NANOTUBES COULD CHANGE THE FUTURE OF COMPUTER TECHNOLOGY

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ABSTRACT

Carbon nanotubes are the technology of the future. This technology is still in its infancy due to the fact that the technology is less than ten years old. This technology was discovered by accident, nanotubes are a residue from vaporizing carbon. Simro Iijima noticed that this soot had interesting qualities. Nanotubes are excellent conductors of electricity, heat, and have superior strength. Researchers have been able to make nanotube switches and transistors that are sized at the molecular level. Where this technology could be put to use is in the computer industry, because nanotubes dissipates heat and conduct electricity a hundred times better than copper wires. Utilizing wires the size of atoms allows computers to be miniaturized. Nanotubes should have many uses from holding hydrogen for fuel cell cars to transistors and diodes at the molecular level.

Keywords: Nanotubes, nanotechnology**,** carbon nanotubes, Sumio Iijima

INTRODUCTION

Sumio Iijima, a Japanese electron microscope expert, was studying the material deposited on the cathode during the arc-evaporation synthesis of fullerenes and he discovered carbon nanotubes. His discovery might just be as important to science as the discovery of electricity. Nanotubes are as narrow as the double-stranded DNA molecule that carries our genetic information and look like rolled up chicken wire that is capped at both ends. Carbon nanotubes have unique properties. They have the ability to act as superconductors, semi-conductors and resistors when exposed to electricity. Another unique trait that the nanotube has is that it can conduct heat. One of the major problems facing the computer industry is the way to keep computer chips cool, and researchers have been experimenting with carbon silicon hybrid chips and plain carbon chips. Nanotubes can also be designed into display screens that would be as thin as wall posters. This technology is currently expensive, about $100 per gram. Nanotube experts predict that this technology will be in use by the general public in five to ten years. There are many people and companies that are interested in nanotubes starting with NASA who is exploring a space elevator, which is something like a 23,000 satellite-to–earth cable. NEC and Samsung are working on creating ultra thin display screens.

Eventually researchers believe nanotubes could provide medical researchers with a means to build artificial muscles. Another application of nanotubes being explored is as receptacles or storage tanks for hydrogen molecules to be used in fuel cells. One practical application of this technology is using it as a power source for automobiles. This technology is less than ten years old with tons of room for exploration and growth.

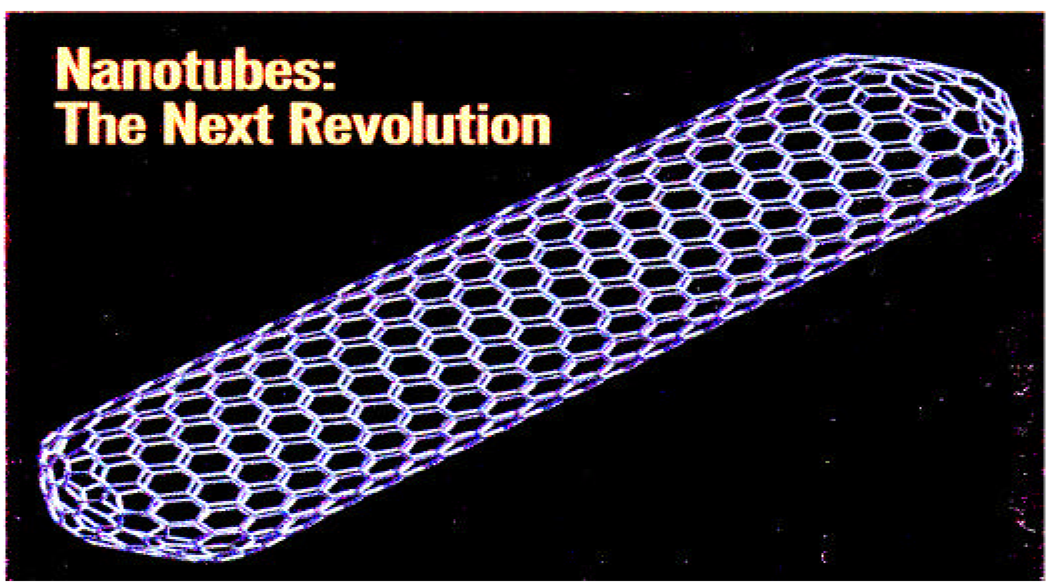
WELCOME TO NANOWORLD

Technology that is years away from practical applications, nanotubes have a cult following in university science department. The question is will they live up to their practical potential. There's a publication called *Nanotimes* and chat rooms that are dedicated to the latest in nano news.

