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Introduction to Nanoradio

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Abstract A nanoradio is the smallest radio receiver in the world. It often consists of a key circuitry with a single carbon nanotube. Due to the small dimension, such a nanoscale device has potential applications in many fields, including medicine and sensor technology. A single carbon nanotube served as all the four essential components (antenna, tuner, amplifier and demodulator) of a radio at the same time. Nanoradios operate differently from conventional radios. Nanoradio can improve everything from cell phones to medical diagnostics. This paper provides an introduction to nanoradio.

Keywords nanoradio, carbon nanotube, nanoelectronics

Introduction

Since 1959, remotely monitored implanted medical devices have been one of the key paradigms in biomedical science and engineering. Several modalities have been explored for transmitting energy and information through biological media, including microwave, ultrasound, infrared, and photonic. A tiny sensor capable of witnessing biological processes at the smallest of scales would support a wide range of biomedical research and therapy applications.

The advent in 2007 of the nanoradio, with its micron-sized antenna has led to speculation that in vivo RF wireless nano networks may soon be possible. As shown in Figure 1, a nanoradio is a mechanical oscillator consisting of a vibrating carbon nanotube carrying electric charge at the tip of the tube and therefore capable of translating its mechanical vibrations into a radiated electromagnetic signal [1]. The existence of nanoradio presses the question: could an RF transmitter be made small enough to allow neuron by neuron telemetry from the human brain? [2].

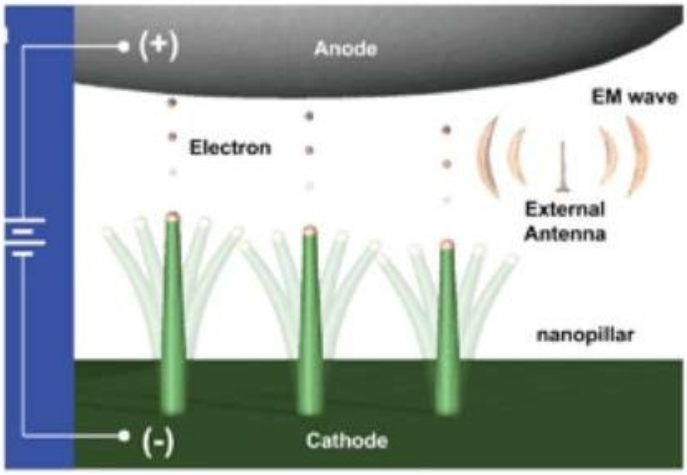

Figure 1: How nanoradio works [1]

Overview of Nanotechnology

Richard Feymann, the Nobel Prize-winning physicist, introduced the world to nanotechnology in 1959. The term "nanotechnology" was coined in 1974 by Norio Tanigutchi, a professor at Tokyo Science University. Nanotechnology involves the manipulation of atoms and molecules at the nanoscale so that materials have new unique properties. It is the science of small things—at the atomic level or nanoscale level [3]. Nanotechnology also includes domains like nanoscience, nanomaterials, nanomedicine, nanomeasurement, nanomanipulation, nanoelectronics, and nanorobotics. Techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. The processes used to make and manipulate such materials are known as *nanotechnology*, the materials or objects themselves are called *nanomaterials*, and the study and discovery of these materials is known as *nanoscience*.

Nanomaterials are basically chemical substances or materials that are manufactured and used at a very small scale. Nanoscale materials can be engineered from minerals and nearly any chemical substance. Engineered nanomaterials have been deliberately manufactured by humans to have certain required properties. Nanomaterials may also be produced incidentally as a byproduct of mechanical or industrial processes [4]. They can be classified in 0D, 1D, 2D and 3D nanomaterials. Nanomaterials such as carbon nanotubes are 100 times stronger than steel but six times lighter!

Nanotechnology has the idea that the technology of the future will be built on atoms. It has impact on every area of science and technology. Nanotechnology involves imaging, measuring, modeling, and manipulating matter at the nano scale. At this level, the physical, chemical, and biological properties of materials fundamentally differ from the properties of individual atoms and molecules or bulk matter [5].

Nanotechnology covers a wide variety of disciplines like physics, chemistry, biology, biotechnology, information technology, engineering, and their potential applications [6]. Nanotechnology features two primary approaches, which are "bottom up" where materials or devices are self-assembled from molecular components, and "top down" where nanoscale objects are constructed by micro-scale and macro-scale devices.

What is a Nanoradio?

