

Retinal Implant Project

CNF Project Number: 2504-16

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Primary Sources of Research Funding: Louis Stokes Cleveland VA Medical Center; NIH/NIBIB U01EB018873; NIH/NIBIB R01EB022013, Massachusetts Lions Eye Research Fund

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Primary CNF Tools Used: PT-72, lithography toolset/MA6, DWL2000, evaporators, AJA sputter, Gamma spray coater, SEMs, gold electro-plating, Class 2 lithography toolset, Oxford PECVD, Oxford 100 etcher, Glenn 1000, YES polyimide oven, VersaLaser engraver/cutter

Abstract:

The purpose of the Retinal Implant Project is to restore useful vision to patients who are blind with degenerative retinal diseases. The primary illnesses we hope to treat are retinitis pigmentosa (a primary cause of inherited blindness) and age-related macular degeneration (the leading cause of blindness in the developed world). Both these diseases cause the eventual destruction of the photoreceptor cells — rods and cones — in the retina, leaving intact the ganglion cells which transmit electrical impulses (and hence visual information) to the brain. The ganglion cells may be stimulated, however, with biphasic current pulses from a microfabricated electrode array. Blind surgical volunteers have consistently described visual percepts that resulted from such stimuli, and this has led our team to develop a wireless, implantable retinal prosthesis.

Summary of Research:

The implanted portion of our device consists of power and data secondary receiving coils, and in a sealed titanium (Ti) can a small number of discrete components, and a custom designed application specific integrated circuit (ASIC) which consists of circuitry for clock and data recovery, current drivers for electrodes in a stimulating electrode array, and a programmable function generator capable of stimulating with a wide range of pulse widths and amplitudes. The current outputs drive high-charge capacity sputtered iridium oxide film (SIROF) stimulating electrodes, which in turn give rise to the visual percepts mentioned above.

CNF-fabricated components of this system have included various proof-of-concept test structures and tools used in the research effort and an integrated combination flexible circuit and stimulating electrode array. Si wafers serve as carriers for these freestanding films during processing. The electrode leads are fabricated inside of 'sandwiches' of polyimide and amorphous silicon carbide (SiC), while the SIROF electrodes are reactively sputter-deposited.

Assembly of the intraocular components of the prosthesis is accomplished by flip chip solder ball bonding of the IC and solder attachment of discrete components onto an internal flexible circuit board which is hermetically sealed into an ultraminiature Ti can. The RF coils are soldered and glued to the integrated external flex-array which is in turn thermosonically bonded to the hermetic feedthrough of the Ti can. Finally, the thermosonic bonds are protected and insulated with an over-mold. An external patient interface unit, will consist of a video camera for capturing images, a digital signal processor, and a radio frequency (RF) transmitter and coil to relay power and data to the implanted device.

Scientific challenges still remain in realizing a chronically implantable retinal prosthesis. While our first-generation device was primarily encapsulated in polymers for short term proof-of-concept implant studies, our second-generation system focused on a system which would last many years *in vivo*. Our more recent efforts have focused on developing a device with 256+ stimulation channels

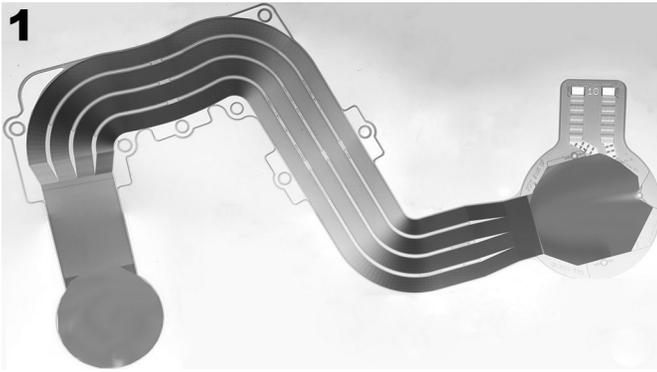


Figure 1, above: A picture of a single complete electrode array.