What are Nanotubes?

An electron microscope expert Sumio Iijima at NEC CORPORATION in Japan discovered carbon nanotubes in 1991, when he was investigating the residue deposited during a process that synthesized fullerenes (a molecular form of carbon noted for its cage like appearance).

These microscopic tubes are made of a remarkable form of soot and have chemical properties that make them stronger than steel and lighter than plastic. They consist of concentric shells of graphite, with each shell rolled into a cylinder so the lattice of carbon atoms remains continuous. The number of shells varies from one to as many as fifty with the spacing between each layer matching closely the layer spacing in graphite (around .0.34 nm). Carbon nanotubes consist of almost 1000 atoms (10). The cylindrical walls of the nanotubes are composed of carbon atoms arranged in a super strong, hexagonal "chicken wire" pattern, and the end caps are formed by hexagons and pentagons, which lend curvature of the caps and relieve bond strain. Carbon nanotubes are usually 1-50 nanometers in diameter (one-50000^{th} the diameter of a human hair) and typically a few microns long, although recently single-wall nanotubes have been grown to over 300 microns (13). Making them perhaps the largest aspect-ratio molecule known. Because of their chemical structure, nanotubes are stronger than metal and superb conductors of electricity and heat; they can be used as wires, semicon-ductors or superconductors. Some engineers see nanotubes as an alternative to silicon, another medium for building transistors, diodes and other semiconductor devices (5).



This nanotube would be about 1.4 nanometers.

Fabrication Methods

There are various techniques that are capable of synthesizing carbon nanotubes. The carbon arc method, used initially for producing carbon fullernes, is the easiest way to produce carbon nanotubes. Chemical vapor disposition in an apparatus used for creating vapor grown carbon fibers has also produced carbon nanotubes. Finally, laser vaporization of a carbon block has produced the most uniform single wall carbon nanotubes.

Initially, the carbon arc method was developed to produce carbon 60 fullerenes. This method creates nanotubes through arc-vaporation of two carbon rods placed end to end separated by approximately 1mm. A direct current of 50 to 100 A driven by approximately 20 V creates a high temperature discharge between the two electrodes. This discharge vaporizes one of the carbon rods and forms a small rod shaped deposit on the other rod. Producing nanotubes in high yield depends on the uniformity of the plasma arc and the temperature of the deposit form on the carbon electrode (4).

The laser vaporization method produces single walled carbon nanotubes in high yields. A graphite target is heated to 1200 °C in a quartz tube. A Nd-YAG laser ablates carbon off of this graphite target. At the end of the furnace, a water-cooled brass cone collects the soot from the ablation. This soot contains a high percentage of single wall carbon nanotubes (2).

Nanotube Strength

Researchers at Washington University in St. Louis have been putting carbon nanotubes in a new tensile tester (stretched by applying a force) and coming up with some remarkable findings of strength. In some instances, they took measurements in the mirco-Newtons range (14). Because nanotubes are multiwalled, researchers were careful to attach the cantilevers only to the outermost shell. A relatively weak interaction between nesting nanotubes lets the outer layer carry the load. For the first time, researchers measured the tensile strength of a single nanotube, namely the outer most shell. And the highest strength value, 63 Gpa, exceeds that of any reported for any type of material. Taking the lower density of the carbon nanotubes into account, the outer shell of the nanotubes about 80 times stronger than high-grade steel (15).

High Conductivity

Nanotubes have other qualities that are whetting the appetites of engineers. They're excellent conductors of electricity and heat, and they can be used as wires, semiconductors or superconductors. They can also emit electrons, so they can be used in ultra thin display screens. Carbon nanotubes have a very low field-emission voltage, which means lower voltage is needed to emit the electrons that produce an image. Carbon nanotubes carry an extremely high current and carry it with such extremely little resistance, it is possible that they can carry current as well as it can be carried (12). Nanotubes can carry about 100 times the current that would destroy an ordinary electronic interconnector.

Heat Conduction

A filament of pure carbon less than one ten thousandth the width of a human hair, may be the best heat-conductor man has yet discovered. Heat energy in a nanotube is carried by sound waves. In materials that are optimal conductors of heat, these waves move very rapidly in an essentially one-dimensional direction. Sound waves bearing thermal energy travel straight down individual nanotubes at roughly 10,000 meters per second, behavior consistent with superior thermal conductivity (11). As computing power has skyrocketed, the heat generated by each circuit on a microchip has proved a headache for computer designers and manufacturers. There are few ways to dissipate the considerable heat that results from millions of circuits operating in tandem. Next generation computer designs might circumvent this problem with judiciously placed carbon nanotubes to direct the heat away from sensitive circuits.

