

# Artificial Vision–A Bionic Eye

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## Abstract

For those millions of us whose vision isn't perfect, there are glasses. But for those hundreds of thousands who are blind, devices that merely assist the eyes just aren't enough. What they need are alternative routes by which the sights of the world can enter the brain and be interpreted. Technology has created many path ways for the mankind. Now technology has improved to that extent wherein the entire human body can be controlled using a single electronic chip. We have seen prosthetics that helped to overcome handicaps. Bio medical engineers play a vital role in shaping the course of these prosthetics. Now it is the turn of artificial vision through bionic eyes. Chips designed specially to imitate the characteristics of the damaged retina and the cones and rods of the organ of sight are implanted with a microsurgery. Linking electronics and biotechnology, the scientists have made the commitment to the development of technology that will provide or restore vision for the visually impaired around the world. Whether it is Bio medical, Computer, Electrical, or Mechanical Engineers all of them have a role to play in the personification of Bionic Eyes. There is hope for the blind in the form of bionic eyes. This technology can add life to their vision less eyes.

## Keywords

Electronic Microchip, Artificial Silicon Retina, MARC System, Digital Camera, Implantation

## I. Introduction

Belonging to the community of engineers there is no frontier that we cannot conquer. If scientists give birth to ideas, then it is we engineers who put life into those ideas. Today, we talk of artificial intelligence that has created waves of interest in the field of robotics. When this has been possible, then there is a possibility for artificial vision. 'Bionic eye' also called a Bio Electronic eye, is the electronic device that replaces functionality of a part or whole of the eye. It is still at a very early stage in its development, but if successful, it could restore vision to people who have lost sight during their lifetime. This technology can add life to their visionless eyes [1].

A bionic eye works by stimulating nerves, which are activated by electrical impulses. In this case the patient has a small device implanted into the body that can receive radio signals and transmit those signals to brain through nerves and can interpret the image. One of the most dramatic applications of bionics is the creation of artificial eyes. Early efforts used silicon-based photo detectors, but silicon is toxic to the human body and reacts unfavorably with fluids in the eye. Now, scientists at the Space Vacuum Epitaxy Centre (SVEC) based at the University of Houston, Texas, are using a new material they have developed, tiny ceramic photocells that could detect incoming light and so repair malfunctioning human eyes [2].

## II. System Overview

### A. Human Eye



Fig. 1: Human Eye

We are able to see because light from an object can move through space and reach our eyes. Once light reaches our eyes, signals are sent to our brain, and our brain deciphers the information in order to detect the appearance, location and movement of the objects we are sighting at. The internal working of eye is as follows [3],

1. The light is projected onto the retina.
2. The retina sends messages to the brain through the optic nerve.
3. The brain interprets what the object is.

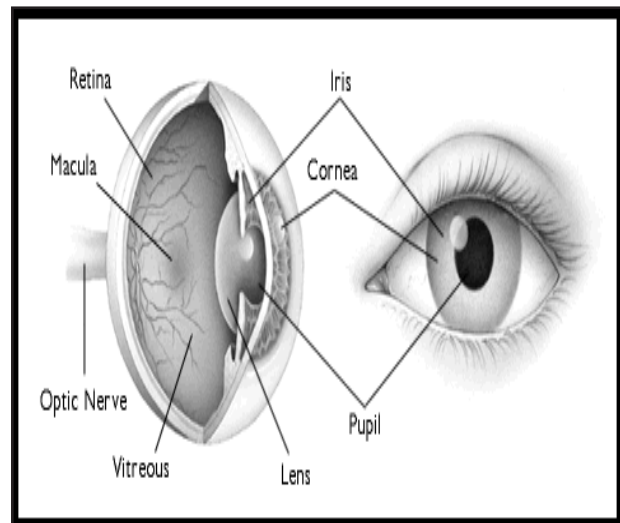


Fig. 2: Internal Structure of Human Eye

The eyeball is set in a protective cone-shaped cavity in the skull called the orbit or socket and measures approximately one inch in diameter. The orbit is surrounded by layers of soft, fatty tissue which protect the eye and enable it to turn easily. The important part of an eye that is responsible for vision is retina. The retina is complex in itself. This thin membrane at the back of the eye is a vital part of your ability to see. Its main function is to receive and transmit images to the brain. In humans there are three main types of light sensitive cells in the retina. They are [3],

