Carbon nanotubes

Introduction

Carbon nanotubes are the allotops of carbon , they have a cylindrical nano structure.

Nano structure are construct with a length to diameter ratio of 28000000: 1 , this is significantly larger than any other material. They have many novel properties and are many useful in nanotechnology , electronics , optics , material science and architectural field. They have great strength and unique electrical properties .

However their useusge is limited in day to day life because of their toxicity .

includes the spherical bucky ball (c60). It is often see that end of nanotube are hemispherical buckyball structure . It is qurt intresting to know that the radius of a nanoube is approximately 1/50000of the human hair. The nature of the bonding of a nanotube is described by appling orbital hybridation . They have sp2 bonds as graphite have .

Most single-walled nanotubes (SWNT) have diameter close to 1nanometer, with a tube length is many millions of times longer. The structure of a SWNT can be conceptualized by wrapping a one-atom-thick layer of graphite called graphene into a seamless cylinder. The way the graphene sheet is wrapped is represented by a pair of indices (n, m) called the chiral vector. The integersnandmdenote thenumber of unitvectoralong two directions in the honeycomb crystal latticeof graphene. Ifm= 0, the nanotubes are called " zigzag". Ifn= m, the nanotubes are called " armchair". Otherwise, they are called " chiral". (The (n, m) nanotube naming scheme can be thought of as a vector (Ch) in an infinite graphene sheet that describes how to " roll up" the graphene sheet to make the nanotube. Tdenotes the tube axis, anda1anda2are the unit vectors of graphene in real space.)

Single-walled nanotubes exhibit electric properties that are not shared by the multi-walled carbon nanotube (MWNT) . Single-walled nanotubes are the most likely candidate for miniaturizing electronics beyond the micro electromechanical scale currently used in electronics. The most basic building block of these systems is the electric wire, and SWNTs can be excellent conductors. Application of SWNTs are useful in the development of the first intramolecularfield effect transistor(FET). Production of the first intramolecularlogic gateusing SWNT FETs has recently become possible . To create a logic gate you must have both a p-FET and an n-FET. Because SWNTs are p-FETs when exposed to oxygen and n-FETs otherwise, it is possible to protect half of an SWNT from oxygen exposure, while exposing the other half to oxygen. This results in a single SWNT that acts as a NOT logic gate with both p and n-type FETs within the same molecule.

Single-walled nanotubes are still very expensive to produce, around $1500 per gram as of 2000, and the development of more affordable synthesis techniques is vital to the future of carbon nanotechnology. If cheaper means of synthesis cannot be discovered, it would make it financially impossible to apply this technology to commercial-scale applications.

Multi-walled nanotubes (MWNT) consist of multiple rolled layers (concentric tubes) of graphite. There are two models which can be used to describe the structures of multi-walled nanotubes. Russai doll model, sheets of graphite are arranged in concentric cylinders, e. g. a (0, 8) single-walled nanotube

(SWNT) within a larger (0, 10) single-walled nanotube. In theParchamenmodel, a single sheet of graphite is rolled in around itself, resembling a scroll of parchment or a rolled newspaper. The interlayer distance in multi-walled nanotubes is close to the distance between graphene layers in graphite, approximately 3. 3 Å.

The special place of double-walled carbon nanotubes (DWNT) must be emphasized here because their morphology and properties are similar to SWNT but their resistance to chemicals is significantly improved. This is especially important when functionalizationis required (this means grafting of chemical functions at the surface of the nanotubes) to add new properties to the CNT. In the case of SWNT, covalent functionalization will break some C= C, leaving “ holes” in the structure on the nanotube and thus modifying both its mechanical and electrical properties. In the case of DWNT, only the outer wall is modified. DWNT synthesis on the gram-scale was first proposed in 2003by the CCVD technique, from the selective reduction of oxide solutions in methane and hydrogen.

A nanotorus is theoretically described as carbon nanotube bent into atorus(doughnut shape). Nanotori are predicted to have many unique properties, such as magnetic moments 1000 times larger than previously expected for certain specific radii. Properties such as magnet moment, thermal stability etc. vary widely depending on radius of torus.

Carbon nanobudare a newly created material combining two previously discovered allotropes of carbon: carbon nanotubes and fullerenes. In this new material fullerene-like “ buds” are covalently bonded to the outer sidewalls of the underlying carbon nanotube. This hybrid material has useful properties of both fullerenes and carbon nanotubes. In particular, they have been found to be exceptionally good field emitters. In composite materials, the attached fullerene molecules may function as molecular anchors preventing slipping of the nanotubes, thus improving the composite’s mechanical properties.

Strength

Carbon nanotubes are the strongest and stiffest materials yet discovered in terms oftensil strenghtandelectic modulas 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 63gigapascal(GPa). (This, for illustration, translates into the ability to endure tension of 6300kg on a cable with cross-section of 1mm2.) Since carbon nanotubes have a low density for a solid of 1. 3 to 1. 4g·cm−3, itsspecific strenghtof up to 48, 000kN·m·kg−1is the best of known materials, compared to high-carbon steel’s 154kN·m·kg−1.

