

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Biomedical Nanotechnology

Lec - 10

Carbon Nanotubes and its Bio-Applications

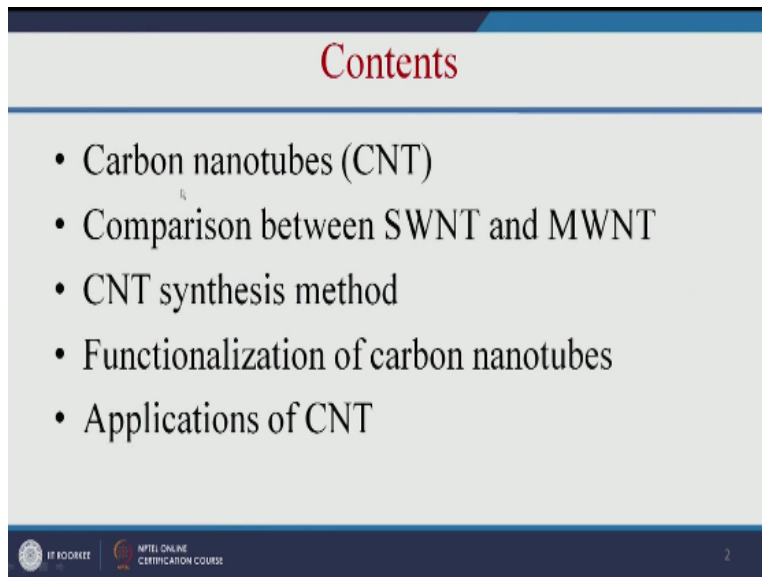
Dr. Arup Kumar Das

Department of Mechanical and Industrial Engineering

Indian Institute of Technology Roorkee

Hello everyone I welcome you all to the 10th lecture of this course. The 10 lecture is on carbon nano tube and needs bio applications, so in lecture we are going to learn what is carbon nano tube.

(Refer Slide Time: 00:31)



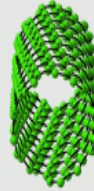
And what is a difference between single wall nano tube and multi wall tube and we are going to learn how to synthesis this carbon nano tubes and also we are going to learn how to functionalize this carbon nano tube the various applications of carbon nano tube and also there are various applications of carbon nano tube.

(Refer Slide Time: 00:47)

Carbon nanotubes (CNT)

- CNT can be described as a sheet of graphene rolled into a cylinder
- Constructed from hexagonal rings of carbon
- Can have one layer or multiple layers
- *Can have caps at the ends making them look like pills*

Graphene sheet



<http://www.photon.t.u-tokyo.ac.jp/~maruyama/agallery/agallery.html>



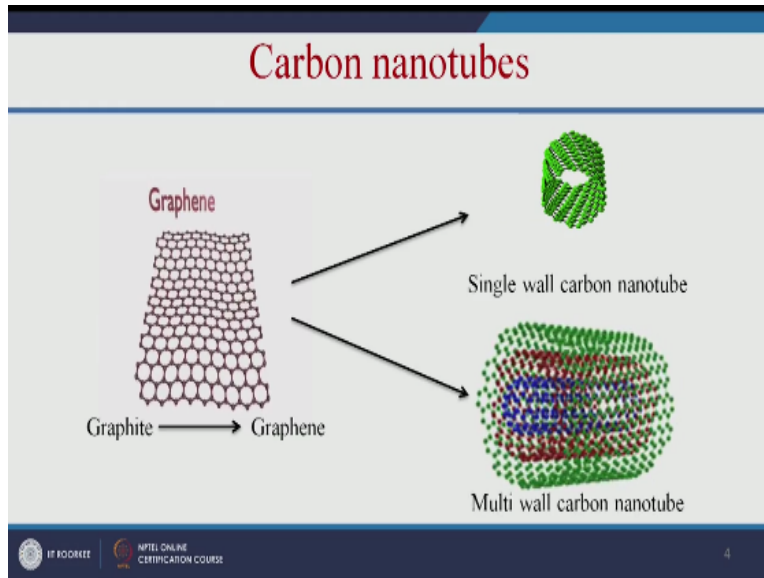
INTEL ONLINE
CERTIFICATION COURSE

3

So let us see what is carbon nano tube the carbon nano tube can be described as a sheet of graphene rolled into a cylinder so here you can see this animation this is a graphene sheet it is rolled into cylindrical shape this is called as carbon nano tube and this graphing it is mainly made up of hexagonal rings of carbon and this carbon nano tubes can have 1 layer or multiple layer of graphene sheet if it is having 1 layer that is single wall carbon nano tube if it is having multiple layer that is called as multi wall carbon nano tubes.

And this carbon nano tube can have caps at the ends okay so we can have caps at the ends of this tube so that we can load any therapeutic molecule are we can load any anti cancer drugs inside the carbon nano tubes and we can use it for various therapeutic application.

(Refer Slide Time: 01:40)



So from where we get this graphene so we get the graphene from the graphite okay so the single layer of graphene if it is rolled into tubular form that is called as single wall carbon nano tube and if you are using multi layers of graphene that is called as multi wall carbon nano tubes.

(Refer Slide Time: 02:00)

Structure and morphology

- The bonding in carbon nanotubes is sp^2 with each atom joined to three neighbours, as in graphite.
- The tubes can therefore be considered as rolled-up graphene sheets (graphene is an individual graphite layer)
- This bonding structure, which is stronger than the sp^3 bonds found in diamond, provides the molecules with their unique strength.
- Under high pressure, nanotubes can merge together, giving the possibility of producing strong, unlimited length wires through high-pressure nanotube linking.

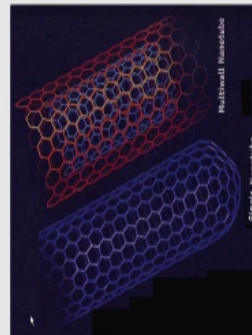
Let us see the structure and morphology of carbon nano tubes so the bonding in the carbon nano tubes is sp^2 with each atom joined to 3 neighbors as in graphite okay, so that tubes can therefore be considered as rolled up graphene sheets and this bonding structure which is stronger than the sp^3 bonds found in diamond and also under high pressure this nano tubes can join together and form a nano wires.

(Refer Slide Time: 02:30)

Classification of carbon nanotubes

Carbon nanotubes are classified in following two types,

- SWNTs- Single walled carbon nanotubes
- MWNTs- Multiple walled carbon nanotubes



So let us see the different between the single wall carbon nano tubes and multi wall carbon nano tubes.

(Refer Slide Time: 02:38)

Comparison between SWNT and MWNT

Table 1- Comparison between SWNT and MWNT

Sr. No.	SWNT	MWNT
1.	Single layer of graphene.	Multiple layer of graphene
2.	Catalyst is required for synthesis.	Can be produced without catalyst.
3.	Bulk synthesis is difficult as it requires proper control over growth and atmospheric condition.	Bulk synthesis is easy.
4.	Purity is poor.	Purity is high.
5.	A chance of defect is more during functionalization.	A chance of defect is less but once occurred it's difficult to improve.
6.	Less accumulation in body.	More accumulation in body.
7.	Characterization and evaluation is easy.	It has very complex structure.
8.	It can be easily twisted and are more pliable.	It can not be easily twisted.



