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CARBON NANOTUBE COMPUTER

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Abstract: **Many potential applications have been proposed for carbon nanotubes, including conductive and high-strength composites; energy storage and energy conversion devices; sensors; field emission displays and radiation sources; hydrogen storage media; and probes, and interconnects. Some of these applications are now realized in products. Others are demonstrated in early to advanced devices, and nanometer-sized semiconductor devices is one such application. Nanotube cost, polydispersity in nanotube type, and limitations in processing and assembly methods are important barriers for some applications of single-walled nanotubes. Problem is, carbon nanotubes aren't perfect either. They don't always grow in perfectly straight lines, and a fraction of the tubes grown aren't able to "switch off" like a regular transistor. The Stanford team used a technique of "burning" off some of the imperfect carbon nanotubes while also working their way around other imperfections by using a complex algorithm. They do not, for example, always grow in parallel lines, which has led researchers to devise techniques to grow 99.5 percent of CNTs in straight lines, according to the press release. But with billions of nanotubes on a chip, even a small misalignment of the tubes can cause errors. A fraction of the CNTs also behave like metallic wires that always conduct electricity, instead of acting like semiconductors that can be switched off.**

The final design consists of a very basic computer with 178 transistors that can do tasks like counting and number sorting and switch between functions. The rise of carbon nanotube computers in the future is for sure and the basic algorithm to prove this concept is illustrated in depth. CNTs are prominent among a variety of emerging technologies that are being considered for the next generation of highly energy efficient electronic systems.This may take some time to make this kind of computer designed by using nanotubes available for all but once it is developed it is going to lead to a new era in the world of computers.

Keywords: **Computer, Carbon NanoTubes**

I. INTRODUCTION

Moore's law predicts that computer chips will be half in size and cost every 18 months. On April 13, 2005, Gordon Moore stated in an interview that this law cannot be sustained indefinitely. The reason for this is that the silicon technology ceases to downsize the chip to cope up with Moore's law predictions any longer. However, nanotechnology may offer a solution to this potential problem. Nanotechnology opens new avenues to fabricate chips using carbon nanotubes and keeps the prediction of Moore's law alive for the next few decades. It is expected to be the next industrial revolution that can radically transform the computer industry. In this paper, we narrate the evolution of nanocomputers and the upcoming new nanotechnology-based parallel architectures. Nano computing which is the computational aspect of nano architectures is an emerging technology and is at the early stage of its development.

II. EVOLUTION OF CARBON NANOTUBE COMPUTERS

A nanometer is a unit of length in the metric system that is equal to one millionth of a millimeter. Generally, nanotechnology deals with structures of the size of 100 nanometers or smaller and involves developing materials or devices within that size. Nanotechnology creates many new materials and devices with a wide range of applications in medicine, electronics, and computers.Carbon Nanotubes A nanotube is a tube-like structure having a diameter close to 1 nanometer. Carbon nanotubes form hollow three dimensional tubes by interconnecting six carbon rings and are extremely thin (their diameter is about 10,000 times smaller than a human hair). Carbon nanotubes are molecular cylinders that are rapidly extending our ability to fabricate nanoscale devices by providing molecular probes, pipes, wires, bearings and springs. They are the strongest and stiffest materials known, and thus have many potential applications in various technologies. A carbon nanotube is like a cylinder rolled up from a single sheet of graphite, whose atoms are arranged in hexagons (see Fig 1). This type of structure can be used in many applications to improve the scalability, efficiency and reliability of computing. In this paper we will concentrate on computer related applications.

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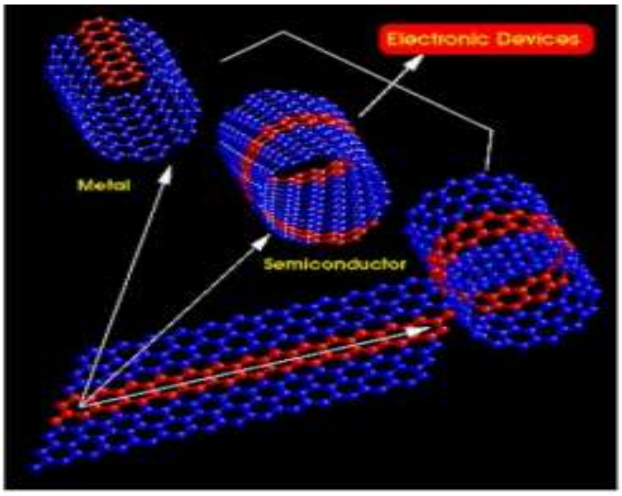

Fig 1: A carbon nanotube is like a cylinder rolled up from a single sheet of graphite, whose atoms are arranged in hexagons.

