Project Report

On

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***Abstract*—This paper mainly focuses on the application of nano-carbon tubes as a source of power generation. Due to its nanostructure, it can employed for power production via thermionic waves, substitute for solar cell and in Li-ion batteries. It also provides space for future research.**

Keywords*: *Carbon NanoTube (CNT), Chemical Vapour Deposition (CVD), Single-Walled Carbon NanoTube (SWCNT), Multi-Walled Carbon NanoTube (MWCNT)

I. INTRODUCTION

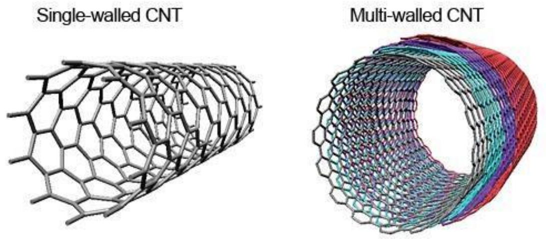
Since their discovery by Sumio Iijima in 1991, nano-carbon tubes have opened up a new area for research and development. Carbon nano-tube can be defined as rolled up graphene sheets. CNTs possess a combination of unique physical and chemical properties that make them potentially useful in many applications in nanotechnology, optics, electronics etc. they exhibit extra-ordinary strength and unique electrical properties, and are efficient conductors of heat.

Production of electricity via CNTs by the phenomenon of discharging of powerful electrical waves due to electron entrainment uncovered the immense potential of CNTs as a clean and green energy source. They can also be employed to harness solar energy.

Collectively saying, CNT has a potential to act as an ultra small and efficient source of energy generation.

II. CARBON NANO-TUBES

Carbon is a non-metallic, tetravalent chemical atom which has a unique property of forming allotropes and isotopes. Carbon nanotubes are allotropes of carbon with a nanostructure that can have a length-to-diameter ratio upto 132,000,000:1. We can say that CNT is a one-dimensional wire or a seamless cylinder with diameter of order of a few nanometres made by rolling a sheet of graphene which is a one-atom thick sheet of carbon with two-dimensional honeycomb structure. The chemical bonding of nanotubes is composed entirely of sp^2 bonds, similar to graphite. *A. Types Of Nanotubes:*



Single-Walled Carbon Nanotubes (SWCNTs): These can be conceptualised by wrapping a single graphene sheet into a seamless cylinder.

Multi-Walled Carbon Nanotubes (MWCNTs): These can be considered to be a coaxial assembly of cylinders of SWCNT, one within another; the separation between tubes is about 3.4Å. *B. Structure Of CNTs:*

Nanotubes are cylindrical structures based on the hexagonal lattice of carbon atoms. Three types of nanotubes are possible called Armchair, Zig-Zag and Chiral, depending on how the graphene sheet is “rolled up”, represented by a pair of indices (n, m) called the Chiral Vector.

C. Methods Of Production Of CNTs:

Carbon Arc Discharge Method: It creates CNTs through arc vaporisation of two graphite rods placed end to end separated by 2mm in an enclosure usually filled with inert gas at low pressure. The anode is consumed in a cigar like deposit forms on the cathode. The outer shell of this deposit is grey and hard with black soft inner core that contains MWCNTs. SWCNTs are produced with mixed metal catalyst inserted at anode.

Laser Method: In this setup flow tube is heated to 1200 °C by a tube furnace then laser pulse enters the tube & strike a target of a mixture of graphite and metal catalyst such as Co and Ni. SWCNTs condense from laser vaporization plume and are deposited on a collector outside furnace zone.

Chemical Vapour Deposition: Chemical vapour deposition is a technique whereby gaseous reactants can be deposited on to a substrate. Pyrolysis of hydrocarbons in the presence of Ni, Co, Fe metal catalyst can generate MWCNT and SWCNT. MWCNTs are produced at lower temperature (300 °C-800 °C) in an inert atmosphere where as SWCNTs at higher temperature (600 °C-1150 °C).

Some of the other Methods are:

1. *Ball Milling.*
2. *Electrolysis. D.*

Properties:

Electrical Properties: Because of the symmetry and unique electronic structure of graphene, the structure of nanotubes strongly affects its electrical properties. For a given (n, m) nanotube, if n=m, the nanotube is metallic, if n=m is a multiple of 3, then the nanotube is semiconducting with a very small band gap, otherwise the nanotubes is a moderate semiconductor. Metallic nanotubes can carry an electrical current density of 4 x10^9 A/cm^2, which is approximately 1,000 times greater than that of metals like copper. The band gap of SWCNTs varies from 0 to 2 eV, whereas MWCNTs are zero-gap metal. MWCNTs with inter-connected inner shells show superconductivity with a relatively high transition temperature T_c =12K.

Thermal Properties: All nanotubes are expected to be very good thermal conductors along the tube, exhibiting a property known as “ballistic conduction”, but insulators laterally to the tube axis.
SWCNTs have a room temperature thermal conductivity along its axis of about 3500$Wm^{-1}k^{-1}$. Compare to copper which transmits 385$Wm^{-1}k^{-1}$. The temperature stability of CNTs is estimated to be upto 2800 °C in vacuum and about 750°C in air.

III. POWER GENERATION USING CNTs

A. Thermionic emitters:

Carbon nanotubes are expected to be very good thermal conductors, by virtue of their property of ballistic conduction. Ballistic conduction or ballistic transport refers to the transport of electrons with negligible electrical resistivity due to scattering. It is the unimpeded flow of energy carrying particles i.e. charge over relatively long distances in a material. CNTs are also eligible for possible thermionic emissions due to their potentially low work function, their ability to be produced in aligned in arrays and their nanoscale tip geometry based on their diameters.

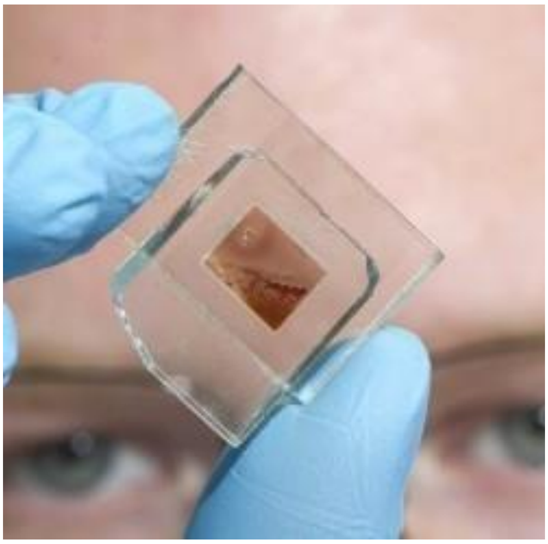
Thermionic emission is a process whereby an increase in temperature will promote electron tunnelling through a micro scale vacuum gap from a low work function emitter to an appropriate collector [1]. Testing of various configurations for thermionic emitters is done under following heads- application of purified CNT to metal retainer, CNT grown directly on metal retainer by CVD and carbon nanotubes incorporated into matrix and then applied to metal retainer. The factors which may affect the result are- carbon nanotube orientation (aligned or randomly arranged) and ohmic contact to the metal retainer.

The above described property of CNTs to produce thermionic waves and ballistic conduction is used to generate power by coating thermally and electrically conducting CNT by a layer of reactive fuel. The reactive fuel has the property of producing heat by decomposition. When the fuel is ignited at one end of the CNT by means of a laser beam or a high voltage spark, a fast moving thermal wave is generated which travels along the length of the CNT, as shown in figure. From the fuel, heat goes into the CNT, where it travels thousands times faster than their speed in the fuel itself.

Due to the nanostructure of CNT, heat wave is guided along the structure with a speed 10,000 times faster than this chemical reaction, at a temperature of 300 Kelvin. This heat, in turn, pushes out the electrons from the CNT which produces electric current. One remarkable thing associated with this discovery is that the amount of power released is much higher than the prediction of standard thermoelectric calculations. When they are heated up, they are exhibiting features which are not shown by any ordinary semiconductor devices.

B. Polymeric Solar Cells:

Single wall carbon nanotubes have recently been incorporated into poly(3octylthiophene) (P3OT) to promote exciton dissociation and improve electron transport in a polymeric solar cell [1]. Conducting polymers like P3OT has a promising application in photovoltaic community because they produce excitons, which are quantum-mechanical particles of bound electron hole pairs, on optical absorption. When polymer is placed in a structured device with a suitable dopant to promote dissociation of exciton, hole conduction proceeds through polymer, leading to photocurrent. The use of SWCNTs in these polymers is a good dopant choice because electron affinity is higher for SWCNT as compared to P3OT and the electron transport in a metallic SWCNT is of a ballistic conductor. Also, the high aspect ratio of the SWCNTs leads to low doping level which is necessary to achieve high electrical conductivity, while the mechanical properties are retained which are beneficial to flexible polymeric device.



Thus, CNTs serve as an alternative for costly silicon for window based collection of solar energy. The concept prototype employs two sheets of electrically conductive glass with a layer of SWCNT sandwiched between them. Due to its compact size, it remains transparent, thus allowing light to pass through it and also collects energy from the sun. When the sunlight falls on the cells, electrons are generated in the CNT. Due to the flow of electrons, it can be used to power electrical and electronic devices. It has also been demonstrated that CNT layer can be spraycoated on the glass, thus allowing larger area of glass substrate to be under function.

C. *Proton Exchange Membrane Fuel Cells:*

Proton Exchange Membrane Fuel Cells (PEMFC) is a potential candidate for an environmentally benign and efficient electric power generation technology. In PEMFC, Platinum is used as a catalyst [2]. CNTs are used in fuel cells because they have the potential for significant enhancement in electrical conductivity and the support to the metal catalyst. The limiting factors of device performance which can be affected through CNT are enhanced oxidation of hydrogen gas, electron transport from anode to cathode and reduction of oxygen gas. The enhancement in electrical conductivity is achieved by using highly conductive SWCNT and MWCNT which results in the improvement of power output.

D. *Lithium-ion Batteries:*

Lithium-ion batteries work on the efficient cycling of Li^+ between the cathode and anode where rapid charging, high ionic storage and slow discharge constitute the ideal characteristics of the device. CNT can be introduced into the device since the anode has been conventionally constructed from graphite [1].Due to higher electrical conductivity and specific surface area as compared to graphite, addition of CNTs may improve the battery capacity. It has also been found experimentally that if CNT is used for one of the electrodes of the battery, the amount of power delivered increases by ten times because the CNTs store a large number of Li^+ ions due to which they act as the positive electrode in lithium batteries. In addition to high power output, there was no significant change in material's property, even after thousand cycles of charging and discharging.

IV. APPLICATIONS AND FUTURE SCOPE

The use of CNTs as an alternative for silicon based solar cells for harnessing solar energy can be employed in high skyscrapers and structures. Since they are transparent and allow light to pass through them, therefore they can be window-based and are useful for those structures where there is space constraint for an additional setup of energy collecting units like solar panels. Since they are not as efficient as their conventional sources of harnessing solar energy, therefore much research and development is needed in this respect but they do provide a promising application in energy generation in the upcoming future.

The CNTs are also employed in generating significant amount of power as compared to their size by the flow of thermopower waves through the tube. It has been suggested that these specially coated carbon nanotubes can be used to power ultra-small electronic devices and sensors. When the fuel coated CNT is ignited by the heat pulse, the heat wave travels along the tube and after the heat wave has passed, the CNT remains hot for several hundred milliseconds. The large temperature difference across the nanotube generated by the reaction wave to produce electric pulse is the driving concept of thermopower wave generator. The electricity produced could be used to power high-load micro devices such as long distance radio transmitters.

Combination of CNT, bucky balls and polymers can be used to produce inexpensive solar cells which can be formed by simply painting a surface.

Windmill blades can be made by an epoxy containing CNT. The strength and the low weight allow production of larger blades which, in turn increases the amount of energy generated by the windmill.

V. CONCLUSION

Carbon nanotubes have been explored to have various advantages over conventional sources of energy production. Being an entity of nanoscale structure, it promises to find an application in microelectronic devices. It can be employed to work as a successful technology in those sectors where efficiency and space are the major concerns. Due to its unique electrical and thermal properties, it has found application in fuel cells, solar cells and power generators. Carbon nanotubes are being manufactured in large quantities at reasonable prices, which opens up the possibility for cost effective production of nanotube based devices. It can be considered as a cleaner, more efficient and reliable source of power generation. Yet, additional research and development is needed to bring nano carbon tubes on a larger scale so that it may revolutionise the present energy scenario.

VI. REFERENCES

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