Other uses for the carbon nanotubes could be as heat sinks in electric motors to allow for the introduction of plastic parts that might otherwise melt under the motors' intense heat. These tiny structures could also be placed in materials that are called upon to withstand extreme heat, such as those that form the exterior panels of airplanes and rockets.

Pricey Technology

Even if the technological properties "are extremely good" the introduction of nanotubes will be slow because of costs and other factors. Demand hasn't caught up with the buzz nanotubes are creating in university physics departments and places like IBM. Currently nanotubes cost $100 per gram. Given the amount of money that has been invested in competing technologies, don't expect a speedy race to make nanotubes the building material of the next generation of electronics. Silicon has reached a very high level of sophistication, and there is a tremendous infrastructure built around silicon.

Future Uses

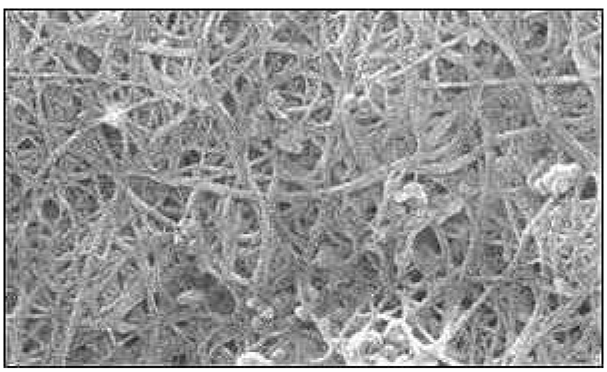
NASA will put this technology into use in the future. Researchers are exploring the possibility of using nanotubes to make a space elevator, something like a 23000-mile satellite to Earth cable (16). Another use is nanotube monitors that will be so slim; they can be hung like posters. This will be a major advance in monitor design. Because conventional monitors require high voltage, you need a big power supply. If the voltage requirement is small, you don't need a big power supply, and the whole package becomes much smaller (7).

Nanotubes could also have many other uses. Extremely small electrical wires could make use of nanotubes' electricity and heat conducting capabilities to make computer circuits smaller and faster. They also have the highest and most stable electron emissions recorded. Many engineers see nanotubes as an alternative to silicon, the medium in which transistors, diodes and other semiconductor device structures are usually built today (6). Carbon nanotubes may revolutionize electronics. The silicon chip may one day yield to the carbon chip, with its microelectronic circuitry fashioned from pure carbon. Nanotubes have been shown to be capable of providing wiring and miniaturizing devices far smaller than is feasible with existing electronic technologies today. In 1998 Cess Dekker and colleagues at the Delft University of Technology in the Netherlands demonstrated a transistor that used a nanotube as one of the components. Transistors are the principal switching devices in computer circuits, and are key elements in all information technology. To make a nanotube transistor, the Dutch researchers used not a 'metallic' conducting nanotube but a semi conducting one, stretched between two metal electrodes. Despite its small size, the transistor functioned just like those used in conventional silicon circuits (9).

Alternative Uses

There are some other uses for nanotubes that are not directly connected to computers and their peripherals. Chinese and American scientists have developed a method of storing quantities of hydrogen inside nanotubes. This development is another step in the search for technological solutions to the problems that currently prevent hydrogen from being used as a practical, everyday fuel. The gas produces no pollution and no greenhouse emissions when burned in pure oxygen and is considered by many to be a clean energy source and a replacement for fossil fuels when current reserves run out (1). Hydrogen still has a long way to go before it becomes a real alternative to fossil fuels. One of the limitations is that nanotechnology is currently very, very expensive. It cost $1,000,000 to produce only one kilo of carbon nanotubes. Until nanotubes become cheaper to produce, fossil fuels will be the fuel of choice. It is projected however, that a nanotube fuel cell could be built by 2004.

The newest use for nanotubes is in the construction of artificial muscles. Collaboration by Australian, American, and German researchers has led to sheets of nanotubes that are able to exert more stress than the body's muscles; eventually, they believe, nanotubes could provide the materials to build artificial muscles. Like natural muscles, providing an electrical charge causes the individual fibers to expand and the whole structure to move. However, any application of this work in replacing biological muscles is "nearer to fiction than reality".



This "paper" is made of nanotubes and contracts when charged. It has been shown that the tiny nanotubes expand and contract their length by about 1% when an electric charge is applied and then removed (3).

