Judging Form

#101

Region: 2 **Entry #:** 123Q

Title: ClaritÂ© - A Better Cohlear Implant

Entry Level:

K-3 **(4-6)** **7-9** **10-12**

A Better Cochlear Implant

Abstract

The cochlear implant is a device that assists people with profound hearing loss to gain some ability to hear. Nearly half a million people have received these implants to date. Early childhood is a critical time in the development of language and speech, and these devices can help children as young as twelve months. The current design is significantly limited, as it enables people to hear only high frequencies. Many sounds such as the human voice are often distorted, yielding a low-quality result. Currently, the implant is only inserted partially into the cochlea. Our new design will vastly improve the quality of sound for patients, enabling them to hear a wider range of frequencies. To make this possible, our design, using nano - technology and graphene, will be inserted into the cochlea through its entire length. The device will enable finer discrimination of frequencies and thus remarkably enhance sound quality.

A Better Cochlear Implant

Present Technology

Hearing is a very complex mechanism. It involves the ear, the auditory nerve, and the auditory cortex in the brain. The ear itself is divided into three parts – the outer ear, the middle ear and the inner ear. The outer ear and the middle ear conduct sound waves to the inner ear, creating movement of the fluid in the inner ear. The inner ear contains the cochlea, which is the sensory organ of hearing and translates sound waves into electrical impulses.

The cochlea is a spiral, hollow structure which consists of three chambers: the scala vestibuli, the scala tympani, and the scala media. The basilar membrane separates the scala media from the scala tympani. The Organ of Corti lies on the basilar membrane and consists of a layer of nerve cells which are topped with bundles of hair-like structures called stereocilia. Movement of the fluid in the cochlea causes the hair bundles to deflect which, in turn, sends electric signals up the auditory nerve to the brain. Hair bundles are arranged by frequency along the basilar membrane. High frequencies stimulate the hair bundles in the widest part of the cochlea while low frequencies stimulate those in the narrowest regions. The brain then interprets these electrical signals as sound. The human ear is capable of hearing sounds composed of frequencies in the range from 20 Hz to 20,000 Hz.

Hearing loss can be categorized depending on what part of the auditory system is damaged. It can be conductive, sensorineural, or mixed. Conductive hearing loss involves the outer or middle ear. Sensorineural hearing loss involves the inner ear, auditory nerve and/or brain. Cochlear implants can help people with significant sensorineural hearing loss that are not helped by hearing aids. If the hair cells are damaged, sound may reach the cochlea but not be transmitted to the auditory nerve. A cochlear implant can bypass the hair cells and electrically stimulate the auditory nerve directly.

A cochlear implant consists of two portions: an external part that is behind the ear and includes a microphone and a speech processor, and a surgically implanted internal part consisting of a receiver/stimulator and an electrode array. The microphone collects the sound while the speech processor receives the sounds picked up by the microphone. The speech processor then breaks down the sound into its individual frequencies. These frequencies are changed into electrical impulses and sent to a transmitter, and then on to the surgically implanted receiver/stimulator. The stimulator feeds the impulses to the electrode array, which is implanted into the cochlea. The electrode array then stimulates different regions along the auditory nerve. These signals are carried to the brain where they are perceived as sound.

Current implants do not restore normal hearing as present day implants contain a maximum of 22 electrodes. Instead, they can give a deaf person a useful representation of sounds in the environment and help him or her to understand speech. A cochlear implant is very different from a hearing aid. Hearing aids amplify sounds so they may be detected by damaged ears. Cochlear implants bypass damaged portions of the ear and directly stimulate the auditory nerve. Hearing through a present day cochlear implant is different from normal hearing and takes time to learn. However, it allows many people to recognize warning signals, understand other sounds, and enjoy a conversation.

History

The cochlear implant has been in use since the early 1980's. However, the concept of improving hearing for people with profound hearing loss by stimulating the auditory nerve was introduced in the late 18th century by Alessandro Volta. He was the first to describe an electrical stimulation in his ear canal after inserting metal rods connected to batteries. He received an unpleasant jolt sensation and heard a crackling sound.

