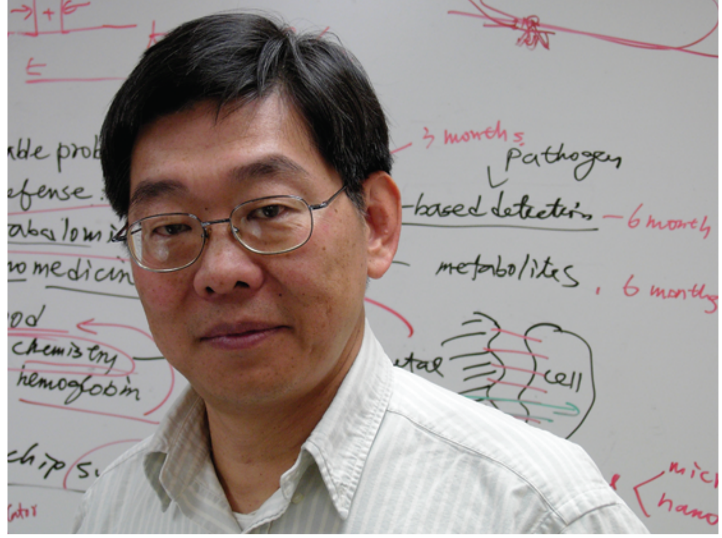
R E S E A R C H   N O T E

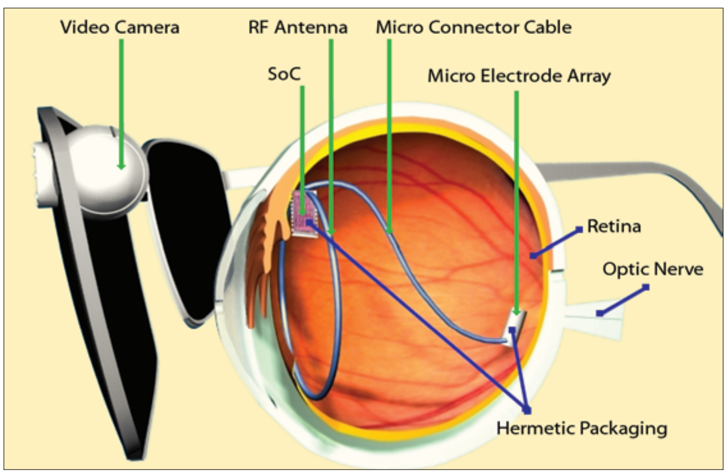
Retinal Implant Research:

The Possiblility of Artificial Vision

by Yu-Chong Tai and Wolfgang Fink



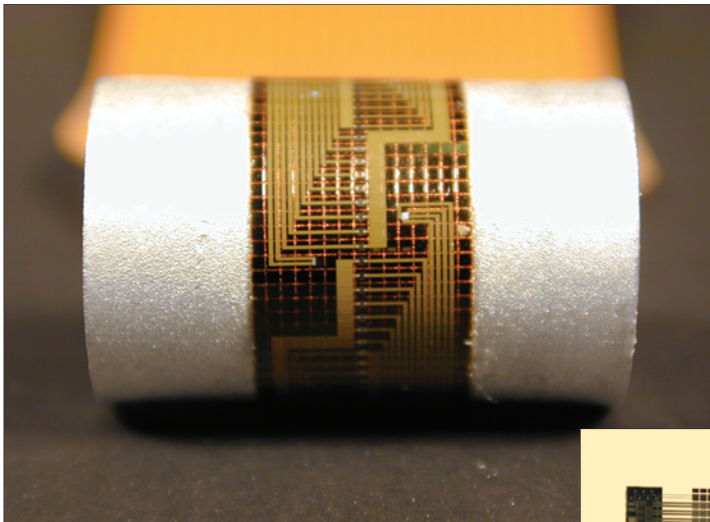
Blindness is the second most-feared disease next to cancer. Each year there are about 100,000 people newly diagnosed with blindness due to Retinitis Pigmentosa (RP, an inherited condition in which all photoreceptors are eventually lost) and Age-related Macular Degeneration (AMD). Both diseases primarily affect only the photoreceptors of the retina. Unfortunately there still is no medical cure for either RP or AMD. However, over the past ten years there has been investigation into the possibility of creating a retinal prosthesis that mimics the biological function of the photoreceptors in stimulating downstream neurons in the retina. It has been demonstrated that such a prosthesis, called an epi-retinal multi-electrode array, can allow patients to "see" again through electrical stimulation from a 4 x 4 electrode array placed directly on the surface of the macula (the precision vision region of the retina). This technology is similar to the cochlear implant which uses a small number of electrodes to mimic lost function in the auditory system. A 4 x 4, or 16-pixel array, however, cannot produce the useful ambulatory vision needed for a blind patient to use their visual system in an autonomous manner. Thus, this epi-retinal implant technology has to improve dramatically. A healthy retina has over 100 million photoreceptors. A retinal implant that enables ambulatory vision would need thousands, if not tens of thousands, of stimulating electrodes.



