo catalysis and reduces the overall quantum efficiency, what essentially happens is this, when you are generating these kind of species in the valence band and in the conduction band.

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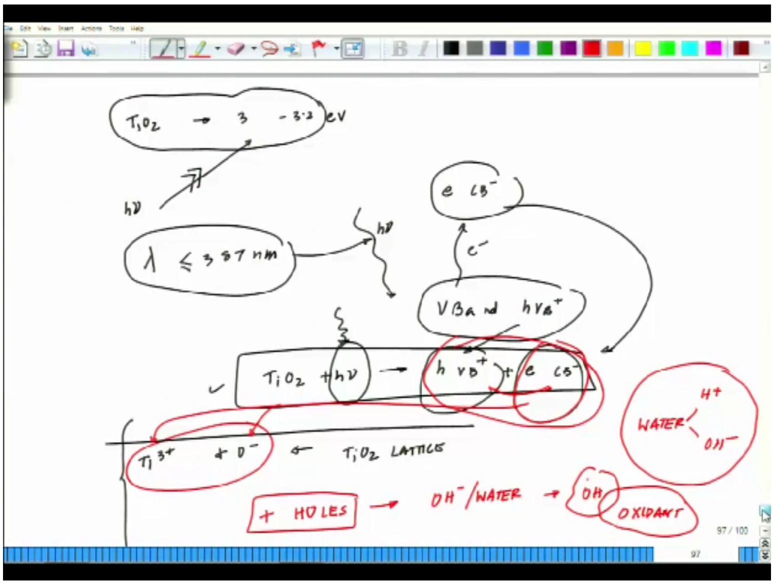

This is the conduction band, so these are happening for a very delta T period of time, sometime per second, some exceptional small period of time, even before something happens these 2 recombine and this is the huge problem of recombination which is rate limiting ok. So recombination of photo generated charge carriers is a big issue, it is a drawback, so let us summarize the schematic of Tio2 as photo catalytic mechanism.

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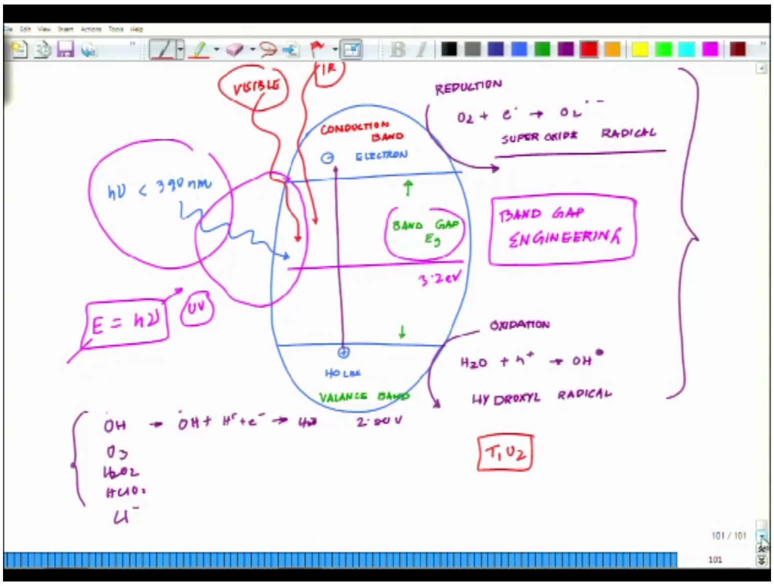

So this is how it looks like, so you have the valence band sitting here, you have the conduction band sitting here and you have the light which is falling out here, the h mu as we talked about less than 300 nanometer 390 nanometer, so here you are having the holes which are positive deficiency in electron and you are having the electrons ok and this is your conduction band whereas this molecule is your valence band ok.

So now you have a band gap in-between which is Eg which is your band gap, so whenever there is an excitation the electron which is moving and this process which we have shown through individual reaction, there is an oxidation happening here, so which is essentially, this is that photo oxidation which talked hydroxyl radical is generated here whereas in the conduction band there is the reduction which is happening.

And in that reduction reaction O2+electrion making O2.- which is superoxide radical, so this is the schematic of titanium dioxide photo catalytic mechanism and there are series of oxidant half-cell reaction which is happening and those oxygen which are generated are OH which is hydroxyl radical, O3 which is ozone, H2O hydrogen peroxide, hypochlorous acid, HclO3, HclO sorry and chloride.

And each one of them to see their half-cell reaction is something like that which dot +H+, + electron forming water and reduction put oxidation potential sorry the oxidation potential is around 2.80 volt, so likewise there are series of research, these reactions which are happening here which are not a significant, but one of the areas where much of the work has happened in last 20 years is this.