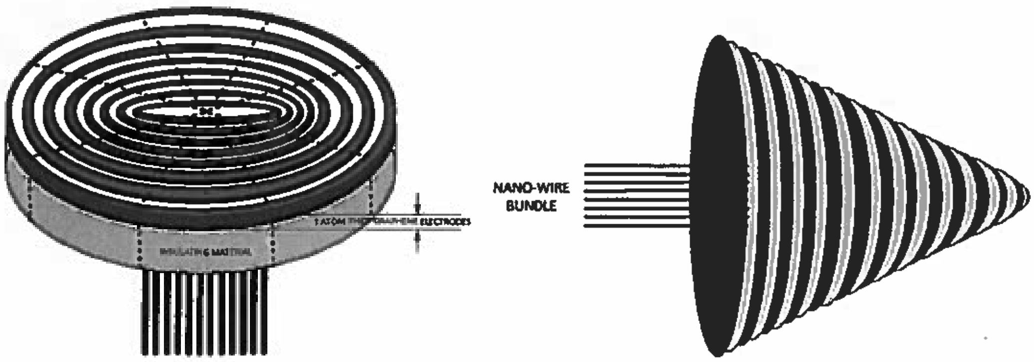
Over the next two centuries, research continued with no significant advancements. In 1964, Dr. Simmons from Stanford University implanted electrodes directly into the central portion of the cochlea and patients could hear simple tunes. Dr. Graeme Clark, an Australian ear surgeon whose father was deaf, was determined to create a better means of communication and researched the ability of providing an electronic hearing device. In 1978, he inserted the first multichannel cochlear implant device. Thousands of people including many children benefitted from these simple devices. However, these early devices were all bulky and crude, and the sound reproduction was poor.

Over the next two decades, multiple advancements were made and currently there are three cochlear implants available in the U.S. Users still rate these systems as average. The very best system on the market scores 35-40% with open word sets, and 65-80% with sentence recognition in adults with acquired deafness. Children who were born deaf score a mean 44% for open word sets, and 61% for sentence recognition. Users describe the quality of sound, including human voice, as quite poor. Some patients may describe the quality as similar to voices of cartoon characters. This leads some people to simply not use the implants or have them removed altogether.

Future Technology

To utilize the entire frequency range of human hearing (20 - 20,000 Hz), approximately 20,000 electrodes will be needed. Each electrode will be placed on the implant to match the spacing of the stereocilia within the ear so that the frequency of each electrode will match with that of the corresponding hair bundle. The frequencies will decrease along the implant with the lowest frequency electrode furthest into the cochlea at the apex.

To make the implant, we will start with a disk made of pure graphene. Graphene was chosen because it is extremely flexible and an excellent electrical conductor. A thin layer of insulating material will be deposited on to the graphene disk. A laser will then be used to precisely etch concentric circles into the graphene disk. This etching will only affect the graphene and leave the insulating material intact. The etched areas in the graphene disk will then be washed away leaving concentric rings of graphene attached to the continuous disk of insulating material. The laser will again be used to bore a hole into each ring of graphene all the way through the insulator. Next, individually insulated nanowires will be threaded through the insulator and electrically attached to each graphene ring. Nanowires were chosen due to their near superconducting properties. Also, nanowires are extremely small in diameter allowing the approximately 20,000 wires in the improved implant to exit the implant and connect to the receiver/stimulator. Wedges will be cut from the disk and rolled into cone shaped implants with the nanowires exiting from the open end of the cone. The implant can be made in different lengths and diameters depending upon individual ear structure as determined by preoperative imaging. The nanowire bundle will then attach to the output of the receiver/stimulator. The concept is shown in the diagrams below.



The speech processor is responsible for converting natural sounds into individual frequency components. It will have the ability to drive these unique frequencies to each graphene ring or electrode such that the signal to each electrode is matched to the frequency of response of the corresponding hair bundle. Additionally, each output can be custom tuned in order to optimize sound quality for an individual user. The speech processor is a part of the external transmitter, held in place magnetically behind the ear. Initially, the device will be preprogrammed with a "normal" hearing pattern based on audiologic analysis. The speech processor output can be further adjusted to optimize the patient's interpretation of sound.