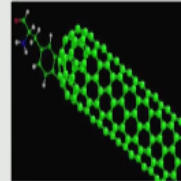
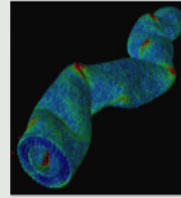
As I told you earlier single wall is single layer of graphing and multi wall is multiple layer of graphing and for synthesis it need catalyst and here we can but it without the catalyst also and here the bulk syntheses is difficult but here bulk syntheses is easy and the purity is poor here and purity is high so the main important point is less accumulation of the body single wall nano tubes it will accumulation less in the body and multi wall nano tubes it accumulate more in the body.

So depends on your application you have to select weather you need single wall nano wall tube or multi wall nano tubes because in some cases we need less circulation and in some cases we need more accumulation.

(Refer Slide Time: 03:22)

CNT properties

- The strongest and most flexible molecular material because of C-C covalent bonding and hexagonal network architecture
- Strength to weight ratio ~500 times greater than Al, steel, titanium
- Maximum strain ~10%; much higher than any material
- Very high current carrying capacity
- Other chemical groups can be attached to the tip or sidewall (called 'functionalization')



And let us see some of the properties of carbon nano tubes so this is a strongest and most flexible material because of CC covalent bonding okay and it is 500 times greater than the AL, steel and the maximum strain it can with stand is more than 10% which is higher than any material and it is having very high current carrying capacity and also we can adds any kind of functional group that is called as functionalization adding of functional group is called as functionalization.

(Refer Slide Time: 03:49)

CNT properties

- “CNT is 100 times stronger than stainless steel but six times lighter...”
- “CNT is as hard as diamond and its thermal capacity is twice that of pure diamond...”
- “CNT’s current-carrying capacity is 1000 times higher than that of copper...”
- “CNT is thermally stable up to 4000 K...”
- “CNT can be metallic or semiconducting, depending on their diameter and atomic arrangement...”



And it is 100 times stronger than stainless steel but it is six times lighter than the stainless steel and it is hard than the diamond okay and it is having high current carrying capacity and high thermal stability and depends on the arrangement of the atoms it can be metallic or semiconducting.

(Refer Slide Time: 04:08)

Carbon nanotube synthesis methods

1. Arc discharge method
2. Chemical vapour deposition (CVD)
3. Laser ablation



So let us see how to synthesis this carbon nano tube so these are 3 approaches available to make the carbon nano tubes that is arc discharge chemical vapour disposition and third one is laser ablation.

(Refer Slide Time: 04:21)

Method	Arc discharge method	Chemical vapour deposition	Laser ablation (vaporization)
Who	Ebbesen and Ajayan, NEC, Japan 1992 ¹³	Endo, Shinshu University, Nagano, Japan ¹³	Smalley, Rice, 1995 ¹⁴
How	Connect two graphite rods to a power supply, place them a few millimetres apart, and throw the switch. At 100 amps, carbon vaporises and forms a hot plasma.	Place substrate in oven, heat to 600 °C, and slowly add a carbon-bearing gas such as methane. As gas decomposes it frees up carbon atoms, which recombine in the form of NTs	Blast graphite with intense laser pulses; use the laser pulses rather than electricity to generate carbon gas from which the NTs form; try various conditions until hit on one that produces prodigious amounts of SWNTs
Typical yield	30 to 90%	20 to 100 %	Up to 70%
SWNT	Short tubes with diameters of 0.6 - 1.4 nm	Long tubes with diameters ranging from 0.6-4 nm	Long bundles of tubes (5-20 microns), with individual diameter from 1-2 nm.
MWNT	Short tubes with inner diameter of 1-3 nm and outer diameter of approximately 10 nm	Long tubes with diameter ranging from 10-240 nm	Not very much interest in this technique, as it is too expensive, but MWNT synthesis is possible.
Pro	Can easily produce SWNT, MWNTs. SWNTs have few structural defects; MWNTs without catalyst, not too expensive, open air synthesis possible	Easiest to scale up to industrial production; long length, simple process, SWNT diameter controllable, quite pure	Primarily SWNTs, with good diameter control and few defects. The reaction product is quite pure.
Con	Tubes tend to be short with random sizes and directions; often needs a lot of purification	NTs are usually MWNTs and often riddled with defects	Costly technique, because it requires expensive lasers and high power requirement, but is improving

So let us see how we can use this 3 methods and make the carbon nano tube first one is arc discharge method and here you will connect two graphite rods to a power supply and place them a few millimeters apart okay so that will make the carbon nano tubes here the yield will be like 30 to 90% and you will get short tubes with diameter of 1.4 nano meter and the advantages are like it can easily produce single wall nano tubes and single wall nano tubes have few structural defects.

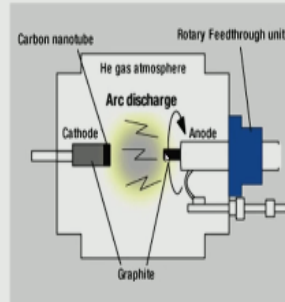
So that is good for functionalization and here we can make multi wall nano tubes without any catalysis okay and it is not an expensive method so the next method is chemical vapour deposition so place a substrate oven and heat to 600⁰ C and slowly add carbon bearing gas such as methane as gas decomposes it produces carbon nano tubes okay and here the yield will be like 20 to 100%

So here we can get the long tubes with the diameter of 10 to 240 nano meter and it is the easiest to scale up the industrial production and here the purity will be high and the next method is laser ablation so here we will be applying the laser light on the graphite and it will produce carbon nano tubes here the yield will be like 70% and the advantages are like primarily it is used for single wall nano tubes and it is a pure material so the reaction product is pure so we can use it for biological application but the problem is this is a little bit costly technique.

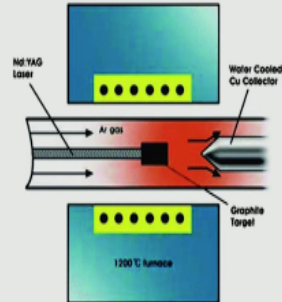
(Refer Slide Time: 05:55)

Nanotube growth method

ARC Discharge



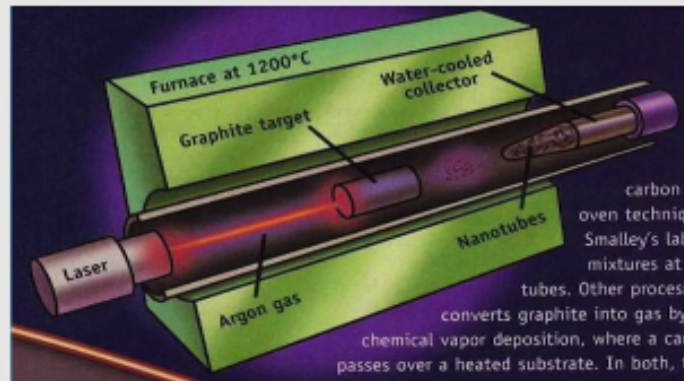
Laser Ablation



So when this arc discharge they will be having this graphite and cathode and anode will be connected and power will be applied and the all the carbon hands will be deposited in this, okay.