- Rod Cells
- Cone Cells
- Ganglion Cells

There are about 125 million rods and cones within the retina that act as the eye's photoreceptors. Rods are able to function in low

light and can create black and white images without much light. Once enough light is available, cones give us the ability to see color and detail of objects. The information received by the rods and cones are then transmitted to the nearly 1 million ganglion cells in the retina. These ganglion cells interpret the messages from the rods and cones and send the information on to the brain by way of the optic nerve [2].

## B. Vision Impairment

Damage or degeneration of the optic nerve, the brain, or any part of the visual pathway between them, can impair vision.

## C. Causes of Blindness

There are a number of retinal diseases that attack these cells, which can lead to blindness. The most notable of these diseases are:

1. Retinitis pigmentosa
2. Age-related macular degeneration

Retinitis Pigmentosa (RP) is the name given to a group of hereditary diseases of the retina of the eye.

In macular degeneration, a layer beneath the retina, called the Retinal Pigment Epithelium (RPE), gradually wears out from its lifelong duties of disposing of retinal waste products [4].

Both of these diseases attack the retina, rendering the rods and cones inoperative, causing either loss of peripheral vision or total blindness. However, it's been found that neither of these retinal diseases affects the ganglion cells or the optic nerve. This means that if scientists can develop artificial cones and rods, information could still be sent to the brain for interpretation.

## D. Corneal Transplants

Surgical removal of opaque or deteriorating corneas and replacement with donor transplants is a common medical practice. Corneal tissue is a vascular; that is, the cornea is free of blood vessels. Therefore corneal tissue is seldom rejected by the body's immune system. Antibodies carried in the blood have no way to reach the transplanted tissue, and therefore long-term success following implant surgery is excellent [5].

## E. The Surgery

This concept of Artificial Vision is also interesting to engineers, because there are a number of technicalities involved in this surgery apart from the anatomical part. The microsurgery starts with three incisions smaller than the diameter of a needle in the white part of the eye. Through the incisions, surgeons introduce a vacuuming device that removes the gel in the middle of the eye and replaces it with saline solution. Surgeons then make a pinpoint opening in the retina to inject fluid in order to lift a portion of the retina from the back of the eye, creating a pocket to accommodate the chip. The retina is resealed over the chip, and doctors inject air into the middle of the eye to force the retina back over the device and close the incisions. During the entire surgery, a biomedical engineer takes part actively to ensure that there is no problem with the chip to be implanted. Artificial retinas constructed at SVEC consist of 100,000 tiny ceramic detectors, each 1/20 the size of a human hair. The assemblage is so small that surgeons can't safely handle it. So, the arrays are attached to a polymer film one millimeter by one millimeter in size. A couple of weeks after insertion into an eyeball, the polymer film will simply dissolve leaving only the array behind [6].

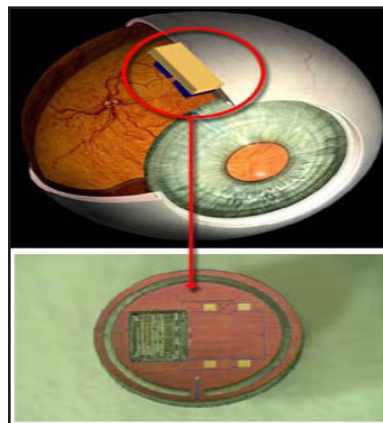


Fig. 3: Implanted Chip

## III. System Features

### A. Artificial Silicon Retina

The brothers Alan Chow and Vincent Chow have developed a microchip containing 3500 photo diodes, which detect light and convert it into electrical impulses, which stimulate healthy retinal ganglion cells. The ASR requires no externally-worn devices. The ASR is a silicon chip 2 mm in diameter and 1/1000 inch in thickness. It contains approximately 3,500 microscopic solar cells called "microphotodiodes," each having its own stimulating electrode. These microphotodiodes are designed to convert the light energy from images into thousands of tiny electrical impulses to stimulate the remaining functional cells of the retina in patients suffering with AMD and RP types of conditions [7].