Breakthroughs

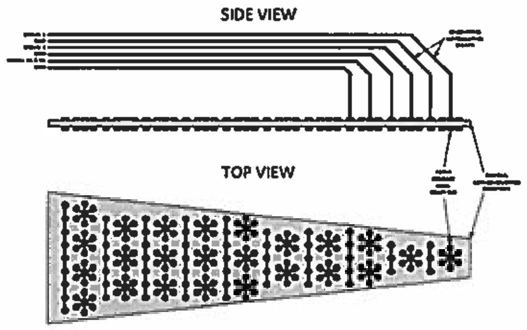
Graphene is a material which has only recently been discovered. It consists of a very thin layer of pure carbon, and is only one atom thick. Currently, one-atom thick sheets of graphene are difficult to manufacture. Our implant will need to have thousands of one-atom thick rings of graphene separated by almost as thin layers of an insulating material. The graphene rings will need to be exposed to the outside of the implant; they will also need to be connected to the speech processor so that the electrical signals can be transmitted accurately to the auditory nerve fibers.

Several new technologies will need to be perfected to accomplish the construction of this cochlear implant. First and foremost, the reliable manufacture of graphene wafers will have to become commercially viable. Next, the technology to manufacture insulated nanowires that can be made to sufficient length will need to be developed. Also, the process of laser etching, boring and cutting the stack up of graphene material and insulator will have to be developed, as well as a method to reliably form an electrical bond between the nanowires and the graphene disk. Finally, a method to form the wired wedge into a cone shape that matches the shape of a human cochlea will have to be perfected.

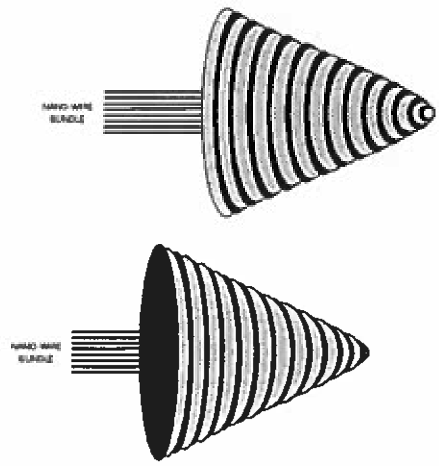
Design Process

After researching cochlear implants that are presently available, many ways to improve the existing implants were explored. It was obvious that the main improvement would be to increase the number of electrodes from the twenty two that today's implants use. It is believed that this increase in the number of electrodes would lead to a vast improvement in sound reproduction. The downside of a large increase of electrodes is the small scale on which the implant would have to be produced.

Initially, an implant made from a thin strip of material with embedded conductive pads that got progressively narrower was considered. This concept was rejected due to perceived difficulty in inserting the thin strip into the cochlea. The thin strip of flexible material would lack rigidity needed to thread it deep into the cochlea. Also, it would be difficult to fit such a large number of conventional electrodes into a single strip. Initial version of the implant is shown below:



In order to improve the rigidity of the implant, a conical structure was considered to allow the device to be more easily inserted into the ear. We considered the challenge of how to place the electrodes on the exterior of the conical structure. It was proposed that nanowires could be wound around the cone at small intervals to create the electrodes. The upside is that the implant could be inserted into the cochlea without regard to rotational position. The downside is the immense manufacturing challenge of precisely winding the nanowires around the conical implant. Second version of the implant is shown in the figure below:



The next two implant concepts use processes similar to those in the manufacture of integrated circuits. The third implant design built upon the previous conical concept but used concentric rings of graphene in place of the wrapped nanowires. This is the implant that we proceeded with, and is described in the Future Technology section.

Going one step further, a fourth implant was proposed that would have replaced the nanowires with etched traces, similar to those in an integrated circuit. These etched traces would have been placed on the inner surface of the cone in order to route all the signals into the implant. This concept was rejected, as it would add more complexity and it would be difficult to connect these etched traces to external wiring. Also, the extra steps involved would add additional cost, thus reducing the pool of people that could afford this new technological advance.

