International Journal of Pharmaceutical Development & Technology

e ISSN - 2248 - 910X

www.ijpdt.com

Print ISSN - 2248 - 9096

# THE BIONIC EYE

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**ABSTRACT**

Aim of bionic eye is to restore vision to patients who have gone blind due to macular degeneration or retinitis pigmentosa. In the past 20 years, biotechnology has become the fastest-growing area of scientific research, with new devices going into clinical trials at a breakneck pace.2013 has been a year of turning science fiction into reality. One technology that immediately comes to mind is the bionic eye. While in the works for years, the first artificial retina and surgical implant procedure were just recently approved by the FDA. Designed by Second Sight, the Argus II Retinal Prosthesis System uses camera-mounted glasses to turn visual information into data that can be wirelessly transmitted to the bionic implant on the eye. The device has been specifically designed for – and testing with – patients who suffer from retinitis pigmentosa: an inherited degenerative disease leading to severe deterioration of sight or total blindness. Around 1.5 million people worldwide suffer from the condition, including 100,000 America. The Argus II Retinal Prosthesis System can provide sight -- the detection of light -- to people who have gone blind from degenerative eye diseases like macular degeneration and retinitis pigmentosa. Ten percent of people over the age of 55 suffer from various stages of macular degeneration. Retinitis pigmentosa is an inherited disease that affects about 1.5 million people around the globe. Both 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.

**Keywords:** Bionic eye, Retinitis pigmentosa, Photoreceptors.

## INTRODUCTION

### Retinal Implants

Since the late 20th century, restoring vision to blind people by means of artificial eye prostheses has been the goal of numerous research groups and some private companies around the world. Similar to cochlear implants, the key concept is to stimulate the visual nervous system with electric pulses, bypassing the damaged or degenerated photoreceptors on the human retina. The two most common approaches to retinal implants are called "epiretinal" and "subretinal" implants, corresponding to eye prostheses located either on top or behind the retina respectively [1].

### Retinal Structure and Functionality

Figure depicts the schematic nervous structure of the human retina. We can differentiate between three layers of cells. The first, located furthest away from the eye lens, consists of the photoreceptors (rods and cones) whose purpose is to transduce incoming light into electrical signals that are then further propagated to the intermediate layer, which is mainly composed of bipolar cells. These bipolar cells, which are connected to photoreceptors as well as cell types such as horizontal cells and amacrine cells, passed on the electrical signal to the retinal ganglion cells (RGC). The uppermost layer, consisting of RGCs, collects the electric pulses from the horizontal cells and passes them on to the thalamus via the optic nerve. From there, signals are propagated to the primary visual cortex. There are some key aspects worth mentioning about the signal processing within the human retina. First, while bipolar cells, as well as horizontal and amacrine, generate graded potentials, the RGCs generate action potentials instead. Further, the density of each cell type is not uniform across the retina. While there is an extremely high density of rods and cones in the area of the fovea, with in addition only very few photoreceptors connected to RGCs via the intermediate layer, a far lower density of photoreceptors is found in the peripheral areas of the retina with many photoreceptors connected to a single RGC. The latter also has direct implications on the receptive field of a RGC, as it tends to increase rapidly towards the outer regions of the retina, simply because of the lower photoreceptor density and the increased number of photoreceptors being connected to the same RGC.

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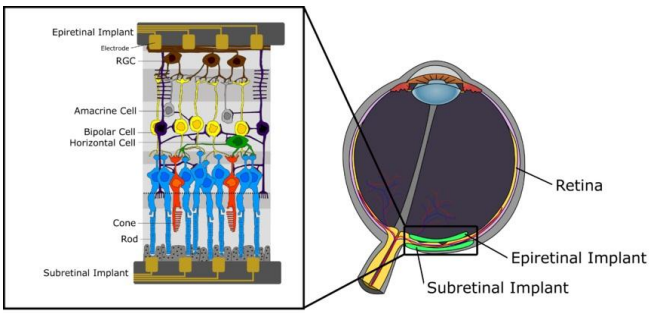



