Conceptual Design of Continuous Processes for Carbon Nanotubes

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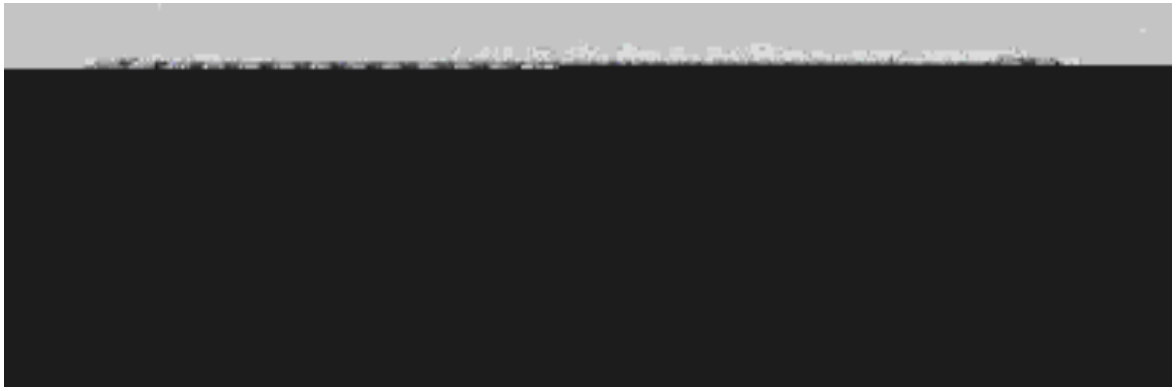
- Discovered by Iijima and co-workers in 1991

- CNT structures consist of carbon filaments with a small diameter (nm) and a large length (!m)

- A molecular model of a single wall carbon nanotube



- High Aspect Ratio Structures

- High Mechanical Strength: Tensile Strength (60 GPa) and Young Modulus (1 – 5 TPa)

- High Electrical Conductivity (typically 10^{-6} ohm m)

- High Thermal Conductivity (1750 – 5800 W/mK)

- High Current Density (10^{7} – 10^{9} A/cm^{2})

- Chemical Stability: (not attacked by strong acids/alkali)

- Ideal substitutes to carbon fibers as reinforcements in high strength, low weight and high performance composites

- Application in aerospace construction

Diameter	!m	nm
Strength	Low	High
Stiffness	Low	High
Density	High	Low
Conductivity	Low	High

Carbon Source	Graphite	Graphite	Hydrocarbon, CO
Energy Source	Electricity	Laser	Plasma, Furnace
Growth Temp	2500 – 3000 ^{o} C	1,200 ^{o} C	750 – 1100 ^{o} C
Yield	30 % by weight	Up to 70 %	20 % - 100 %
Scalability	Non – scalable	Non – scalable	NoET(NoE≠0 scalable)TjE

	CNT-PFR Process	CNT-FBR Process
Feed Preparation	- Mixer, Heater - Gas Compressor	- Mixer/Heater - Gas Compressor
Reaction	- Flow Reactor - Heat Exchangers	- Fluidized Bed - Heat Exchangers
Purification	- Filters - Oxidizer - Drier/Annealer - Centrifuge	- Filters - Flotation Column - Drier/Annealer - Cyclone Separator
CO Recycle	- Gas Absorber - Gas Stripper	- Gas Absorber - Gas Stripper

Reactants, Product and Emissions

Feed	kg/hr	Other	kg/hr	Product	kg/hr	Emissions	kg/hr
CO	2,637	O_2	253	CNT	595	$FeCl_2$	0.07
$Fe(CO_5)$	627	H_2O	255			CO_2	2,666
						Fe_2O_3	256
						H_2O	255
Total Mass Flow		3,772 kg/hr		Total Mass Flow		3,772 kg/hr	

Energy Requirements

Steam	Natural Gas	Electricity
12,000 kg/hr	486 kg/hr	1,056 kW

Reactants, Product and Emission

Feed	kg/hr	Others	kg/hr	Product	kg/hr	Emissions	kg/hr
CO	3,471	O_2					

Production Rate	5,000,000 kg/yr	5,000,000 kg/yr
Total Plant Cost	$4.6 million	$4.4 million
Total Product Cost	$186 million	$124 million
Market Price of Carbon Fiber	$90 per kg	$90 per kg
Annual Revenue	$450 million