Under excessive tensile strain, the tubes will undergoplastic deformation, which means the deformation is permanent. This deformation begins at strains of approximately 5% and can increase the maximum strain the tubes undergo before fracture by releasing strain energy.

CNTs are not nearly as strong under compression. Because of their hollow structure and high aspect ratio, they tend to undergobuckingwhen placed under compressive, torsional or bending stress.

Kinetic

Multi-walled nanotubes, multiple concentric nanotubes precisely nested within one another, 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 ofmolecular nanotechnology, the precise positioning of atoms to create useful machines. Already this property has been utilized to create the world’s smallest rotationalmotor. Future applications such as a gigahertz mechanical oscillator are also envisaged.

Because of the symmetry and unique electronic structure of graphene, the structure of a nanotube strongly affects its electrical properties. For a given (n, m) nanotube, ifn= m, the nanotube is metallic; ifn−mis a multiple of 3, then the nanotube is semiconducting with a very small band gap, otherwise the nanotube is a moderatesemiconductor. Thus all armchair (n= m) nanotubes are metallic, and nanotubes (5, 0), (6, 4), (9, 1), etc. are semiconducting. In theory, metallic nanotubes can carry an electrical current density of 4 × 109A/cm2which is more than 1, 000 times greater than metals such ascopper .

All nanotubes are expected to be very goodthermal conductorsalong the tube, exhibiting a property known as “ ballistic conductor,” but good insulators laterally to the tube axis. It is which transmits 385 W·m−1·K−1. The temperature stability of carbon nanotubes is estimated to be up to 2800°C invacuumand about 750°C in air.

Potential and current applications

The joining of two carbon nanotubes with different electrical properties to form adiodehas been proposed

The strength and flexibility of carbon nanotubes makes them of potential use in controlling other nanoscale structures, which suggests they will have an important role innanotechnologyengineering. The highest tensile strength an individual multi-walled carbon nanotube has been tested to be is 63GPa.

In electrical circuits

Carbon nanotubes have many properties—from their unique dimensions to an unusual currentconductonmechanism—that make them ideal components of electrical circuits. For example, they have shown to exhibit strong electron-phonon resonances, which indicate that under certain direct current (DC) bias and doping conditions their current and the average electron velocity, as well as the electron concentration on the tube oscillate at terahertz frequencies[. These resonances could potentially be used to make terahertz sources or sensors.

Nanotube based tranistorhave been made that operate at room temperature and that are capable of digital switching using a single electron.

One major obstacle to realization of nanotubes has been the lack of technology for mass production. However, in 2001 IBM researchers demonstrated how nanotube transistors can be grown in bulk, somewhat like silicon transistors. Their process is called “ constructive destruction” which includes the automatic destruction of defective nanotubes on thewafer.

The IBM process has been developed further and single-chip wafers with over ten billion correctly aligned nanotube junctions have been created. In addition it has been demonstrated that incorrectly aligned nanotubes can be removed automatically using standardphotolithoraphy equipment.

The first nanotube integrated memory circuit was made in 2004. One of the main challenges has been regulating the conductivity of nanotubes. Depending on subtle surface features a nanotube may act as a plainconductoror as a semiconductor. A fully automated method has however been developed to remove non-semiconductor tubes.

Most recently, collaborating American and Chinese researchers at Duke University and Peking University announced a new CVD recipe involving a combination of ethanol and methanol gases and quartz substrates resulting in horizontally aligned arrays of 95-98% semiconducting nanotubes. This is considered a large step towards the ultimate goal of producing perfectly aligned, 100% semiconducting carbon nanotubes for mass production of electronic devices.

Another way to make carbon nanotube transistors has been to use random networks of them. By doing so one averages all of their electrical differences and one can produce devices in large scale at the wafer level. This approach was first patented by Nanomix Inc (date of original application June 2002). It was first published in the academic literature by theusa navel reacherch labority in 2003 through independent research work. This approach also enabled Nanomix to make the first transistor on a flexible and transparent substrate.

Nanotubes are usually grown on nanoparticles of magnetic metal (Fe, Co), which facilitates production of electronic (spinotic) devices. In particular control of current through a field-effect transistor by magnetic field has been demonstrated in such a single-tube nanostructure.

Large structures of carbon nanotubes can be used for thermal management of electronic circuits. An approximately 1mm-thick carbon nanotube layer was used as a special material to fabricate coolers, this materials has very low density, ~20 times lower weight than a similar copper structure, while the cooling properties are similar for the two materials.