(Refer Slide Time: 06:06)

Manufacturing



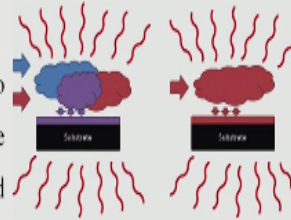
Schematic drawings of a laser ablation apparatus

And in this laser ablation so we will be applying the laser light to the graphite target, okay. And this is kept in the furnace, the furnace is at 1200⁰ Celsius and in presence of argon gas so this laser light will vaporize to the graphite target and it will produce the carbon nano tubes so that will be collected in a water cooled collector.

(Refer Slide Time: 06:28)

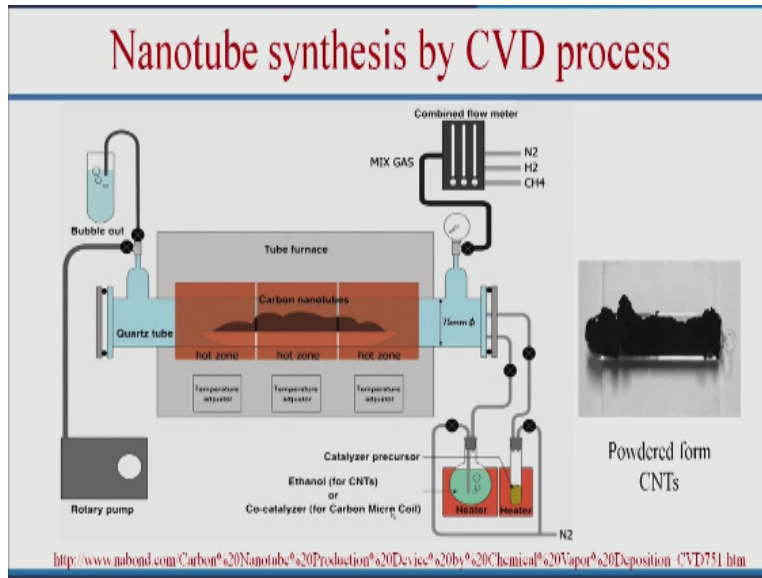
Chemical Vapor Deposition (CVD)

1. Gas enters chamber at room temperature (cooler than the reaction temperature)
2. Gas is heated as it approaches the substrate
3. Gases then react with the substrate or undergo chemical reaction in the "Reaction Zone" before reacting with the substrate forming the deposited material
4. Gaseous products are then removed from the reaction chamber



So next one is CVD that is chemical vapor deposition so here the gas enters the chamber at room temperature that means it is cooler than the reaction temperature and gas is heated as it approaches this substrate and gas then react with the substrate or undergo chemical reaction in the reaction zone, before reacting with the substrate forming the deposited material, here the gas is products are then removed from the reaction chamber, okay.

(Refer Slide Time: 06:53)



So this is a nano tube synthesis by CVD process set up okay. So you will get this kind of powdered form of CNT.

(Refer Slide Time: 07:00)

CVD apparatus



il.com/Carbon%20Nanotube%20Production%20Device%20by%20Chemical%20Vapor%20Dep

And this is the bend stop CVD apparatus.

(Refer Slide Time: 07:04)

Nanotube synthesis by CVD process

- Source of carbon atoms usually comes from an organic compound
- Mixed with a metal catalyst and inert gas
- Atomized and sprayed into reactor with temperatures ranging from 600°C to 1200°C
- Pyrolysis of organic compound deposits carbon (as soot) and carbon nanotubes on reactor wall (usually a tube constructed from quartz)

So here the source of carbon atoms usually comes from an organic compound, okay. So mix with a metal catalyst and inert gas and here it will be atomized and sprayed into reactor with temperatures ranging from 600 → 1200°C. Here the pyrolysis of organic compound deposits carbon and carbon nano tubes on the reactor wall.

(Refer Slide Time: 07:26)

Sources of carbon

- Typical Organic/Catalyst Mixtures
 - Xylene/ferrocene
 - Toluene, benzene, xylene, mesitylene, and n-hexane/ferrocene
 - Ethylene and ethanol/Fe, Co, and Mo alloys (K. Mizuno et al.)
- Typical Carrier Gases
 - Argon
 - Hydrogen

So these are the typical carbon sources Xylene or ferrocene and these are the typical carrier gases like argon and hydrogen can be used for making this CNT using CVD method.

(Refer Slide Time: 07:37)

Limitations of CNTs

- Difficulty of mass production for industrial purposes.
- Secondly is the solubility of CNTs in the water
- The production of structurally and chemically reproducible batches of CNTs with identical characteristics.
- Difficulty in maintaining high quality and minimal impurities.



So the limitation of CNT, the first thing is difficulty for the mass production and second thing is the solubility of CNT in the water okay and also it is very difficult to produce the CNT uniform CNT batch wise, okay. And the fourth one is like difficulty in maintaining high quality and minimal impurities.

(Refer Slide Time: 07:56)

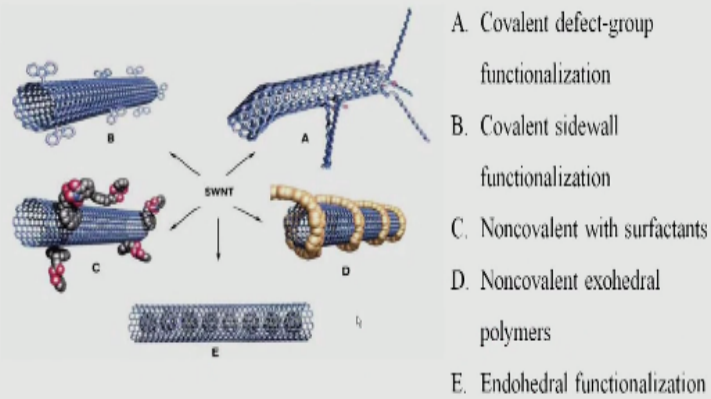
Why functionalisation of CNTs?

- For biological and **biomedical applications**, the lack of solubility of carbon nanotubes in aqueous media has been a major technical barrier.
- To overcome this problem the modification of the surface of CNT i.e. functionalisation is done
- With different molecules it is achieved by adsorption, electrostatic interaction or covalent bonding of different molecules and chemistries that render them more hydrophilic.
- Through such modifications, the **water solubility** of CNT is improved and their biocompatibility profile is completely transformed.
- Moreover, the **aggregation** of individual tubes **through vander Waals** forces are also **reduced** by the functionalisation of their surface.

So to overcome those difficulties we have to functionalize this CNT, okay. For biological application biomedical applications so the lack of solubility of carbon atoms in of course media has been imagined technical barrier because this carbon atoms aggregate through Vander Wall forces, so we can overcome this aggregation by doing functionalisation and also it will increase the water solubility of CNT and it will also improve the bio comparability of your CNT.

(Refer Slide Time: 08:27)

Functionalization of carbon nanotubes



So how to functionalize the carbon nano tubes so these are the various approaches for making the carbon atoms functionless carbon atoms, the first one is covalent defect group and next one is covalent side wall, third one is non covalent with surfactants and fourth one is non covalent exohedral polymers and this one is endohedral functionalisation, so let us see one by one.