**Implant Use Case**

Damage to the photoreceptor layer in the human can be caused by Retinitis pigmentosa, age-related macular degeneration and other diseases, eventually resulting in the affected person to become blind. However, the rest of the visual nervous system, both inside the retina as well as the visual nervous pathway in the brain, remains intact for several years after onset of blindness. This allows artificial stimulation of the remaining, still properly functioning retina cells, through electrodes, to restore visual information for the human patient. Thereby a retina prosthesis can be implanted either behind the retina, and is then referred to as subretinal implant. This brings the electrodes closest to the damaged photoreceptors and the still properly functioning bipolar cells, which are the real stimulation target here. (If the stimulation electrodes penetrate the choroid, which contains the blood supply of the retina, the implants are sometimes called "suprachoroidal" implants.) Or the implant may be put on top of the retina, closest to the Ganglion cell layer, aiming at stimulation of the RGCs instead. These implants are referred to as epiretinal implants. Both approaches are currently being investigated by several research groups. They both have significant advantages as well as drawbacks [2].

**Challenges**

A big challenge for retinal implants comes from the extremely high spatial density of nervous cells in the human retina. There are roughly 125 million photoreceptors (rods and cones) and 1.5 million ganglion cells in the human retina, as opposed to approximately only 15000 hair cells in the human cochleal. In the fovea, where the highest visual acuity is achieved, as many as 150000 cones are located within one square millimeter. While there are much fewer RGCs in total compared to photoreceptors, their density in the foveal area is close to the density of cones , imposing a tremendous challenge in addressing the nervous cells in high enough spatial resolution with artificial electrodes. Virtually all current scientific experiments with retinal implants use micro-electrode arrays (MEAs) to stimulate the retina cells. High resolution MEAs achieve an inter-electrode spacing of roughly 50 micrometers, resulting in an electrode density of 400 electrodes per square millimeter. Therefore, a one to one association between electrodes and photoreceptors or RGCs respectively is impossible in the foveal area with conventional electrode technology. However, spatial density of both photoreceptors as well as RGCs decrease s quickly towards the outer regions of the retina, making one-to-one stimulation between electrodes and peripheral nerve cells more feasible. Another challenge is operating the electrodes within safe limits. Imposing charge densities above 0.1 mC/cm2 may damage the nervous tissue. Generally, the further a cell is away from the stimulating electrode, the larger is the current amplitude required for stimulation of the cell. Furthermore, the lower the stimulation threshold, the smaller the electrode may be designed and the compacter the electrodes may be placed on the MEAs, thereby enhancing the spatial stimulation resolution. Stimulation threshold is defined as the minimal stimulation strength necessary to trigger a nervous response in at least 50% of the stimulation pulses. For these reasons, a primary goal in designing retinal implants is to use as low a stimulation current as possible while still guaranteeing a reliable stimulation (i.e. generation of an action potential in the case of RGCs) of the target cell. This can either be achieved by placing the electrode as close as possible to the area of the target cell that reacts most sensitive to an applied electric field pulse or by making the cell projections, i.e. dendrites and/or axons, grow on top the electrode, allowing a stimulation of the cell with very low currents even if the cell body is located far away. Further, an implant fixed to the retina automatically follows the movements of the eyeball. While this entails some significant benefits, it also means that any connection to the implant - for adjusting parameters, reading out data, or providing external power for the stimulation - requires a cable that moves with the implant. As we move our eyes approximately three times a second, this exposes the cable and involved connections to severe mechanical stress. For a device that should remain functioning for an entire life time without external intervention, this imposes a severe challenge on the materials and technologies involved [3].

**SUB-RETINAL IMPLANTS**

As the name already suggest, sub-retinal implants are visual prosthesis located behind the retina. Therefore, the implant is located closest to the damaged photoreceptors, aiming at bypassing the rods and cones and stimulating the bipolar cells in the next nervous layer in the retina. The main advantage of this approach lies in relatively little visual signal processing that takes place between the photoreceptors and the bipolar cells that need to be imitated by the implant. That is, raw visual information, for example captured by a video camera may be forwarded directly, or with only relatively rudimentary signal processing respectively, to the MEA stimulating the bipolar cells, rendering the procedure rather simple from a signal processing point of view. However, this approach has some severe disadvantages. The high spatial resolution of photoreceptors in the human retina imposes a big challenge in developing and designing a MEA with sufficiently high stimulation resolution and therefore low inter-electrode spacing. Furthermore, the stacking of the nervous layers in z-direction (with the x-y plane tangential to the retina

curvature) adds another difficulty when it comes to placing the electrodes close to the bipolar cells. With the MAE located behind the retina, there is a significant spatial gap between the electrodes and the target cells that needs to be overcome. As mentioned above, an increased electrode to target cell distance forces the MAE to operate with higher currents, enlarging the electrode size, the number of cells within the stimulation range of a single electrode and the spatial separation between adjacent electrodes. All of this results in a decreased stimulation resolution as well as opposing the retina to the risk of tissue damage caused by too high charge densities. As shown below, one way to overcome large distances between electrodes and the target cells is to make the cells grow their projections over longer distances directly on top the electrode [4].