As paper batteries

Apaper battery is abatteryengineered to use a paper-thin sheet ofcellulose (which is the major constituent of regular paper, among other things) infused with alignedcarbon nanotubes . The nanotubes act aselectrods; allowing the storage devices to conduct electricity. The battery, which functions as both a lithium-ion battery and asupercapacitor can provide a long, steady power output comparable to a conventional battery, as well as a supercapacitor’s quick burst of high energy—and while a conventional battery contains a number of separate components, the paper battery integrates all of the battery components in a single structure, making it more energy efficient.

Solar cells

Solar cells developed at the new jerrsyinstitute of technology use a carbon nanotube complex, formed by a mixture of carbon nanotubes and carbonbulkyball to form snake-like structures. Buckyballs trap electrons, although they can’t make electrons flow. Add sunlight to excite thepolymer, and the buckyballs will grab the electrons. Nanotubes, behaving like copper wires, will then be able to make the electrons or current flow.

Ultracapacitors

Mit uses nanotubes to improveultracapicator. The activated charcoal used in conventional ultracapacitors has many small hollow spaces of various size, which create together a large surface to store electric charge. But as charge is quantized into elementary charges, i. e. electrons, and each such elementary charge needs a minimum space, a significant fraction of the electrode surface is not available for storage because the hollow spaces are not compatible with the charge’s requirements. With a nanotube electrode the spaces may be tailored to size—few too large or too small—and consequently the capacity should be increased considerably

Optical properties of carbon nanotubes

Withinmaterial science, theoptical properties of carbon nanotubesrefer specifically to theabosorbtion, photoluminesence, andRaman spectroscopyofcarbon nanotubes. Spectroscopic methods offer the possibility of quick and non-destructive characterization of relatively large amounts ofcarbon nanotubes. There is a strong demand for such characterization from the industrial point of view: numerous parameters of thenanotube synthesiscan be changed, intentionally or unintentionally, to alter the nanotube quality. As shown below, optical absorption, photoluminescence and Raman spectroscopies allow quick and reliable characterization of this “ nanotube quality” in terms of non-tubular carbon content, structure (chirality) of the produced nanotubes, and structural defects. Those features determine nearly any other properties such as optical, mechanical, and electrical properties.

carbonnanotubesare unique “ one dimensional systems” which can be envisioned as rolled single sheets ofgraphite(or more preciselygraphene). This rolling can be done at different angles and curvatures resulting in different nanotube properties. The diameter typically varies in the range 0. 4-40nm (i. e. “ only” ~100 times), but the length can vary ~10, 000 times reaching 4cm. Thus the nanotubeaspect ratio, or the length-to-diameter ratio, can be as high as 28, 000, 000: 1, which is unequalled by any other material. Consequently, all the properties of the carbon nanotubes relative to those of typical semiconductors are extremelyanisotropic(directionally dependent) and tunable.

Whereas mechanical, electrical and electrochemical (superconductor) properties of the carbon nanotubes are well established and have immediateappplications, the practical use of optical properties is yet unclear. The aforementioned tunability of properties is potentially useful in opticsandphotonics. In particular, light-emitting diodes (LEDs)photo-dectors ased on a single nanotube have been produced in the lab. Their unique feature is not the efficiency, which is yet relatively low, but the narrow selectivity in the wavelenghtof emission and detection of light and the possibility of its fine tuning through the nanotube structure. In addition, bolometerand optoelectronic memorydevices have been realised on ensembles of single-walled carbon nanotubes.[2]

Carbon nanotubes as a black body

An idealblack bodyshould haveemissivityorabsorbanceof 1. 0, which is difficult to attain in practice, especially in a wide spectra range. Vertically aligned “ forests” of single-wall carbon nanotubes can have absorbances of 0. 98-0. 99 from thefar-ultraviolet(200nm) tofar-infrared(200μm) frequencies. Super black, a coating based on chemically etched nicle-phopsphoras alloy, is another material approaching the absorption of 1. 0.

These SWNT forests (buckypaper) were grown by the super-growth CVD method to about 10 μm height. Two factors could contribute to strong light absorption by these structures: (i) a distribution of CNT chiralities resulted in various bandgaps for individual CNTs. Thus a compound material was formed with broadband absorption. (ii) Light might be trapped in those forests due to multiple reflections

Nanotubes As Space Elevators

A space elevator would extend 22, 000 miles above the Earth to a station, and then another 40, 000 miles to a weighted structure for stability

Scientists from Cambridge University have developed a light, flexible, and strong type of carbon nanotube material that may bring space elevators closer to reality. Motivated by a $4 million prize from NASA, the scientists found a way to combine multiple separate nanotubes together to form long strands. Until now, carbon nanotubes have been too brittle to be formed into such long pieces.[3]

Conclusion

Carbon nano tubes are very important material and are precious in day to day life , space research, nanotechnology , telecommunication , optics etc. However they are still not been used in their full extent because they are very expensive and are toxic in nature. We have to somehow find a cheap source of carbon nanotubes in the future.