People have manipulated these molecule to reduce this band gap from in titanium oxide 3.2 electron volt to lower amount and this could be done by coupling some molecule here at the nano level. So which falls under the whole area of band gap engineering, where you are ensuring that this material generate electron at a lower energy you do not need intense because if you follow is equal to E=h mu right.

Where E is the energy and mu is the frequency, now if you have to use high wavelength sorry high frequency, high energy something like an UV which is pretty high energy material high energy intense light you have to produce. Now instead if you could do it in visible light which is the low energy much more and even if you could do it in say IR light infrared which is much lower energy.

So those are some of the engineering aspects of Tio2 molecule which happened where people have shown, they could use the visible light for a visible light active titanium dioxide photo catalysis for environmental application and that needed a lot of those modification using different kind of materials. So people have shown that they can go all the way I will just take this.

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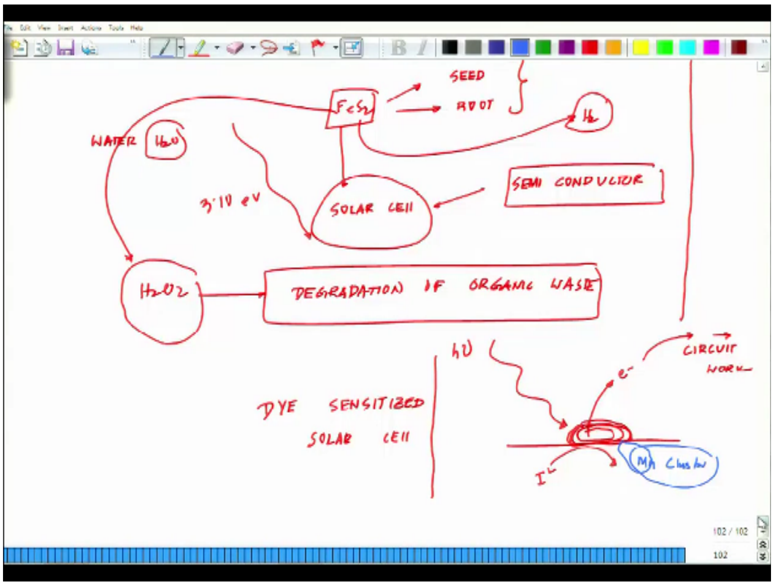

So as of now it is 3.10 electron volt, it has been reduced now almost to in a 2.86 electron volt ok. So there are several studies which are happening in that area, but what is important is this is one of the emerging field where there is lot of application of nanomaterials, nano engineering which is happening exactly in the same line I will draw your attention to the next molecule which is FeS2 pyrite.

If you look at pyrite, pyrite had been used and we have talked extensively about pyrite, pyrite has been used in agriculture without discoveries showing that it is a seed stimulant it is used as root treatment ok. Now pyrite is one of the profound solar cell material which absorb the pyrite red region, so it means this is a semiconductor ok. And pyrite as another application exactly like titanium dioxide.

Since pyrite in the presence of water do it generate H2O2, this H2O2 could be used for degradation of organic waste, realize same molecule almost the same geometry of the same strategy it is following. So pyrite has multiple applications, pyrite could be used as in agricultural material, pyrite could be used as a attempts have been made to make it as a solar cell material, pyrite could be used for organic waste.

And maybe pyrites be used for I know hydrogen generation ok, so there are multiple such application, so what I wish to highlight and another thing what I did not talk to you is something called a dye-sensitized solar cell, when you talk about dye sensitized solar cell it is something like this and naturally you understand it dye-sensitized solar cells are following the same logics what I told you.

So you have a photo reactive material out here, this photo reactive material receives light of X,Y,Z wavelength whatever excites its electron, it generates an electron ok. This electron is then put into the circuit to do the necessary work ok, whereas this moiety which is now devoid of electron is being got back to its ground state by iodine molecules which are their I2 I3 and lot of shuffling which happened which in nature provides that infinite source of electron for nature is manganese cluster.

In nature, nature does it is in manganese cluster if you go back to the photosynthesis where I started so nature uses manganese cluster as its electron source, but infinite electron source where else out here in dye-sensitized solar cells or Grätzel cells you can pick up any of those reviews, it is iron molecule which supplies that addition of electrons. So coming back where I started this journey with you people.