Fig. 4: Magnified Image of ASR

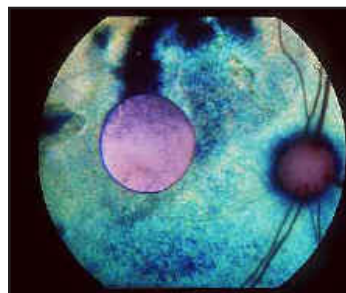


Fig. 5: ASR Implant in Eye

The ASR is powered solely by incident light and does not require the use of external wires or batteries. When surgically implanted under the retina, in a location known as the sub retinal space, the ASR is designed to produce visual signals similar to those produced by the photoreceptor layer. From their sub retinal location these artificial "photoelectric" signals from the ASR are in a position to induce biological visual signals in the remaining functional retinal cells which may be processed and sent via the optic nerve to the brain. The original Optobionics Corp. stopped operations, but Dr. Chow acquired the Optobionics name, the

ASR implants and will be reorganizing a new company under the same name. The ASR microchip is a 2mm in diameter silicon chip (same concept as computer chips) containing ~5,000 microscopic solar cells called “Microphotodiodes” that each have their own stimulating electrode [8].



Fig. 6: The Dot Above the Date on this Penny is the Full Size of the ASR

As you can see in the picture at the top of this page, the ASR is an extremely tiny device, smaller than the surface of a pencil eraser. It has a diameter of just 2 mm (.078 inch) and is thinner than a human hair. There is good reason for its microscopic size. In order for an artificial retina to work it has to be small enough so that doctors can transplant it in the eye without damaging the other structures within the eye [2].

### B. MARC System

The intermediary device is the MARC system. The schematic of the components of the MARC to be implanted consists of a secondary receiving coil mounted in close proximity to the cornea, a power and signal transceiver and processing chip, a stimulation-current driver, and a proposed electrode array fabricated on a material such as silicone rubber, thin silicon, or polyimide with ribbon cables connecting the devices. The biocompatibility of polyimide is being studied, and its thin, lightweight consistency suggests its possible use as a non-intrusive material for an electrode array. Titanium tacks or cyanoacrylate glue may be used to hold the electrode array in place [9].

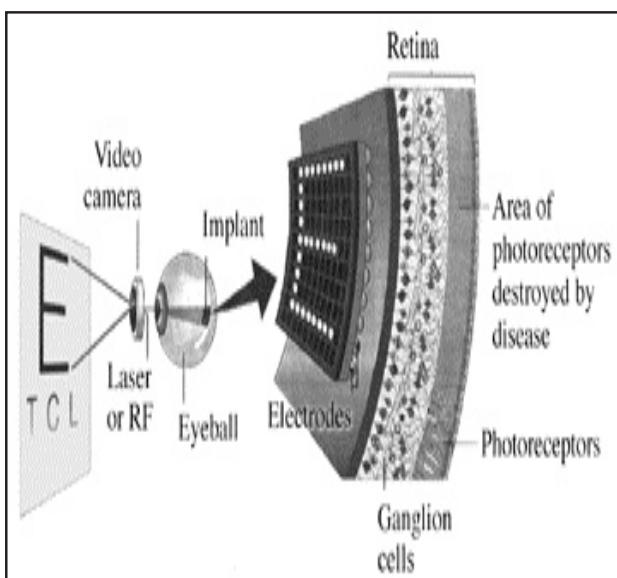


Fig. 7: The MARC System

The MARC system will operate in the following manner. An external camera will acquire an image, whereupon it will be encoded into data stream which will be transmitted via RF

telemetry to an intraocular transceiver. A data signal will be transmitted by modulating the amplitude of a higher frequency carrier signal. The signal will be rectified and filtered, and the MARC will be capable of extracting power, data, and a clock signal. The subsequently derived image will then be stimulated upon the patient's retina [10].