(Refer Slide Time: 08:52)

Chemical functionalization methods

- Endohedral Functionalization

Modification of CNT by putting nanoparticles *inside* the tube.

- Change the hydrophobic structure to hydrophilic and make them as solvents.
- Filling nanotubes with nanoparticles to add the characteristics of the Nanoparticles inside the Carbon Nanotubes to fantastic phenomenal of CNT.
- Putting CNT inside the suspension containing nanoparticles so that it can penetrate the tube internal site and stay inside the CNT
- Depends on surface energy (surface tension) of the liquid.
- Experiments show that if surface tension of the liquid is more than 200 mN/m, liquid can fill the nanotubes

So let us see endohedral functionalisation, so here modification CNT by putting nano particles inside the tube, okay. So we have to incubate the CNT inside this suspension of solution which containing nano particles so that it can penetrate the tube internal side and stay inside the tube, okay. And here the endohedral functionalisation depends on this surface tension of the liquid and if the surface tension off the liquid is more than 200 the liquid can fill the nano tubes.

(Refer Slide Time: 09:19)

Exohedral functionalization

Exohedral Functionalization is modification of external part of CNTs like side walls .

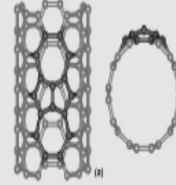
This method itself is subcategorized into three main methods :

1. Covalent Exohedral functionalization-Defects

- defect in CNT = best place for functionalization.

2. Covalent Exohedral functionalization -Functional groups

- Side wall functionalization & to attach more functionalized group.



And again this exohedral functionalisation is sub categories into three main methods the first one is covalent exohedral functionalisation that means when you make the carbon atoms there will be some defects, so this defect in this CNT's is the best place for functionalisation, next one is covalent exohedral functionalisation so here we can add the functional group to the side walls of the carbon nano tubes.

(Refer Slide Time: 09:45)

Exohedral functionalization

3. Noncovalent exohedral functionalization-

Polymer wrapping

- wrapping CNT in polymer, surfactants and peptides (smaller amino acids in length).
- By wrapping the polymer around the CNT there is a phenomena called Pi stacking.
- Pi stacking is when the P orbitals of CNT and functionalized group interact with each other and cause less stability.

In this type of functionalization **electrical and optical properties of CNTs are not damaged** and perturbed but because of poor interaction of p orbitals, **stability is quite low** .

As experiments show there is an improved electrical property of the polymer

And third one is non covalent exohedral functionalization here you will be adding the polymer or surfactants so which will be wrapping this CNT okay, so by wrapping the polymer around this CNT there is a phenomena called Pi stacking, so what is Pi stacking? It is when the P orbital's of CNT and functionalized group interact with each other and cause less stability, okay. So in this type of functionalization the electrical and the optical properties of CNT's are not damaged. But the stability is quite low, okay.

(Refer Slide Time: 10:20)

Chemical functionalisations

There are also several chemical functionalizations :

- **Amidation – Formation of Carbon Nanotube-Acyl Amides**
- **Fluorination of Nanotubes**
- Chlorination of Carbon Nanotubes
- Bromination of MWCNTs
- Hydrogenation of Carbon Nanotubes.
- Addition of Radicals
- Addition of Nucleophilic Carbenes
- Sidewall Functionalization through Electrophilic Addition etc...

And these are the saw the other types of chemical functionalization but in this we are going to discuss only Amidation and Fluorination.

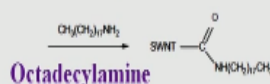
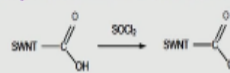
(Refer Slide Time: 10:28)

Amidation of CNTs

- Amide is an organic compound as a functional group that has (**R-C=O**) attached to a nitrogen atom
- This kind of functionalization can only be done of the CNTs which are already are **carboxyl-functionalized (-COOH)**.
- Treat it with Thionyl chloride (SOCl_2) to substitute the (-OH) with chlorine and then add octadecylamine as shown in figure



Thionyl chloride to substitute the (-OH)



So amidation means addition of amide group but we cannot add the amide group directly the first we have to functionalize the carbon atoms with COOH and followed by that we can add the amide group.

(Refer Slide Time: 10:38)

Fluorination of MWNT

- This process can be done on already functionalized CNTs by carboxyl group then they can be functionalized by fluorine, further functionalization meaning that we can remove the fluorine and attach other functional groups.
- This process can be continued by removing fluorine and replacing it with other functional group.
- By this process there will be no damage imposed to CNT sidewalls and temperature is low about 150 °C to 500 °C. In this case, maximum fluorination can be achieved using iodine **pentafluoride** IF_5 , which leads to composition of C-F bonds.

Similarly we can also add the fluorine group using Pentafluoride IF_5 okay.

(Refer Slide Time: 10:44)

Fluorination of MWNT



- Experiments show electrical resistance of fluorinated SWCNTs has dramatically increased.
- Further functionalization, substituting fluorine can be done in the group of f-CNT.

4

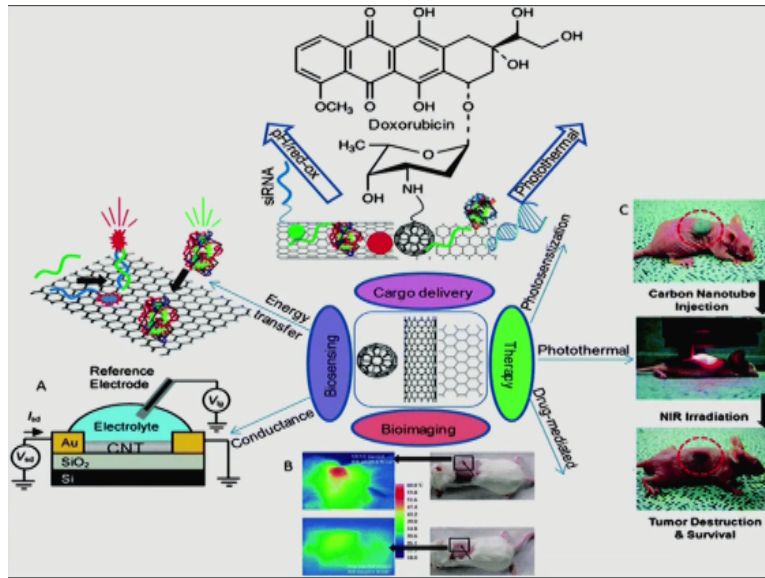
So this will also add the fluorine group so when you add the fluorine group so it is increasing the electrical resistance and also we can substitute the fluorine with some other chemical group and use it for various applications.

(Refer Slide Time: 10:58)

Bio-applications of CNT

So let us see the various applications of carbon nano tube.

(Refer Slide Time: 11:02)



So this carbon nano tubes can be useful for bio imaging and also it could be useful for drug derive application and we can also use it for bio sensing and for therapeutic or therapist application so let us see one by one.

(Refer Slide Time: 11:20)

Biological applications: Bio-sensing

Many spherical nano-particles have been fabricated for biological applications.