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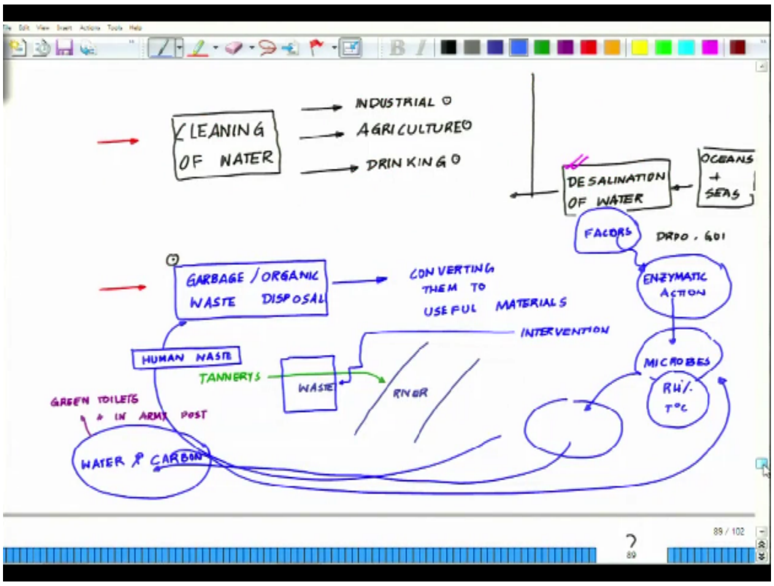

These are some of the points what I again wish to highlight, so the future when you talk about I told you cleaning of water industrial agricultural drinking, garbage and waste disposal, desalination of water and what you are looking forward to is multifunctional sustainable green material.

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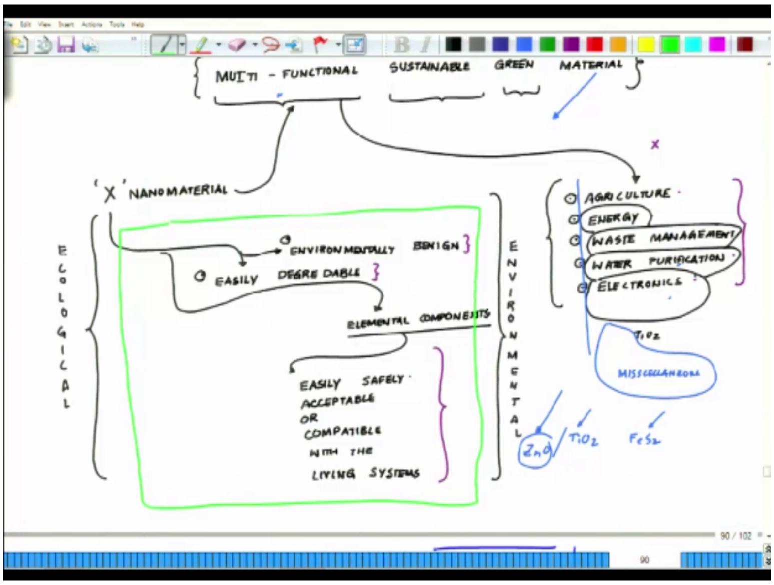

So if you look through the last 5 lectures what I have been given is basically we I must stressing upon multifunctional sustainable green material having multiple applications agriculture, energy, waste management, water purification, electronics and other miscellaneous application ok. And in that context we have talked about 2 case studies and case 2. So there are many such material which I could not cover.

But you know they all multifunction, similarly titanium oxide that is Zno zinc oxide which is also photo catalytically could be used for breaking down of the purification of water, zinc oxide is being extensively used. Yet these are some of the properties what has to be kept in mind they should be environmentally benign, easily degradable and we save acceptable comfortable with the living systems.

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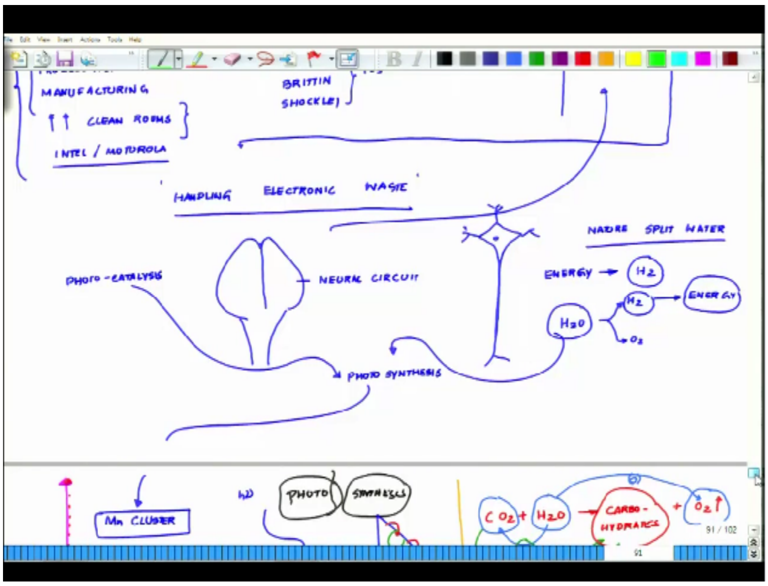

This along with some of the other aspect which I highlighted out here.