In late 2010, a German research group in collaboration with the private German company "Retina Implant AG", published results from studies involving tests with subretinal implants in human subjects. A three by three millimeter microphotodiode array (MPDA) containing 1500 pixels, which each pixel consisting of an individual light-sensing photodiodes and an electrode, was implanted behind the retina of three patients suffering from blindness due to macular degeneration. The pixels were located approximately 70 micrometer apart from each other, yielding a spatial resolution of roughly 160 electrodes per square millimeter – or, as indicated by the authors of the paper, a visual cone angle of 15 arcmin for each electrode. It should be noted, that, in contrast to implants using external video cameras to generate visual input, each pixel of the MPDA itself contains a light-sensitive photodiode, autonomously generating the electric current from the light received through the eyeball for its own associated electrode. So each MPDA pixel corresponds in its full functionality to a photoreceptor cell. This has a major advantage: Since the MPDA is fixed behind the human retina, it automatically drags along when the eyeball is being moved. And since the MPDA itself receives the visual input to generate the electric currents for the stimulation electrodes, movements of the head or the eyeball are handled naturally and need no artificial processing. In one of the patients, the MPDA was placed directly beneath the macula, leading to superior results in experimental tests as opposed to the other two patients, whose MPDA was implanted further away from the center of the retina. The results achieved by the patient with the implant behind the macula were quite extraordinary. He was able to recognize letters (5-8cm large) and read words as well as distinguish black-white patterns with different orientations.

The experimental results with the MPDA implants have also drawn attention to another visual phenomenon, revealing an additional advantage of the MPDA approach over implants using external imaging devices: Subsequent stimulation of retinal cells quickly leads to decreased responses, suggesting that retinal neurons become inhibited after being stimulated repeatedly within a short period of time. This entails that a visual input projected onto a MEA fixed on or behind the retina will result in a sensed image that quickly fades away, even though the electric stimulation of the electrodes remains constant. This is due to the fixed electrodes on the retina stimulating the same cells on the retina all the time, rendering the cells less and less sensitive to a constant stimulus over time. However, the process is reversible, and the cells regain their initial sensitivity once the stimulus is absent again. As mentioned in the human eye actually continuously adjusts in small, unnoticeable eye movements, resulting in the same visual stimulus to be projected onto slightly different retinal spots over time, even as we tend to focus and fix the eye on some target object. This successfully circumvents the fading cell response phenomenon. With the implant serving both as photoreceptor and electrode stimulator, as it is the case with the MPDA, the natural small eye adjustments can be readily used to handle this effect in a straight forward way. Other implant approaches using external visual input (i.e. from video cameras) will suffer from their projected images fading away if stimulated continuously. Fast, artificial jittering of the camera images may not solve the problem as this external movement may not be in accordance with the eye movement and therefore, the visual cortex may interpret this simply as a wiggly or blurry scene instead of the desired steady long term projection of the fixed image. A further advantage of subretinal implants is the precise correlation between stimulated areas on the retina and perceived location of the stimulus in the visual field of the human subject. In contrast to RGCs, whose location on the retina may not directly correspond to the location of their individual receptive fields, the stimulation of a bipolar cell is perceived exactly at that point in the visual field that corresponds to the geometric location on the retina where that bipolar cell resides. A clear disadvantage of subretinal implants is the invasive surgical procedure involved.