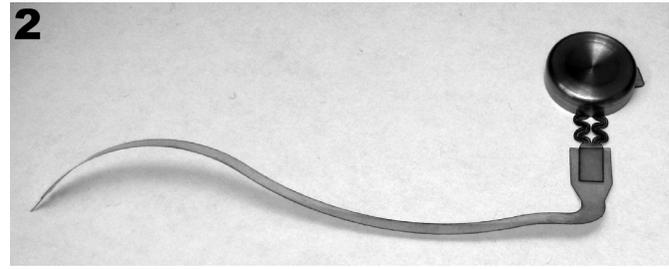
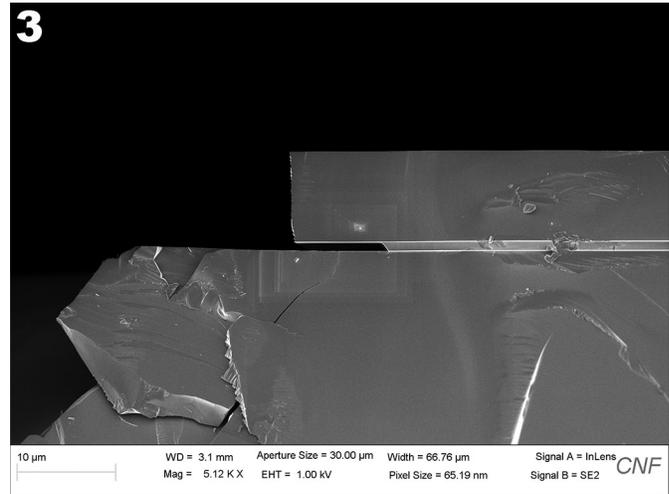


Figure 2, above right: A picture of a VersaLaser-cut mechanical mockup of an indwelling brain electrode system including a titanium hermetic enclosure.

Figure 3, below right: An SEM picture of the partial release of the buried oxide layer of an SOI test sample using the Primaxx vapor HF etch system.



which is still small enough and of a configuration to be easily implanted in the ocular orbit and continue to function for many years *in vivo*. Thus, a major effort has been the development of a technological platform to build a robust, hermetically packaged, high-density subretinal visual prosthesis with a lifetime of > 10 years in biological saline that is scalable to hundreds of I/O channels.

Recent efforts in the CNF have included, among other things, optimizing a reliable microfabrication process for the flexible micro-electrode array (see Figure 1). This included microfabricating a mechanical support for the implantable radio frequency power and communication coil. We have also explored a process of fabricating indwelling electrodes for long-term implantation in brain tissue. A preliminary VersaLaser-cut mockup of such an electrode is shown attached to a titanium hermetic enclosure in Figure 2 in order to evaluate mechanical properties and the overall size and shape. Additionally, we explored a method of fabricating part of that electrode array in Si and releasing it from an SOI substrate using the Primaxx vapor HF etch tool to etch the buried oxide layer (Figure 3).

The project has continued the development and implementation of a microfabrication process to incor-

porate SU-8-based 3D electrodes into a hybrid electrode array to achieve a more optimal interface between the electrode and the target neural cells. Fabrication work at the CNF has included process development required for such high aspect structures including the challenges of lithography with the presence of such extreme topography. Many of these lithography processes have been successfully realized using the Gamma spray coating tool.

The latest microfabrication processes utilize numerous CNF tools including the Heidelberg 2000 mask writer, MA6 aligner, polyimide YES curing oven, PT72 RIE, SC4500 evaporator, Gamma spray coater, Au electroplating station, K and S Au ball bonder, Oxford PECVD, Oxford 100 etch tool, parylene coater, as well as numerous metrology tools.

References:

- [1] J. F. Rizzo, J. Wyatt, J. Loewenstein, S. Kelly, and D. Shire, "Methods and Perceptual Thresholds for Short-Term Electrical Stimulation of Human Retina with Microelectrode Arrays," *Investigative Ophthalmology and Visual Science*, vol. 44, no. 12, Dec. 2003, pp. 5355-5361.