Consequences

An improved cochlear implant will have significant consequences on the hearing impaired community. The consequences are likely to run the spectrum from very positive to negative, both on patients receiving the implant and a large part of the deaf community. The positive consequences will include enabling the hearing impaired to hear a wider range of frequencies, thus gaining the ability to hear sounds more naturally. The hearing impaired will be able to hear the delicate songs of birds and the symphonies of Beethoven equal to those with no hearing impairment. The improved implant will also allow the language centers of the brain to develop properly when it is used on the very young.

The negative consequences might include a backlash from the deaf community who do not think of deafness as being a handicap. The deaf community might look down upon the recipients of the implant. Another negative consequence may be that society will view this implant as giving the patients supernormal hearing ability. This may lead to general questions regarding the appropriate use of certain medically implanted devices that can give the public the perception that patients receive greater abilities than their natural counterparts.

Biblioghraphy

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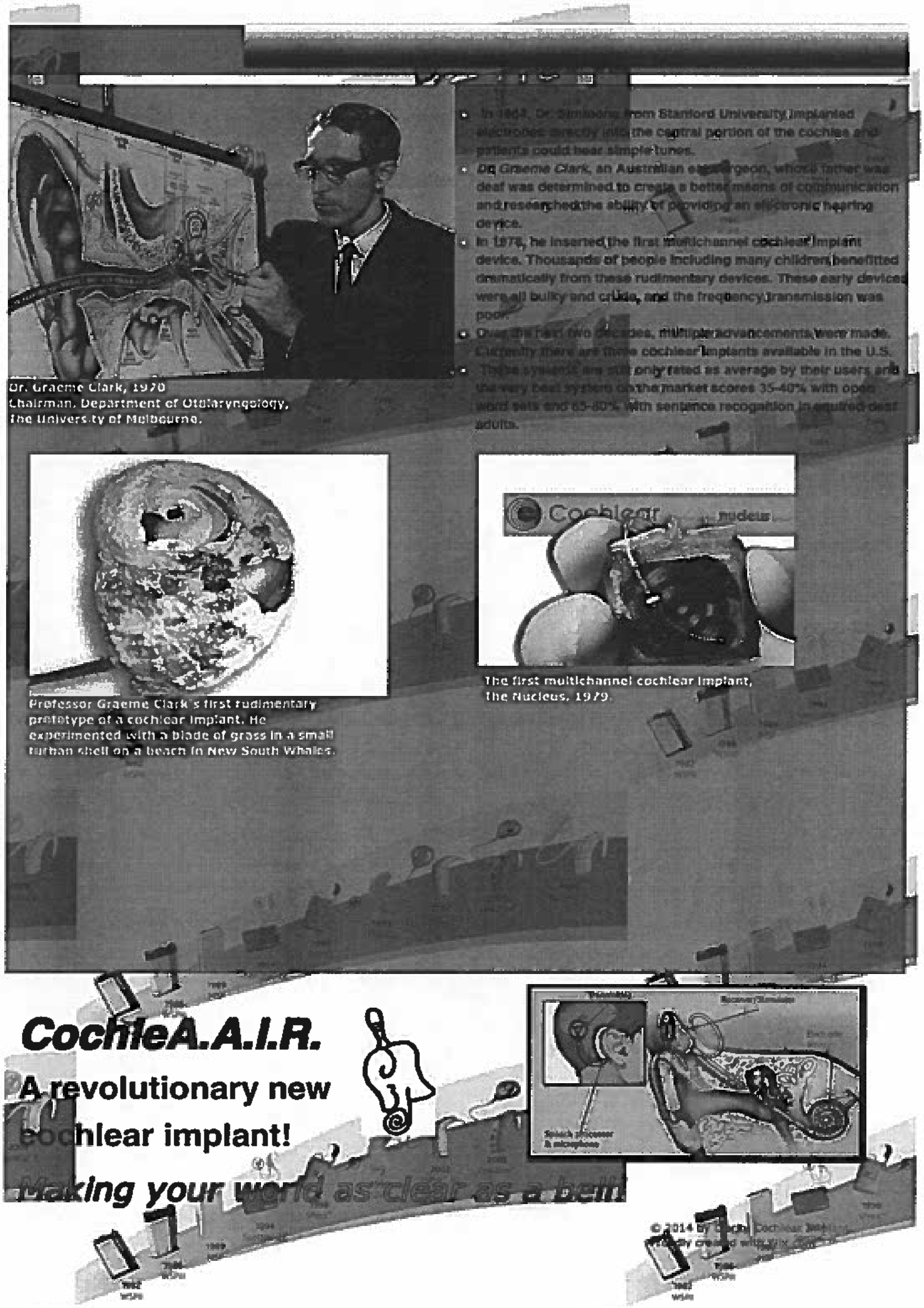
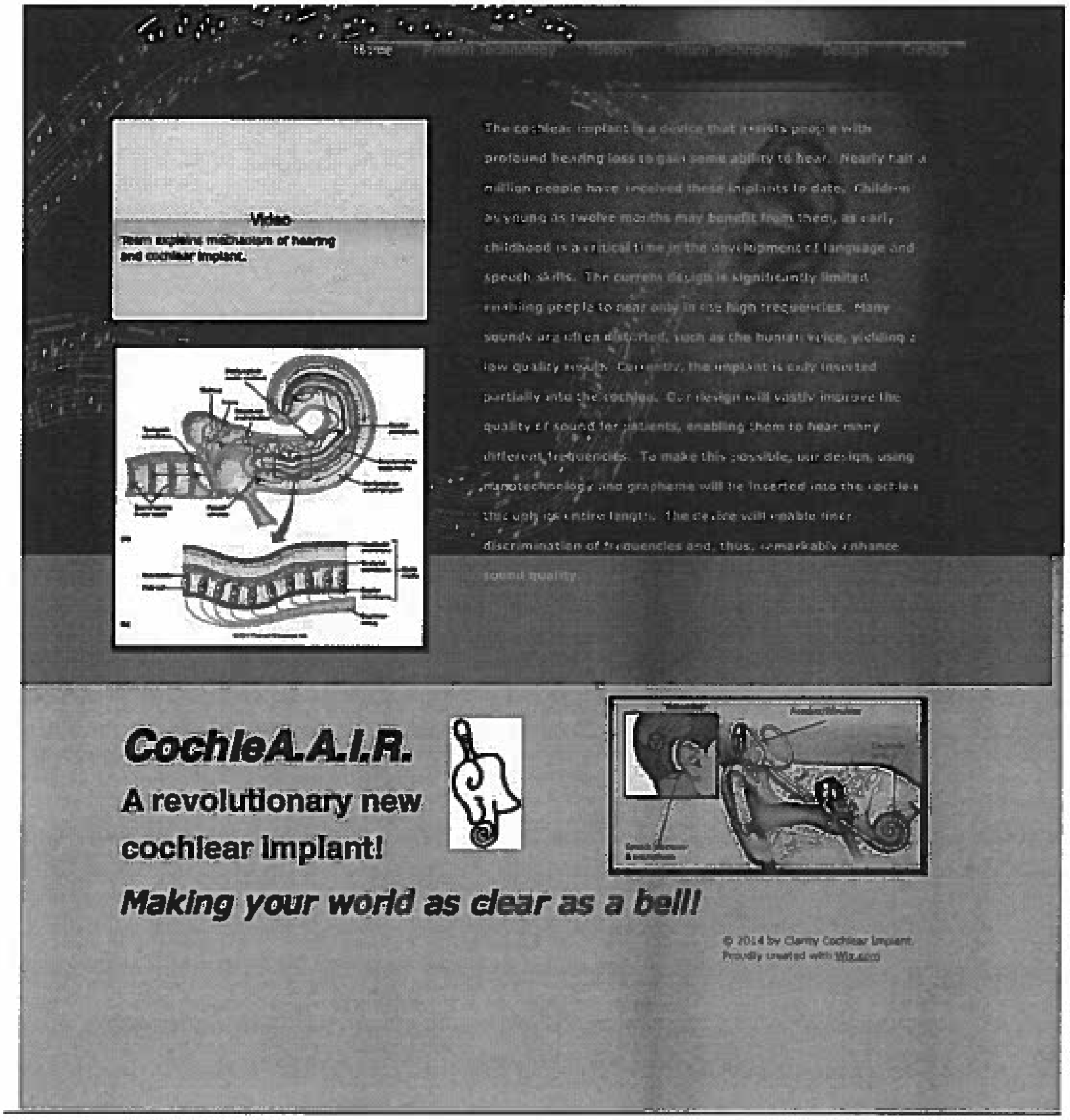

