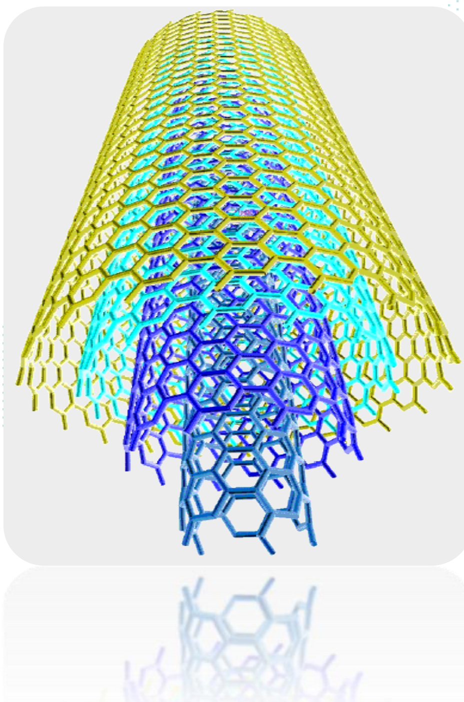
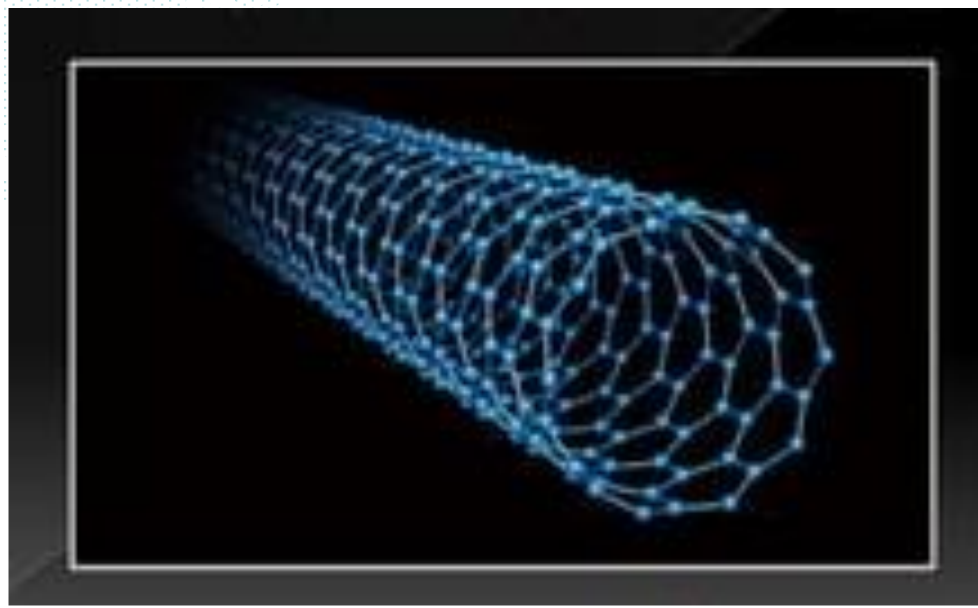
CNT

Synthesis, functionalization and applications





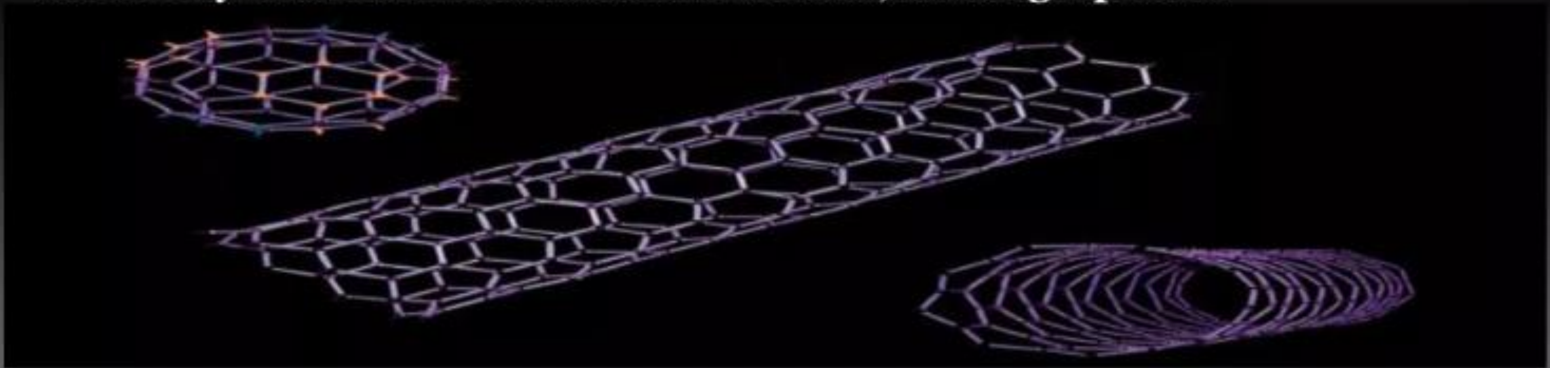
What is a Carbon Nanotube?

#A Carbon Nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nanometre scale.

#Carbon Nanotubes are formed from essentially the graphite sheet and the graphite layer appears somewhat like a rolled-up continuous unbroken hexagonal mesh and carbon molecules at the apexes of the hexagons.

#Nanotubes are members of the fullerene structural family.

#Their name is derived from their long, hollow structure with the walls formed by one atom thick sheets of carbon, called graphene.



Types Of Carbon Nanotubes

Classified mainly in two types:

1. **SINGLE WALLED NANOTUBES**
2. **MULTI WALLED NANOTUBES**

OTHER RELATED STRUCTURES:

#TORUS

#NANOBUD

#GRAPHENATED CARBON NANOTUBES (g-CNTS)

#NITROGEN DOPED CARBON NANOTUBES (N-CNTS)

#PEAPOD

#CUP-STACKED CARBON NANOTUBES

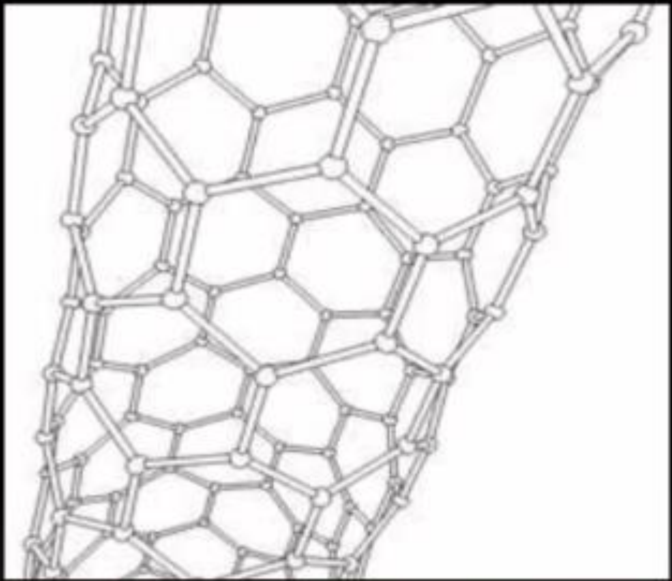
SINGLE WALLED NANOTUBES

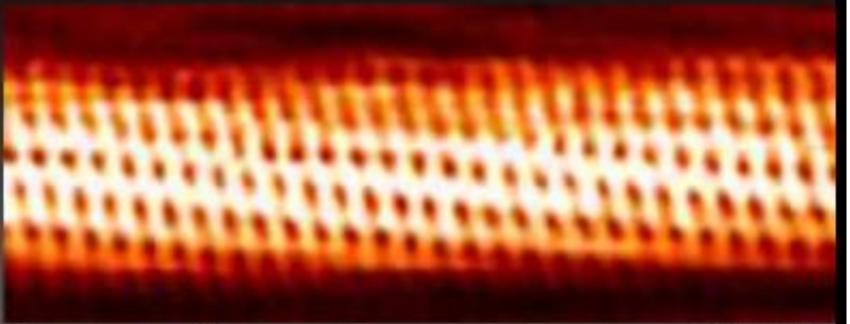
Diameter :- 1 nanometer

Band gap :- 0-2ev

A one atom thick layer of graphene into seamless cylinder .

Their electrical conductivity can show metallic or semiconducting behaviour.

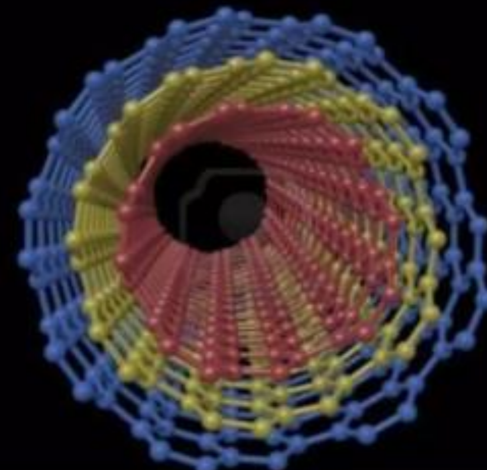




A scanning tunnelling microscopy image of SWNT

MULTI WALLED NANOTUBES

Multi-walled nanotubes (MWNT) consis
of multiple rolled layers (concentric tube
of graphene.



Interlayer distance :- 3.4 Å

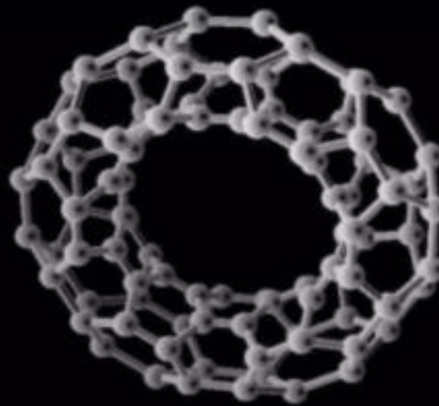
To describe structure of MWNT there ar
two models:-

1. Russian doll model

2. Parchment model

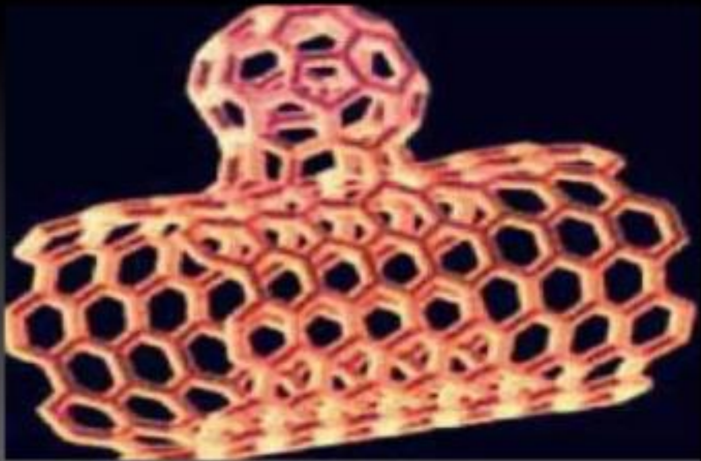
TORUS :-

It is a carbon nanotube bent in a torus shape (i.e. doughnut shape)



NANOBUD :-

Carbon Nanobud are created combining carbon nanotubes and fullerenes.



GRAPHENATED CARBON NANOTUBE :-

They are new hybrids that combines graphitic foliates grown along the sidewalls of MWNT.

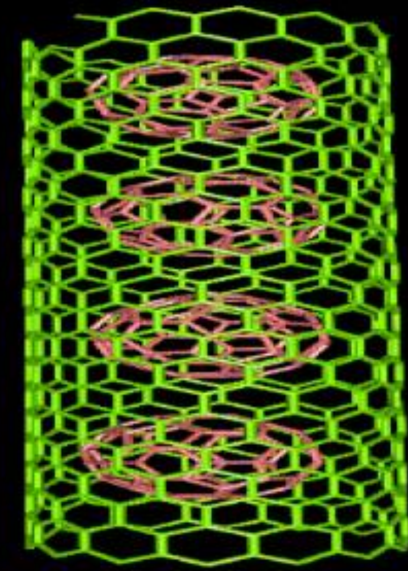
NITROGEN DOPED CARBON NANOTUBE :-

These are used for enhancing storage capacity of Li-ion batteries.

N-doping provides defects in the walls of CNT's allowing for Li ions to diffuse into inter-wall space.

Peapod :-

A carbon peapod is a novel hybrid carbon material which traps fullerene inside a Carbon nanotube.



CUP-STACKED CARBON NANOTUBES :-

CSCNTs exhibit semiconducting behaviours due to the stacking microstructure of graphene layers.

PROPERTIES OF CARBON NANOTUBES

Strength :-

Carbon nanotubes are the strongest, flexible and stiffest materials yet discovered in terms of tensile strength and elastic modulus respectively.

Hardness :-

The hardness (152 Gpa) and bulk modulus (462–546 Gpa) of carbon nanotubes are greater than diamond, which is considered the hardest material.

Electrical Properties:-

Because of the symmetry and unique electronic structure of graphene, nanotube has a very high current carrying capacity.

Thermal Conductivity:-

All nanotubes are expected to be very good thermal conductors along the tube.

EM Wave absorption:-

There has been some research on filling MWNTs with metals, such as Fe, Ni, Co, etc., to increase the absorption effectiveness of MWNTs in the microwave regime.

Thermal properties:-

All nanotubes are expected to be very good thermal conductors along the tube, but good insulators laterally to the tube axis.

Mechanical Properties of Engineering Fibers

Fiber material	Specific Density	Young's modulus(Tpa)	Strength (Gpa)	Strain at break(%)
Carbon Nanotube	1.3 – 2	1	10 – 60	10
HS Steel	7.8	0.2	4.1	<10
Carbon fiber-PAN	1.7 – 2	0.2 – 0.6	1.7 – 5	0.3 – 2.4
Carbon fiber-Pitch	2 – 2.2	0.4 – 0.96	2.2 – 3.3	0.27 – 0.6
E/s-Glass	2.5	0.07 – 0.08	2.4 – 4.5	4.8
Kevlar-49	1.4	0.13	3.6 – 4.1	2.8

Properties of Conductive Materials

Material	Thermal conductivity	Electrical conductivity
Carbon Nanotube	> 3000	10^6 – 10^7
Copper	400	6 x 10^7
Carbon fiber-Pitch	1000	2 - 8.5 x 10^6
Carbon fiber-PAN	8 - 105	6.5 - 14 x 10^6

PROBLEMS RELATED TO CARBON NANOTUBES

Toxicity:-

Under some conditions, nanotubes can cross membrane barriers, which suggests that if raw materials reach the organs they can induce harmful effects such as inflammatory and fibrotic reactions.

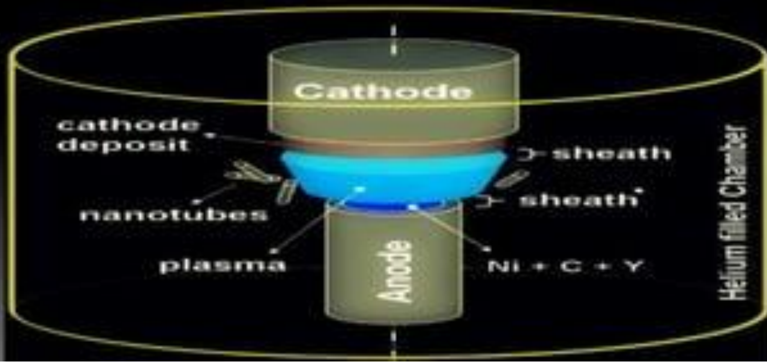
Crystallographic defect:-

As with any material, the existence of a crystallographic defect affects the material properties. Defects can occur in the form of atomic vacancies.

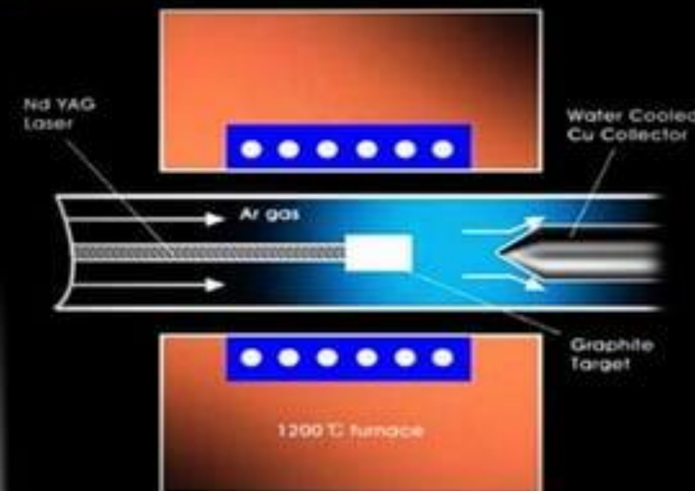
SYNTHESIS OF CARBON NANOTUBES

There are three methods using which we can produce carbon nanotubes.

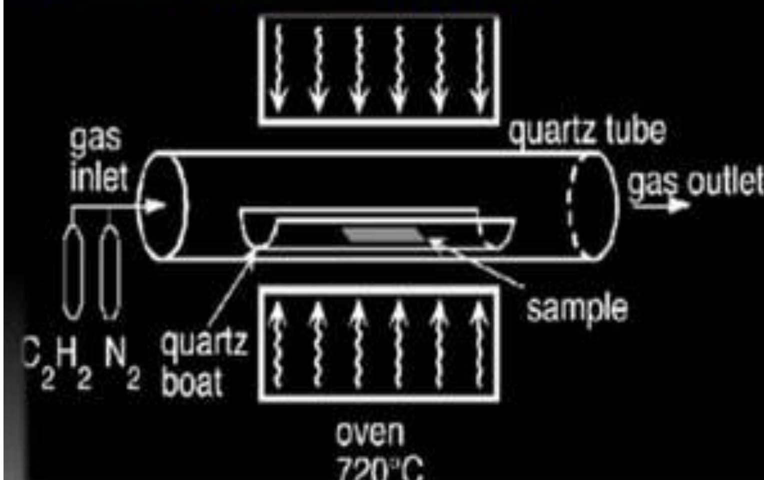
1. ARC DISCHARGE METHOD :-



2. LASER ABLATION :-



3. CHEMICAL VAPOR DEPOSITION (CVD) :-



POTENTIAL APPLICATION OF CNT

1. STRUCTURAL
2. ELECTROMAGNETIC
3. ELECTRO ACOUSTIC
4. CHEMICAL
5. MECHANICAL
6. ELECTRICAL CIRCUITS
    a. **Interconnects**
    b. **Transistors**
    c. **Electronic design and design automation**
7. MEDICINE

Carbon Nanotubes applications

Carbon Nanotubes (CNT) 1D

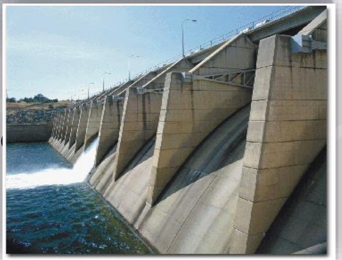
Fantastic **Mechanical properties**

•stiffness and strength due to Sp2 bond

•Much stronger structure than diamond

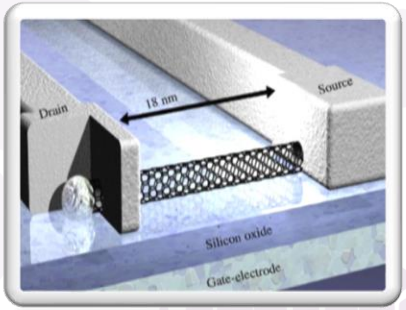
•May replace steel in the future

•Construction purposes like using nanocomposites -bridges an



Light- Low mass

Aerospace industry to build aircrafts and satellites.



Thermal and **Electrical** conductivity

Electrical devices as interconnects transistors , CMOS industry, Nanaowires

Carbon Nanotube - Applications

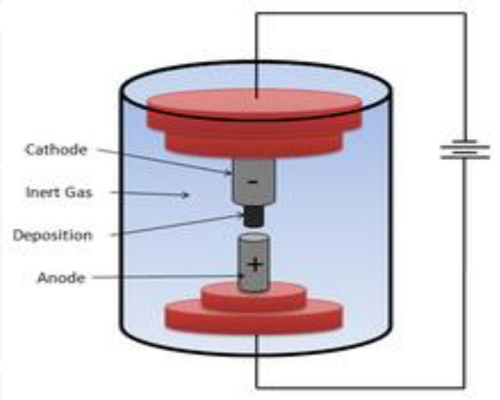
- Energy storage,
- Device modelling,
- Automotive parts,
- Boat hulls,
- Sporting goods,
- Water filters,
- Thin-film electronics,
- Coatings,
- Actuators, and
- Electromagnetic shields

Arc discharge

first and simplest method to synthesize Carbon Nanotubes.
Two pure graphite electrodes are connected to DC generator in atmosphere of helium.
An inert gas is added to the chamber which does not react with carbon.
Electric current is run thorough electrodes and therefore Carbon is deposited into cathode from anode and CNT are shaped in the middle .
quite perfect about few micro meters long
inner tube is 1-3 nm and outer tube in MWNT 10 nm in diameter.