**EPIRETINAL IMPLANTS**

Epiretinal implants are located on top of the retina and therefore closest to the retina ganglion cells (RGCs). For that reason, epiretinal implants aim at stimulating the RGCs directly, bypassing not only the damaged photoreceptors, but also any intermediate neural visual processing by the bipolar, horizontal and amacrine cells. This has some advantages: First of all, the surgical procedure for an epiretinal implant is far less critical than for a subretinal implant, since the prosthesis need not be implanted from behind the eye. Also, there are much fewer RGCs than photoreceptors or bipolar cells, allowing a more course grained stimulation with increased inter-electrode distance (at least in the peripheral regions of the retina), or an electrode density even superior to that of the actual RGC density, allowing for more flexibility and accuracy when stimulating the cells. A study on the epiretinal stimulation of peripheral parasol cells conducted on macaque retina provides quantitative details. Parasol cells are one type of RGCs forming the second most dense visual pathway in the retina. Their main purpose is to encode the movement of

objects in the visual field, thus sensing motion. The experiments were performed in vitro by placing the macaque retina tissue on a 61 electrode MEA (60 micrometer inter-electrode spacing). 25 individual parasol cells were indentified and stimulated electronically while properties such as stimulation threshold and best stimulation location were analyzed. The threshold current was defined as the lowest current that triggered a spike on the target cell in 50% of the stimulus pulses (pulse duration: 50 milliseconds) and was determined by incrementally increasing the stimulation strength until sufficient spiking response was registered. Please note two aspects: First, parasol cells as RGCs exhibit action potential behavior, as opposed to bipolar cells which work with graded potentials. Second, the electrodes on the MAE were both used for the stimulation pulses as well as for recording the spiking response from the target cells. 25 parasol cells were located on the 61 electrode MAE with a electrode density significantly higher than the parasol cell density, effectively yielding multiple electrodes within the receptive fields of a single parasol cell. In addition to measuring the stimulation thresholds necessary to trigger a reliable cell response, also the location of best stimulation was determined. The location of best stimulation refers to the location of the stimulating electrode with respect to the target cell where the lowest stimulation threshold was achieved. Surprisingly, this was found out to not be on the cell soma, as one would expect, but roughly 13 micrometers further down the axon path. From there on, the experiments showed the expected quadratic increase in stimulation threshold currents with respect to increasing electrode to soma distance. The study results also showed that all stimulation thresholds were well below the safety limits (around 0.05mC/cm2, as opposed to 0.1mC/cm2 being a (low) safety limit) and that the cell response to a stimulation pulse was fast (0.2 ms latency on average) and precise (small variance on latency). Further, the superior electrode density over parasol cell density allowed a reliable addressing of individual cells by the stimulation of the appropriate electrode, while preventing neighboring cells from also evoking a spike [5].

## OVERVIEW OF ALTERNATIVE TECHNICAL APPROACHES

In this section, we give a short overview over some alternative approaches and technologies currently being under research.

### Nanotube Electrode

Classic MAEs contain electrodes made out of titanium nitride or indium tin oxide exposing the implant to severe issues with long-term biocompatibility. A promising alternative to metallic electrodes consists of carbon nano tubes (CNT) which combine a number of very advantageous properties. First, they are fully bio compatible since they are made from pure carbon. Second, their robustness makes them suited for long term implantation, a key property for visual prosthesis. Further, the good electric conductivity allows them to operate as electrodes. And finally, their very porous nature leads to extremely large contact surfaces, encouraging the neurons to grow on top the CNTs, thus improving the neuron to electrode contact and lowering the stimulation currents necessary to elicit a cell response. However, CNT electrodes have only emerged recently and at this point only few scientific results are available.