In 1962, Dr. Simmons from Stanford University implanted electrodes directly into the central portion of the cochlea and patients could hear simple tunes.
Dr. Graeme Clark, an Australian ear surgeon, whose father was deaf was determined to create a better means of communication and researched the ability of providing an electronic hearing device.
In 1978, he inserted the first multichannel cochlear implant device. Thousands of people including many children benefitted dramatically from these rudimentary devices. These early devices were all bulky and crude, and the frequency transmission was poor.
Over the next two decades, multiple advancements were made. Currently there are three cochlear implants available in the U.S.
These systems are still only rated as average by their users and the very best system on the market scores 35-40% with open word sets and 65-80% with sentence recognition in acquired-deaf adults.
Dr. Graeme Clark, 1970
Chairman, Department of Otolaryngology,
The University of Melbourne.
Cochlear nucleus
Professor Graeme Clark's first rudimentary prototype of a cochlear implant. He experimented with a blade of grass in a small turban shell on a beach in New South Whales.
The first multichannel cochlear implant,
The Nucleus, 1979.
CochleA.A.I.R.
A revolutionary new cochlear implant!
Making your world as clear as a bell!
Receiver/Stimulator
Speech processor & microphone


Home
Video
Team explains mechanism of hearing and cochlear implant.
The cochlear implant is a device that assists people with profound hearing loss to gain some ability to hear. Nearly half a million people have received these implants to date. Children as young as twelve months may benefit from them, as early childhood is a critical time in the development of language and speech skills. The current design is significantly limited, enabling people to hear only in the high frequencies. Many sounds are often distorted, such as the human voice, yielding a low quality result. Currently, the implant is only inserted partially into the cochlea. Our design will vastly improve the quality of sound for patients, enabling them to hear many different frequencies. To make this possible, our design, using nanotechnology and graphene will be inserted into the cochlea through its entire length. The device will enable finer discrimination of frequencies and, thus, remarkably enhance sound quality.
CochleA.A.I.R.
A revolutionary new cochlear implant!
Making your world as clear as a bell!
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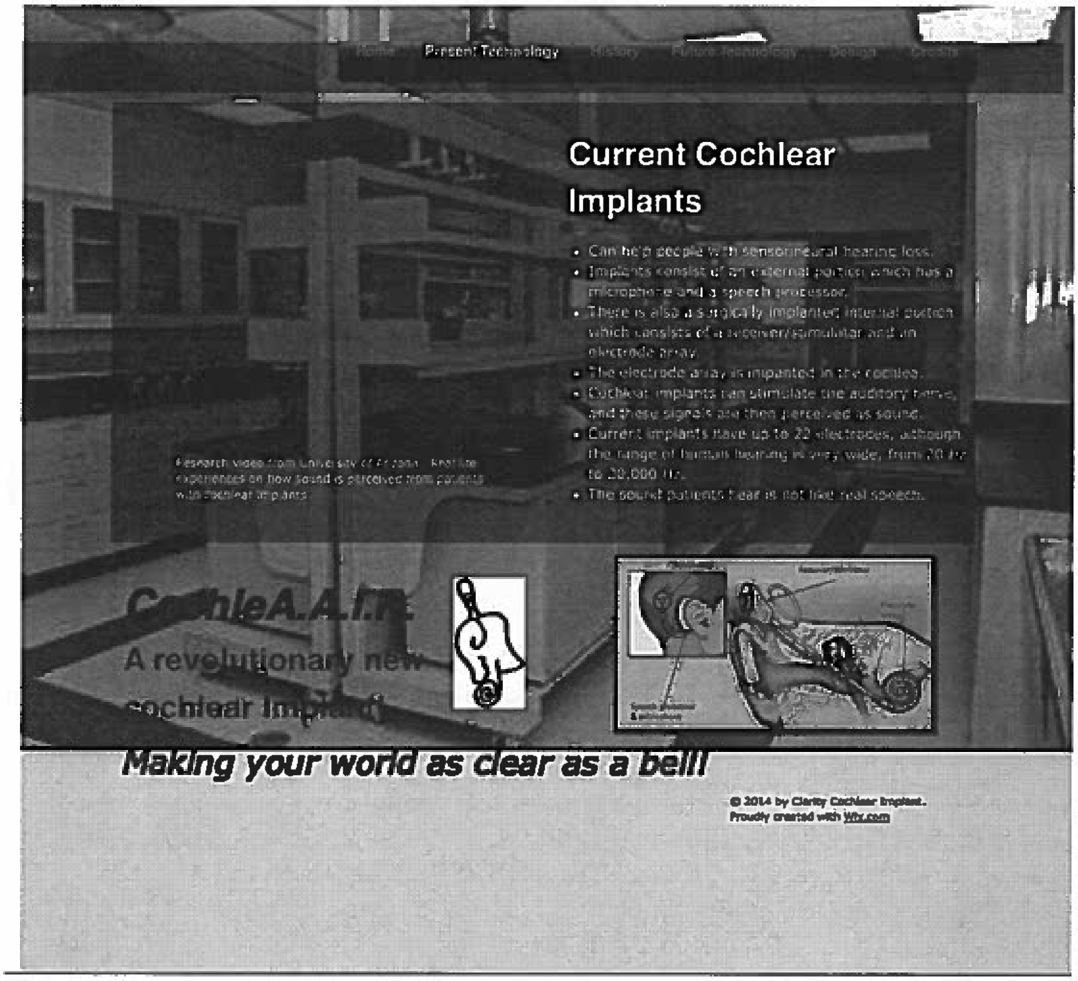
Present Technology
Current Cochlear Implants
Can help people with sensorineural hearing loss.
The sound patients hear is not like real speech.
Making your world as clear as a bell!
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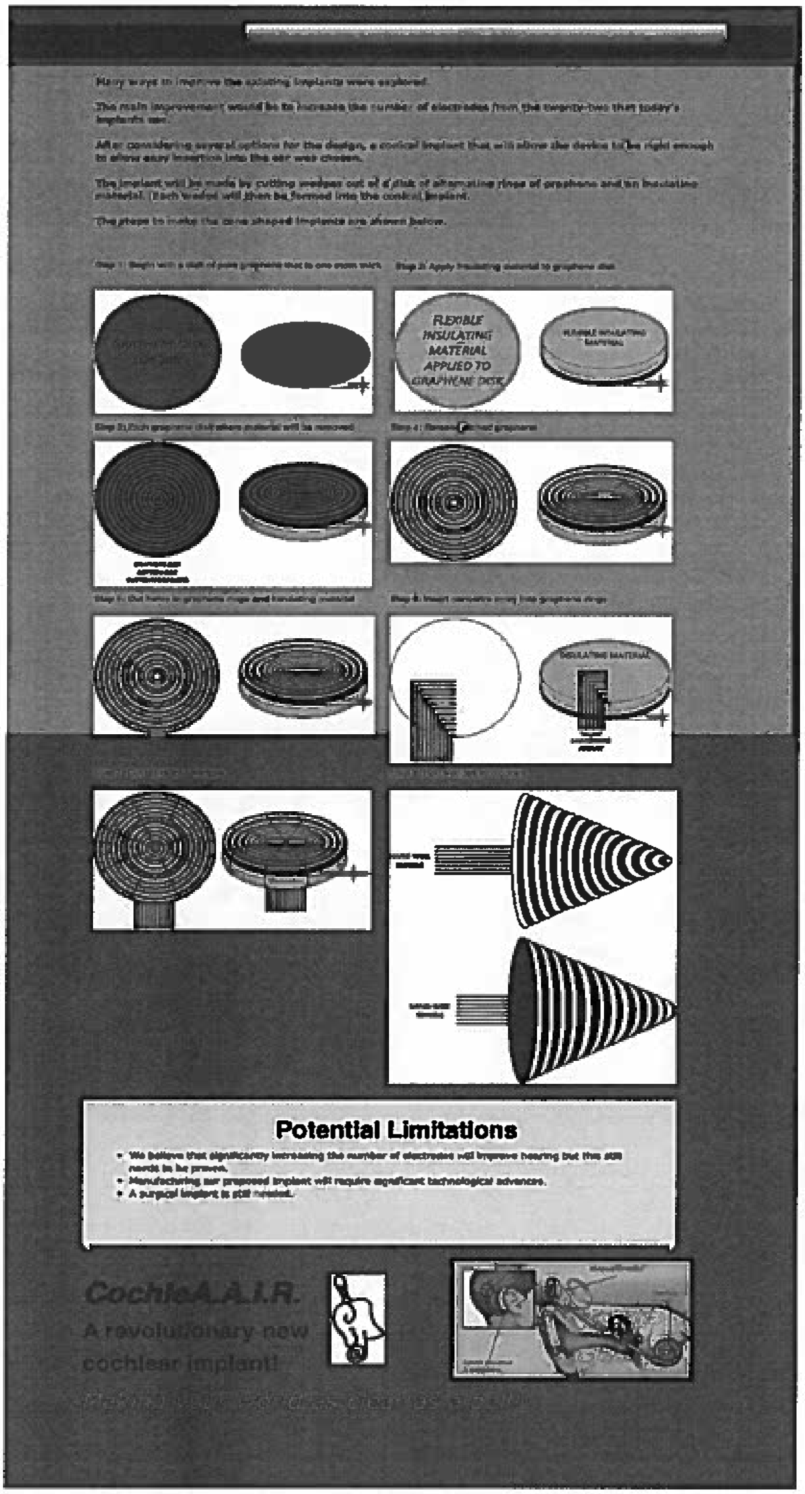
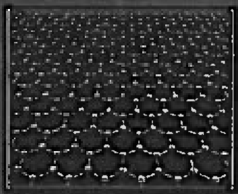