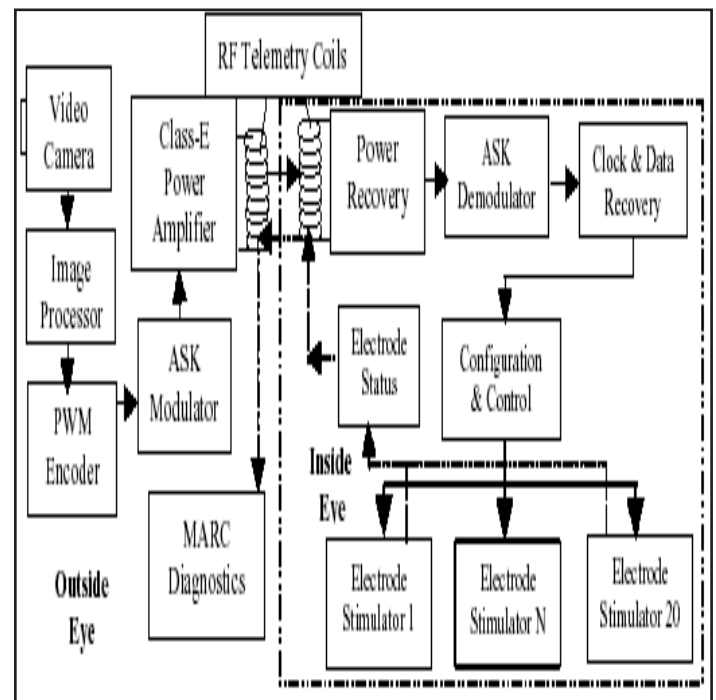


Fig. 8: Circuit of MARC System

The MARC system would consist of two parts which separately reside exterior and interior to the eyeball. Each part is equipped with both a transmitter and a receiver. The primary coil can be driven with a 0.5-10 MHz carrier signal, accompanied by a 10 kHz amplitude modulated (AM/ASK) signal which provides data for setting the configuration of the stimulating electrodes. A DC power supply is obtained by the rectification of the incoming RF signal. The receiver on the secondary side extracts four bits of data for each pixel from the incoming RF signal and provides filtering, demodulation, and amplification. The extracted data is interpreted by the electrode signal driver which finally generates appropriate currents for the stimulating electrodes in terms of magnitude, pulse width, and frequency [11].

### C. Engineering Details

First, for visually impaired people to derive the greatest benefit from an enhanced-vision system, the image must be adapted to their particular blind areas and areas of poor acuity or contrast sensitivity. Then the information arriving instantaneously at the eye must be shifted around those areas. The thrust of all prosthetic vision devices is to use an electrode array to give the user perceptions of points of light (phosphenes) that are correlated with the outside world. Thus, to achieve the expected shift of the image across the stimulating electrode array, the camera capturing the image must follow the wearer's eye or pupil movements by monitoring the front of the eye under Infrared (IR) illumination. The eye-position monitor controls the image camera's orientation. If the main image-acquisition camera is not mounted on the head, compensation for head movement will be needed, as well. Finally, if a retinal prosthesis is to receive power and signal input from outside the eye via an IR beam entering the pupil, the transmitter

must be aligned with the intraocular chip. The beam has two roles: it sends power, and it is pulse or amplitude-modulated to transmit image data. Under the control of eye movement, the main imaging camera for each eye can swivel in any direction. Each of these cameras--located just outside the users' field of view to avoid blocking whatever peripheral vision they might have--captures the image of the outside world and transmits the information through an optical fiber to a signal-processing computer worn on the body. The chip which is inserted on the retina is coded using the computer programmatic languages. After the implantation, the working of the bionic eye is compared with the normal view through necessary algorithms so that measures are taken that can rectify the abnormalities.