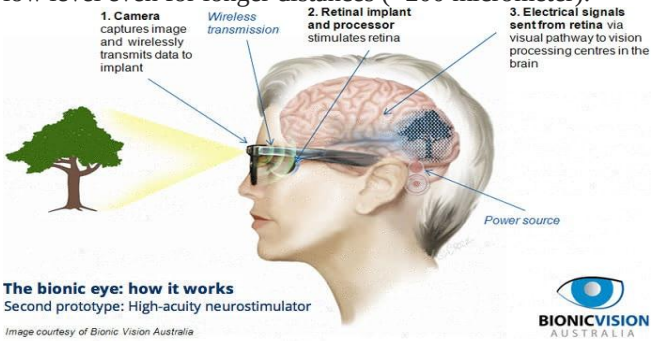
### Wireless Implant Approaches

One of the main technical challenges with retinal implant relates to the cabling that connects the MEA with the external stimuli, the power supply as well as the control signals. The mechanical stress on the cabling affects its long term stability and durability, imposing a big challenge on the materials used. Wireless technologies could be a way to circumvent any cabling between the actual retinal implant and external devices. The energy of the incoming light through the eye is not sufficient to trigger neural responses. Therefore, to make a wireless implant work, extra power must be provided to the implant. An approach presented by the Stanford School of Medicine uses an infrared LCD display to project the scene captured by a video camera onto goggles, reflecting infrared pulses onto the chip located on the retina. The chip also uses a photovoltaic rechargeable battery to provide the power required to transfer the IR light into sufficiently strong stimulation pulses. Similar to the subretinal approach, this also allows the eye to naturally fix and focus onto objects in the scene, as the eye is free to move, allowing different parts of the IR image on the goggles to be projected onto different areas on the chip located on the retina. Instead of using infrared light, inductive coils can also be used to transmit electrical power and data signals from external devices to the implant on the retina. This technology has been successfully implemented and tested in the EPIRET3 retinal implant. However, those tests were more a proof-of-concept, as only the patient's ability to sense a visual signal upon applying a stimulus on the electrodes was tested [6].

### Directed Neural Growth

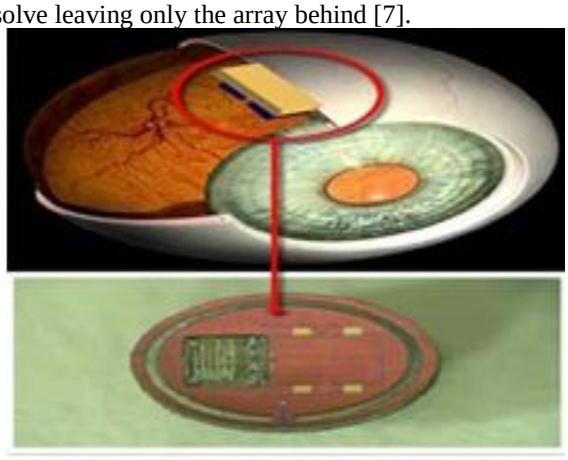
One way to allow a very precise neural stimulation with extremely low currents and even over longer distances is to make the neurons grow their projections onto the electrode. By applying the right chemical solution onto the retinal tissue, neural growth can be encouraged. This can be achieved by applying a layer of Laminin onto the MEA's surface. In order to control the neural paths, the Laminin is not applied uniformly across the MEA surface, but in narrow paths forming a pattern corresponding to the connections, the neurons should form. This process of applying the Laminin in a precise, patterend way, is called "microcontact printing". The successful directed neural growth achieved with this method allowed applying significantly lower stimulation currents compared to classic electrode stimulation while still able to reliably trigger neural response. Furthermore, the stimulation threshold no

longer follows the quadratic increase with respect to electrode-soma distance, but remains constant at the same low level even for longer distances (>200 micrometer).




**The Surgery**

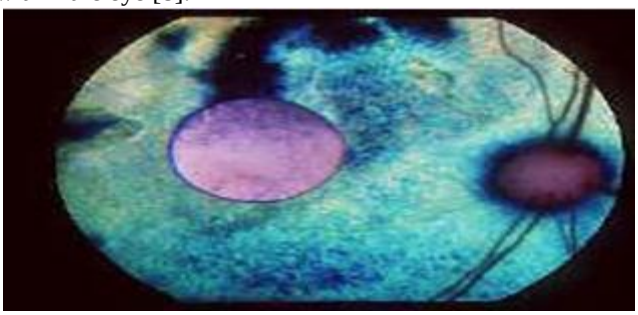
This concept of Artificial Vision is also interesting to engineers, because there are a number of technicalities involved in this surgery apart from the anatomical part. The microsurgery starts with three incisions smaller than the diameter of a needle in the white part of the eye. Through the incisions, 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 [7].



**SYSTEM FEATURES**

**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 "micro photodiodes," each having its own stimulating electrode. These micro photodiodes 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 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 "Micro photodiodes" that each have their own stimulating electrode. 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 [8].

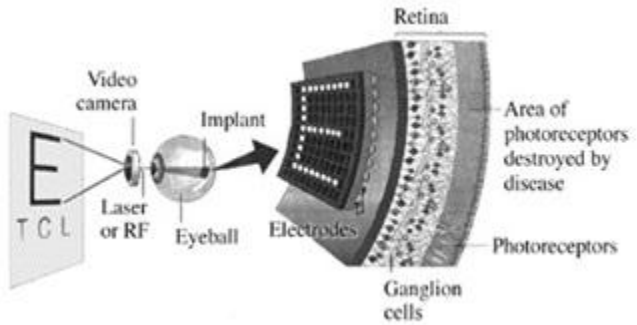


**Graphene implants**

Scientists are a step nearer to making a true artificial eye after using the properties of graphene—a form of pure carbon— to make an interface to the optical nerve. "In contrast to the traditionally used materials, graphene has excellent biocompatibility thanks to its great flexibility and chemical durability. With its outstanding electronic properties, graphene provides an efficient interface for communication between the retina prosthesis and nerve tissue," physicists at the Technische Universität München (TUM) said. TUM noted retina implants can become optical prostheses for blind people whose optical nerves are still intact. Implants convert incident light into