A nanoradio was first observed by a Japanese physicist Sumio Iijima in 1991 who saw a "a luminous discharge of electricity" coming from a carbon nanotube. A nanoradio is a nanotechnology acting as a radio transmitter and receiver by using carbon nanotubes. Nanoradio is also called carbon nanotube radio. Due to their small size, nanoradios have many distinct properties. The nanoradio operates different from conventional radios. Whereas traditional radios are electrical in nature, the nanotube radio is based on the mechanical resonance of a nanomaterial. The nanotube absorbs electromagnetic waves and converts them to mechanical vibrations.

A nanotube is a hollow cylindrical molecule usually made of carbon. Carbon nanotube (CNT) is an interesting nanomaterial with unique electrical and mechanical properties. CNTs are essentially allotropes of carbon with a cylindrical nanostructure.

They have been synthesized with length-to-diameter ratio of up to 132,000,000 : 1. Nanotubes are regarded as members of the fullerene structural family. They can be considered as nearly one-dimensional structures. Several techniques have been developed to produce nanotubes in various sizes, including arc discharge, laser ablation, high pressure carbon monoxide, and chemical vapor deposition (CVD). Carbon in general, and especially nanotubes, form an attractive material for electrochemical applications because carbon is a relatively cheap, low density, environmentally friendly, and highly polarizable material [7]. Figure 2 shows a typical carbon nanotube [8].

The conventional radio is a device based on wireless transmission of signals by modulating the frequencies of radio waves. It often has the antenna, tuner, demodulator and amplifier. Carbon nanotubes can function as these parts without the need of extra circuitry. A single carbon nanotube served as all the four essential components (antenna, tuner, amplifier and demodulator) of a radio at the same time. The nanoradio acts as a micron sized antenna by vibrating with the same frequency as the signal from incoming electromagnetic waves, i.e. the antenna receives signals via high-frequency mechanical vibrations of the nanotube rather than electrically. The nanoradio can also function as a tuner, enabling the radio to tune into specific frequencies. The nanoradio acts

naturally as an amplifier. It nanoradio can function as a demodulator without the need of circuitry [9]. Figure 3 shows an all-in-one nanotude radio [10].

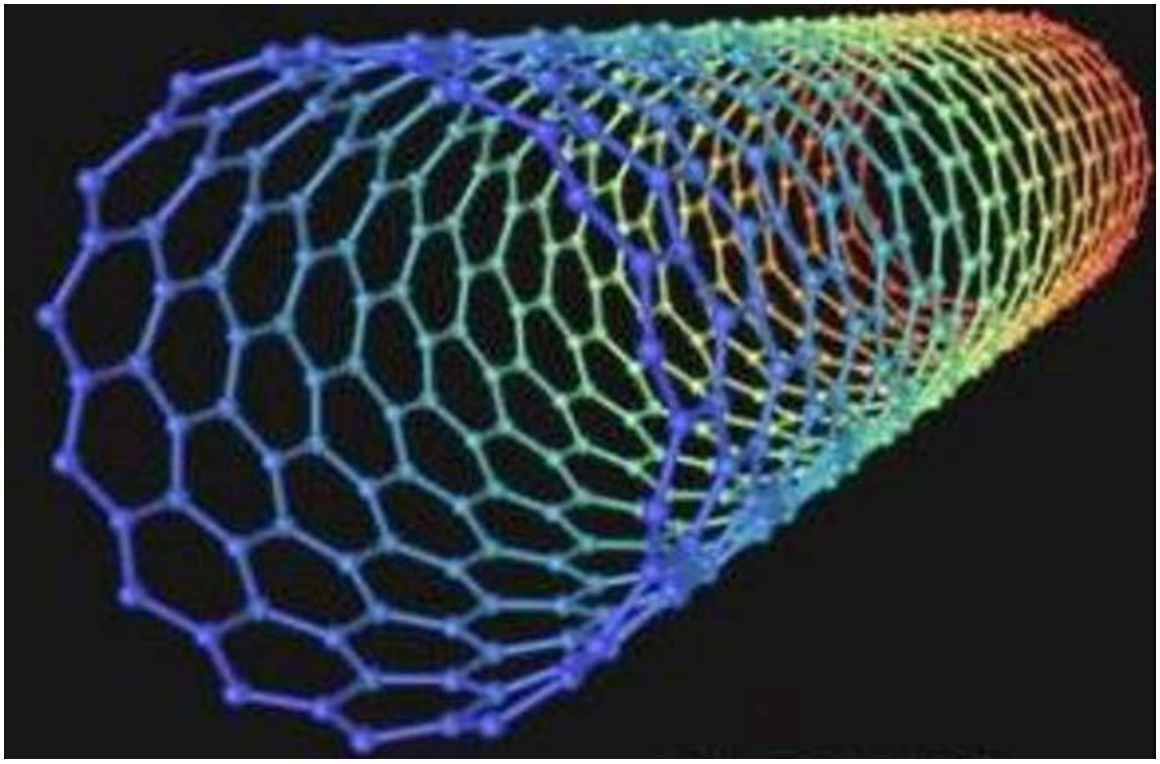

Figure 2: A typical carbon nanotube [8]