Nanotubes offer some advantages relative to nanoparticles by the following aspects:

1. Larger inner volumes – can be filled with chemical or biological species.
2. Open mouths of nanotubes make the inner surface accessible.
3. Distinct inner and outer surface can be modified separately.

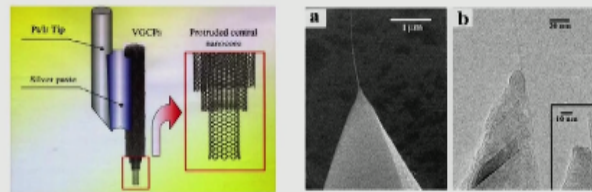
For biological applications so here the nano tube offer some advantages related to nano particles by the following aspects, the first thing is larger inner volumes so the larger inner volumes can be filled with chemical or biological species so it can be loaded with any kind of drug or any kind of imaging agent, so next one is the open mouths of nano tubes so make the inner surface accessible. And third one is distinct inner and outer surface so which can be modified separately.

(Refer Slide Time: 11:48)

Biological applications: AFM tips

Carbon nanotubes as AFM probe tips:

- Small diameter – maximum resolution
- Excellent chemical and mechanical robustness
- High aspect ratio



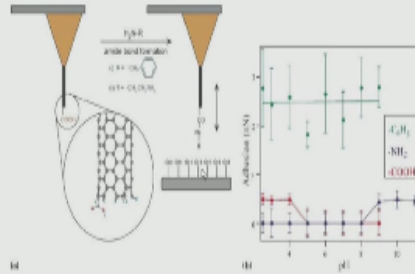
So let us see how we can use carbon nano tubes as a AFM probe tips so it is having small diameter and maximum resolution so it is a excellent chemical and mechanical robustness makes it suitable for AFM probe tips.

(Refer Slide Time: 12:01)

Biological applications: Functional AFM tips

Molecular-recognition AFM probe tips:

- Certain biomolecule is attached to the CNT tip
- This tip is used to study the chemical forces between molecules – Chemical force microscopy

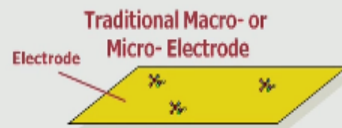


So let us see how to make functional AFM tips certain bio molecules can be attached to the CNT tip okay, so this tip is use to study the chemical forces between the molecules, so it is also called as chemical force microscopy⁶. So here you can see here that tip is having this some COH functional group suppose your sample is having NH₂ so it can react and we can measure the force, so this is called as chemical force microscopy.

(Refer Slide Time: 12:28)

Microelectrode for sensors

- Nanoscale electrodes create a dramatic improvement in signal detection over traditional electrodes.

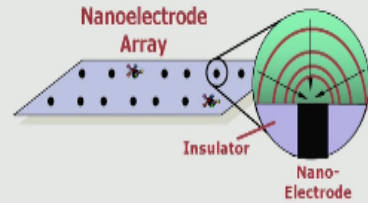


- **Scale difference** between macro- /micro- electrodes and molecules is tremendous
- **Background noise** on electrode surface is therefore significant
- **Significant amount** of target molecules required

Let us say the comparison between the microelectrode and nano electrode for sensor application, in micro electrode the scale difference is very high because the molecules is in the range of nano scale and your electrode is in the range of micro scale, so the background noise will be very high and here we need more amount of target molecules for sensing the target molecule.

(Refer Slide Time: 12:52)

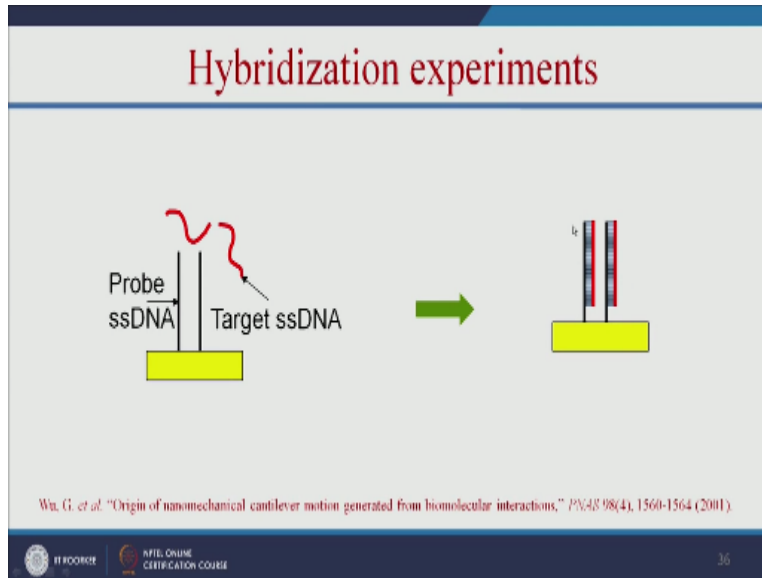
Nanoelectrode for sensors



- CNT tips are at the scale close to molecules
- Dramatically reduced background noise
- Multiple electrodes results in magnified signal for statistical reliability.
- Can be combined with other electro catalytic mechanism for magnified signals.

So but when we use CNT tips for making a nano electrode for sensing application it will reduce the background noise because the nano tubes is very, very small scale and it can match externally with your target molecule because that is also the range of nano scale okay, so based on that here the nano tips will be having high sensitivity.

(Refer Slide Time: 13:14)



So let us see how we can use it hybridization experiments to make the CNT sensors, so here we will adding single sensor DNS to your cover and will take the target single sensor DNA, from your patients serum and when you put into this sensor this will combine in form this kind of bond that is your hybridization okay. So if the patients DNA is forming a bond with the probe DNA that means that person is having the particular disease.

(Refer Slide Time: 13:46)

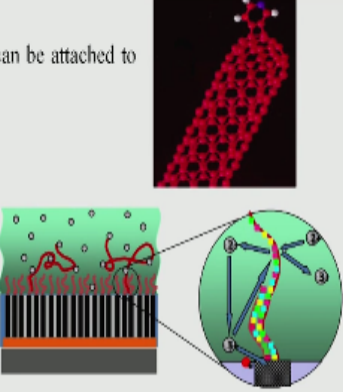


So you will be having a probe single standard DNA and another one is target DNA, for example so this DNA where taking from some patients serum so when it come and form a bond with this probe DNA by hybridization okay, so the electrical connectivity property of this CNT will be changed, so based on that we can detect the disease.

(Refer Slide Time: 14:30)

CNT based biosensors

- Probe molecules for a given target can be attached to CNT tips for biosensor development
- High specificity
- Direct, fast response
- High sensitivity
- Single molecule and cell signal capture and detection



The diagram illustrates the structure and function of a CNT-based biosensor. The top portion shows a single carbon nanotube (CNT) with red probe molecules attached to its tips. The bottom portion shows a dense array of CNTs on a substrate, with red probe molecules attached to their tips. A circular inset provides a magnified view of the probe molecules and their interaction with the CNT tips.

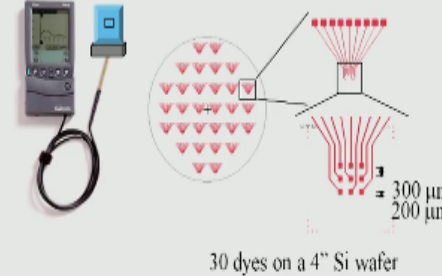
So as I told you earlier so this probe molecule for a given target can be attached to the CNT tips or making bio sensor just it has high specificity and it is very fast and direct response and it has high sensitivity even a single molecule can be also detected.