Feynman Prize winners Marvin L. Cohen and Steven G. Louie of the University of California at Berkeley addressed at the 11th Foresight Conference on Molecular Nanotechnology (2007) "Molecular nanotechnology will be the ultimate manufacturing technology. It will be able to inexpensively arrange the fundamental building blocks of matter. It will allow us to make molecular computers, remarkably light and strong, molecular medical devices and a host of other manufactured products that will revolutionize our world." Here, we list the milestones towards nano computers.

Carbon nanotubes (CNTs) are an allotrope of carbon. A carbon nanotube computer is one with a processor that uses carbon nanotubes as its semiconductor material. A carbon nanotube is a one atom thick sheet of graphite (called graphene) rolled up into a seamless cylinder with diameter of the order of a nanometer. This results in an essentially one dimensional nanostructure where the length-to diameter ratio exceeds 10,000. Carbon nanotubes (CNTs) can have silicon's semiconductor nature, giving them the on-again off-again electrical abilities crucial to making chip transistors. And they have a superb ability to transmit electrons when switched on. But they'll be impractical for computer chips unless chipmakers can find a way to place them very precisely and in large quantities.

In the last 25 years a number of solid state devices have come into use. Most of these devices use semiconductor crystals. Field of electronics has been revolutionized since the discovery of the transistor in 1948. Technological development, such as the invention of integrated circuits, has further increased the dependence on semiconducting materials. From the point of band theory of electrical conductivity, semiconductors differ from conductors and insulators in that they have a narrow forbidden energy gap. Metals' addition of impurities as well as rise of temperature result in decrease in the electrical conductivity whereas in semiconductors, in contrast to the conductors the electrical conductivity increases. Of all the elements in the periodic table, eleven elements are semiconductors. Germanium and silicon are important semiconductors which are widely used in the manufacturing of diodes and transistors.

III. INVENTION OF CARBON NANOTUBE COMPUTER

The standard semiconductor for processors is silicon, which is expected to eventually reach its functional limits for applications that require increasingly small devices. Carbon nanotubes have often been thought to be an ideal successor to silicon for processor fabrication. The material can replace silicon wafers in manufacturing while retaining existing fabrication infrastructure. Carbon nanotubes could improve on silicon's performance through the material's superior heat dissipation and a theoretical order of magnitude increase in electrical efficiency.A carbon nanotube computer could, in theory, be faster and smaller. However, the material is challenging to work with. For example, carbon nanotubes are made on a quartz substrate and can grow erratically, with some tubes conducting electricity like a metal.The prototype computer operates at 5 volts and is not very power-efficient. Nevertheless, given time, it can perform any calculation.

Researchers in the US have unveiled the **first computer to be built entirely from carbon nanotube (CNT) transistors**. Their prototype is nothing fancy – or fast – in terms of computing power, but it can use a simple operating system to switch between two different tasks: counting and sorting numbers.People have been making CNT transistors and circuits for over a decade, but using them to build complex electronic systems has proved tricky. **Max Shulaker** and his colleagues at Stanford University in the US have overcome many of the traditional difficulties associated with building CNT chips. They devised an algorithm to bypass CNTs that were not aligned parallel on the chip and also got rid of 'metallic' CNTs (which always conduct electricity rather than acting as semiconductors) by passing electricity through them until they vaporized. The resulting parallel semiconducting CNTs could then be made into functioning circuits.The rudimentary CNT computer, developed by the researchers at Stanford, is said to run a simple operating system that is capable of multitasking, according to a synopsis of the article.Made of 178 transistors, each containing between 10 and 200 carbon nanotubes, the computer can do four tasks summarized as instruction fetch, data fetch, arithmetic operation and write-back, and run two different programs concurrently.