Drawback

If both of the electrodes are made of graphite (mixture of CNTs along with fullerene, sheets of graphite, amorphous carbon)
more work to separate CNTs from its **undesirable by-products**.
4000 °C which is an extremely high temperature .
Electric arc method good for scientific study but not for industrial use .



- **Magnetic field in arc discharge synthesis**

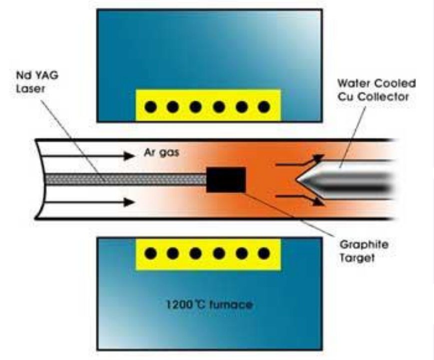
applying a magnetic field around the arc plasma for alignment purposes
a magnetic field have a high purity and fewer defects
electronic devices as nanowires for device fabrication .

- **Plasma rotating arc discharge**

In this method the arc discharge technique is done by plasma rotating. As a result increased plasma volume more stable and homogenous plasma has been observed.

The rotation speed is 5000 rpm and temperature is found to be 1025°C which is high.
No catalyst is used in this method and after purification yield is increased to 90% .

Laser ablation



laser is used to vaporize carbon from graphite ,a high temperature reactor at 1200 °C
inert gas is helium or argon
The process of laser ablation is like arc discharge method but in a lower temperature.

- Continuous Laser
- Pulsed Laser

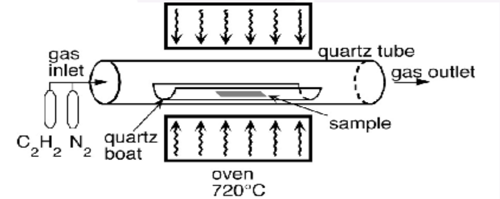
difference is that pulsed laser requires much higher light density.

If we use pure graphite electrodes we can obtain MWNTs ,but to have uniform SWNTs, a mixture of graphite with Co, Ni, Fe or Y

The yield of this process is low and contains carbon Nanotubes along with Carbon Nanoparticles which is not ideal for industrial applications.

have a very high quality 10-15 μm in length.
Research to scale up the yield of this process.

Chemical vapor deposition



The other common method is called Chemical vapor deposition (CVD)

several gases such as methane (CH_4), carbon monoxide (CO) and acetylene (C2H2)
Heated substrate which is coated by catalyst like Ni, Al_2O_3, and SiO_2
Inert gas such as nitrogen and hydrogen.

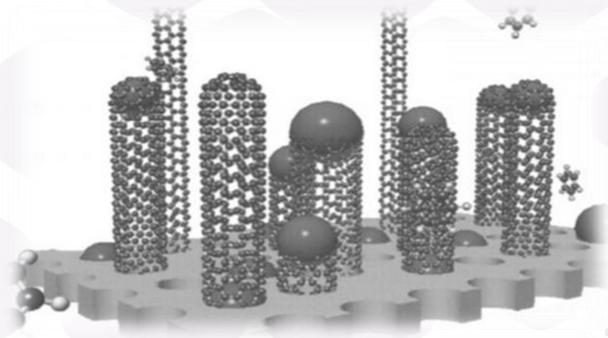
The energy source decomposes the molecule into active carbon atoms which then will be diffused on the substrate and CNTs begin to grow

The temperature 650–1000 °C which is quite high. The diameter of each nanoparticle defines the diameter of grow .

it is possible to have control over the diameter and length of grown CNT.

CVD process has mostly two main steps which first is preparing substrate by sputtering then to use thermal annealing to have catalyst nanoparticles on the substrate .

- ✓Large scale production and high yield production
- ✓Low cost
- ✓Continuous production instead of batch production
- ✓Control of the quality and CNT
- ✓Ability to manipulate
- ✓ No separation of unwanted by-products



CVD process is extremely sensitive to the condition parameters .
Continues reactor and discontinuous reactor.
According to the original work done by Izaskun Bustero an optimal condition for CVD process for best yield

Optimal operating conditions	
Reaction time	10 min
Temperature	1000 °C
Catalyst mass	0.5 g
Ratio H_2/CH_4 in gaseous stream	1

The End