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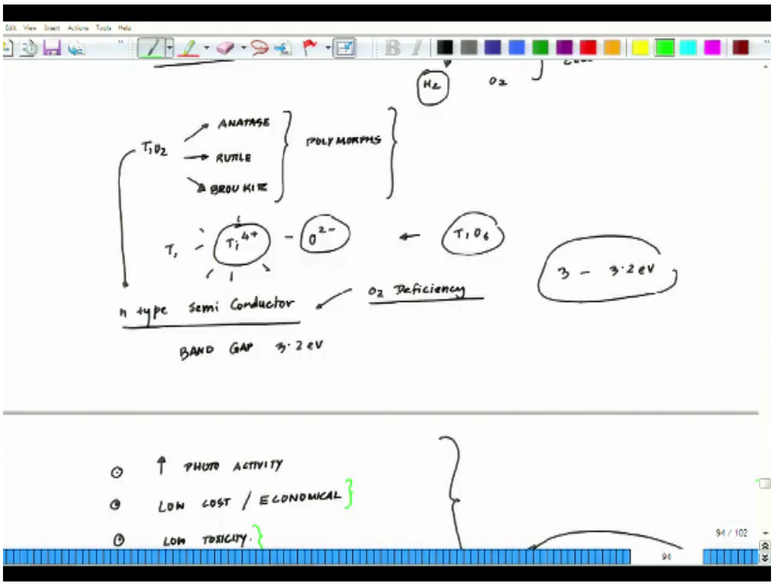

Low cost, low toxicity, good thermal and chemical stability. These properties are to be kept in mind while we talk about synthesizing any of these materials. So future much trust will be on understand the economics of the nanomaterials, their multifunctionality, their sustainability, their green manufacturing technologies, in second thing much of these synthesis the futuristic industries would not be the big industries.

This will be small, small units, so big reactor concept will slowly kind of you know falls down and it will be small reactor concept where you have multiple units just like human body, smaller units to do the reaction, with this I would request you to explore whenever you pick up any nanomaterial try to see or any material matter a fact what all usage it could have other than the one which you working.

Because that will give you a very different perspective of looking at a material, the same thing could be used for multiple things. Say for example chlorophyll, chlorophyll plant is using for as its electron donor by talking sunlight, but then chlorophyll one day maybe you could be used as a semiconductor material which has to you stabilize it in artificial or synthetic settings.

Because it is all in the plant much more you know stabilized and another aspect what I wish to highlight here one of the mentor once taught me is that in nature nothing is permanent, we see leafs they become yellow after a while few months whatever, nature make things nature break things, nature does not learn about anything called permanency. There is nothing is permanent in nature.

If something is permanent in nature then there is a problem you cannot degrade it, you cannot get rid of it, so whenever you make material, whenever you think of materials you should think one of the prime concept of sustainability is that it should not be everlasting, it should breakdown, it should fall apart. So that it degrades and again you create. So nature make sure the earth the universe.

These are all reactors where trillions and zillions of reaction are happening every moment and it is evolving, it is evolving from the world if I look at the prebiotics to till this date nature is evolving, nature used to use it as electron donor as H2S hydrogen sulfide, today in nature has evolved to water as its electron donor. I do not know where the future goes, may be march somewhere we will see there in maybe another electron donor.

Nature is continuously evolving, you just have to try to get the card of nature, how nature is performing its reaction, how nature is making a difference, a huge difference in our life and the movie learn about it, in the movie we will be able to appreciate 2 concept which I highlight one nothing is permanent, nothing ever should be permanent except change, so any material we make if it cannot be destroyed.

If it cannot be got rid of and there are issues with such material and you should have a finite life should get degraded new materials will come and that is where much of the sustainability issues of future will be green synthesis getting materials I have self-life, you can get rid of in, that, again become they become elements and again you recombine them and much of the synthesis should be at low temperature.

Because that is where you cut down in the cost and they should or should be reducible, the electronics if you look at it started with silicon now moving started with sulfides, move to silicon, crystalline silicon as I talked about Bardeen, Brittin and Shocklei and then move to now moving towards carbon and maybe carbon and sulfides again. So we as a race it slowly realizing that multifunctionality, sustainability and non-permanency are the key to our progress, thank you.