#### IV. Working Procedure

An artificial eye provokes visual sensations in the brain by directly stimulating different parts of the optic nerve.

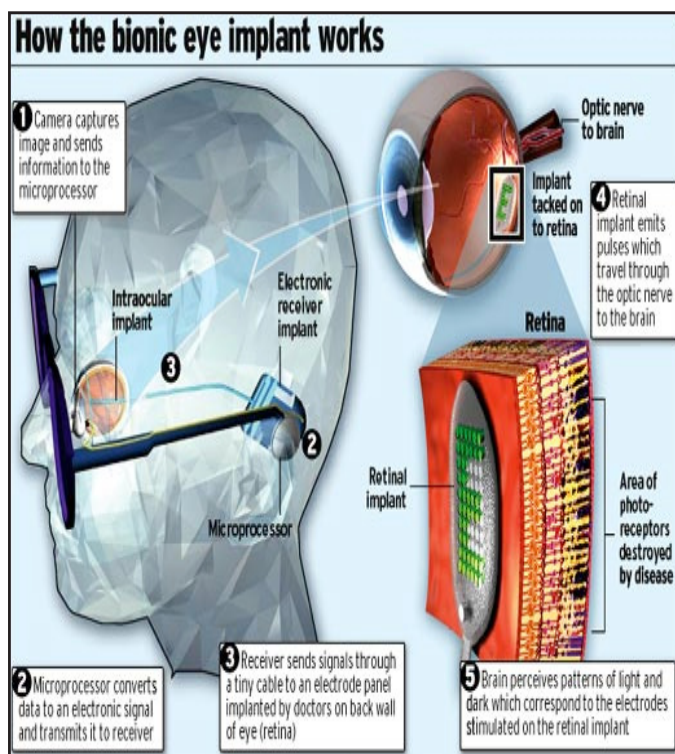


Fig. 9: Working of Bionic Eye

A bionic eye works by stimulating nerves, which are activated by electrical impulses. In this case the patient has a small device implanted into the body that can receive radio signals and transmit those signals to nerves. The Argus II implant consists of an array of electrodes that are attached to the retina and used in conjunction with an external camera and video processing system to provide a rudimentary form of sight to implanted subjects. The Argus II Retinal Prosthesis System can provide sight, the detection of light, to people who have gone blind from degenerative eye diseases. Diseases damage the eyes' photoreceptors, the cells at the back of the retina that perceive light patterns and pass them on to the brain in the form of nerve impulses, where the impulse patterns are then interpreted as images. The Argus II system takes the place of these photoreceptors. The second incarnation of Second Sight's retinal prosthesis consists of five main parts:

- Digital Camera - built into a pair of glasses, captures images in real-time sends images to microchip.
- Video processing microchip - built into a handheld unit, processes images into electrical pulses representing patterns of

- light and dark; sends pulses to radio transmitter in glasses
- Radio transmitter - wirelessly transmits pulses to receiver implanted above the ear or under the eye
- Radio receiver - receiver sends pulses to the retinal implant by a hair-thin, implanted wire
- Retinal implant - array of 60 electrodes on a chip measuring 1 mm by 1 mm [12]

The entire system runs on a battery pack that is housed with the video processing unit. When the camera captures an image-of, say, a tree-the image is in the form of light and dark pixels. It sends this image to the video processor, which converts the tree-shaped pattern of pixels into a series of electrical pulses that represent "light" and "dark." The processor sends these pulses to a radio transmitter on the glasses, which then transmits the pulses in radio form to a receiver implanted underneath the subject's skin. The receiver is directly connected via a wire to the electrode array implanted at the back of the eye, and it sends the pulses down the wire. When the pulses reach the retinal implant, they excite the electrode array. The array acts as the artificial equivalent of the retina's photoreceptors. The electrodes are stimulated in accordance with the encoded pattern of light and dark that represents the tree, as the retina's photoreceptors would be if they were working (except that the pattern wouldn't be digitally encoded). The electrical signals generated by the stimulated electrodes then travel as neural signals to the visual center of the brain by way of the normal pathways used by healthy eyes -- the optic nerves. In macular degeneration and retinitis pimentos, the optical neural pathways aren't damaged. The brain, in turn, interprets these signals as a tree, and tells the subject, "You're seeing a tree" [12].