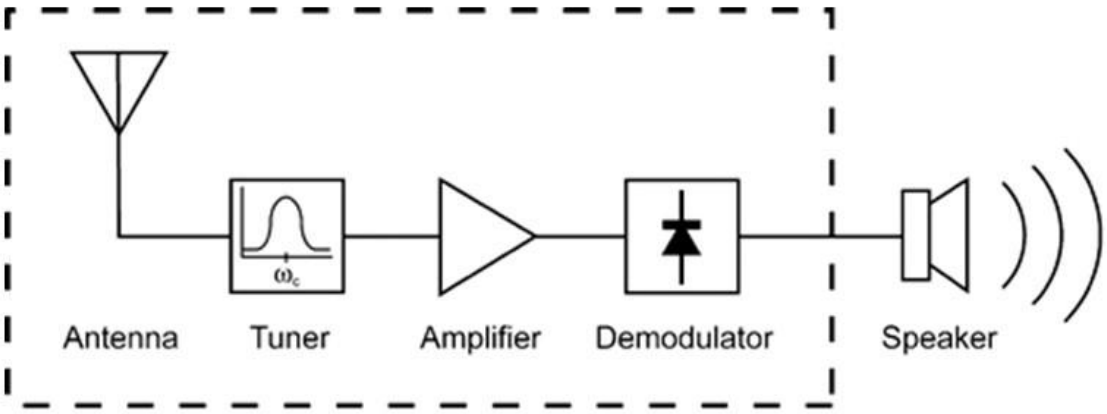

Figure 3: All-in-one nanotube radio [10]

Applications

The possibility of building components at the nanoscale revolutionized the way we think about systems. Due to the tiny size, nanoradios has many possible applications such as medicine and electronics.

- *Medicine:* Nanoradios can be used to prevent damage to healthy cells (as in chemotherapy) by remotely communicating with the radio to release drugs and specifically target cancerous cells. Nanoradios can also be used to monitor insulin levels of diabetes patients and use that information to release a drug or chemical [9].
- *Nanoelectronics*: Over the past century, radio has shrunk dramatically from the wooden radios of the 1930s to the pocket-sized transistor radios of the 1950s and more recently to the single-chip radios found in cell phones and wireless sensors. Nanoelectronic systems are considered crucial to the

continued miniaturization of electronic devices. Any wireless device, from cell phones to environmental sensors, could benefit from nanoradios. Nanoradios could also steer wireless communications into entirely new realms. Electronics manufacturers have made microscale radios, creating new products such as radio frequency identification (RFID) tags.

In 2007, physicists at the University of California, Berkeley, US have built the smallest radio yet - a single carbon nanotube one ten-thousandth the diameter of a human hair that requires only a battery and earphones to tune in to your favorite station [11]. Scientists at the Lawrence Berkeley National Laboratory have gone one better – announcing the creation of the world's first complete nanoradio. Professor Fan and his research group at the Tsinghua University, China developed the smallest loudspeaker of the world using CNT thin films by a simple fabrication process [12].

Challenges

Countless challenges are raised in the design and implementation of nanoradios. The antenna constitutes the major size limitation of the communication link. It will always be the largest and most intrusive component of the antenna/sensor. A major challenge with nanotube application is the purification of the reaction product along with the largescale synthesis. The nanoradio is often configured as a receiver, but it will soon work as a transmitter. Due to these challenges, the real applications of nanoradios are still under development.

Conclusion

A nanoradio is a carbon nanotube anchored to an electrode, with a second electrode just beyond its free end. It works by using physical vibrations. Nanoradios may not change how we listen to music in radio, but they could have a significant impact on medicine.

Researchers in California had developed a nanosized carbon nanotube based radio device, while researchers in China had developed a nanosized flexible, CNT loudspeakers, In the near future, scientists will able to integrate the nanosized radio and loudspeaker in order to fabricate a fully operating radio. More information about nanoradio can be found in related journals:

- *Nanotechnology*
- *Nanoscale.*
- *Nano Letters*
- *Nano Communication Networks*
- *Journal of Nanoscience and Nanotechnology,*
- *Journal of Micro and Nano-Manufacturing*
- *Journal of Nanoengineering and Nanomanufacturing*
- *NASA Tech Briefs Magazine*

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