Retinal Implant Project

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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 that 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 integrated circuit (IC) 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 iridium oxide stimulating electrodes, which in turn give rise to the visual percepts mentioned above.

To date, the CNF-fabricated components of this system have been various proof-of-concept test structures and tools used in the research effort and an integrated combination of the external flexible circuit and a 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 IrO\textsubscript{x} electrodes themselves are fabricated by reactive sputtering.

Assembly of the intraocular components of the prosthesis is accomplished by flip chip stud bumping 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 coils are soldered and glued to the integrated external flex-array which is in turn thermo-sonically bonded to the hermetic feedthrough of the Ti can. Finally, the thermo-sonic bonds are protected and insulated with an overmold. An external patient interface unit, under development by our team, will consist of a video camera for capturing images in the patient’s environment, a digital signal processor, and a radio frequency (RF) transmitter and coil to relay power and data to the implanted device. The patients will also be offered the ability to adjust the electrical stimulation parameters to optimize their perception, in much the same manner as modern hearing aids and cochlear implants.

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 device which would last many years \textit{in vivo}. Our latest efforts are on developing a device with 256+ stimulation channels which is still small enough to be implanted in the ocular orbit and continue to function for many years \textit{in vivo}. Thus, a major effort of this past year has been to continue 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.

A key component of a high-density implantable prosthetic package assembly process is the reliable attachment of a flexible, microfabricated electrode array to the feedthroughs that carry signals into and out of the hermetic, sealed prosthetic package that contains the sensitive electronics. The hermetic Ti case is shown in Figure 1 where the feedthroughs are located on the lower surface rather than on the edge as in more traditional Ti can configuration. Also shown are the suture arms for \textit{in vivo} stabilization, the RF coil and a portion of the flex-array. Utilizing the CNF, a flexible, array was microfabricated with 256+ densely-packed sputtered iridium oxide film (SIROF) stimulation electrodes of a section of which is shown in Figure 2.

We have continued our effort to optimize the prosthesis efficiency by microfabricating custom acute electrode arrays, shown in Figure 3, to study the stimulus pulse parameters needed for effective retinal stimulation. In addition, we have continued the pursuit of 3D structures to improve electrode-cell coupling, and thus device performance. Through our efforts at the CNF, we have successfully developed a microfabricated polyimide-backed subretinal penetrating electrode array, an SEM image of two electrodes is shown in Figure 4. The purpose of the structure is to cause the electrode to penetrate into the retinal tissue placing it in very close proximity to the target cells. The structure was formed with SU-8 and has SIROF, a high charge transfer material, on the tip as the stimulating electrode. These structures have been electrochemically evaluated and compared to traditional planar SIROF electrodes on the same polyimide substrate.

References:

