A

Seminar report

On

Diamond Chip

Submitted in partial fulfillment of the requirement for the award of degree of Bachelor of Technology in CSE

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Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a project report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

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Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

Preface

I have made this report file on the topic **Diamond Chip;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

CONTENTS

INTRODUCTION

Electronics without silicon is unbelievable, but it will come true with the evolution of Diamond or Carbon chip. Now a day we are using silicon for the manufacturing of Electronic Chip's. It has many disadvantages when it is used in power electronic applications, such as bulk in size, slow operating speed etc. Carbon, Silicon and Germanium are belonging to the same group in the periodic table. They have four valance electrons in their outer shell.

Pure Silicon and Germanium are semiconductors in normal temperature. So in the earlier days they are used widely for the manufacturing of electronic components. But later it is found that Germanium has many disadvantages
Compared to silicon, such as large reverse current, less stability towards temperature etc so in the industry focused in developing electronic components using silicon wafers

Now research people found that Carbon is more advantages than Silicon. By using carbon as the manufacturing material, we can achieve smaller, faster and stronger chips. They are succeeded in making smaller prototypes of Carbon chip. They invented a major component using carbon that is "CARBON NANOTUBE", which is widely used in most modern microprocessors and it will be a major component in the Diamond chip

5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674
13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761
31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160

WHAT IS DIAMOND CHIP?

In single definition, Diamond Chip or carbon Chip is an electronic chip manufactured on a Diamond structural Carbon wafer, or it can be also defined as the electronic component manufactured using carbon as the wafer.

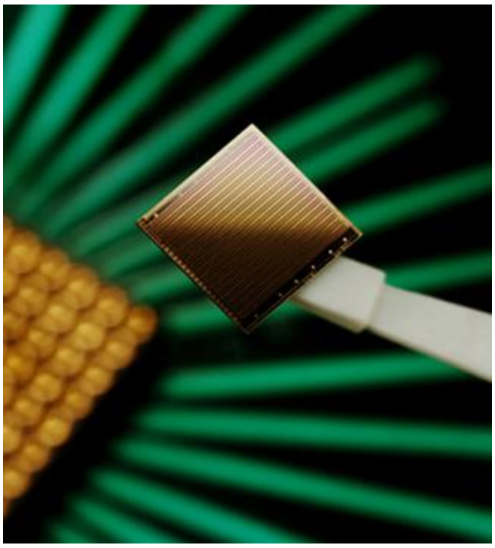
The major component using carbon is (cnt) Carbon Nanotube. Carbon Nanotube is a nano dimensional made by using carbon. It has many unique properties.

HOW IS IT POSSIBLE?

Pure Diamond structural carbon is non-conducting in nature. In order to make it conducting we have to perform doping process. We are using Boron as the p-type doping Agent and the Nitrogen as the n-type doping agent. The doping process is similar to that in the case of Silicon chip manufacturing. But this process will take more time compared with that of silicon because it is very difficult to diffuse through strongly bonded diamond structure. CNT (Carbon Nanotube) is already a semi conductor.

INVENTION:

A diamond semiconductor operates on 81GHz frequency, and is more than twice the speed of earlier devices. This particular chip was first developed by Nippon Telegraph & Telephone Corporation(NTT), Japan.



SOME FACTS:

Unlike silicon & germanium, pure carbon is not a semiconductor in room temperature. Therefore, in order to make it a semiconductor, we use some of the allotropes of carbon.

GRAPHENE is one of the allotropes of carbon which acts as semiconductor. Thus, NANOTUBES, which are derived from GRAPHENE, will also act as semiconductor.

GRAPHENE:

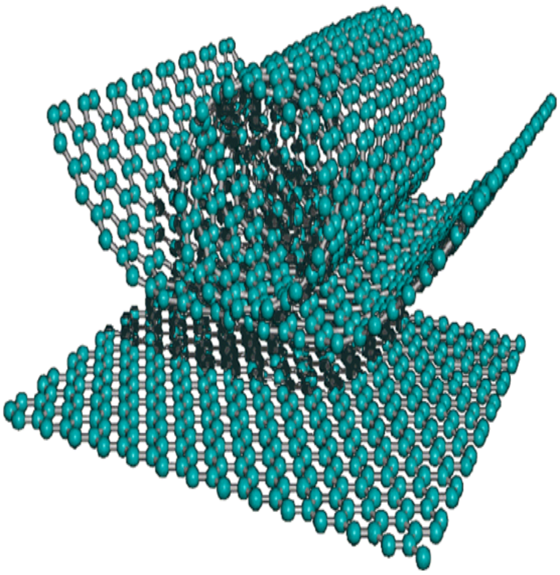
Graphene is an allotrope of carbon, whose structure is one-atom-thick planar sheet of sp2-bonded carbon atoms that are densely packed in a honeycomb crystal lattice.

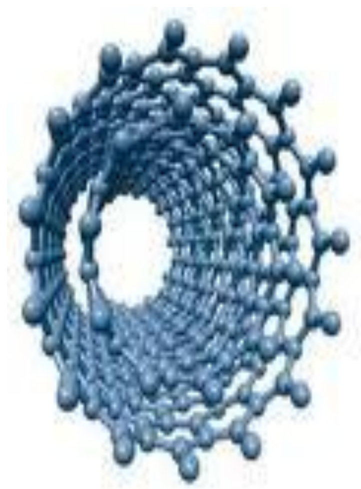
➢ PROPERTIES OF GRAPHENE:

a. Graphene has remarkably high electron mobility at room temperature.
b. Graphene structure can be doped easily by using chemical dopants and can be converted back to its undoped form just by heating slowly in vacuum.

CARBON NANOTUBES (CNT):

Folding the Graphene sheet into a tube like structure produces CARBON NANOTUBES. It is a nanosize cylinder of carbon atoms.They are made of one or several concentric walls in which carbon atoms are arranged in hexagonal pattern, having a less than one nanometer diameter.





HOW TO MAKE CARBON NANOTUBES?

In a vacuum chamber, the researchers vaporized the metals tantalum and iron, which settled in layers on a silicon wafer. Then they placed the coated wafer at one end of a quartz tube, which was inserted into a furnace. At the wafer's end of the tube, the furnace temperature was 475 degrees C; but at the opposite end, the temperature varied. The researchers pumped ethylene gas into the tube from the end opposite the wafer. When the temperature at that end approached 800 degrees, the ethylene decomposed, and the iron on the wafer catalyzed the formation of carbon nanotubes.

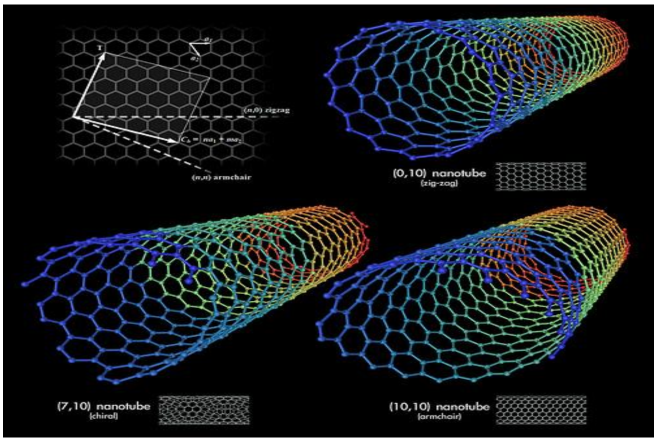
TYPES OF CARBON NANOTUBES(CNT):

Carbon nanotubes are primarily of two types:

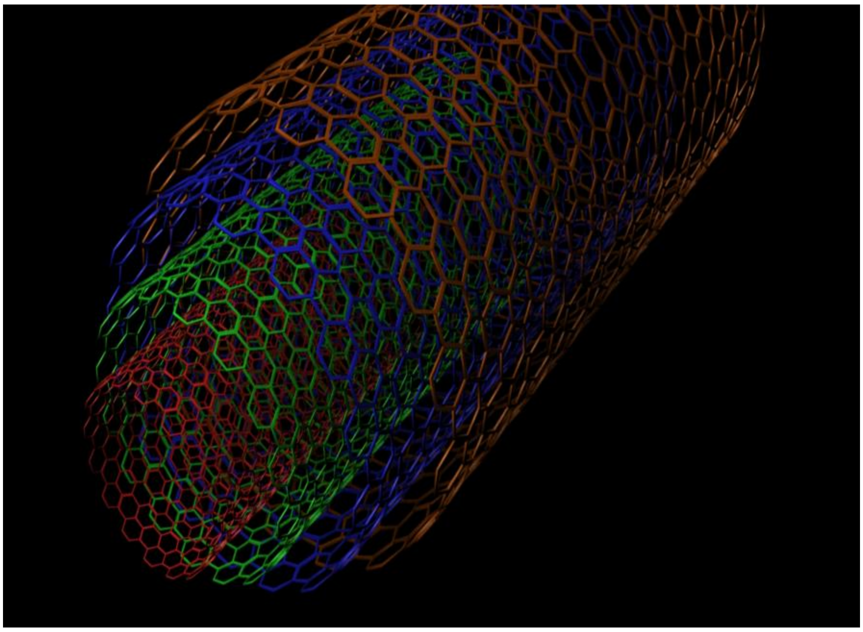
1. Single Walled Nanotubes (SWNT):

   Single walled nanotubes are of 3 types as follows:

   a. Zigzag
   b. Chiral
   c. Armchair



2. Multi Walled Nanotubes (MWNT)

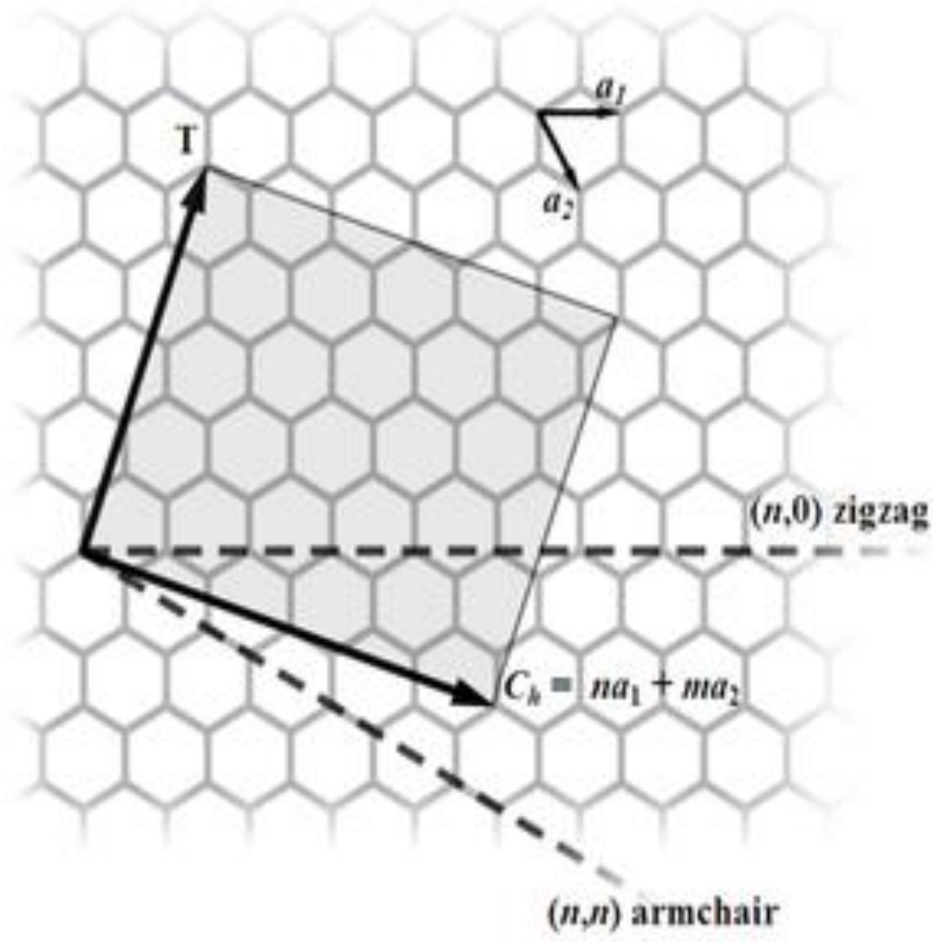


HOW NANOTUBES ACTS AS SEMICONDUCTOR

For a given (n,m) nanotube, where n and m are integer variables.

If n=m then nanotube is metallic;

If n-m is multiple of 3 then the nanotube is a semiconductor.



Thus all armchair nanotubes (n=m), are metallic;

And some zigzag and chiral type nanotubes are semiconducting.

e.g.:

Zig-Zag: (3,0); (6,0) etc.

Chiral: (5,2); (7,1) etc.

WHY THE NAME DIAMOND CHIP?

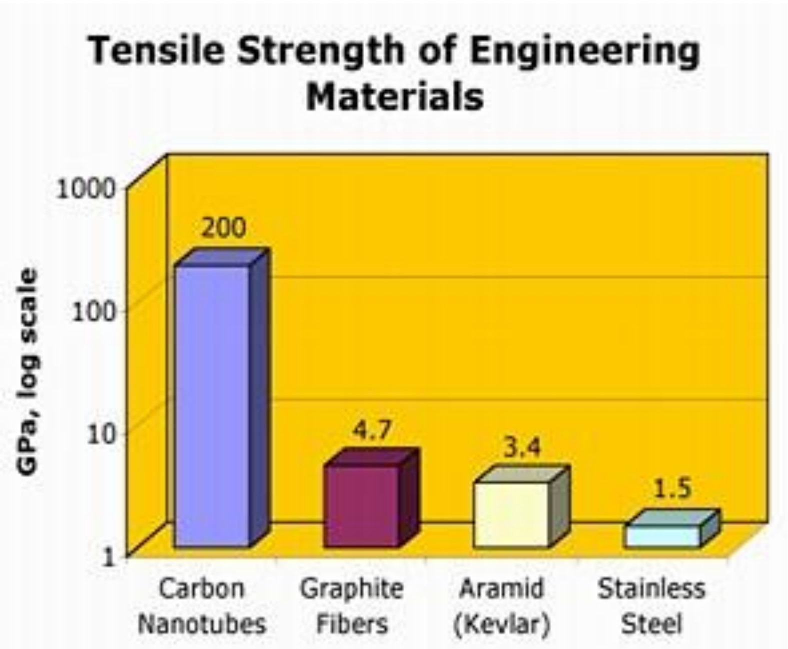
Graphene is sp2 bondage allotropic form of carbon, similar to carbon nanotube (CNT).

Lonsdaleite is sp3 bondage allotropic form of carbon, i.e. 3-dimentional CNT. Crystal structure of Lonsdaleite looks exactly like diamond that is why the name DIAMOND CHIP is given.

Properties of CARBON NANOTUBE:

1. Strength :

Carbon nanotubes are the strongest and stiffest materials yet discovered in terms of tensile strength and elastic modulus respectively. This strength results from the covalent sp^2 bonds formed between the individual carbon atoms. In 2000, a multi-walled carbon nanotube was tested to have a tensile strength of 63 gigapascal.



2. Hardness :

Standard single walled carbon nanotubes can withstand a pressure up to 24GPa without deformation. They then undergo a transformation to super hard phase nanotubes. Maximum pressures measured using current experimental techniques are around 55GPa. However, these new super hard phase nanotubes collapse at an even higher, albeit unknown, pressure.

The bulk modulus of super hard phase nanotubes is 462 to 546 GPa, even higher than that of diamond (420 GPa for single diamond crystal).

- ## 3. Kinetic :

Multi-walled nanotubes are multiple concentric nanotubes precisely nested within one another. These exhibit a striking telescoping property whereby an inner nanotube core may slide, almost without friction, within its outer nanotube shell, thus creating an atomically perfect linear or rotational bearing. This is one of the first true examples of molecular nanotechnology, the precise positioning of atoms to create useful machines. This property has been utilized to create the world's smallest rotational motor. Future applications such as a gigahertz mechanical oscillator are also envisaged.

- ## 4. Electrical :

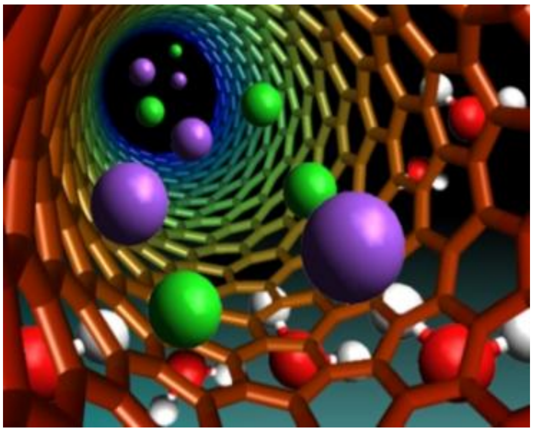
High electrical conductivity (10^{-6} ohm), and for well crystallized nanotubes ballistic transport is observed

Being covalently bonded, as electrical conductors they do not suffer from electro migration or atomic diffusion and thus can carry high current densities (10^{7} -10^{9} A/cm^{2}), which is 1000 times that of copper.

Both metal and semiconductor can be formed.

- **5 Optical**
- **6 Thermal :**

All nanotubes are expected to be very good thermal conductors along the tube, exhibiting a property known as "ballistic conduction", but good insulators laterally to the tube axis. Measurements show that a SWNT has a room-temperature thermal conductivity along its axis of about 3500 $W \cdot m^{-1} \cdot K^{-1}$; compare this to copper, a metal well-known for its good thermal conductivity, which transmits 385 $W \cdot m^{-1} \cdot K^{-1}$. A SWNT has a room-temperature thermal conductivity across its axis (in the radial direction) of about 1.52 $W \cdot m^{-1} \cdot K^{-1}$ which is about as thermally conductive as soil. The temperature stability of carbon nanotubes is estimated to be up to 2800 °C in vacuum and about 750 °C in air.

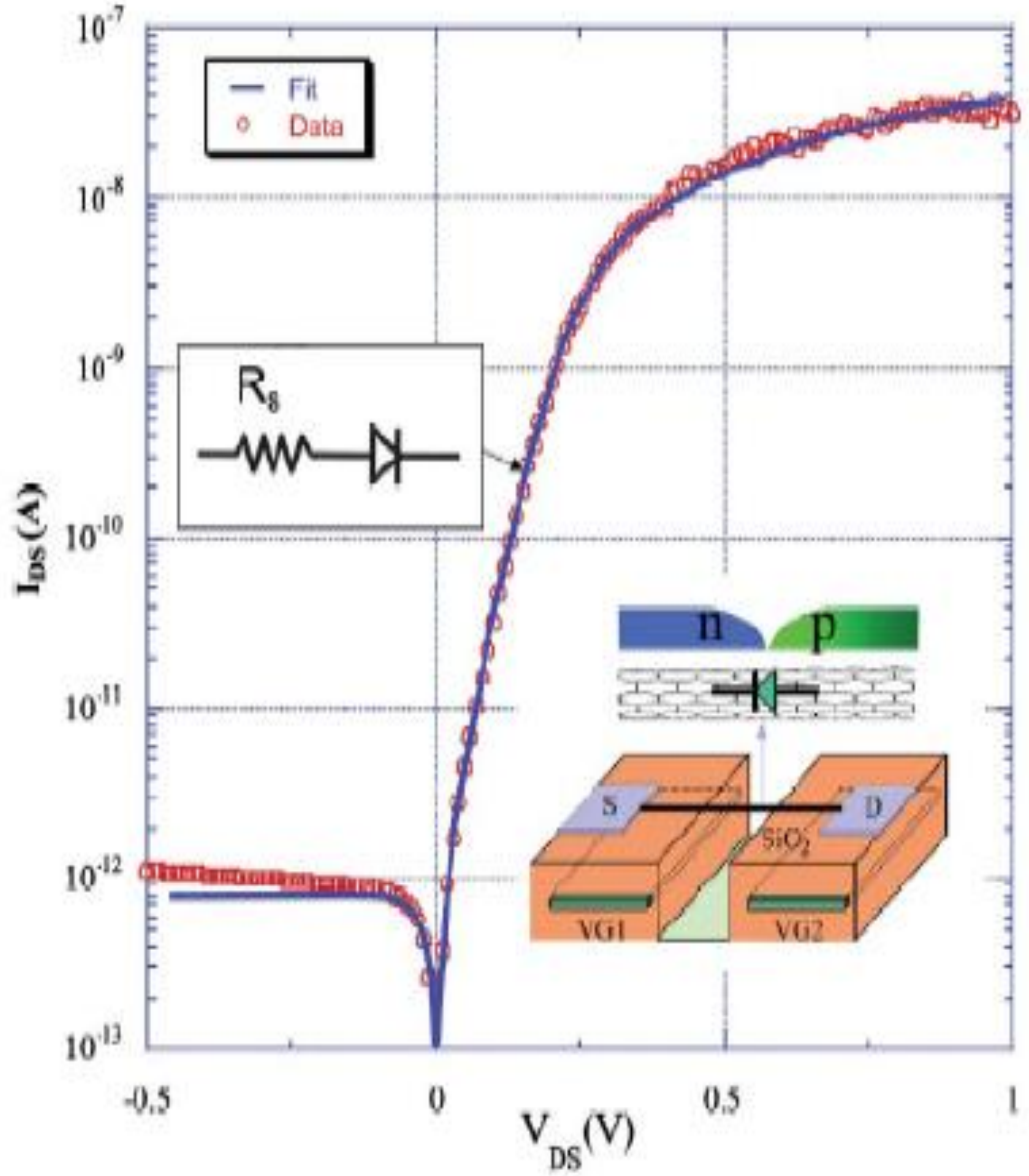


▪ 7 One-dimensional transport :

Because of the nanoscale dimensions, electrons propagate only along the tube's axis and electron transport involves many quantum effects. Because of this, carbon nanotubes are frequently referred to as “one-dimensional”.

CNT CAN FORM IDEAL DIODE:

Using an electric field to create the p and n regions instead. We placed two separate gates underneath a single-walled nanotube so that one gate coupled to one half of the nanotube and the other gated coupled to the other half. By biasing one gate with a negative voltage and the other with a positive voltage, we created a p-n junction that behaved as an almost ideal diode.


Fit
Data
R
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D
SiO2
VG1
VG2
IDS (A)
VDS (V)
-0.5
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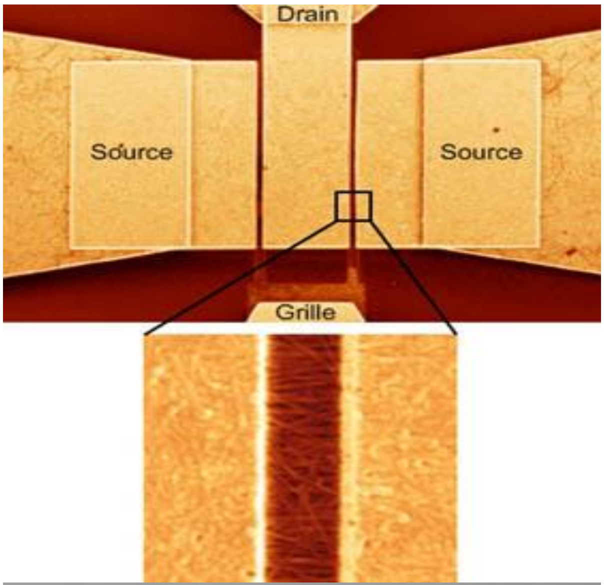
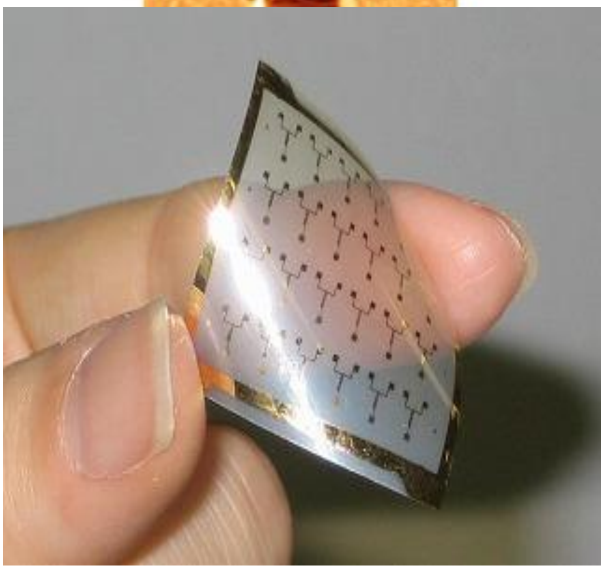
0.5
1

A BRIEF IDEA ABOUT CARBON TRANSISTORS:

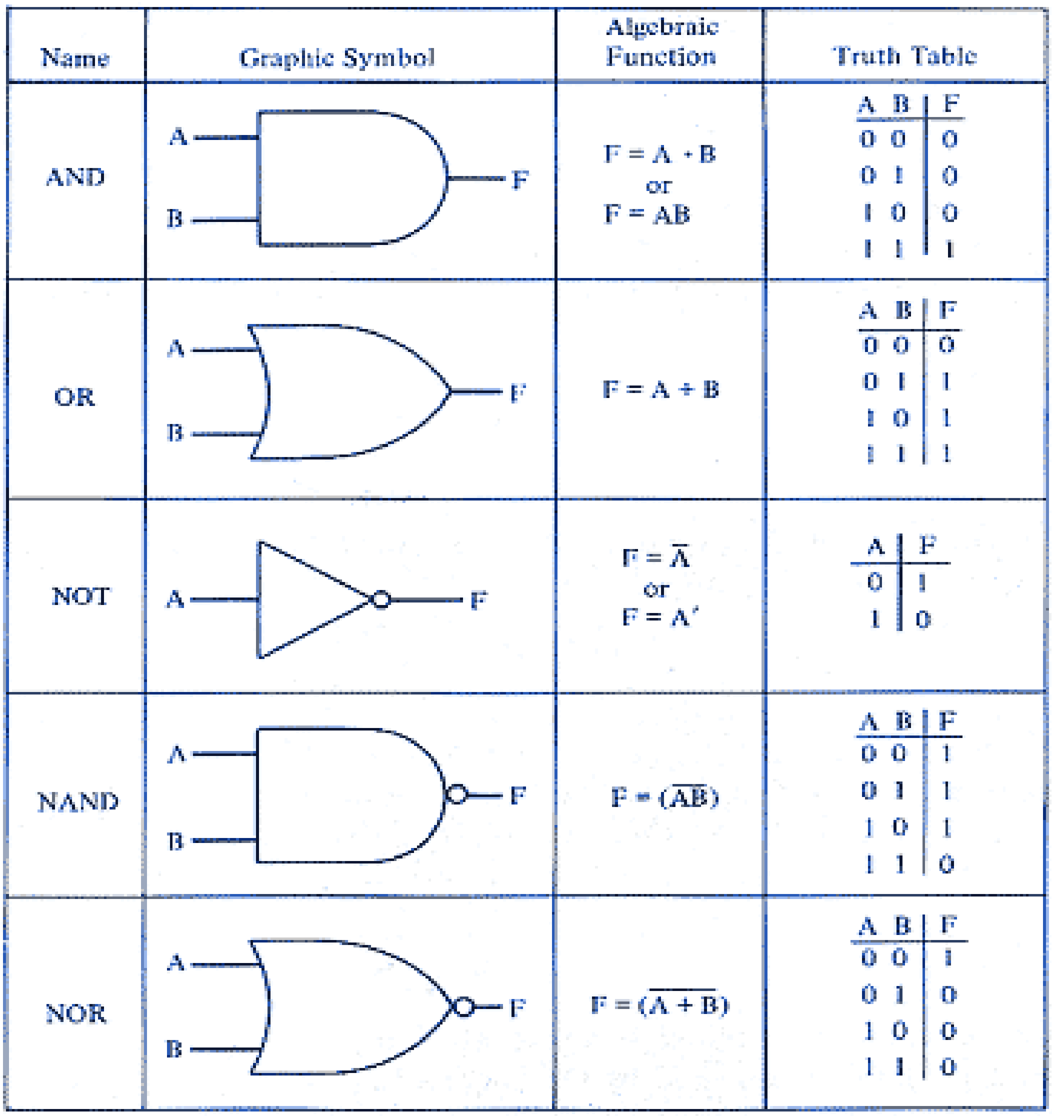
Due to the small size of carbon atoms than silicon, smaller components are possible. CNT conducts electricity faster as electrons travels through straight line without scattering. Thus, we get much stronger, faster and efficient components.





HOW NANOTUBES ARE USEFUL IN DIGITAL LOGIC?

Their simple inverter device consists of a nanotube FET and a large bias resistance: it converts a high input voltage to a low one - that is, "one" to "zero" - and vice versa. By adding an extra FET in parallel, the researchers made a NOR gate. This device needs two "zero" inputs to give a "one" output, or two "ones" to give a "zero”. Any of the standard logic gates - AND, OR, NAND and so on - can be created using different arrangements of these FETs.



Name	Graphic Symbol	Algebraic Function	Truth Table
AND	A, B → F	$F = A \cdot B$ or $F = AB$	A B | F 0 0 | 0 0 1 | 0 1 0 | 0 1 1 | 1
OR	A, B → F	$F = A + B$	A B | F 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 1
NOT	A → F	$F = \overline{A}$ or $F = A'$	A | F 0 | 1 1 | 0
NAND	A, B → F	$F = (\overline{AB})$	A B | F 0 0 | 1 0 1 | 1 1 0 | 1 1 1 | 0
NOR	A, B → F	$F = (\overline{A + B})$	A B | F 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 0

ADVANTAGES OF DIAMOND CHIP:

1 .SMALLER COMPONENTS ARE POSSIBLE:

As the size of the carbon atom is small compared with that of silicon atom, it is possible to etch very smaller lines through diamond structural carbon. We can realize a transistor whose size is one in hundredth of silicon transistor.

2 .IT WORKS AT HIGHER TEMPERATURE:

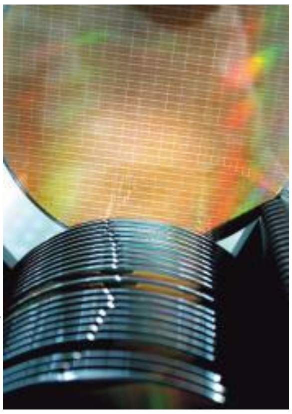
Diamond is very strongly bonded material. It can withstand higher temperatures compared with that of silicon. At very high temperature, crystal structure of the silicon will collapse. But diamond chip can function well in these elevated temperatures. Diamond is very good conductor of heat. So if there is any heat dissipation inside the chip, heat will very quickly transfer to the heat sink or other cooling mechanics.

3 .FASTER THAN SILICON CHIP:

Carbon chip works faster than silicon chip. Mobility of the electrons inside the doped diamond structural carbon is higher than that of in the silicon structure. As the size of the silicon is higher than that of carbon, the chance of collision of electrons with larger silicon atoms increases. But the carbon atom size is small, so the chance of collision decreases. So the mobility of the charge carriers is higher in doped diamond structural carbon compared with that of silicon.

4 .LARGER POWER HANDLING CAPACITY:

For power electronics application silicon is used, but it has many disadvantages such as bulk in size, slow operating speed, less efficiency, lower band gap etc at very high voltages silicon structure will collapse. Diamond has a strongly bonded crystal structure. So carbon chip can work under high power environment. It is assumed that a carbon transistor will deliver one watt of power at rate of 100 GHZ. Now days in all power electronic circuits, we are using certain circuits like relays, or MOSFET inter connection circuits (inverter circuits) for the purpose of interconnecting a low power control circuit with a high power circuit .If we are using carbon chip this inter phase is not needed. We can connect high power circuit direct to the diamond chip



Nanotechnology Applications:

Materials that exhibit different physical properties resulting from changes at the nanoscale have already opened the door to many new applications. Many of these applications are still in various stages of research, but some are already available commercially.

For example, clothing material has been integrated with nanoparticles to create stain resistant cloth. Auto manufacturers enhanced bumpers with nanocrystals, making them stronger. Color filters and colored lamps have been created by altering the optical properties of a suspension (through varying of the size and shape of the colloidal particles in the solution). Carbon nanotubes have been designed for products such as bike frames and tennis rackets to enhance strength and reduce weight.

Nanotechnology applications in areas such as :

- Information and communications,
- materials and manufacturing,

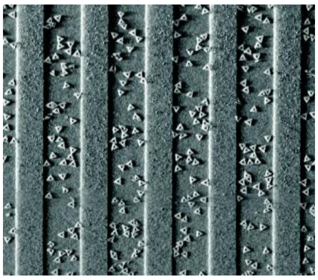
- biomedical,
- energy and environmental,
- transportation,
- Consumer goods.

Information and Communications:

Computers and processors use memory to store information and execute operations to perform desired functions. Each bit of memory holds a binary value, and multiple sets of bits combine to be interpreted as a particular instruction or piece of information. Digital devices are becoming progressively more sophisticated and smaller, requiring more compact components. Different types of memory devices introduced by nanotechnology are enabling the development of complex devices at an extremely small size.

Nanotechnology has enabled many advances in computer memory, increasing storage size, reducing power consumption, and increasing speed. These three factors will enable sophisticated computer controlled devices in the future.

***Nano-RAM* (or NRAM)** is a random access memory that uses carbon nanotubes to determine the state of the memory element, comprising an information bit. This memory is a non-volatile device meaning that its cells maintain their information regardless of whether or not power is supplied to the system (the carbon nanotubes keep their mechanical position whether or not power is supplied). NRAM (which is a proprietary computer memory technology) has been projected to be of very high density and low cost.

***Ferroelectric*-RAM (or FRAM)** is another type of non-volatile memory that takes advantage of Nano technological properties. FRAM is similar to traditional integrated circuit memory, except that the device is fabricated using a layer of ferroelectric polymer rather than a dielectric substrate. A material that exhibits Ferro electricity consists of molecules that have an innate electric polarization. Because of the natural polarization in the ferroelectric material, replacing traditional dielectric with ferroelectric material enable the FRAM memory cells to consume less power and therefore can be designed. 

A third type of memory that has been enhanced using nanotechnology is known as Millipede memory. It was designed to replace magnetic memories such as those commonly used as hard drives. The Millipede memory uses many tiny imprints in a polymer strip to record the stored information. To retrieve the memory information, the Millipede memory uses atomic force sensors that detect the nano-indentations recorded in the film. The resulting storage capacities are typically up to four times greater than those available with traditional magnetic memories. The Millipede memory is also non-volatile, and it is rewritable. In addition to its very high capacity storage, it has been designed to read and write in a parallel process, making its access times low.

Materials and Manufacturing:

DC-PECVD system in action. DC plasma (violet) improves the growth conditions for carbon nanotubes in this chemical vapor deposition chamber. A heating element (red) provides the necessary substrate temperature.

Materials and manufacturing deal with the application of knowledge relating to composition, structure and processing of materials to their properties and applications.

In the last few years there was significant increase in the development of *composite materials* with excellent properties. Composite materials are engineered materials which are made from two or more constituent materials with significantly different physical or chemical properties. Nanotechnology has emerged as a key technology used in fabrication of composite materials.

Though "top-down" fabrication methods are still used, nanotechnology has empowered a "bottom-up" approach to modify the material properties at nanoscale level.

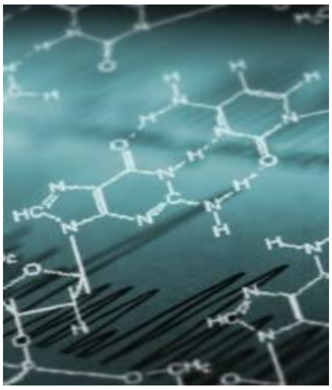
A classic ("top down") method for nanofabrication is *electron beam lithography* (EBL). In EBL a beam of electrons is scanning across a surface covered with a film (called the *resist*). The beam removes selectively either exposed or non-exposed regions of the *resist*. The result is very small structures in the *resist* that can be transferred into another material, for example for the creation of very small electronic devices. EBL can produce structures smaller than 10 nm which can be used in applications such as solar cells and other semiconductor and optoelectronics devices.

Biomedical Applications:

Nanotechnology is expected to have a significant impact on improving the quality of health care through early and reliable diagnostics of diseases, better drugs, targeted drug delivery, improved implants, and other applications.

Biosensors - using a combination of nanomaterials, novel device fabrication techniques and advances in signal processing - are being developed for early detection of several life threatening illnesses. These sensors use carbon nanotubes or silicon nanowires which can host the probe molecule that seeks to identify the signature of a particular condition or illness. Nanobiosensors using this approach are expected to be mass-produced using techniques developed by the computer chip industry.

Nanotechnology will also play an important role in therapeutics. Two areas where nanotechnology is expected to make an impact are *synthesis of improved drugs* using principles of nanotechnology, and *targeted drug delivery*. Specifically, certain families of molecules known as *dendrimers* (these are repeatedly branched molecules) are considered as candidates for effective delivery of drugs. These large polymers have a pouch-like configuration at their centers which can be used to host drugs inside the molecules that carry them to their destination.



Energy and Environmental Applications:

Skyrocketing oil prices, concerns about the environment from increasing greenhouse emissions, and the desire to save the planet from environmental disasters, have turned wide attention to alternative energy sources and to the need to increase the energy efficiency of the systems we use today.

One notable effort involves the *incandescent light bulbs* used widely in homes and offices. These bulbs, commercialized in the late 19th century, are being replaced gradually by devices that provide the same or more visible light for the same level of electrical energy input. The European Union is in the process of phasing out incandescent light bulbs in favor of more energy-efficient lighting. If every filament light bulb in the USA was replaced by a solid state lighting source, the electricity consumption in the US would be reduced by 10%, also cutting carbon emission by about 28 million tons a year.

Transportation Applications:

One of the major contributions that nanotechnology can make in the transportation sector is lighter weight and high strength composite materials ("composites") for the construction of airplanes and automobiles.

Composites are created from two or more materials with significantly different physical or chemical properties. These properties remain distinct within the finished structure. The promise of *Nano composites* is that they will be lighter and stronger than other kinds of widely used composites.

After decades of research and development, composites were first used in civil aviation when Boeing unveiled its 777 airplane in the mid 1990s. Until then, aluminum and other metals were used for airplane bodies. In the next generation of planes (e.g., the Boeing 787 Greamliner), nearly 50% of the material in use is composites.

Consumer Goods Applications:

Nanotechnology is emerging from the science laboratory into the marketplace, and is used today in the design and manufacturing of many commercial devices and systems. Among the fields affected by nanotechnology are medical and environmental applications, food production and processing, energy (storage, conversion and saving), information and communication, and improvements to textile and automotive products.

Applications of nanotechnology in *medicine* include the development of *contrast agents* for cell imaging. These agents assist in visualization of cells, and contribute to biomedical research and to medical diagnostics (detection and classification of diseases). Nanotechnology had also affected *drug delivery systems* and there are designs that call for the use of *nanorobots* to repair damage and detect abnormalities inside the human body.

Nanotechnology is being used for creating fabrics with enhanced properties such as stain, dirt and water resistance. The fabric used in these applications contains tiny nano-whiskers or fiber-like structures that are connected to a common center. The whiskers are hydrophobic - they repel water by causing it to form droplets. The droplets are larger than the spacing between whiskers, therefore remaining on top of the fabric allowing it to be brushed or wiped.

Carbon chip technology goes commercial:

Carbon--the basis of all organic compounds--appears destined to supplant silicon as the material of choice for future semiconductors. According to researchers, various structures based on the element that sits just above silicon on the Periodic Table can surpass silicon's abilities in thermal performance, frequency range and perhaps even superconductivity.

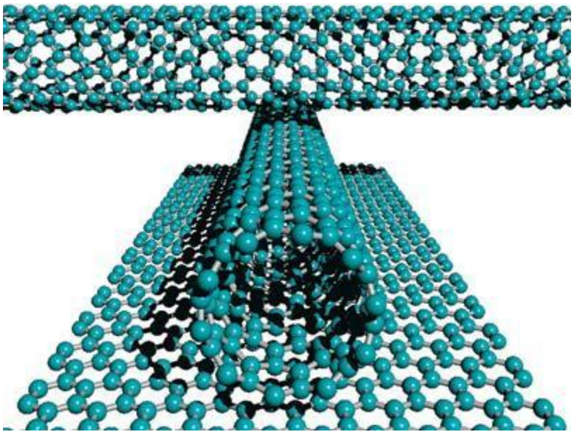
"Of the carbon technologies, diamond is probably the closest [to commercialization§] at this time, as work in diamond has been taking place for 15 years or longer," said Dean Freeman, senior analyst at Gartner Inc. "Most of the others still have a ways to go."

Three-dimensional carbon--diamond--offers 10 times the heat dissipation of silicon, according to suppliers currently hawking 40-nanometer to 15-micron diamond films on silicon wafers. Two-dimensional carbon--3-angstrom-thick monolayers called graphene--could dismantle silicon's roadblock to terahertz performance by attaining 10 times the electron mobility of silicon.

More research work on Carbon Nanotubes:

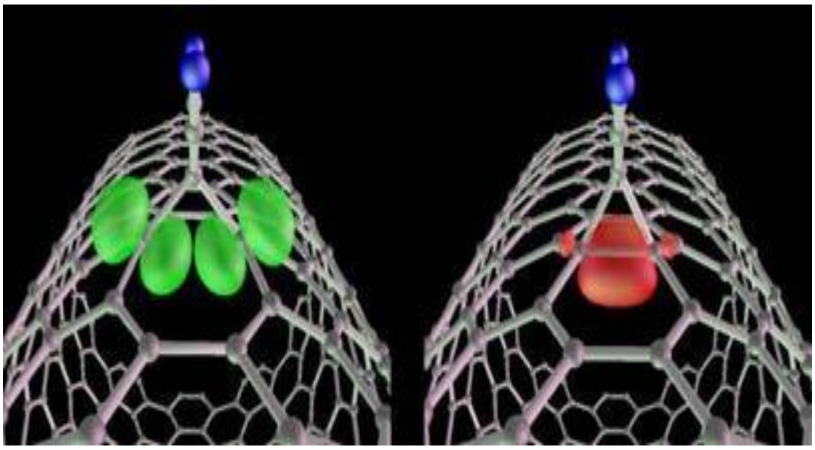
Carbon nanotube is a hot research topic these days as it offers its application in so many things. As the research continues it reveals its possible application in the fields of biology, military, commercial use and engineering.

❖ Carbon Nanotube Sensor:



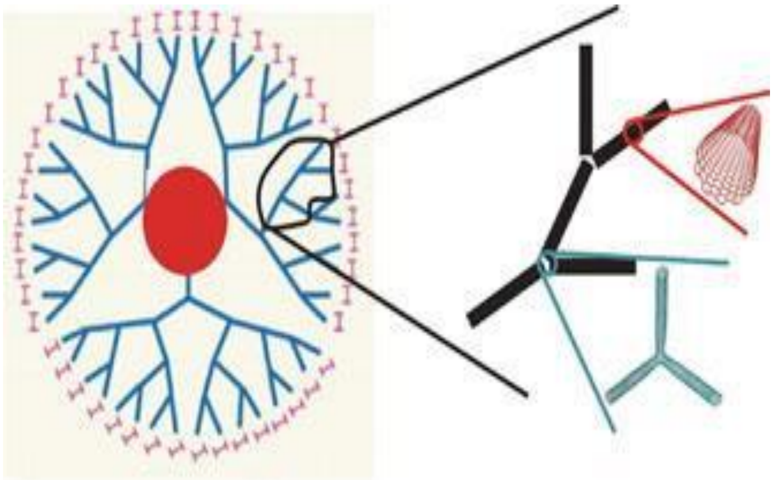
MIT researchers are designing sensors that use carbon nanotubes, shown here in middle and at top, to detect hazardous gases - Image: Chang Young Lee

❖ Carbon Nanotubes conductors:



MIT research on nanotube's exceptional ability to conduct electricity. Some molecules can attach themselves to carbon nanotubes without disturbing the tubes structural integrity

❖ Carbon Nanotube Heat sinks:



MIT research shows a carbon nanotube heat sink concept where the heat source is in center (red) which dissipates to surrounding via tubes - Image: Markus Buehler

❖ Nanotube Batteries:

It seems MIT's has diverged its major research on nanotubes. The above mentioned innovations are really cool for example the heat sink will make it possible to dissipate heat from micro devices without using conventional steel heat sink thus reduces the size. There's been also some research to cure cancer by sucking the faulty cells using these nanotubes. There future is bright!

DNA preservation using diamond chips:

The highest density DNA chip reported to date was developed using a DNA solidification technique for vertical binding to the surface of a chemical vapor deposition (CVD) diamond chip. The covalently bound oligonucleotide was approximately 42 pmol (2.5×10^{13} molecules) per 9 mm^2 of chip surface. Using the oligonucleotide as a linker, large DNA molecules (21 kbp fragment from λ-phage DNA) were covalently bound in the amount of approximately 2.6

fmol (~1.6×10^9 molecules) per 9 mm^2 of chip surface. To test the potential of the technique for repeated utilization of one piece of the DNA chip, PCR enhancement of a 500 bp region within the 21 kbp λ-DNA fragment was applied over 50 times. The results suggest that a diamond DNA chip is excellent for the preservation of limited and/or valuable gene samples. Furthermore, the technique of high density DNA solidification to a CVD diamond chip will be useful for DNA diagnosis in the future.

CONCLUSION:

Carbon is more advantages than Silicon. By using carbon as the manufacturing material, we can achieve smaller, faster and stronger chips. Thus diamond chip replaces the need of silicon in every aspect in future generation.

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