All of this takes some training for subjects to actually see a tree. At first, they see mostly light and dark spots. But after a while, they learn to interpret what the brain is showing them, and eventually perceive that pattern of light and dark as a tree. Thus bionic eye helps a blind people to see the objects and recognize them.



Fig. 10: After Surgery

#### A. Structure of the Micro Detectors

The ceramic micro detectors resemble the ultra-thin films found in modern computer chips. The arrays are stacked in a hexagonal structure, which mimics the arrangement of the rods and cones it has been designed to replace.

#### B. The Prototype Implant

The first implant had just 16 electrodes on the retinal pad and, as a result, visual information was limited. The new device has 60 electrodes and the receiver is shrunk to one-quarter of the original's size. It is now small enough to be inserted into the eye socket itself. The operation to fit the implant will also last just 1.5 hours, down from 7.5 hours.

#### C. Implantation

An incision is made in the white portion of the eye and the retina is elevated by injecting fluid underneath, comparing the space to

a blister forming on the skin after a burn. Within that little blister, we place the artificial retina [2].

A light-sensitive layer covers 65% of the interior surface of the eye. Scientists hope to replace damaged rods and cones in the retina with ceramic micro detector arrays [2].

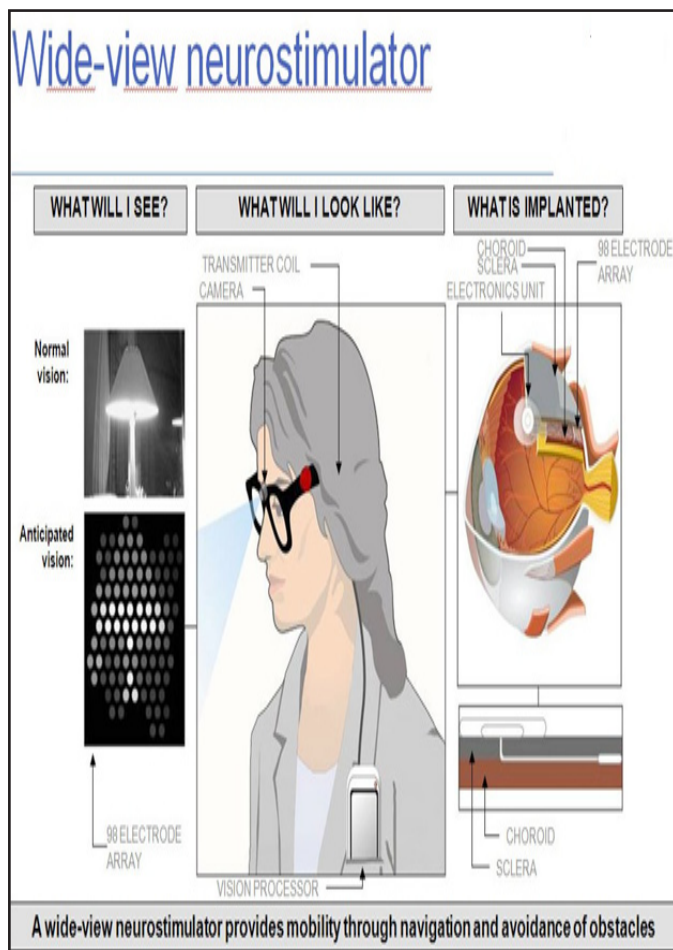


Fig. 11: What the Person Can See?