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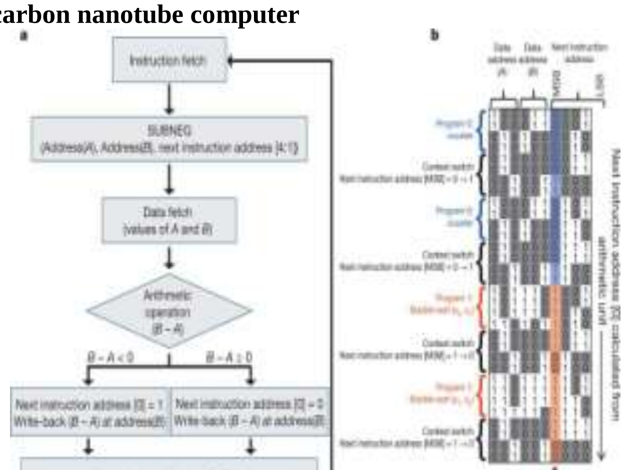
IV. DESIGN OF CARBON NANOTUBE COMPUTER

1. Fabrication flow for the CNT computer. (338 KB)
Steps 1–4 prepare the final substrate for circuit fabrication. Steps 5–8 transfer the CNTs from the quartz wafer (where highly aligned CNTs are grown) to the final SiO_2 substrate. Steps 9–11 continue final device fabrication on the final substrate.
2. Multibit arithmetic unit. (386 KB)
a, Schematic of a two-bit arithmetic unit, comprising six individual arithmetic logic units (ALU) as shown in Fig. 3b. **b**, Measured and expected output waveforms testing all possible input combinations of the two-bit arithmetic unit, showing correct operation.
3. Internal versus external connections of CNT computer. (283 KB)
a, Schematic of the CNT computer, showing that all connections are fabricated on-chip and that only signals reading or writing to or from an external memory are connected off-chip. **b**, SEM of the CNT computer, showing which connections are made to and from the CNT computer from the probe pads. The SEM is color-coded to match the coloured wires in **a**.
4. PMOS-only logic schematics. (71 KB)
a, Schematic of PMOS-only inverter. **b**, Schematic of PMOS-only NAND gate.

Flowchart to implement counting and integer sorting in carbon nanotube computer



Flowchart showing the implementation of the SUBNEG instruction. **b**, Sample program on CNT computer. Each row of the chart is a full SUBNEG instruction. It is composed of two data addresses and a partial next instruction address. The (omitted) least significant bit (LSB) of the next instruction address is calculated by the arithmetic unit of the CNT computer, and the most significant bit (MSB) of the next instruction address indicates the running program, either a counter or bubble-sort algorithm in this instance.

V. ANALYZING CNT COMPUTER

Carbon-nanotube technology is still new, however, and poses many problems. The Stanford team's solution addresses some of the key issues with error correction: Their system can switch off defective carbon nanotubes, and they developed an algorithm
to address misalignments of the carbon nanotubes that could result in short-circuiting of the system. Stanford University in the US has overcome many of the traditional difficulties associated with building CNT chips. They devised an algorithm to bypass CNTs that were not aligned parallel on the chip and also got rid of 'metallic' CNTs (which always conduct electricity rather than acting as semiconductors) by passing electricity through them until they vaporized. The resulting parallel semiconducting CNTs could then be made into functioning circuits. It has long been predicted that CNT technology will one day overtake traditional silicon chips, which are reaching their limits in terms of miniaturization. The development of a functional computer shows this is a real possibility, and the team are confident their prototype can be improved.

VI. CONCLUSION

For the uninitiated, this new development signals a shift from silicon transistor computing, a technology that will soon reach its limit since transistors can only get so small before quantum effects stop them from shrinking any further. Carbon nanotube transistors, however, are now a more realistic solution for future generations of computers because they conduct electricity better than silicon, and can scale smaller.That means carbon nanotube-based computers will be able to deliver faster speeds and more energy efficiency carbon nanotube-based computers will be able to deliver faster speeds and more energy efficiency, a challenge today's semiconductor manufacturers are struggling to address with each new generation of processor. It is expected that nanotechnology will revolutionize the computing, networking and telecommunication industries by producing faster and smaller non silicon-based chipsets, memory, processors, and new generation computers based on carbon nanotubes. Computer scientists predict that nano-computers will radically transform the computer industry in the coming years. The next target of computer engineers and scientists is parallel processors using nanotechnology. Nano-computing which is the computational aspect of nano architectures is an emerging technology and is at the early stage of its development. Keeping these latest trends in mind, it is expected that carbon nanotube computers will create a new era in the world of computers.

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