electrical impulses that the optical nerve transmits to the brain. The impulses are then converted into images. But in many cases, the body rejects the devices, and the signals sent to the brain are less than optimal. Enter graphene, which is thin, transparent and conducts electricity better than copper—and two-dimensional, as it has only a single layer of carbon atoms. "Because of its unusual properties, graphene holds great potential for applications, especially in the field of medical technology," TUM said Scientists are a step nearer to making a true artificial eye after using the properties of graphene—a form of pure carbon— to make an interface to the optical nerve.

**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 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. 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 [9].

**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.

**WORKING PROCEDURE**

**The bionic eye**

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

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.

1) 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

2) Radio transmitter - wirelessly transmits pulses to receiver • implanted above the ear or under the eye

3) Radio receiver - receiver sends pulses to the retinal implant • by a hair-thin, implanted wire

4) 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"

**RESEARCHES**

After more than two decades of research and development, the first retinal prosthesis has received European approval for clinical and commercial use. People blinded by degenerative eye disease will have the option of buying an implant that can restore their vision at least partially.

The first version of the system had 16 electrodes on the implant and is still in clinical trials at the University of California in Los Angeles. Doctors implanted the retinal chip in six subjects, all of whom regained some degree of sight. They are now able to perceive shapes (such as the shaded outline of a tree) and detect movement to varying degrees. The newest version of the system should offer greater image resolution because it has far more electrodes. If the upcoming clinical trials, in which doctors will implant the second-generation device into 75 subjects, are successful, the retinal prosthesis could be commercially available by 2010. The estimated cost is $30,000.

Researchers are already planning a third version that has a thousand electrodes on the retinal implant, which they believe could allow for facial-recognition capabilities.

Walter Wrobel, CEO of Retina Implant AG of Reutlingen, Germany, a startup that is carrying out trials of a similar device in several countries, says the approval is an exciting development for hundreds of thousands of people who suffer from diseases like retinitis pigmentosa.

Second Sight's device, the Argus II, will cost around $115,000 and be available only through a small number of clinics in Switzerland, France, and the U.K. The company hopes to receive approval from the U.S. Food and Drug Administration by next year.

With the Argus II system, a camera mounted on a pair of glasses captures images, and corresponding signals are fed wirelessly to chip implanted near the retina. These signals are sent to an array of implanted electrodes that stimulate retinal cells, producing light in the patient's field of view. The process works for people with retinitis pigmentosa because the disease damages only the light-sensing photoreceptors, leaving the remaining retinal cells healthy.

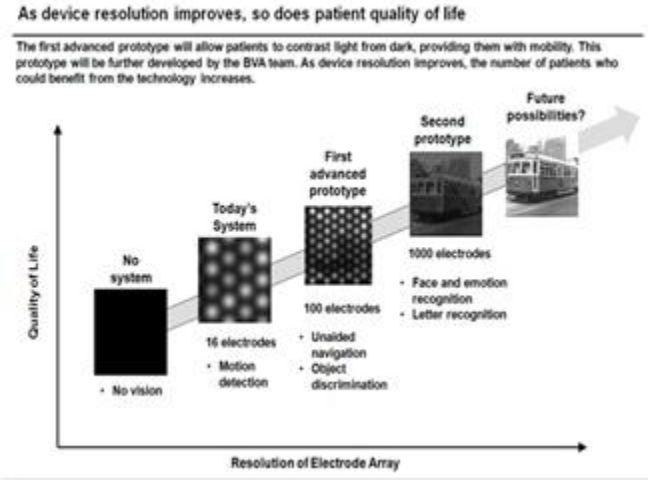
So far, the Argus II can restore only limited vision. "Patients can locate and recognize simple objects, see people in front of them, and follow their movement," says Greenberg. "They can find doors and windows, follow lines, and in the best cases read large print slowly," he says.

Getting this device to market is an important achievement, says Eberhart Zrenner, director of the Institute for Ophthalmic Research at the University of Tübingen in Germany and founder Retinal Implants AG. "On the other hand, the type of vision the Argus II can provide with 60 electrodes is quite limited," he says.

Zrenner is developing a device for Retinal Implants that has more than 1,500 electrodes and captures images using light-sensitive photodiodes on the chip within the eye, instead of with an external camera. "It has the light-sensitive photodiodes positioned under the retina right at the place of the degenerated photoreceptors and therefore needs no camera outside," he says.

Second Sight is also working on larger arrays. But for now, what distinguishes the Argus II from all other

devices is its ability to survive long-term implantation in the human body. The Argus II has been tested in trials involving 30 patients. "We have done something that many people would have thought and did think was impossible," says Greenberg.




**FUTURE TRENDS**

Providing us with a delightful glimpse of the future of humanity and bionic implants, Second Sight — the developer of the first bionic eye to receive FDA approval in the US — is currently working on a firmware upgrade that gives users of the Argus II bionic eye better resolution, focus, and image zooming. The software update even provides users with color recognition, even though the original version of the device only provides black and white vision [10].

The Argus II, to give its proper classification, is a retinal prosthesis. Basically, patients undergo a four-hour operation to implant 60 electrodes into the macula — the central region of the retina that provides central and high-resolution vision. These electrodes are connected to an antenna, which connects via a wireless network to a special pair of spectacles that are equipped with a digital camera and a digital signal processor (DSP). The camera captures what the user is looking at, converts the image into signals that the brain will understand, and transmits them to the retinal implant. These signals stimulate the 60 electrodes in such a way as to produce electrical signals that can be understood by the brain. As you can imagine, an array of 60 electrodes doesn't provide a very high resolution (10×6!), but it's a huge step up from *complete blindness.* Furthermore, if Second Sight changes the hardware, it would need to be re-certified by the FDA, which could take years. A *software* update, however, doesn't require FDA approval (though in the future, as implants become more invasive, that will probably change).

Through a software update called Acuboost, Second Sight says it can improve the resolution, focus, and zooming of images seen by Argus II users. The latest version of the software, which is still being beta tested before being rolled out to users, also has automatic brightness adjustment and color recognition. Creating color vision is interesting, because technically the implant users don't have any color vision (those cells were destroyed by the degenerative eye disease that led to their blindness). It turns out, though, that specific frequencies and delays in electrode stimulation — it's different for every user – can cause the perception of color. This on its own is quite an exciting breakthrough when it comes to understanding the optic nerve's encoding scheme, which we still know so little about.

Second Sight is also looking at upgrading the hardware in spectacles, but again that would trigger a couple of years of jumping through regulatory hoops. There's no timeline on Acuboost being rolled out to users, but Second Sight hopes to do it "shortly."

Meanwhile, over in Germany, the Alpha IMS bionic eye has recently received European regulatory approval. Alpha IMS is a self-contained bionic eye that grants vision by using light that actually enters the eye, rather than using an external camera, thus making it a lot more flexible than the Argus II. Alpha IMS has a massive number of electrodes — 1,500 vs. 60 on the Argus — providing fairly high-resolution sight to its users. In short, Alpha IMS is amazing — but for the foreseeable future, you'll have to visit Europe if you want to have one installed.

Researchers led by Dr. Jose Garrido at the Walter Schottky Institut of the TUM are working with partners from the Institut de la Vision of the Université Pierre et Marie Curie in Paris and the French company Pixium Vision for the project. The artificial retina got the TUM team admitted to the European Union's "Graphene" Flagship Program. Aside from their place in the Graphene flagship program, TUM researchers are also involved in a second [11].

**CONCLUSION**

India has approximately over 15 million blind people. Among those 90% can be cured. Where 50% are cataract patients. Few of the glaucoma patients also can be cured. India needs 2.5 lakhs of donated eyes every year but every year we get only 15% from it. There is a lack of optometrists. Due to several reasons such as superstitious beliefs, lack of knowledge etc. This may lead to increased population of blind hence new technology and research must be encouraged inorder to give sight to many people. The bionic eye is useful to the people whose blindness can be treated.

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. Therefore the bionic eye is being developed rapidly due to its patient compliance and cost effectiveness. It will be soon into the market to give vision and sight to every blind person.

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