Many ways to improve the existing implants were explored.
The main improvement would be to increase the number of electrodes from the twenty-two that today's implants use.
After considering several options for the design, a conical implant that will allow the device to be rigid enough to allow easy insertion into the ear was chosen.
The implant will be made by cutting wedges out of a disk of alternating rings of graphene and an insulating material. Each wedge will then be formed into the conical implant.
The steps to make the cone shaped implants are shown below.
Step 2: Apply insulating material to graphene disc
FLEXIBLE INSULATING MATERIAL APPLIED TO GRAPHENE DISK
Potential Limitations
We believe that significantly increasing the number of electrodes will improve hearing but this still needs to be proven.
Manufacturing our proposed implant will require significant technological advances.
A surgical implant is still needed.
CochleA.A.I.R.
A revolutionary new cochlear implant!

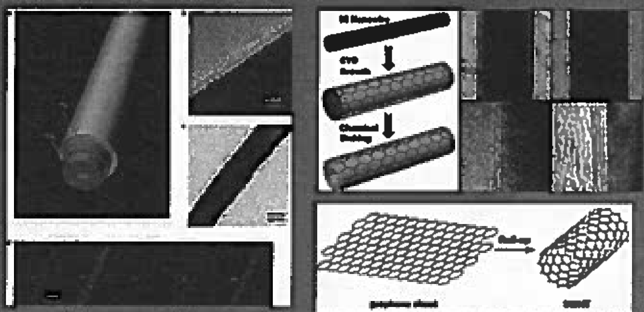
Future Technology

Future Technology & Breakthroughs Needed

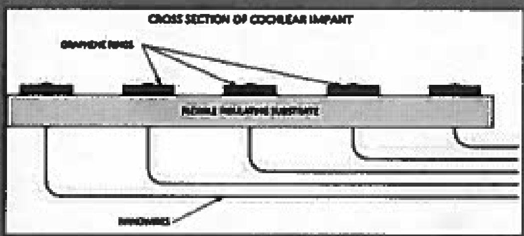
One-atom thick sheets of pure graphene that are readily available



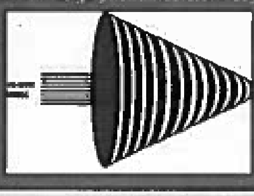
Free standing insulated nanowires



Graphene etching process that leaves concentric circles on a flexible insulating material



Inexpensive method to form the graphene/insulator wedges into very thin cone shapes



CochleA.A.I.R.

A revolutionary new cochlear implant!

Making your world as clear as a bell!