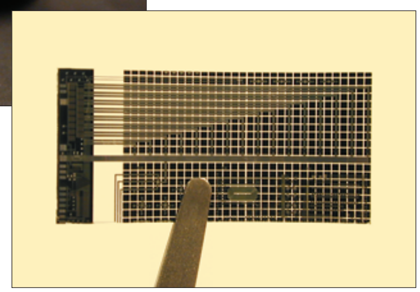
An intraocular epi-retinal prosthesis will use an external camera and external microelectronic systems to capture and process image data and transmit the information to an implanted microelectronic system, all in real time. The external system is being developed by Dr. Wolfgang Fink at Caltech in close collaboration with Dr. Wentai Liu's lab at University of California, Santa Cruz and Dr. Mark Humayun's lab at USC. The implanted system would decode the data and stimulate the retina with a pattern of electrical impulses to produce visual perception. (Image courtesy Humayun et al.)

My lab at Caltech has developed a flexible "smart skin" technology that may just be the answer. The flexible smart skin is made by MEMS technology and is only tens of microns thick. The flexibility of the skin is important because the device can be folded and inserted surgically into the eye through a small, quick-to-heal incision. Furthermore, the skin can conform to the curved surface of the retina to provide intimate contact to the target neurons. Moreover, the skin is integrated with silicon integrated circuits and numerous sensors such that the extension of this technology can provide as many channels as needed for the retinal implant.

As a result of the natural extension of this smart skin technology to the retinal prosthesis, a close col-



Actual smart skin sample demonstrating its flexibility at wrapping around a curved surface.



An IC-integrated flexible parylene smart skin.

laboration between my lab and Dr. Mark Humayun's lab at the Keck School of Medicine of the University of Southern California (Doheny Eye Institute) has been formed (part of the NSF-funded USC/Caltech/UCSC Biomimetic MicroElectronic Systems Engineering Research Center). The long-term goal for my lab is to produce a totally integrated retinal prosthesis that contains a power-delivery secondary coil, a power-and-signal management system-on-a-chip (SoC), and a flexible high-density retinal electrode array. Although this project is just in its initial stages, there have already been two major advancements. The first is the completion of a biocompatibility experiment in which unmodified parylene, the major component of the proposed retinal prosthesis, was placed in the intraocular space of an eye for six months. Our experiments showed that parylene did not cause an immune or foreign-body response for the duration of this implantation. The second is that we have successfully produced flexible gold/parylene 16 x 16 electrode arrays that are currently undergoing soak tests in saline solution.

Dr. Mark Humayun and his team at USC recently reached an important milestone on the clinical side, with the implantation of an active stimulating epi-retinal device in a blind human. The patient had reported vision loss for 50 years from RP and had documented no light perception in the eye before implantation of the device. When a 16-electrode device (4 x 4 matrix) was activated one week after implantation, the patient saw spots at all 16 electrodes. Further testing demonstrated spatial discrimination between two electrodes that allowed the ability to discern gross movement of objects in the field of the patient's camera.

These results are major advancements towards producing a clinically viable, intermediate-density retinal implant in the near future. ENG

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