#### D. Some Facts About Bionic Eyes

Scientists at the Space Vacuum Epitaxy Centre (SVEC) based at the University of Houston, Texas, are using a new material, comprising tiny ceramic photocells that could detect incoming light and repair malfunctioning human eyes. Scientists at SVEC are conducting preliminary tests on the biocompatibility of this ceramic detector. The artificial retinas constructed at SVEC consist of 100,000 tiny ceramic detectors, each 1/20th the size of a human hair. The assemblage is so small that surgeons can't safely handle it. So, the arrays are attached to a polymer film one millimeter in size. After insertion into an eyeball, the polymer film will simply dissolve leaving only the array behind after a couple of weeks [16].

#### V. Prototyping Devices

Researchers at Bionic Vision Australia (BVA) have produced a prototype version of a bionic eye implant that could be ready to start restoring rudimentary vision to blind people as soon as 2013. The system consists of a pair of glasses with a camera built in, a processor that fits in your pocket, and an ocular implant that sits against the retina at the back of the eye and electronically stimulates the retinal neurons that send visual information to the brain. The resulting visual picture is blocky and low-res at this point, but the technology is bound to improve, and even in its

current form it's going to be a major life-changer for those with no vision at all. And the future potential - even for sighted people - is fascinating. There are two prototypes being developed to suit the needs of different patient groups [13].

#### A. Wide-View Device

The first prototype bionic eye, known as the wide-view device, will use around 100 electrodes to stimulate the nerve cells in the back of the eye. This will allow people with severe vision loss to see the contrast between light and dark shapes regain mobility and independence. This device may be most suitable for retinitis pigmentosa patients [14].

#### B. High-Acuity Device

The second prototype, known as the high-acuity device, will use 1000 electrodes to stimulate the retina and will provide patients with more detailed information about the visual field, helping them recognize faces and even read large print. The high-acuity device may be most suitable for patients with age-related macular degeneration; however, it is still some years before the first patient tests will commence [14].

#### C. Diamond Device

Melbourne researchers working to restore sight to the vision impaired believe diamond is the best material with which to build a bionic eye and hope to have a prototype in testing within the next few years.

Kumar Ganesan, a physicist helping to design a bionic eye for Bionic Vision Australia at the University of Melbourne, says metals such as platinum and iridium are currently used for implants. He says even the hardest metals deteriorate within five to 10 years, which is why researchers have turned their focus to diamonds. "We made a diamond device so the implant inside the eye will not deteriorate or will not be damaged by any other means," he said [15].



Fig. 12: How the Bionic Person Looks?

#### VI. Conclusion

Bionic devices are being developed to do more than replace defective parts. Researchers are also using them to fight illnesses. If this system is fully developed it will change the lives of millions of people around the world. We may not restore the vision fully, but we can help them at least to find their way, recognize faces, read books, distinguish between objects such as cups and plates, above all lead an independent life. Though there are a number of challenges to be faced before this technology reach the common man, the path has been laid. It has enabled a formerly blind patient to. But with only 16 electrodes, the device does not allow the patient to see a clear picture. For that, thousands of electrodes are

needed on the same size of chip. The bionic eye has changed the world of the visually challenged people. We are sure that higher quality, better resolution, and even color are possible in the future. Restoration of sight for the blind is no more a dream today. Bionic Eyes have made this true.

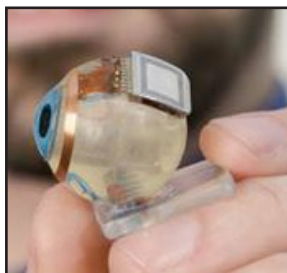


Fig. 13: The Bionic Eye

## VII. Future Scope

Researchers are already planning a third version that has 1,000 electrodes on the retinal implant, which they believe could allow for facial-recognition capabilities and hope to allow the user to see colorful images. Scientists believe the immediate goal after achieving above is to develop a functioning artificial retina with resolution that mimics human sensors. Once this step has been achieved, they says, then attention can be brought to bear on color vision, followed by the replacement of some of the interconnecting neural cells that lead to the optic nerve. So, let us hope to reach all these goals as soon as possible.