(Refer Slide Time: 14:46)

Fabrication of genechip

Potential applications:

- (1) Lab-on-a-chip applications
- (2) Early cancer detection
- (3) Infectious disease detection
- (4) Environmental monitoring
- (5) Pathogen detection



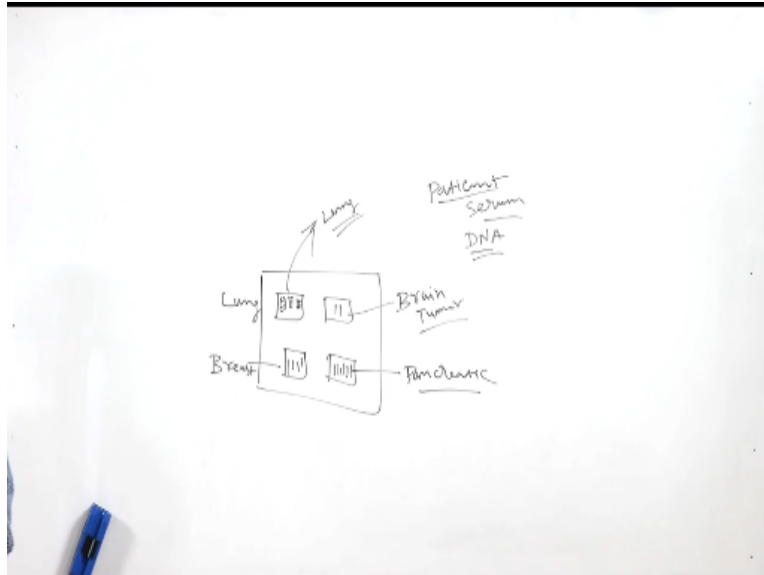
30 dyes on a 4" Si wafer

300 μm
200 μm

IT FOOTAGE NPTEL ONLINE CERTIFICATION COURSE 38

And based on that we can make a genechip or lab on a chip, so the lab on a chip is also the same principle for example.

(Refer Slide Time: 14:56)



If a person is having some kind of cancer so you can make all the DNA probes for example the first box is for a lung cancer and this is for breast cancer so this is for pancreatic cancer okay and this can be for your brain tumor so we can have all the single standard DNA probe in the micro wave chips okay, and when you take the patient serum so we can take the DNA from the patient serum and you can carry to this and minute forms hybridization with the only lung cancer probe that means the person is affected by lung cancer okay.

So instead of going through all the reactions we can have all the things in a simple lab on a chip concept, so all the DNA will be here, so based on that we can easily identify what kind of cancer that particular patient is having and we can also increase the sensitivity and we can save lot of time okay so which will be useful for a Ellice cancer detection and also for various infection disease detection.

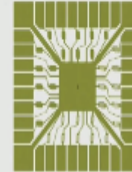
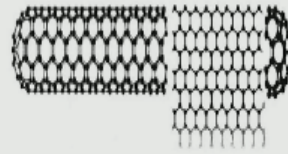
(Refer Slide Time: 16:29)

Single-walled carbon nanotubes for chemical sensors

- Every atom in a single-walled nanotube is on the surface and exposed to environment.
- Charge transfer or small changes in the charge-environment of a nanotube can cause drastic changes to its electrical properties
- Monitoring the change in conductivity forms the basis for sensing

Applications

- Industrial Toxic Chemicals, Safety
- Leak Detection

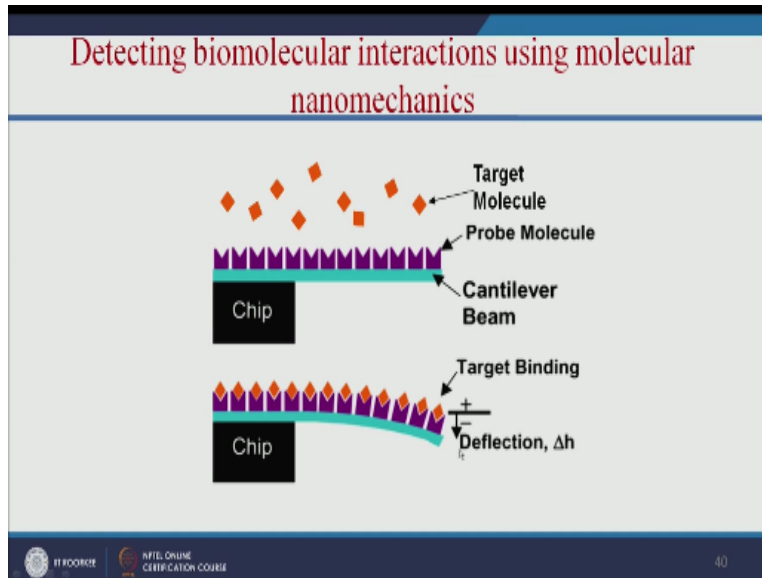


32-channel sensor chip



So let us see how we can use single wall carbon nanotubes for chemical sensor here every atom in a single wall nanotube is on the surface and exposed to environment okay, so charge transfer or small changes in the charge environment of a nanotube it can cause drastic changes to these electrical properties, so based on that we can make a chemical sensor which will be useful for lead direction and other application.

(Refer Slide Time: 16:53)

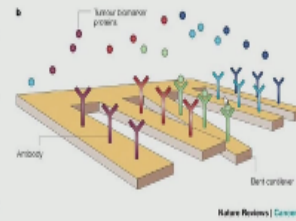


So let us see how we can use that cover nanotube base sensor for detecting the various diseases so we can have this kind of chip and it is a cantilever beam if the patient serum have more amount of particular antigen and if it is comes and bind depress the number of antigen there will be deflection, so we can measure the deflection and we can easily identify the disease.

(Refer Slide Time: 17:18)

Nanocantilever array

- The biomarker proteins are affinity-bound to the cantilevers and cause them to deflect.
- The deflections can be directly observed with lasers.
- Alternatively, the shift in resonant frequencies caused by the binding can be electronically detected.
- As for nanowire sensors, the breakthrough potential in nanocantilever technology is the ability to sense a large number of different proteins at the same time, in real time.



NATURE REVIEWS | CANCER

VOLUME 5 | MARCH 2015 | 441



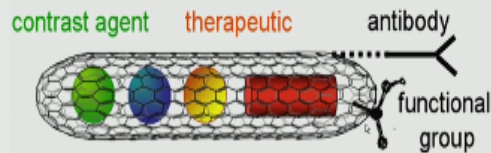
IITB ONLINE
CERTIFICATION COURSE

So with the patient serum having more amount of antigen there will be more amount of deflection so based on that we can make a nano cantilever based array for bio sensing application.

(Refer Slide Time: 17:29)

CNTs for targeted drug delivery

Anti-cancer drugs may be delivered more efficaciously and with fewer systemic side-effects using a "smart" nanotechnology platform than by conventional methods. Small-diameter semiconducting SWNTs represent one such promising platform, due to their strong absorbance in the so-called therapeutic infrared window (between 700-1100 nm, depending on body tissue type).



<http://www.nanomagn.com/cn/drug-delivery-detection>



NITF

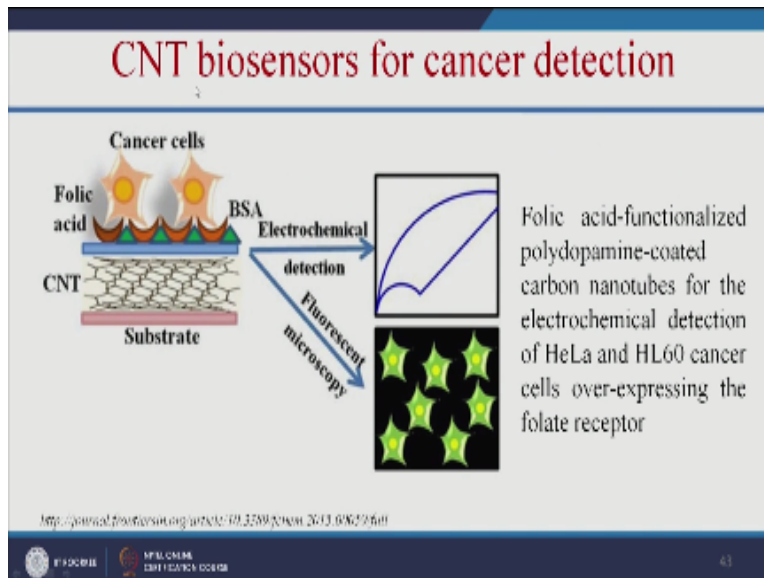


NITF ONLINE
CERTIFICATION COURSE

42

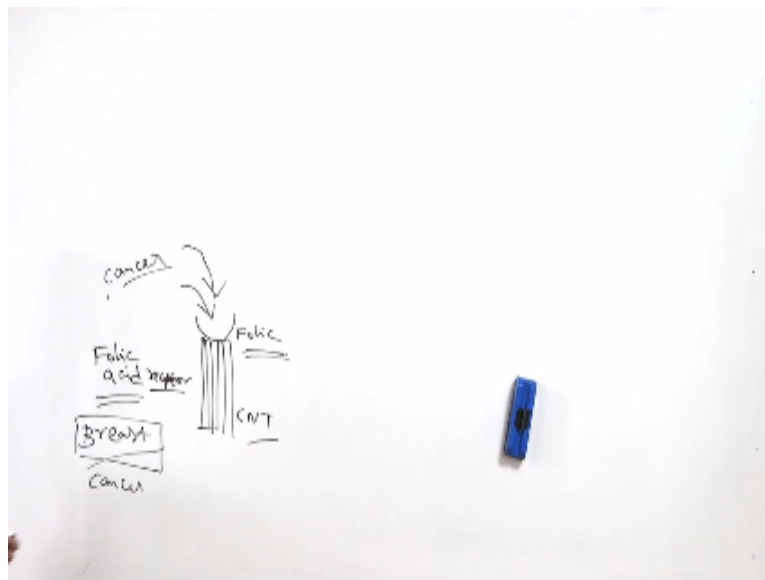
And we can also use cover nanotube for targeted drug delivery so here you can see here this carbon nanotube is loaded with contrast region, so this contrast region is for imaging application and therapeutic is for your it can be any antic drug for therapeutic application and antibodies for targeting your carbon anti body only to the cancers and we can also add functional group which will give the bio comparably to your carbon nanotubes and it will increase the circulation time so this is called as multi function nano particle or also called as theranostic nano particle because it is having both contrast stage and as well as the therapeutic agent.

(Refer Slide Time: 18:09)



So let us see how to make CNT biosensors for cancer direction.

(Refer Slide Time: 18:12)

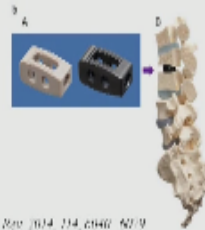
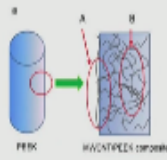


So some of cells will express receptor for folic acid, the some of the cancer cells like breast cancer it will express folic acid receptor so when you make the carbon atoms with the folic acid so this cells can come and bind to the folic acid, so it is not the single carbon atoms it will be a array of carbon nano tubes okay, so it is having folic acid and your cancer cell is having receptor for folic acid so your cancer cells can easily come and bind to the folic acid.

So based on that we can make a sensor for cancer detection so here you can see here this carbon atoms are coated with the folic acid so these are folic acid functionalized polydopamine coated carbon nano tubes and which could be useful for electrochemical detection of breast cancer cells or Hela cells okay, which we are expressing the floate receptor and we can also study the same sample under the fluorescent microscope and we can confirm it.

(Refer Slide Time: 19:41)

CNTs for biomaterials



For application to spine interbody fusion material, a polyetheretherketone (PEEK) composite with MWCNTs possessing excellent mechanical characteristics and bone compatibility has been developed.

©New Day 2014 214-2140-6219



FACULTY OF ENGINEERING



RESEARCH CENTER FOR NANOTECHNOLOGY



FACULTY OF ENGINEERING



RESEARCH CENTER FOR NANOTECHNOLOGY

So next one is we can also use the carbon atoms for biomaterial applications, so for application to spine interbody fusion material a material call PEEK that is polytheretherketone so along with multi wall carbon atoms it is possessing excellent mechanical property as well as bone compatibility so which is useful for making a various bio compatibility materials for bone designing also.

(Refer Slide Time: 20:06)

Nanopore ion conductance

Helps researchers detect errors in the genetic material that may lead to cancer.

- Funnel DNA through, one strand at a time, resulting in more efficient DNA sequencing.
- Monitor shape and electrical properties of each base as they pass through the nanopore
- Properties, which are unique to the bases, allow the nanopore to help decipher information encoded in the DNA.

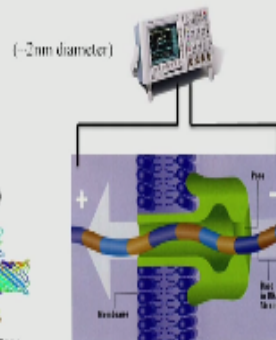
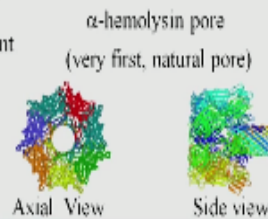
So let us see how we can use this nano pore ion conductance for DNA sequencing, so it will help the researchers to detect the errors in the genetic material that my lead to cancer.

(Refer Slide Time: 20:16)

DNA sequencing with nanopores: The concept

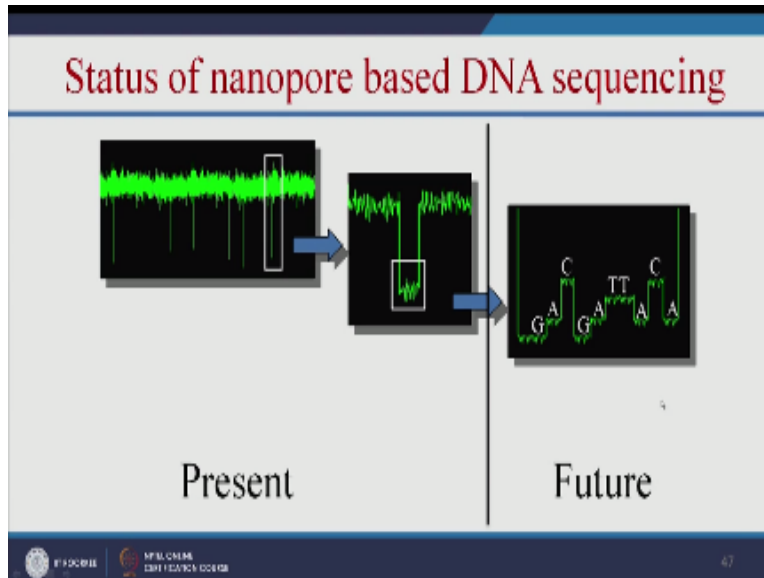
Goal: Very rapid gene sequencing

- Nanopore in membrane
- DNA in buffer
- Voltage clamp
- Measure current



So here you will be passing the DNA through these small pores and it will be like your DNA sequencing only and we can use the protein called α -hemolysin but the drawback is like it is a toxic protein.

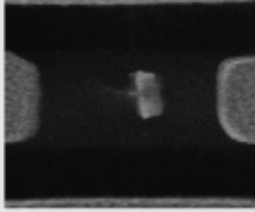
(Refer Slide Time: 20:32)



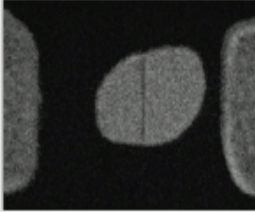
So we can use the carbon atoms for such kind of application so here you can use the carbon atoms for the same application so when you pass the single standard DNA through the carbon atom there will be a decay in the current, this is the present scenario but in future researchers are trying to develop very specific sensor when the G pass through this carbon atoms it will have a different kind of current decay, and A and C. So we can easily sequence the DNA and it can be a like low cost DNA sequencing device.

(Refer Slide Time: 21:02)

Real "Nanomotors"





"machine-like" nanoscale behaviour



A tiny blade of gold attached to a carbon "nanotube", and an electrical current allows it to spin.

Nature 2003 421, 683

 EPSCOR MPLC/IME
MPL Research Center48

And we can also make carbon nano tube based nano motors you can see here it is like a nano scale motor and this is made up of like gold attached to carbon atom and due to electrical current it is spinning in this direction.

(Refer Slide Time: 21:21)

Cellular internalization of carbon nanotubes via “nanoneedle” mechanism vs endocytotic pathway

(A) Functionalized CNT rapidly penetrates the cell membrane directly to the nucleus, where it releases the cargo (red circles).

(B) Functionalized CNT is internalized in the cell by endocytosis and delivered to the endosome, which matures to a lysosome. The accumulation into the lysosome causes swelling and rupture of the vesicle followed by the release of the functionalized CNT into the cytoplasm. The cargo is then able to diffuse through the cytoplasm.

<http://www.nature.com/nature/nanotechnology/2011/04/29/110110a>

EPICURE | MFLCIMS | DDT HEALTH CARES

So let us see how this carbon atoms can be taken up by the cell, the one is nano needle mechanism the other is endocytotic pathway, so in this nano needle mechanism it will directly inject the cells and it will release the drug and the other one endocytotic pathway so here the CNT will be attached to the cell and endocytotics will happen and your CNT will be in endosome and this endosome will combine with the lysosome and it form the lysosome and it will degrade and it will release the drug molecules into the cytoplasm.

(Refer Slide Time: 21:56)

Pencil and paper to create strain and chemical sensors

- Students from Northwestern University managed to use pencils and regular paper to create functional sensor devices.
- They created two types of sensors - strain sensors and chemical vapor sensors.
- The students had a discussion about the [conductive properties of graphene](#). They realized that [when you draw a line on a piece of paper with a pencil, the pencil's graphite sheds numerous graphene sheets](#).

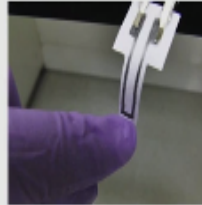
So let us see how to create a simple strain and chemical sensor using pencil and paper, so students from Northwestern University, so they used pencil and paper to create functional sensor devices. So the graphicness very good conductive property so when you draw a line on a piece of paper with the pencil, the pencil shades numerous grapheme sheets, okay.

(Refer Slide Time: 22:23)

Pencil and paper to create strain and chemical sensors

- They started exploring what these graphene sheets can be used for, and the first thing they tried is making a basic electrode.
- The students found out that if you curl the paper in one direction, it increases the conductivity (because the graphene particles are compressed) while curling in the other direction decreased the conductivity. So this is in fact a simple strain sensor.

Pencil and paper strain sensor

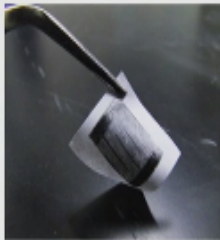


So based on that we can make a strain or chemical sensor, so if we make this kind of line on the paper and if you curl the paper in one direction it increases the conductivity, because the graphene particles are compressed, okay. So while curling in the other direction it decrease the conductivity, so this is a simple strain sensor.

(Refer Slide Time: 22:46)

Pencil-drawn chemiresistor

- In a second experiment, they used bendable toy pencils in which the graphite is mixed with a polymer binder (instead of the normally used clay).
- When they created an electrode with this pencil, they found out that the conductivity was affected by the presence of volatile chemical vapors (because the polymer binder absorbs the vapors and expands, which decreases conductivity), such as those from toxic industrial solvents. So this can be made into a simple chemical vapor sensor.



<http://www.scribd.com/researchers-use-pencil-and-paper-to-create-strain-and-chemical-sensor>

52

So in the second experiment they have shown that how we can use that bendable type pencil for making chemical sensor, so here they use bendable type pencil in which the graphite is mixed with a polymer binder okay, so when they create an electrode with this pencil they found out that conductivity was affected by the presence of volatile chemical vapours, because the polymer binder observe the vapour and expands and which decreases the conductivity, okay.

So we can use the simple paper and pencil for making chemical sensor as well as the strain sensor, so as a summary of this lecture so we have learnt what is carbon atoms and how to synthesis carbon atoms by various methods and also we have leant how to functionalized the carbon atoms and also various bio applications of this carbon atoms. So I will end my lecture here thank you all for listening, I will see you in another interesting lecture.

For Further Details Contact

Coordinator, Educational Technology Cell

Indian Institute of Technology Roorkee

Roorkee – 247667

E Mail: etcell.iitrke@gmail.com. etcell@iitr.ernet.in

Website: www.iitr.ac.in/centers/ETC, www.nptel.ac.in

Production Team

Sarath Koovery

Mohan Raj. S

Jithin. K

Pankaj Saini

Graphics

Binoy. V. P

Camera

Arun. S

Online Editing

Arun. S

Video Editing

Arun. S

NPTEL Coordinator

Prof. B. K. Gandhi

An Educational Technology Cell

IIT Roorkee Production

© Copyright All Rights Reserved