

A Novel Process and nano material for  
production of Carbon Nano Tubes and its  
application in High Tech. Industries

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# Today's Scenario

- Two major Problems:
  - Energy
  - Environment
  - State of the Art Technologies:

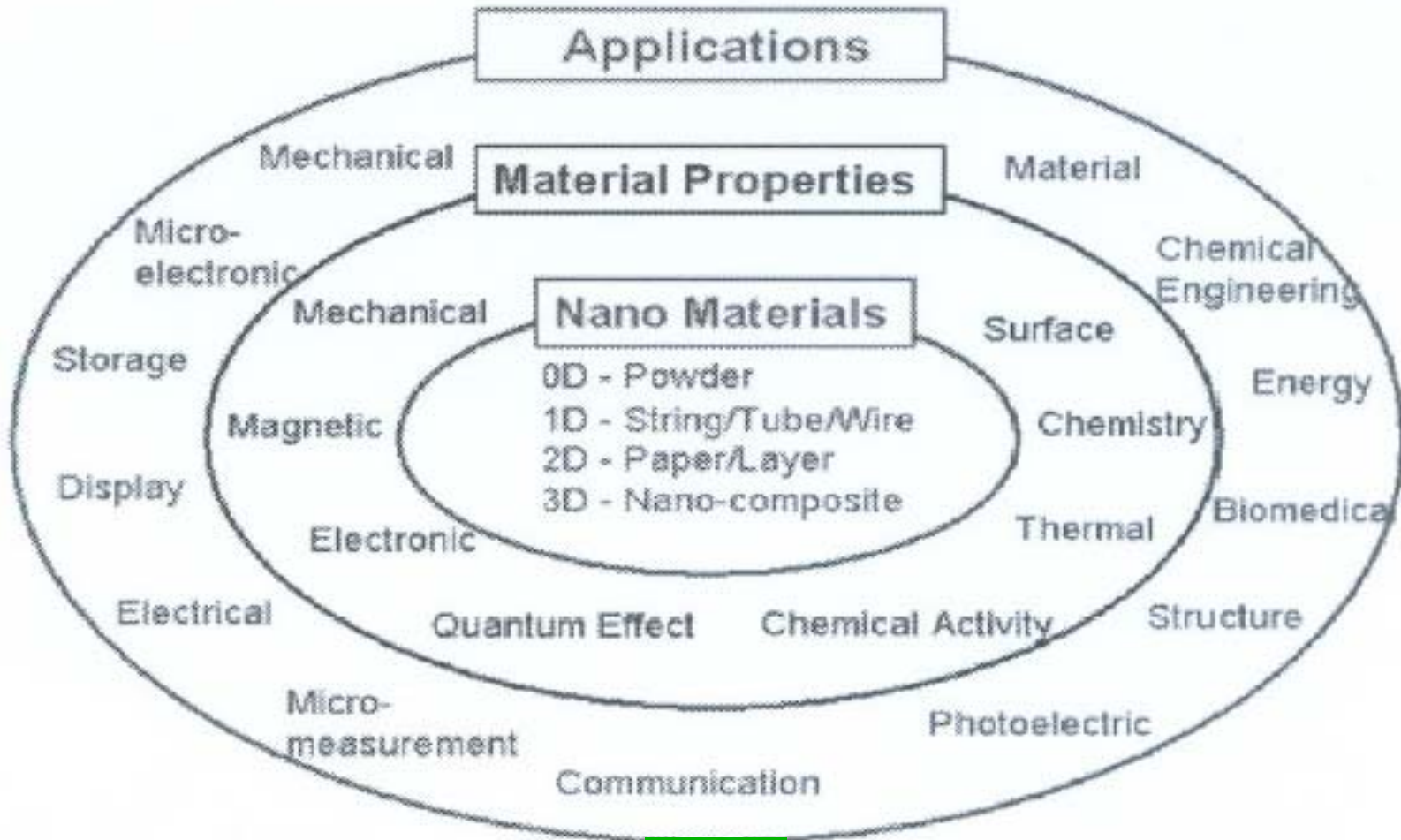


# Nano Technology

- Engineering at the Molecular Level.
- Design and manufacture of extremely small components.
- They are built at the molecular level of matter, are characterized by large surface area in comparison with their volumes.
- Their behavior: Laws of quantum mechanics.



# Nano Technology



# Carbon Nanotubes (CNT's)

- CNT's: an innovative nano/micro structural material (discovered in NEC Japan in 1991).
- Self assembled carbon structure with diameter as small as 1 nm.
- One CNT is 10,000 times thinner than human hair.



# CNT's

- Crowned the king of nano technology.
- Useful structural, electrical, thermal and chemical properties.
- Enables variety of products stronger, cheaper, cleaner and more efficient.
- Very precise in their function.



# Nanoengineered Materials

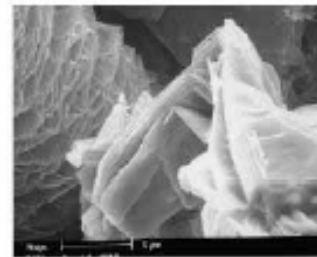
- Nanotubes

- SWNT
- MWNT(including DWNT)



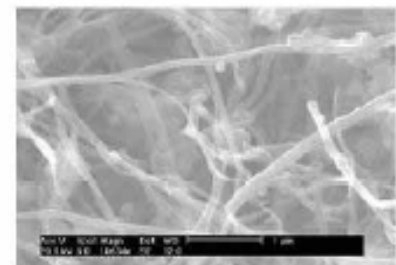
- Nanoplatelets

- Graphite (GNP)
- Montmorillonite (Nanoclay)



- Nanofiber

- Vapor-grown graphite (Pyrograf)
- Electrospun/phase separated LC fibers



- Nanocomposite fibers

- Organic polymer co-electrospun with CNT, GNP, VGNF
- Inorganic matrix fibril reinforced by CNT, GNP, VGNF



# Structural properties high performance fibers

	Weight kg/m <sup>3</sup>	E-modulus GPa	Strength GPa	Strgth/Wgth MPa.m <sup>3</sup> /kg
Steel	7900	200	0,4	0,05
E-glass	2560	70	2,4	0,9
Aramide	1440	130	3,6	2,5
Carbon	1800	700	5,0	2,8
HMPE	980	95	3,0	3,1
PBO	1550	230	5,8	3,7
M5				
CNTpotential	1300	1000	100	76,9
CNTcurrent	1300		2-4	1,5-3





# Engineering Properties

Properties	Nano tubes	By comparison
Size (in diameter)	SWCNT: 0.6-1.8 nm MWCNT: 20-50 nm	Electron beam lithography can create line 50 nm wide, a few nm thick
Current carrying capacity	Estimated at 1 billion amps/cm <sup>2</sup> MWCNT	Copper wires burn out at about 1 million amps/cm <sup>2</sup>

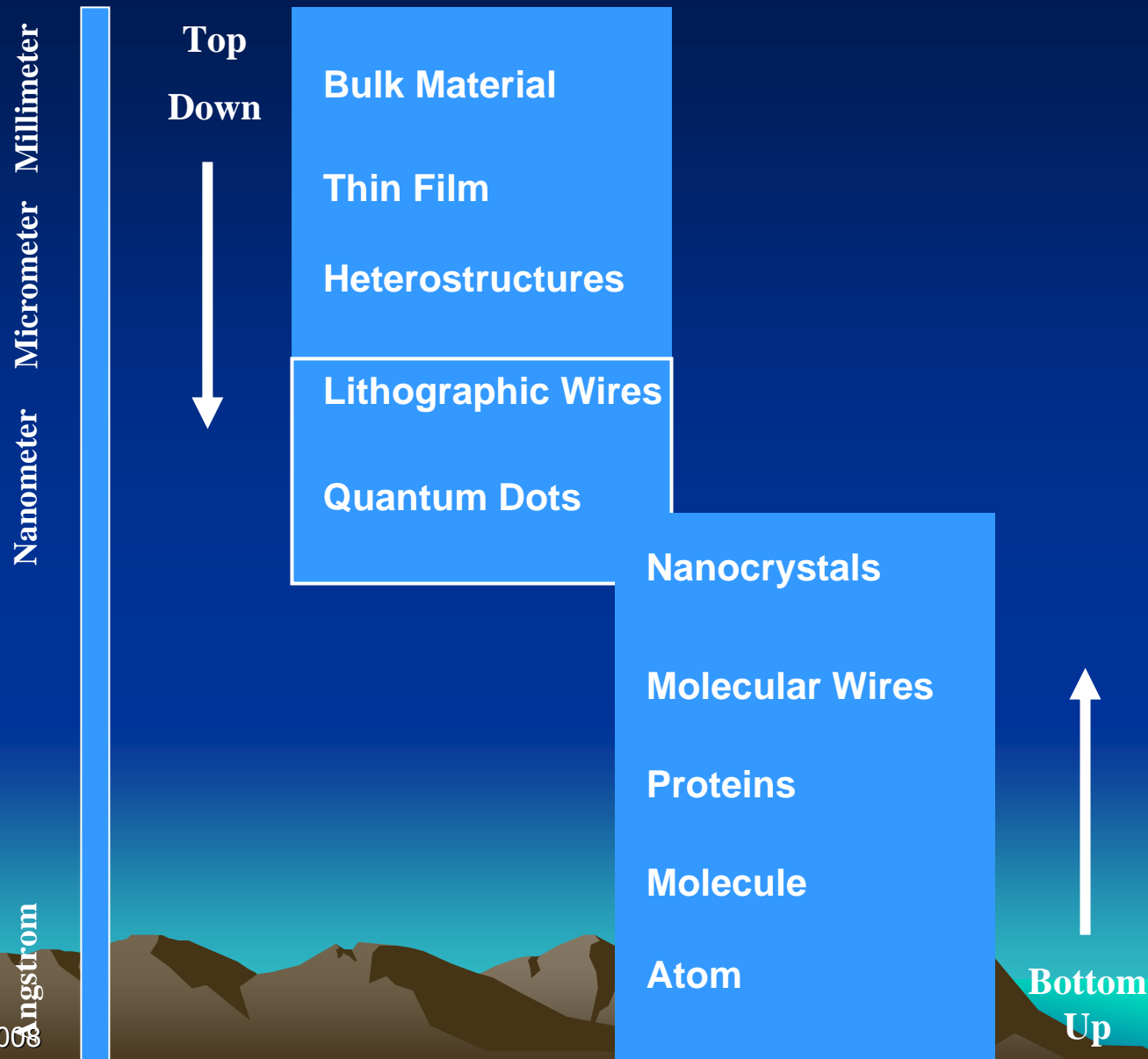


# Engineering Properties

Field Emission	Can attract phosphors at 1-3 volts.	Mo tips require field 50-100 volts (limited life time)
Heat Transmission	As high as 6,000 watts/meter/K at RT.	Pure diamond transmits heat 3,320 watts/meter/K at RT.
Temperature Stability	2,800 °C (vacuum) 750 °C (in air)	Metal wires in microchips melt at 600-1000 °C. <sup>10</sup>