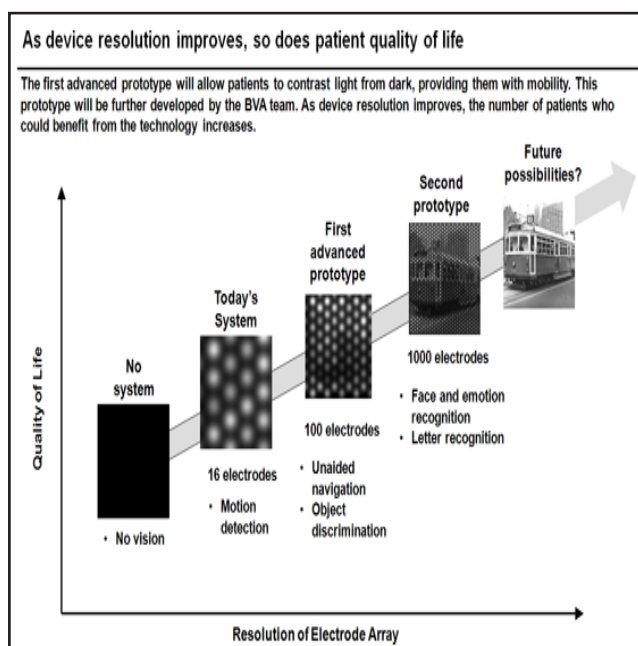


Fig. 14: The Resolution Challenge

The researchers note the device has some limitations, and it will not restore perfect vision. However, they are sure it will give people the advantage of having a general sense of their surroundings. Hopefully, the technology may enable people to recognize faces and facial expressions. "The thing is to significantly improve the quality of life for blind patients".

## References

- [1] Nagarjuna Sharma, "Bionic Eye", Scribd, 2010.
- [2] Chandu Gude, "Bionic Eye", Scribd, 2009.
- [3] Salma Khanam, Department of Instrumentation Technology, KBN College of Engineering, Scribd

- [4] Sahana Satish, "Artificial Vision – A Bionic Eye", Scribd, 2010.
- [5] Medline Plus, "Corneal Transplants", U.S. National Library of Medicine 8600 Rockville Pike 26 January 2012.
- [6] Scientists at Johns Hopkins University, MIT, Bionic Eyes, NASA Science News 2002
- [7] "Doe Technologies Drive Initial Success of Bionic Eye", Artificial Retina News, U.S. Department of Energy office of Science, 2009.
- [8] "ASR Device", Optobionics (2011), [Online] Available: <http://www.optobionics.com/asrdevice.shtml>. Retrieved 20 March 2011.
- [9] M.S Humayun, J.D Weiland, G.Chader, "Basic research, biomedical engineering and clinical advances", 2007, pp. 151-206.
- [10] Kosta Grammatidis, Rob Spence, "Building the bionic eye; Hacking the human", Future of Journalism conference, [Online] Available: <http://www.eyeborgproject.com>
- [11] Praveenkumar Narayana, Guhan Senthil, "Bionic Eye Powered By Nanogenerator", 2011 International Conference on Life Science and Technology, IPCBEE Vol. 3(2011) © (2011) IACSIT Press, Singapore.
- [12] Julia Layton, "How does a 'bionic eye' allow blind people to see?", Discovery Communications, LLC.
- [13] Loz Blain, "HEALTH AND WELLBEING", First advanced prototype revealed for the Australian bionic eye, Gizmag, March 31, 2010.
- [14] Australian Research Council, "Bionic Eye", Retina Australia (Qld)
- [15] Ashley Hall, "Diamond shines as basis for bionic eye prototype", ABC News, December 09, 2010.
- [16] A. Polman et al., "Epitaxy", J. Appl. Phys., Vol. 75, No. 6, 15, 1994.



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