Nanotubes could also be a benefit to chemistry. Researchers have carried out chemical reactions inside what are now being called the world's smallest test tubes. They have also demonstrated that you can put materials into nanotubes and manipulate them to induce a chemical reaction. Among the highlights of nanotube research to date is the demonstration that tubes can be opened and filled with a variety of materials including biological molecules. In one experiment a Professor from the University of Berkley opened the ends of the tubes and filled them with molten silver nitrate. Then decomposed the silver nitrate into metallic silver by heating the tubes with a beam from an electron microscope. The result was a chain of tiny silver beads created within the tubes (8). Nanotubes are extremely stable. They do not react with any other compounds.

CONCLUSION

Nanotubes are still an experimental technology and will not be used in large-scale computer construction for quite some time. But uses for these tiny tubes are being developed every day. From making computers the size of a quarter to artificial muscles, carbon nanotubes might just be the biggest discovery since the utilization of electricity in light bulbs. This technology might stay too expensive for practical applications, but it could also revolutionize the world. What makes this technology so fascinating is that it was discovered by accident. In another ten years the computer industry might totally switch to nanotubes replacing the copper wires and silicon chips. In the future, manufacturers could make computers small enough to be worn as jewelry or hidden in our pockets.

REFERENCES

1. "Artificial Muscles made from Nanotubes". (2000, May). BBC NEWS. Retrieved Nov. 12, 2000. From the World Wide Web: http://wwww.robotbooks.com/nanotubes.htm
2. Bower, C., Zhu, W., and Jin, S. (2000, August 12). "Formation of low resistance ohmic contacts between carbon nanotubes and metal electrodes by rapid thermal annealing method". Journal of Physics. 33(16), 1953-6.
3. "Carbon tubes could store hydrogen fuel". (1999, Nov 8). BBC NEWS Sci/Tech [online]. Retrieved Nov 12, 2000. From the World Wide Web: http://news2.thls.bbc.co.uk/hi/english/sci/tech/newsid_509000.stm
4. "Carbon Nanotubes". (2000, August) [Online]. Retrieved Nov 12, 2000. From the World Wide Web: http://www.phys.ttu.edu/~thaide/thesis/CARBON_NANOTUBES.htm
5. Claye, A., Fischer, J. (2000, August). Solid-state Electrochemistry of Li Single Wall Carbon Nanotube System. Journal of the Electrochemical Society, 147, 2845-52.
6. Collins, Philip G. (2000, August 16). Nanoscale Electronic Devices on Carbon Nanotubes. Foresight Institute [online]. Retrieved Nov 11, 2000. From the World Wide Web: http://www.foresight.org/conferences/MNTO5/papers/Collins.htm
7. Dineen, J. K. (2000, July 10). Welcome to Nanoworld. Computerworld, 34, 57.
8. Freemantle, Michael. (2000, September 4). World's Smallest Test Tubes. Chemical & Engineering News, 78, 36-44.
9. "Focus on Carbon Nanotubes". (2000, November). Nature [online]. Retrieved Nov. 12, 2000. From the World Wide Web: http://helix.nature.com/nsn/991202.htm
10. Harris, Peter J. F. (1999). Carbon Nanotubes and Related Structures. [Online]. Retrieved Nov. 12, 2000. From the World Wide Web: http://www.rdg.ac.uk/~scharip/tubes.htm
11. "In another coup for carbon nanotubes". (2000, September 20). University of Pennsylvania: Science Daily Magazine [online]. Retrieved Nov. 13, 2000. From the World Wide Web: http://www.sciencedaily.com/releases/2000/09/000913213024.htm
12. Lee, J., Park, C., & Kim, J. (2000, August 21). High Conductivity of Carbon Nanotubes. Applied Physics Letters, 77 (6), 830-2.

13. Shaffer, Milo. (2000). Polymer Group: Milo Shaffer: Carbon Nanotubes [online]. Retrieved Nov 10, 2000. From the World Wide Web: http://www.msm.com.ac.uk/polymer/member/msmps100/CNT.htm

14. Sharke, Paul. (2000, August 12). Nanotubes Flaunt Strength. Mechanical Engineering 122(4), 12.

15. "Tensile Test Measure Strength of Carbon Nanotubes". (2000, January). [Online]. Retrieved Nov. 13, 2000. From the World Wide Web: http://composite.about.com/iam/=dpile&terms=%2barbon+%2bnanotubes.htm

16. Vetrova, Olga (2000, May 2). All Aboard the Nanotube. World Link Magazine [online]. Retrieved Nov. 12, 2000. From the World Wide Web: http://www.worldlink.com/discuss/MsgReader$227.htm