# Approaches to Nanoscale Structures

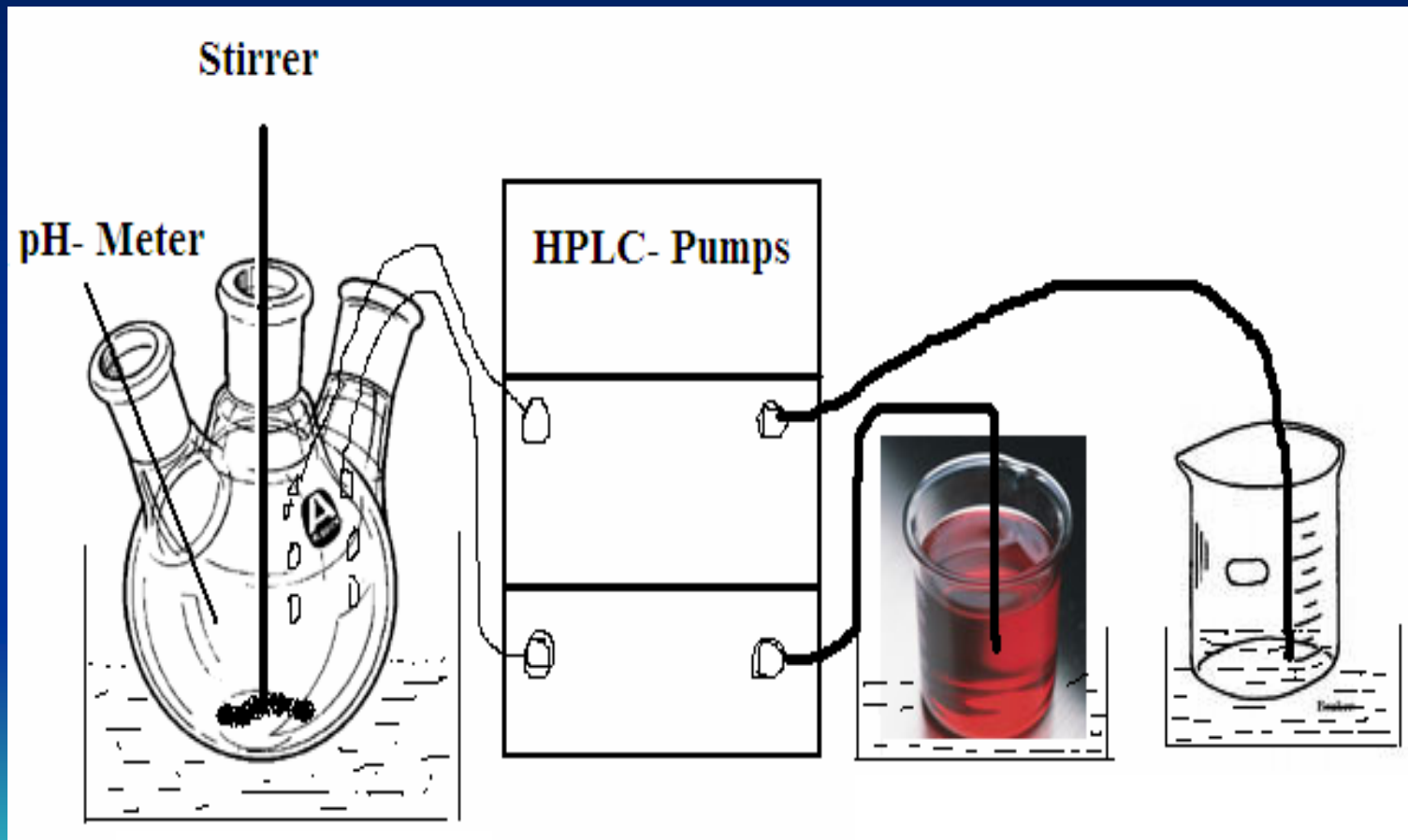


# Present CNT'S Synthesis Processes

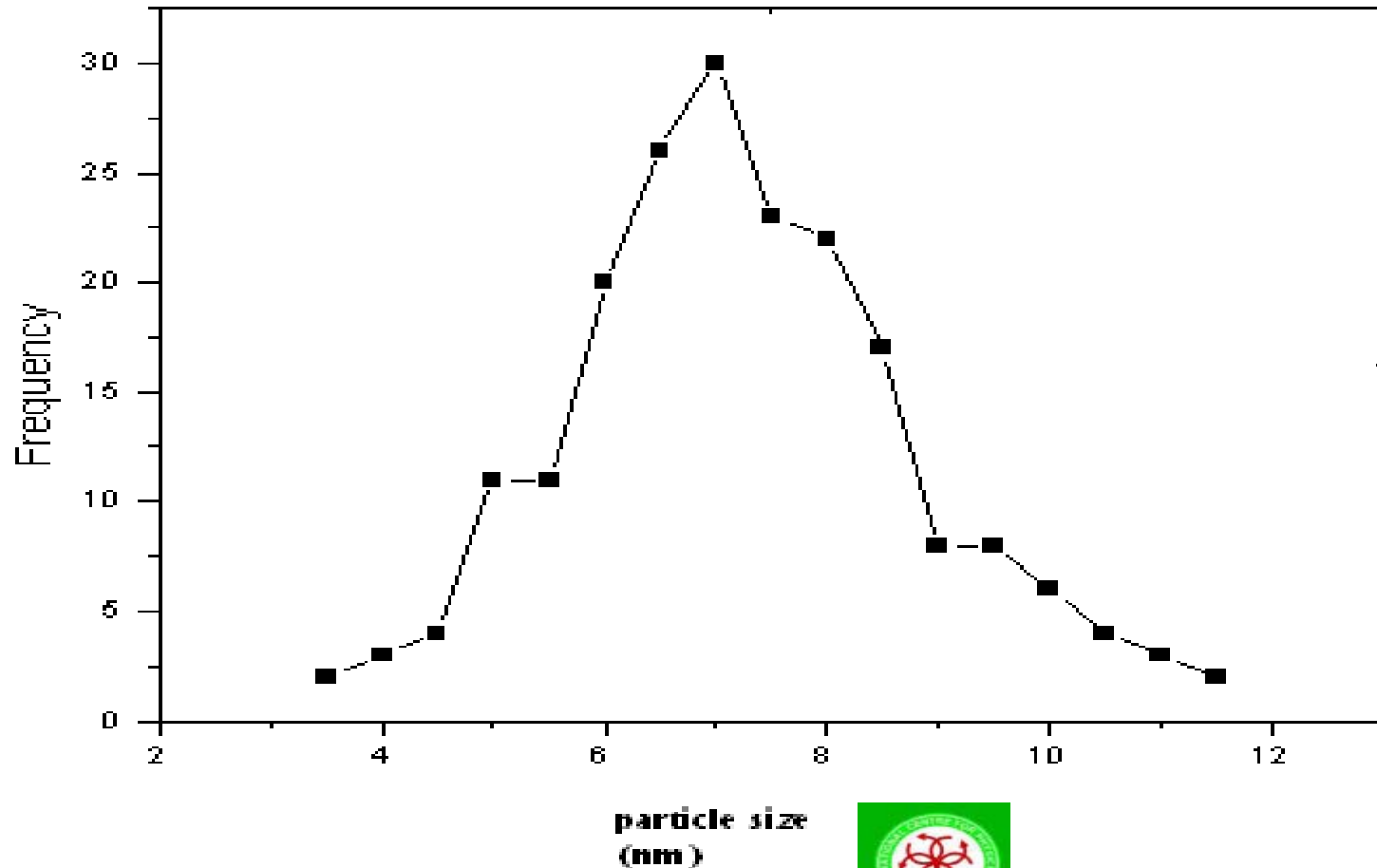
- CVD, PVD, Arc-evaporation, Catalytic Process, Laser Assisted Catalytic Growth, Solution Chemistry, Arrested Evaporation.
- 2-step process
  - 1. CNT's Production.
  - 2. Purification (86-93%)



# The CNTs Nano catalyst

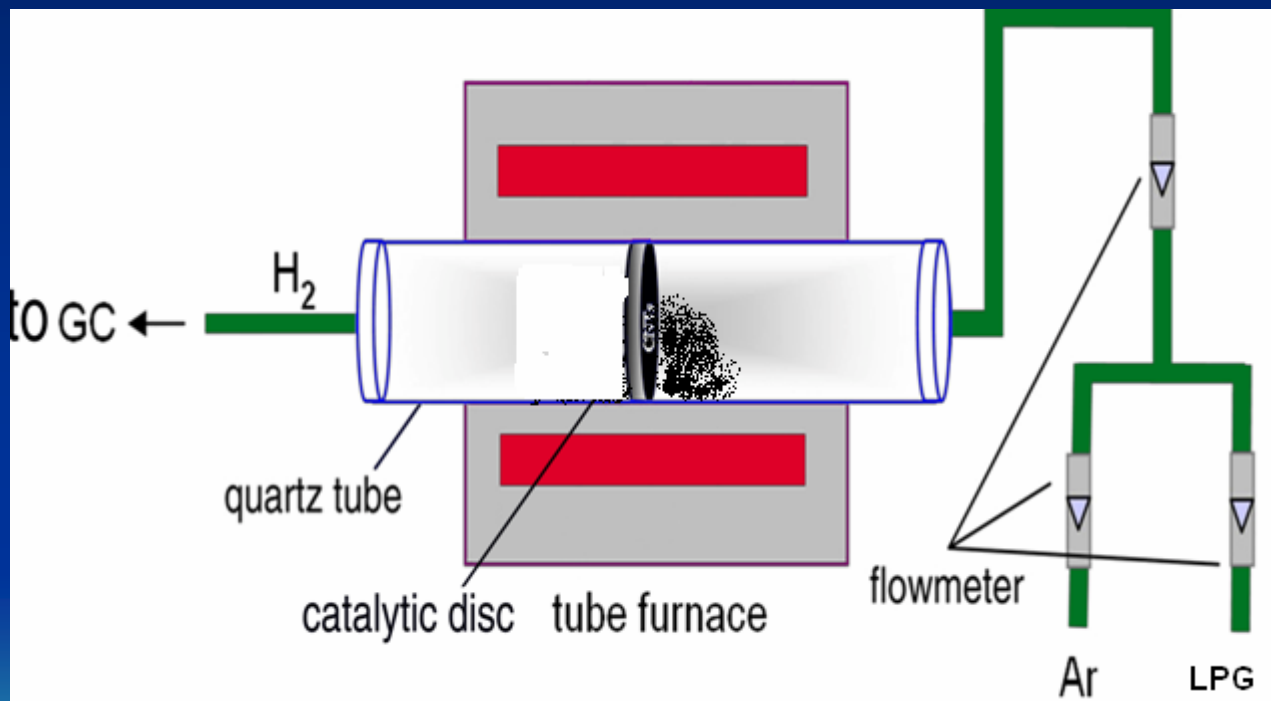


# The nano material Ni:Cu/Al (modified)



# The CNTs production Process

US Patent No. 12/032680, Feb. 2008.



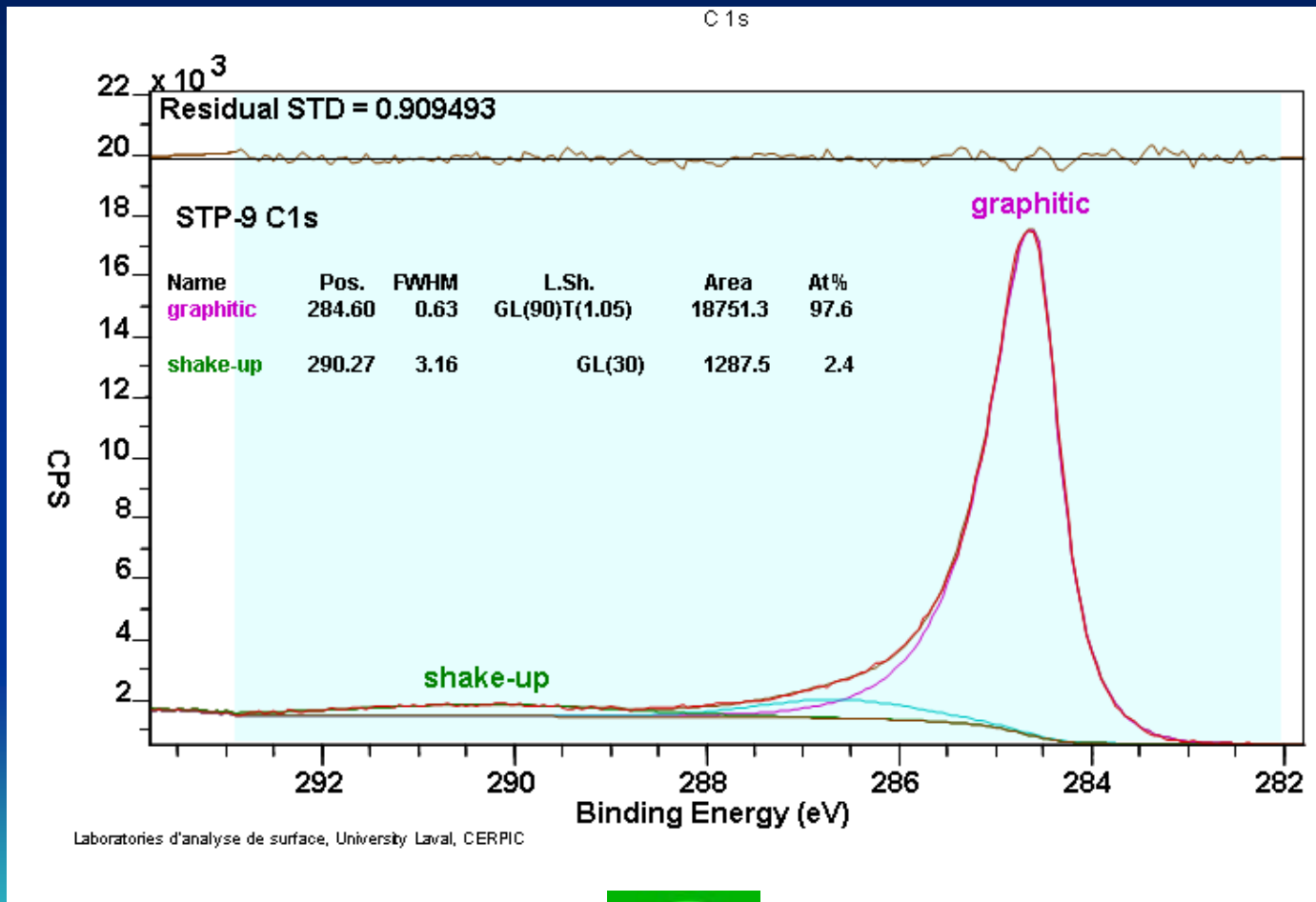
# The Advantages

- Simple (No high pressure Equipment requirement).
- Worked at lower temperature/Atmospheric Pressure, single step process.
- No formation of CO/CO<sub>2</sub>
- Does not require any purification.
- 96-97% Purity.
- The nano material can be reused.

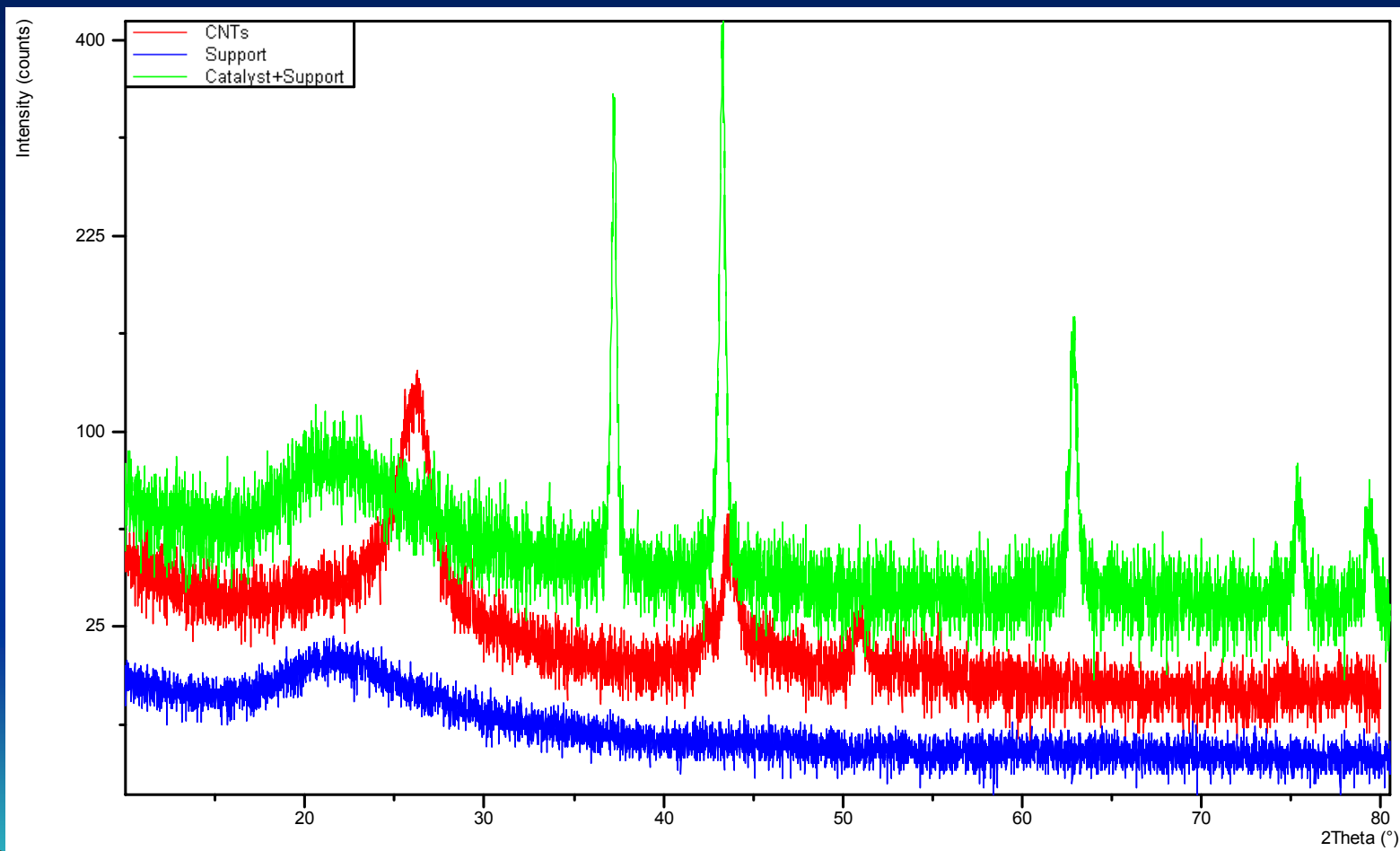




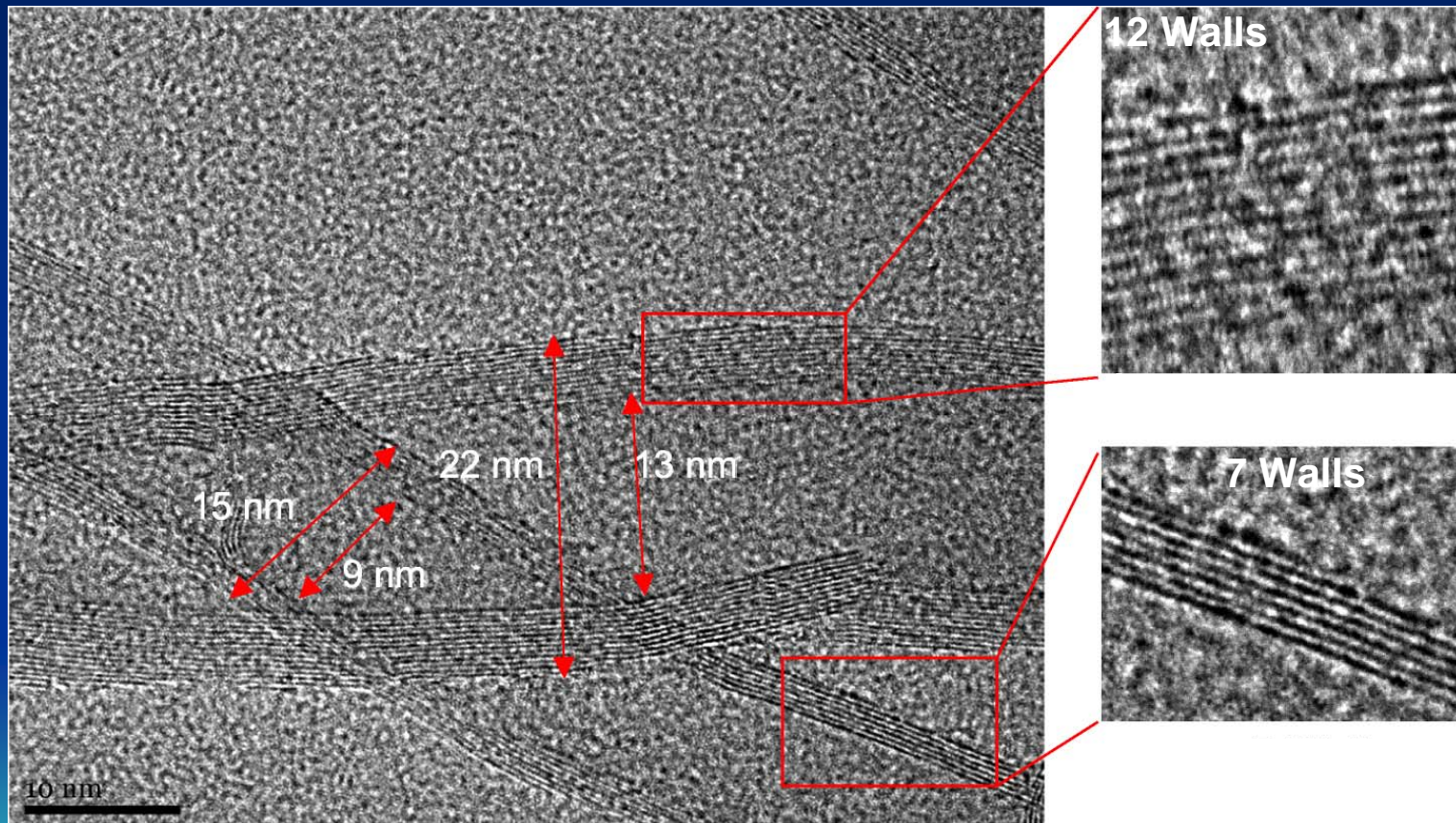
# The XPS Analysis



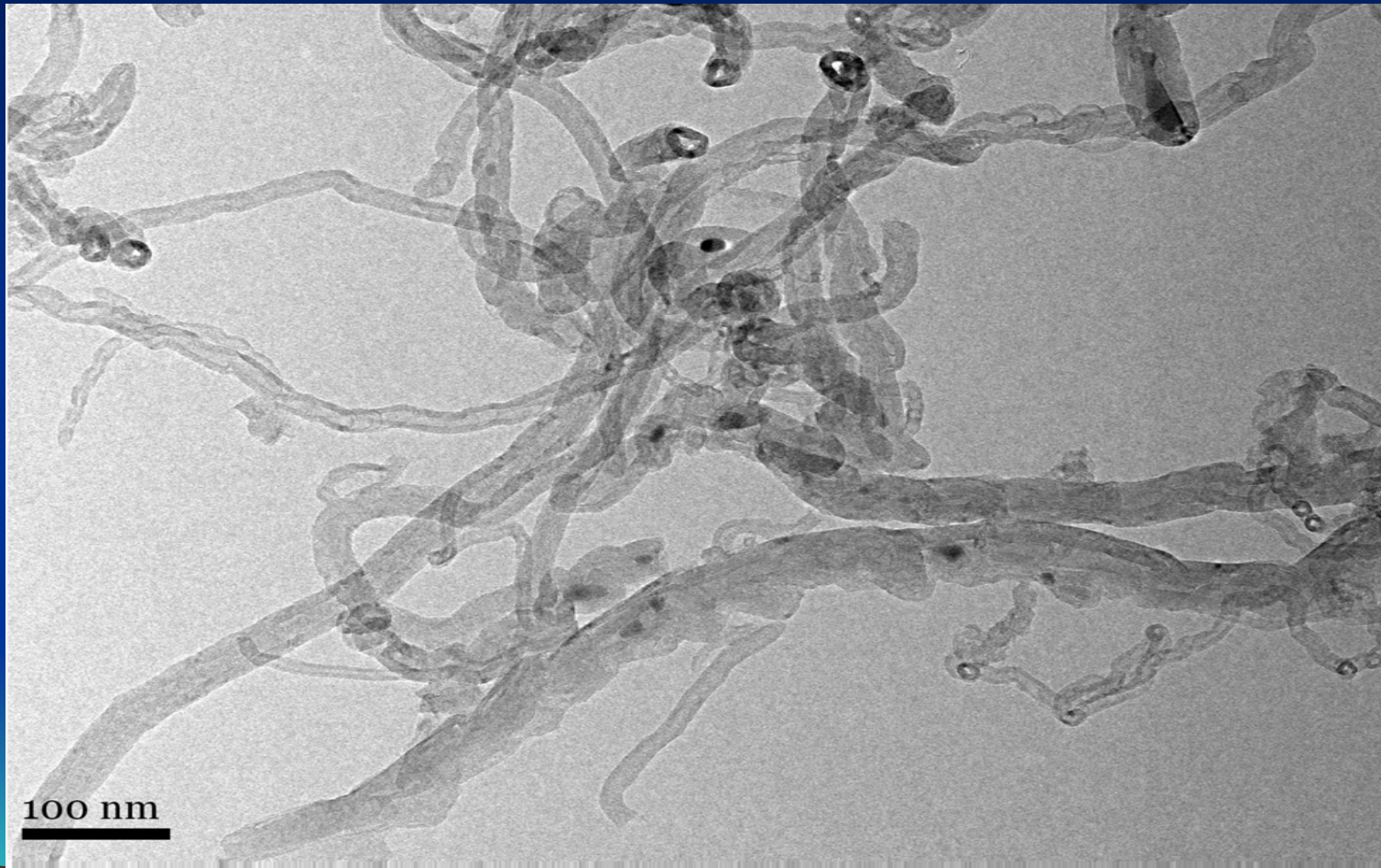
# The XRD Analysis



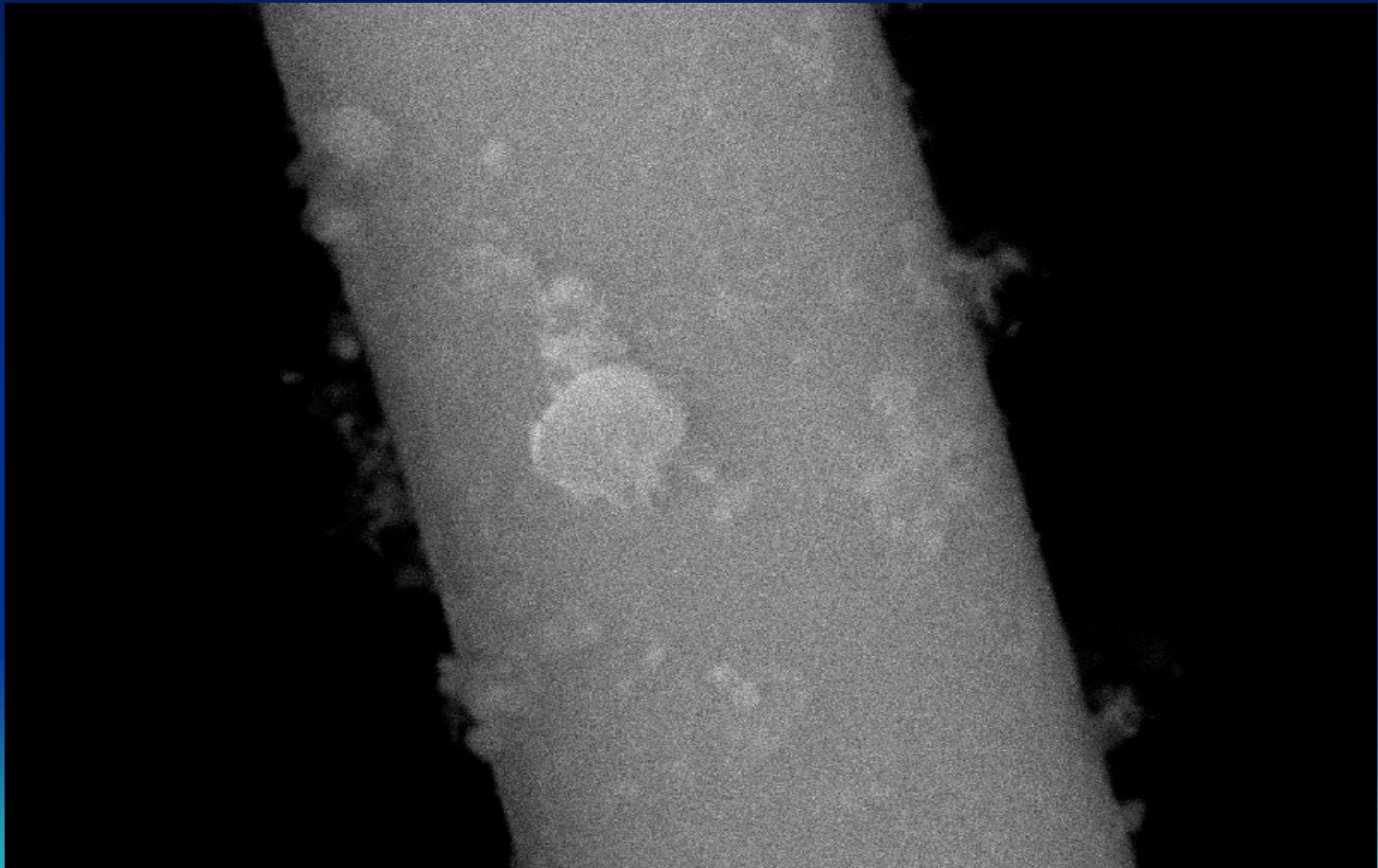
# THE HRTEM Characterization



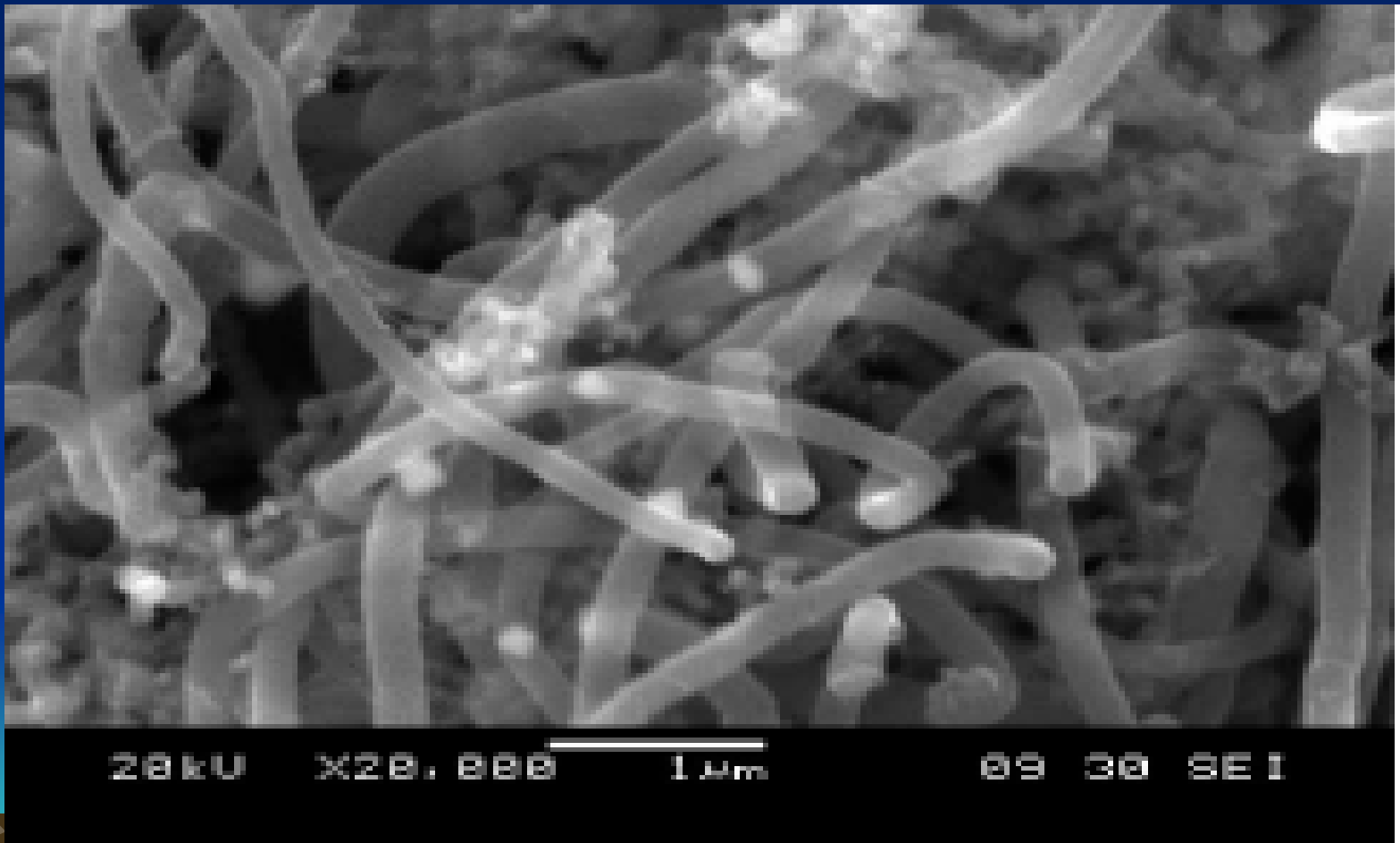
# Low Resolution TEM Study



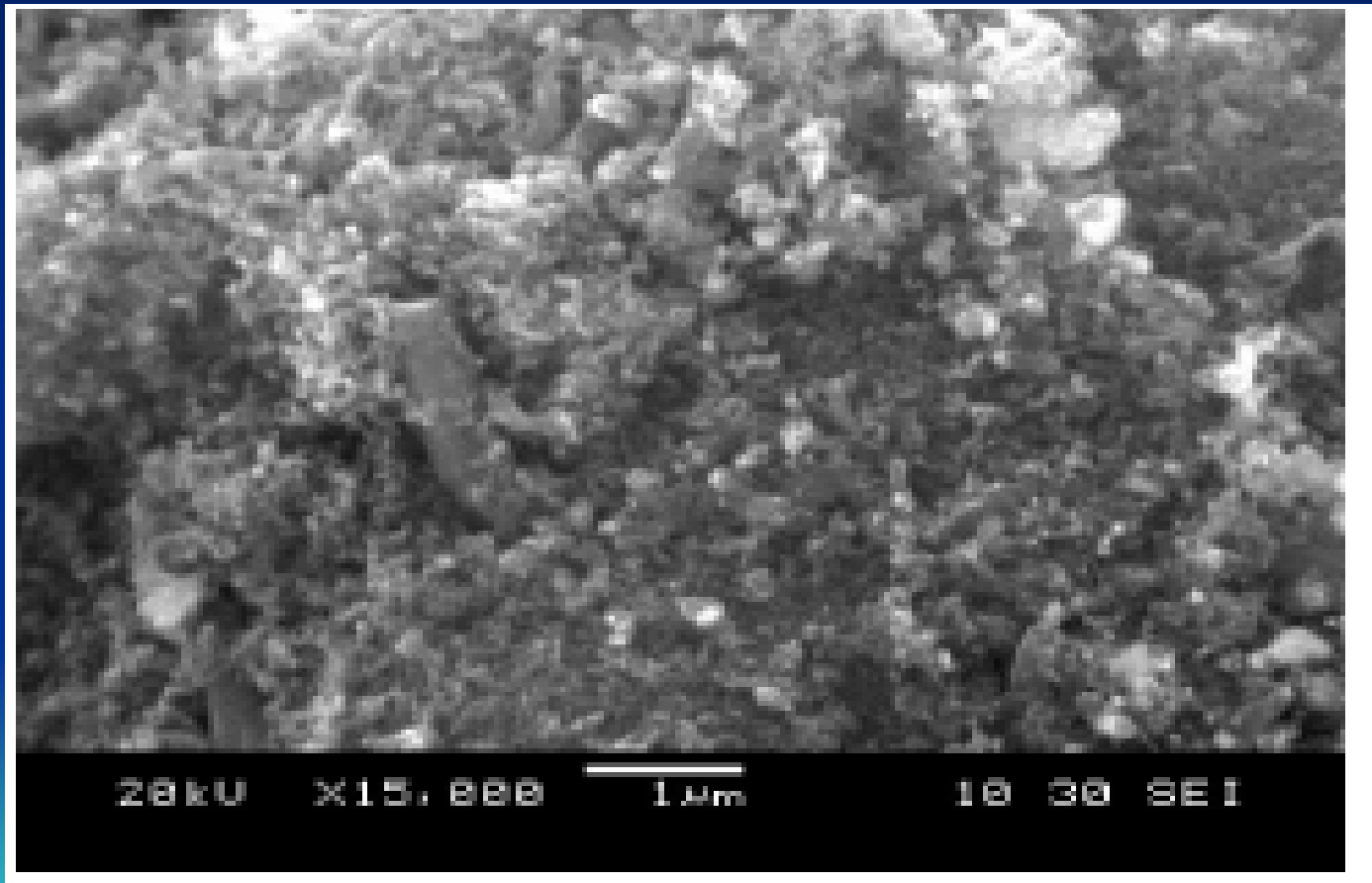
# The SWCNT's 2-4 nm



# The Carbon Fibers



# The graphitic Carbon

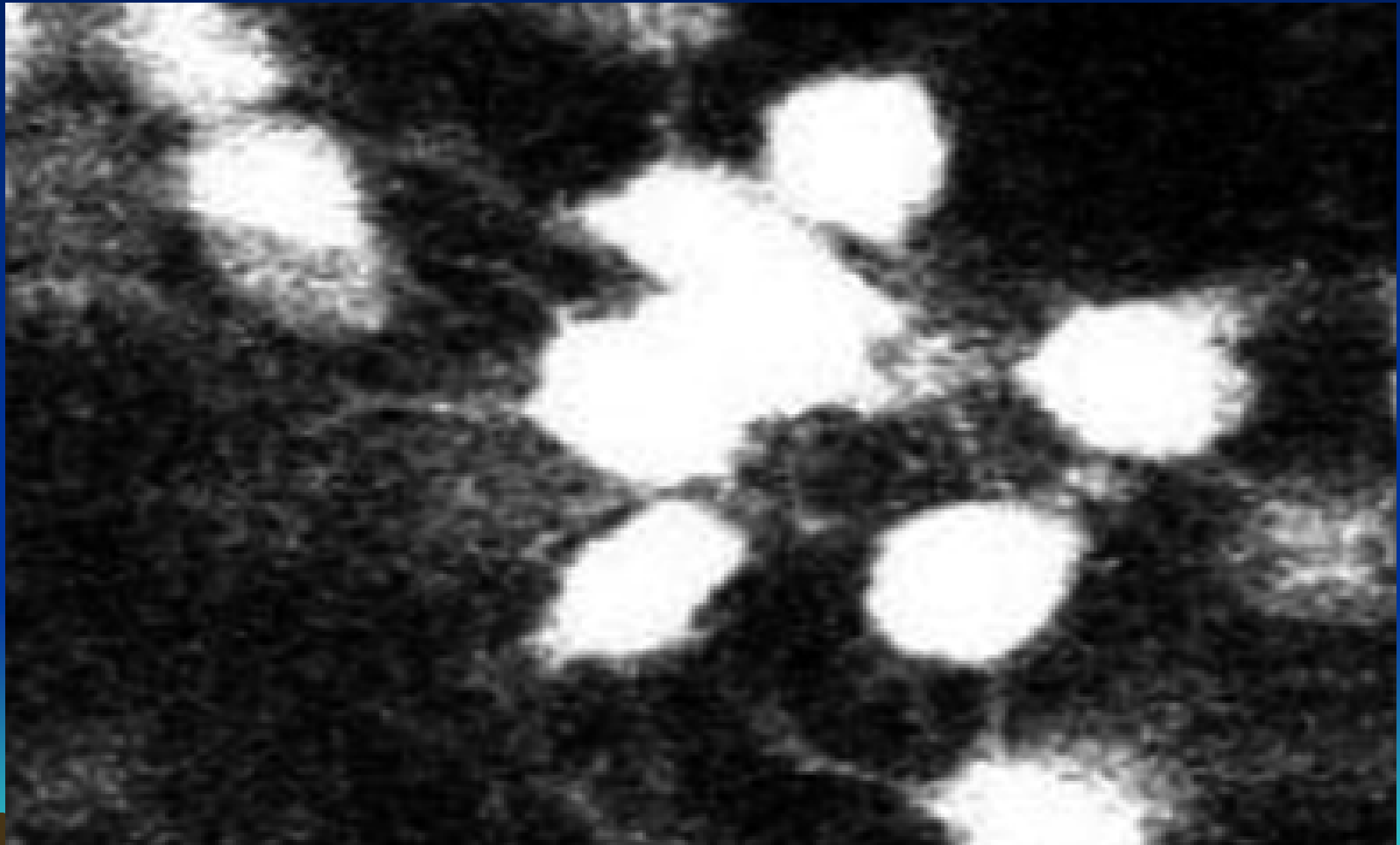


# The balloon type carbon





**Multiphoton quantum dots  
nano particles with special light properties that can be  
used for imaging in biological materials.**



# The Deveolped CNT's properties

Material	Elastic Modulus (GP <sub>a</sub> )	Strain (%)	Yield Strength (GP <sub>a</sub> )	Density (g/cm <sup>3</sup> )
SWCNT	1146	3.8	49	1.47
MWCNT	1180	1.2	3.9	1.82
C-Fibers	175	1.2	2.5	1.70
Titanium	103	15	0.9	4.5
Steel	207	9	0.8	7.8
Aluminates.	69	16	0.5	2.7



# The Industrial Applications

- CNT's: Stronger than steel, faster than silicon, and much lighter than Aluminum.
- Construction Engineering: From good load-bearing reinforcement in composites materials).
- Mechanical, Automotive and Aerospace Engineering (Auto/air/space body parts)

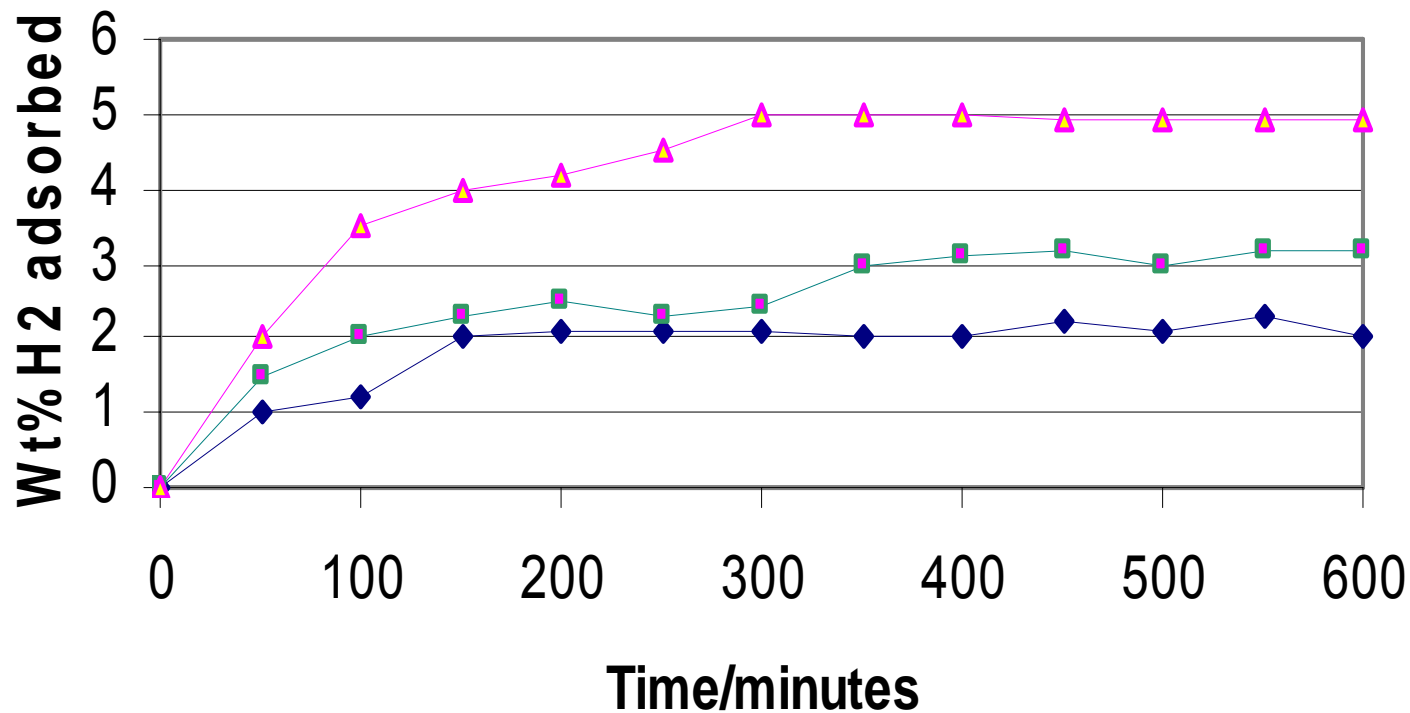


# The Industrial Applications

- Electrochemical Engineering (Rechargeable batteries and fuel Cells).
- Biomedical Engineering (Nanoprobes and Sensors).
- Electrical Engineering (Transistors, Logic Gates, Microelectronics, Gas discharge tubes)
- And many more.



# As Hydrogen Storage at 100, 150, 200 Psig Pressure and at RT.



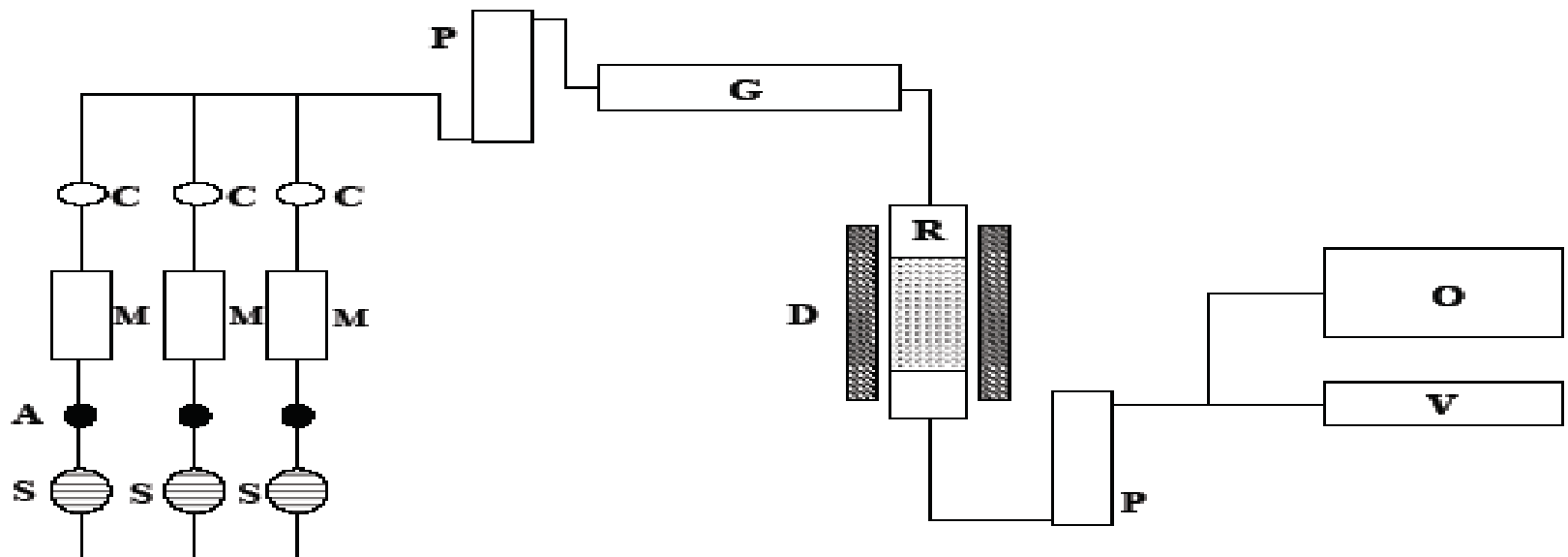
# Green Energy Technology

- Conversion of LPG.
  - Ni:Cu/CNTS

\* 20% less C-emission.



# The Technology



## Keys:

**S** gas cylinders

**A** gas flow controllers

**M** flow meters

**C** greaseless stopcocks

**P** molecular sieve traps

**G** gaseous mixture

**R** reactor

**D** furnace

**O** online gas chromatograph

**V** vent

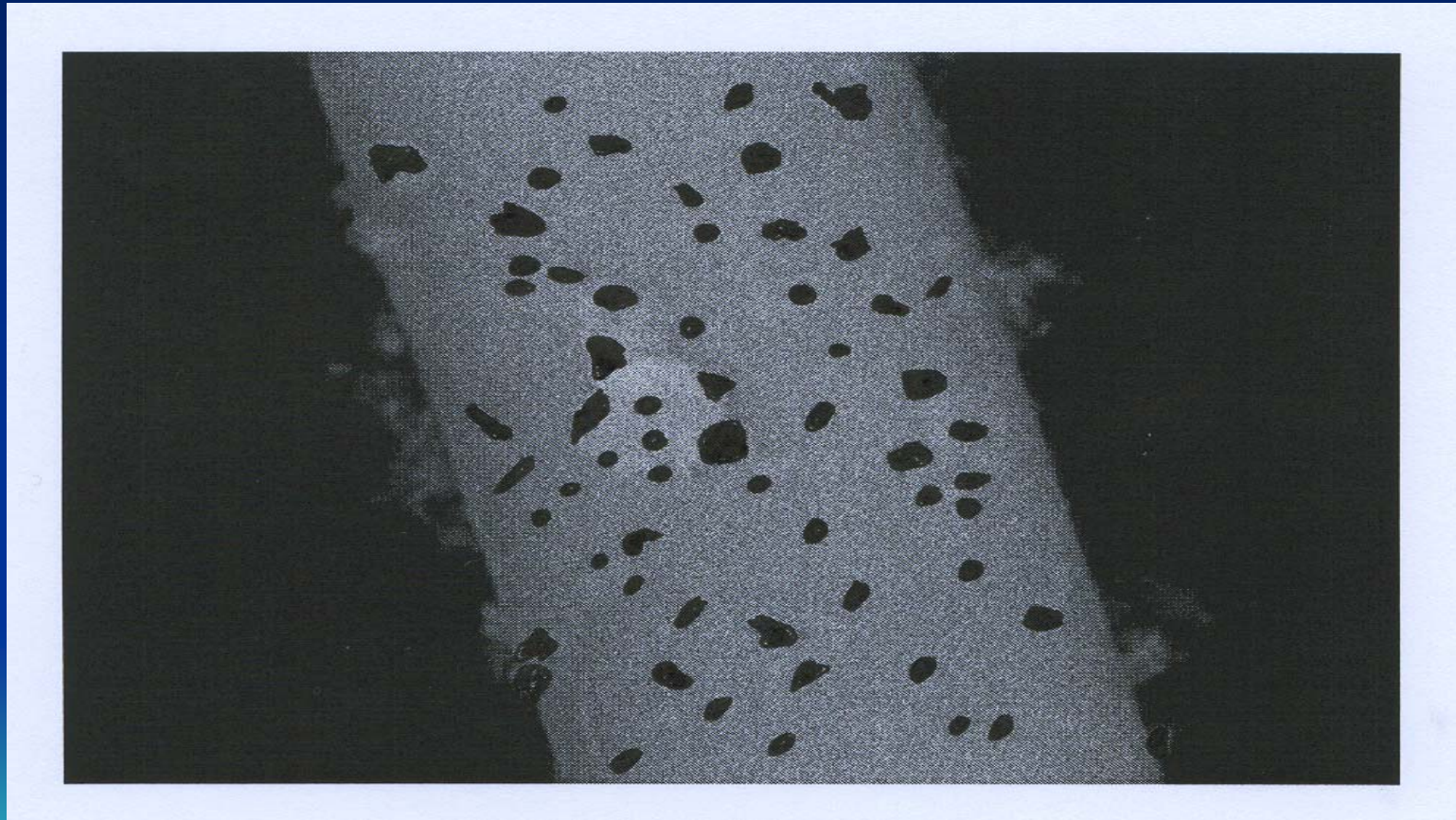


Component	Concentration in Feed Gas (% mol/mol)	Concentration in Strip Gas (% mol/mol)
Hydrogen (H <sub>2</sub> )	0.00	20.39
Nitrogen (N <sub>2</sub> )	8.04	8.02
Methane (CH <sub>4</sub> )	42.39	50.07
Ethane (C <sub>2</sub> H <sub>6</sub> )	24.82	3.29
Propane (C <sub>3</sub> H <sub>8</sub> )	13.73	13.61
iso-Butane (i-C <sub>4</sub> H <sub>10</sub> )	6.01	2.46
normal-Butane (n-C <sub>4</sub> H <sub>10</sub> )	4.67	2.05
iso-Pentane (i-C <sub>5</sub> H <sub>12</sub> )	0.31	0.10
normal-Pentane (n-C <sub>5</sub> H <sub>12</sub> )	0.02	0.00
Hexane plus higher (C <sub>6++</sub> )	0.01	0.01





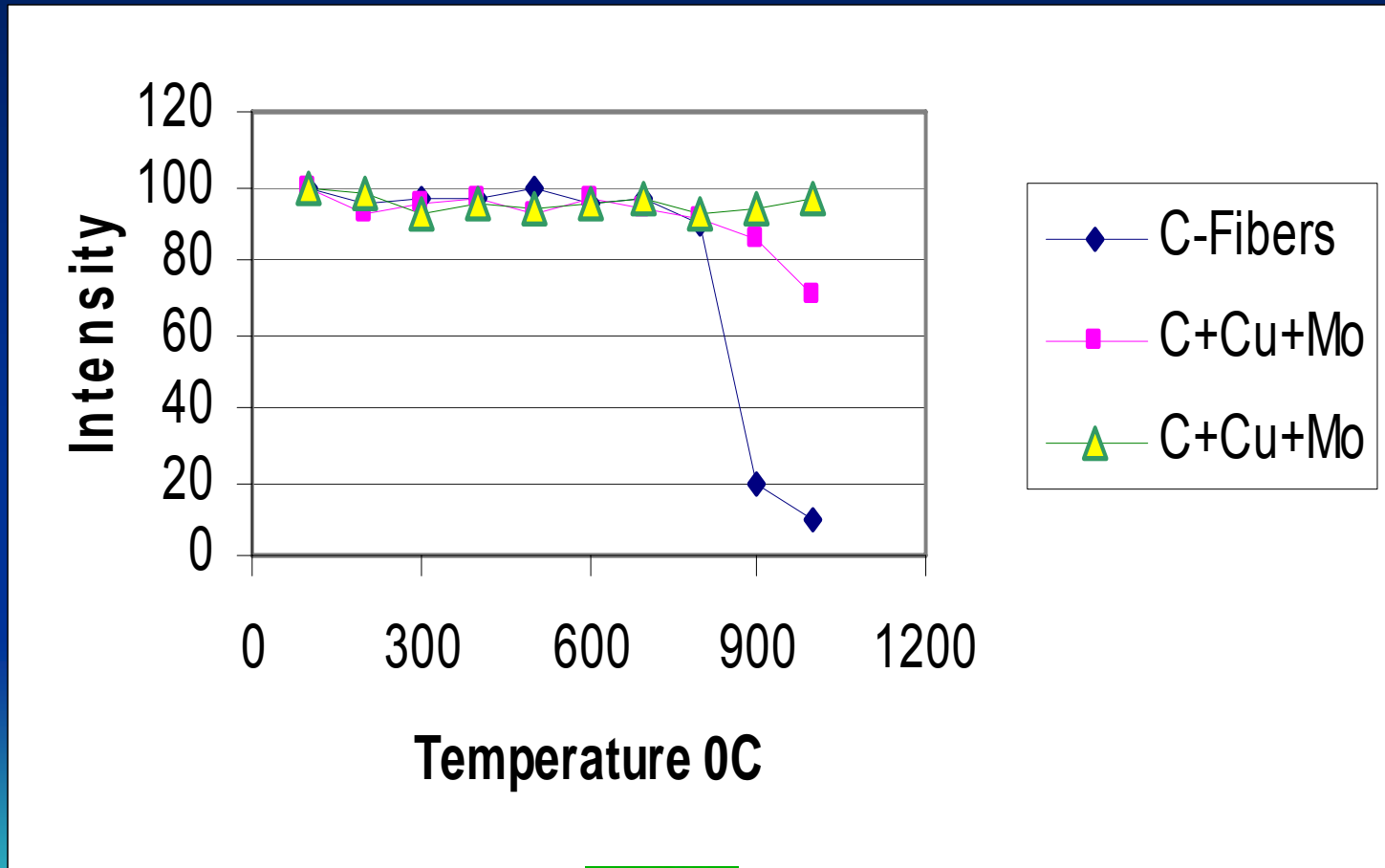
# Application as High Temp. Resistant Material (Cu:Mo/CNT).



# Depth Profiling (Cu:Mo/CNT).

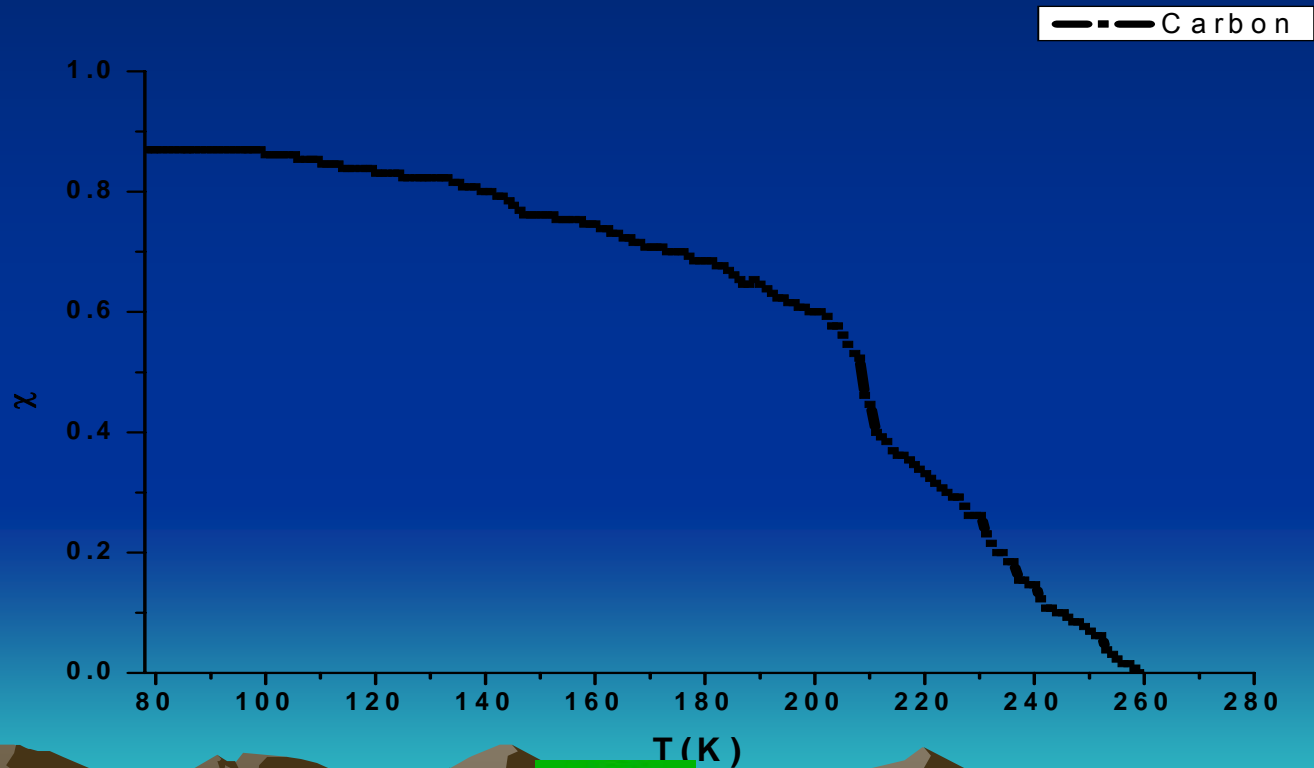


# Cu:Mo/CNT's (The TGA Study)

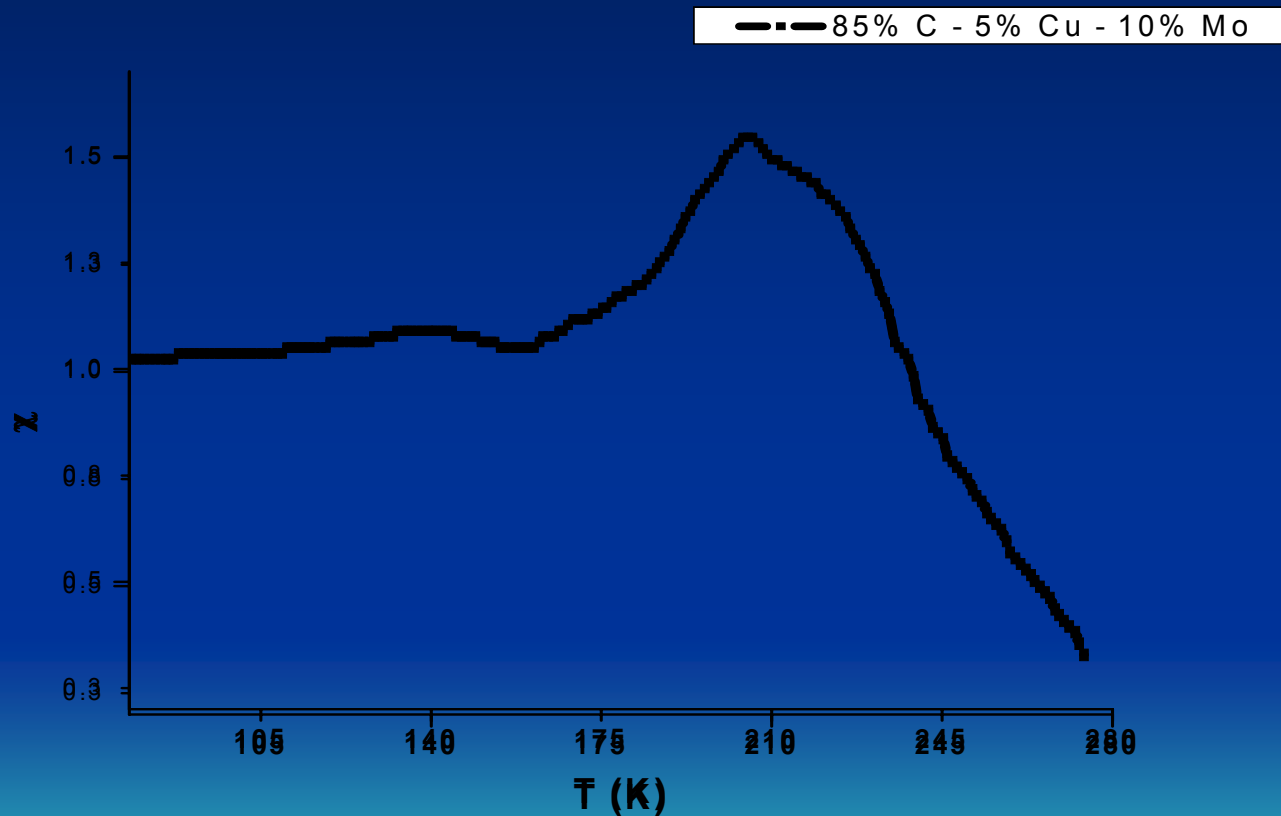


# Magnetic Materials

- Pure Graphitic Carbon (Paramagnetic)

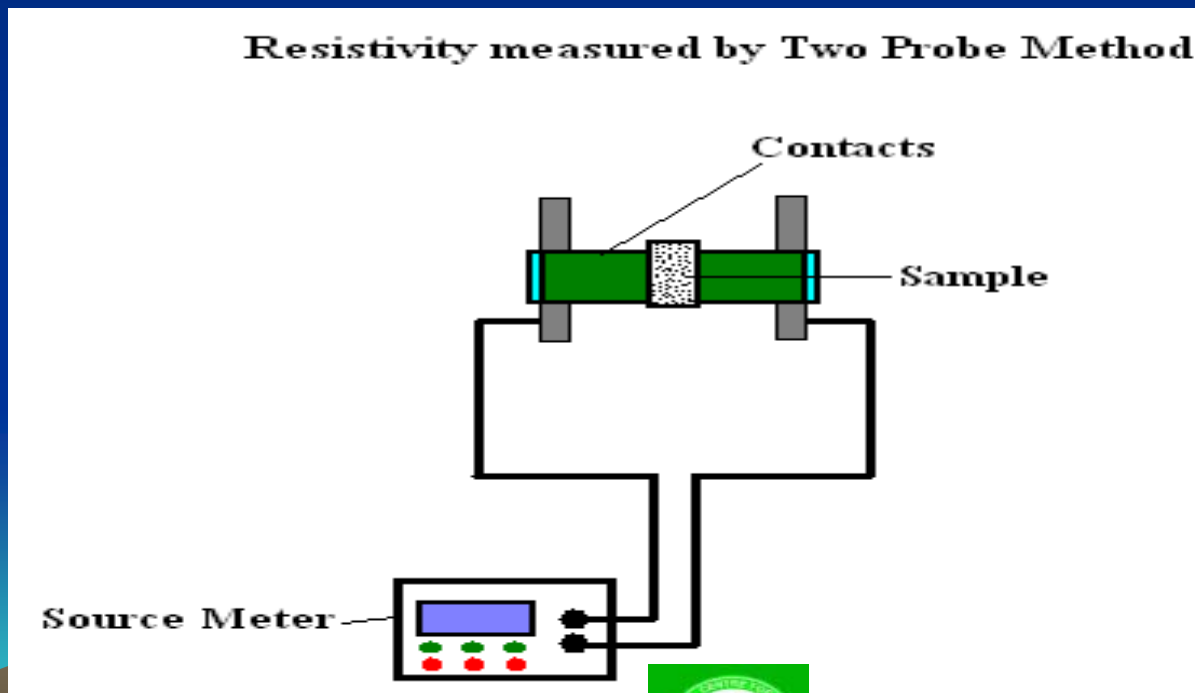


# Cu:Mo/CNT's (Anti Ferromagnetic)



# Functionlization of CNTs

- MWCNTs (2%) + PMMA (98%)
- Resistivity Measurements by two probe method ( $M \Omega \text{ cm}$ ): To-days material:  $K \Omega \text{ cm}$
- (good insulator)



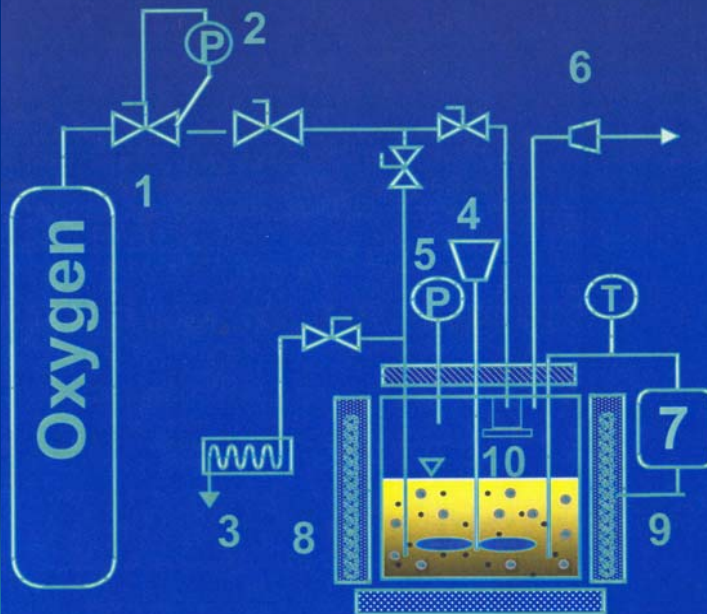
# Environmental Applications.

- Ce: MnO<sub>x</sub>/CNT's
- Degradation of Organic Industrial Pollutants (Nano Catalytic Wet Oxidation Technology)



# The Technology

## EXPERIMENTAL



- 1- Oxygen cylinder
- 2- Pressure regulator
- 3- Liquid sampling
- 4- Magnet drive
- 5- Pressure gauge
- 6- Relief valve
- 7- Temperature controller
- 8- Slurry reactor
- 9- Heating jacket
- 10- Reagent injection device

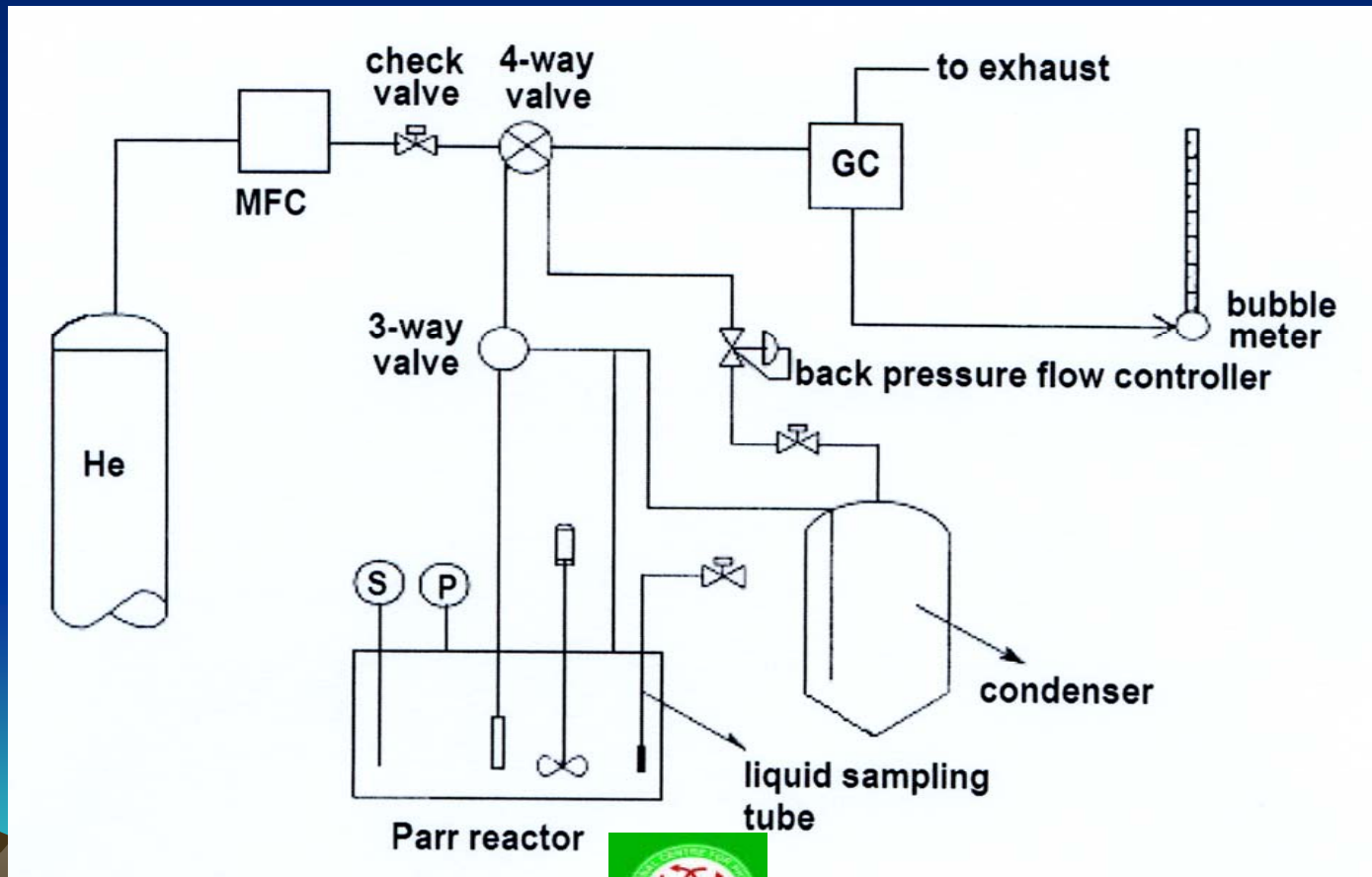


# Petrochemical Industries

- Ni:Cu/CNT's
- Reduction of Sulfur by 30-40% in Petroleum Products (diesel Fuel).
- Desulphurization Process



# The Technology



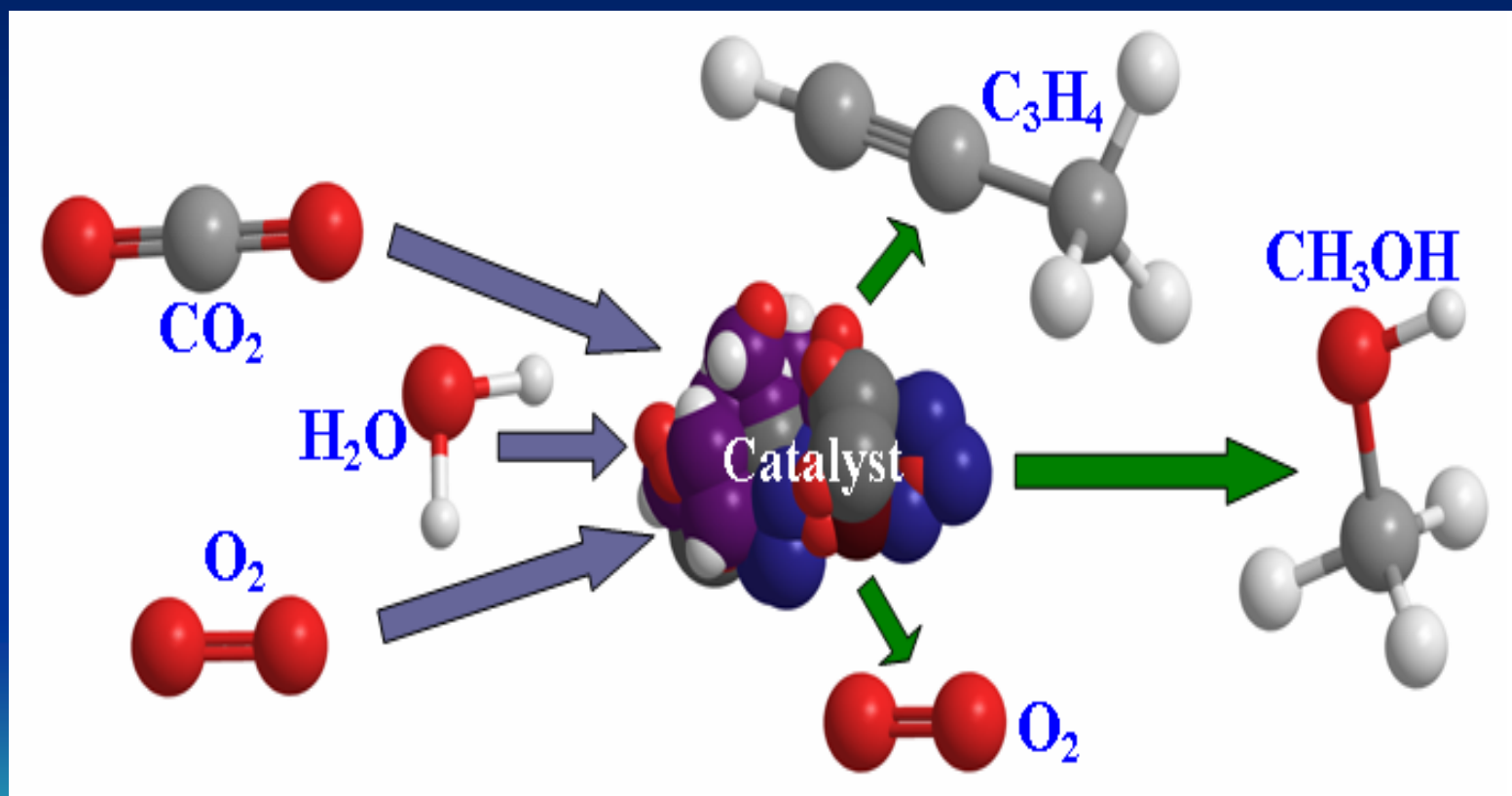
# Alternate Energy

US Patent No. 11751026, 2007.

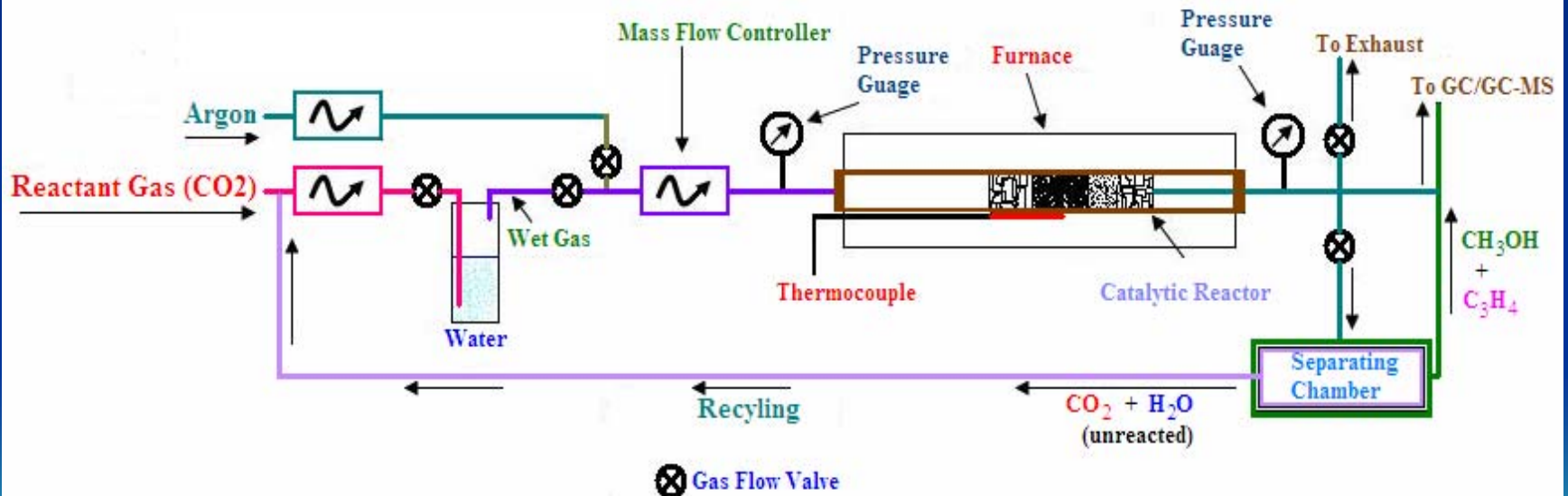
- Ru:Mn:Co/CNT's
- Conversion of CO/CO<sub>2</sub> into hydrogen/Alcohol (21<sup>st</sup> Century Technology).



# The Reaction Chemistry

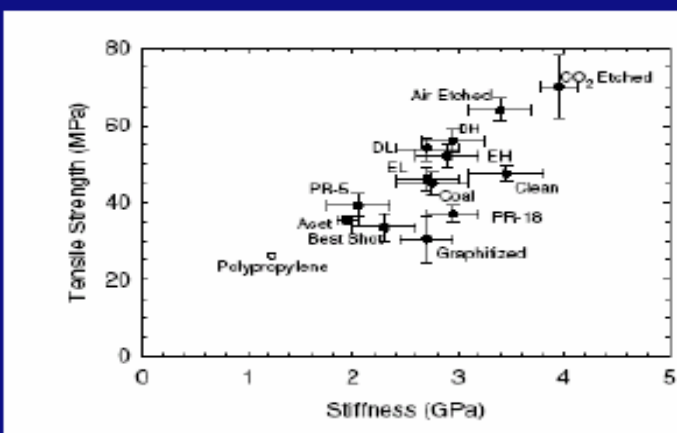
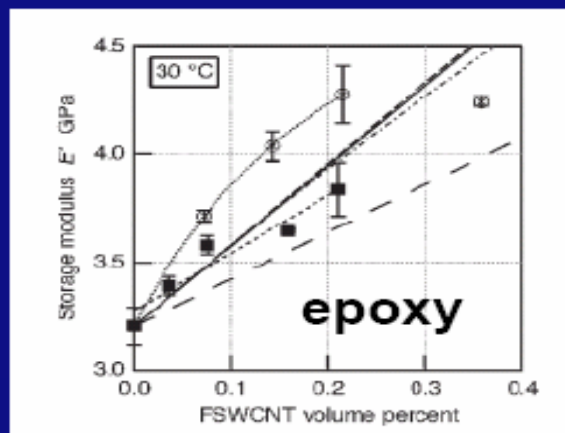
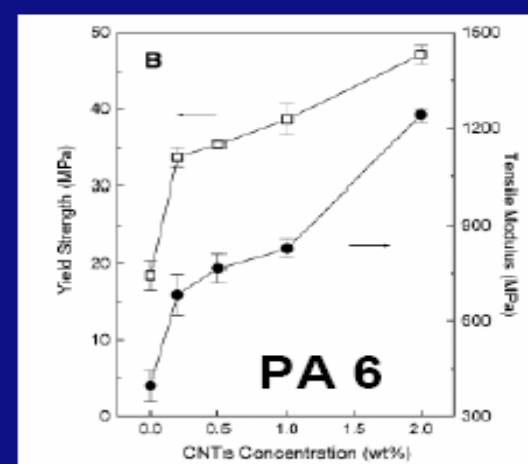
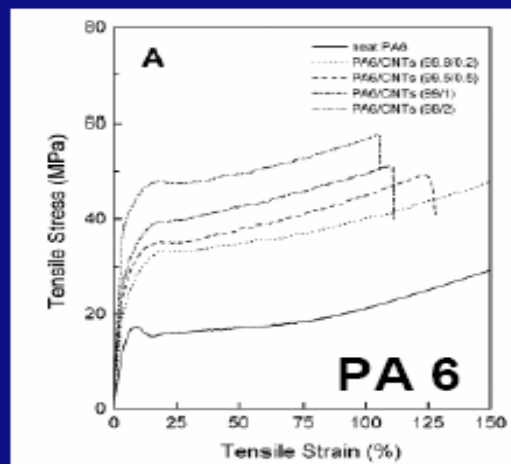
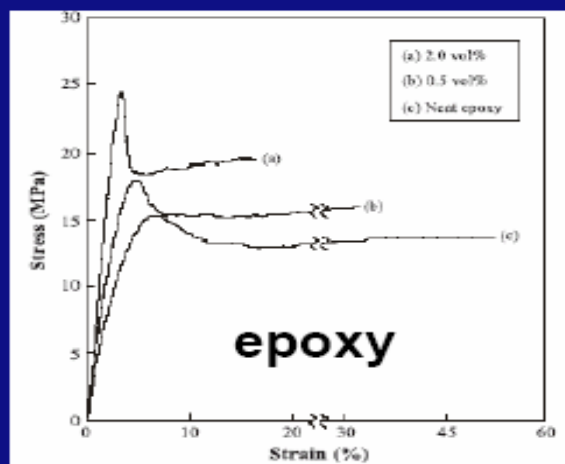


# The Technology



# Polymer CNT Composites

## Mechanical Reinforcement



iPP



# Gold Nano Particles



Gold  
Bulk

Au-539  
35nm

Au-534  
20nm

Au-532  
16nm

Au-527  
7nm



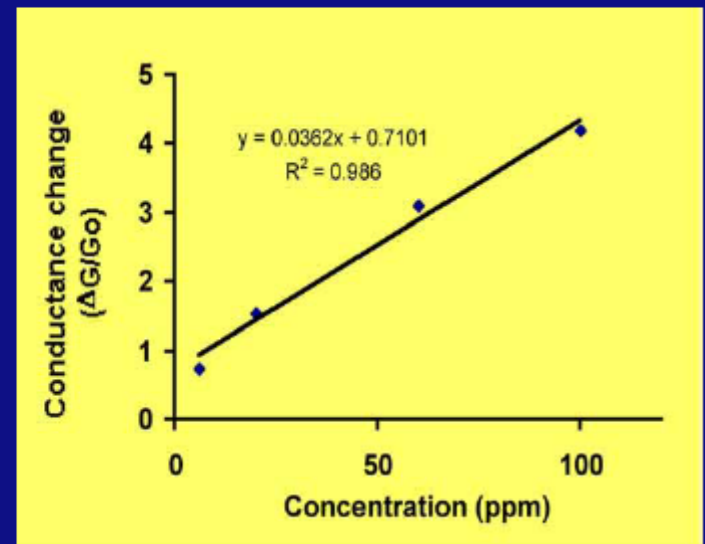
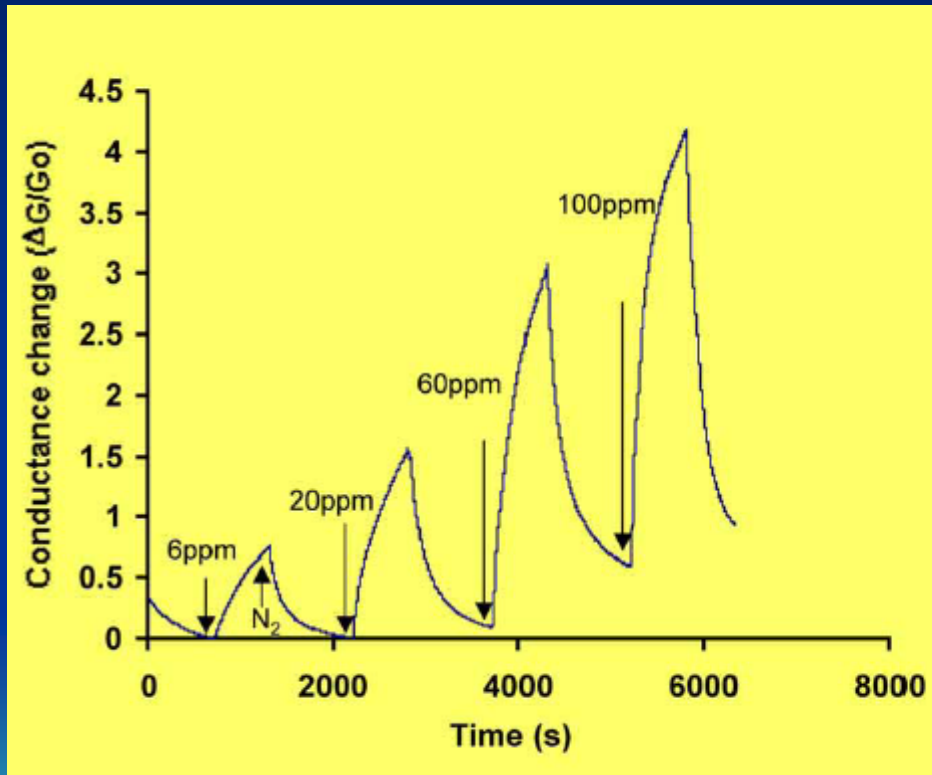
# Biomedical Applications

- Au/CNT's
  - Anticancer Treatment.
- As Chemical Sensors:
  - 3 ml of Au Colloid particles + 3 ml of water
  - 5-10 drops 1M NaCl (Red solution)
  - 5-10 drops 1M sucrose (Blue Solution)
- \* Direct measurements of UV range.





# The Chemical Sensor Response Sugar Level in Blood



# Au/CNTs as alternate energy source.

Catalyst	Reactants	MS Peaks (Strip gas after 3 hours)	Possible Products
Au(3%)/CNTs	CO <sub>2</sub> + H <sub>2</sub> O	46 (30%) 16 (15%) 14(7%) Balance (Unreacted CO <sub>2</sub> +H <sub>2</sub> O)	C <sub>2</sub> H <sub>5</sub> OH C <sub>2</sub> H <sub>3</sub> CH <sub>2</sub>



# Energy/Electronic Applications

## US Patent No.11/852294

- Ag/CNT's
- Conversion of Ethylene to Ethylene Oxide for Polymer industries
- Present Technology, % Conversion = 57%
- Our Technology, % Conversion= 70%



# For Electronic Applications

- Cell Phones : Present Technology,  
Au/Ni (Cyanide Based Process)

Our Technology = Ag/CNTs (Non Cyanide Process).

25% More efficient than present material.



# Agriculture Applications, Ag/CNT'S spray on Bugs.



# For Food Industries

## US Patent No. 11/766244

- Present Technology = 25% Ni/SiO<sub>2</sub>
  - Saturated Fats in Edible Food Products = 40-70 ppm (C18-0)
  - Temperature = 160 °C
- **Our Technology 15%Ni/CNTs**
- **Temperature of Reaction = 140 °C**
- Saturated Fats = 25 ppm. (C18-0)



# Concluding Remarks

- A new World awaits our exploration.
- Things act differently in this world, but that is its attraction.
- It is a world of small things and of complex things.
- When we understand them and control them, they will have an enormous impact in our lives.

