Electroformed Microelectrode Array for a Human Retinal Prosthesis Interface

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To provide basic visual function (enough pixels for facial recognition, or to navigate through a building) a retinal prosthesis device requires an implantable package with a sophisticated image-processing IC and neural interface.[1] We have developed such a device, including a curved array of 3200 electroformed independent stimulating microelectrodes that conform to the retinal surface on the inside of the human eye.

The retinal prosthesis package satisfies requirements including: (1) the entire prosthesis device (packaged IC) fits through a 4-mm incision in the eye wall, (2) the microelectrode array independently transmits each pixel of a 40 x 80 array from the flat surface of the image-processing IC to the curved surface of the retina with high spatial resolution, (3) each microelectrode can be placed in intimate contact with the retinal surface without damaging delicate retinal tissue, (4) each microelectrode in the array has less than 1 megohm impedance at 1 kHz, (5) the package exposes the eye to only biocompatible materials, (6) the package interfaces to control instrumentation external to the eye, and (7) the entire prosthetic device survives steam sterilization.

A completely new technology was needed to form the microelectrode array of connections between the chip's 3200 pixels and in-vivo human retinal tissue. The package's microelectrode array was constructed by electroplating metal through the entire 1-mm thickness of microchannel glass plates (over 200,000 microchannels per device, with aspect ratio 200:1). Under a well-controlled electroplating process this results in a dense, highly-ordered array of individual uniform parallel microwires captured in a glass matrix ("microwire glass" or MWG; see Figure 1). Advantages of MWG include (1) it is inherently a 3-D structure which can be spherically polished on one side to match the normal retinal curvature, (2) biocompatible glass matrices are commercially available, and (3) the dense array of microwires greatly reduces alignment requirements during chip packaging.

Major difficulties in the electroplating process included obtaining nearly perfect filling of all microchannels with metal throughout the microchannel glass, and electroplating a millimeter thickness of metal with sufficiently low stress that the glass matrix does not crack. Overcoming these difficulties required not only control of the plating process, but also proper selection and preparation of the microchannel glass for electroplating. For example, we discuss techniques to avoid trapping gas bubbles in microchannels which impede metal deposition.

The microelectrode impedance for each unit cell is minimized by maximizing surface area: each pixel is connected to multiple microwires, and additional microwire surface is exposed by etching to remove a portion of the glass matrix near the surface (see Figure 1).

Assembly of the microelectrode array and the image-processing chip was accomplished using an indium bump-bonding technique. Each pixel has a 20µm x 30µm, 10µm-high indium bump for connection to the package. The microwire glass package is joined to the image-processing chip by pressing the ends of the microwires into the indium bumps. This results in a strong mechanical as well as electrical connection.

The package also incorporates an electroplated 10-trace microcable, which passes from the image processing chip through the eye wall incision to external instrumentation during surgery (see Figure 2). This microcable was required to have low-resistance traces for chip power and signal propagation, yet be extremely flexible. Each trace of the microcable is joined directly to the corresponding chip bond pad using lead-free solder (Ag-filled epoxy has also been used, but it has higher resistance than solder).

A biocompatible epoxy (EpoTech 353ND) is used as a non-conductive filler between the MWG and chip, and for sealing the package. This epoxy performs well under steam sterilization. After sterilization, device verification is performed in saline solution. FDA approval is being sought by the Washington National Eye Center, which will conduct all human acute trials.

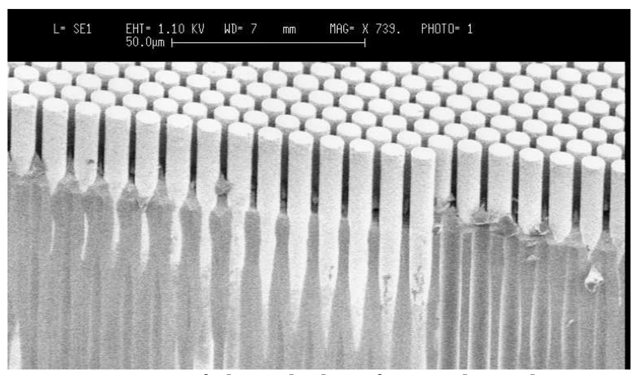

Figure 1 – SEM of cleaved edge of microelectrode array. The microwire diameter is ~5.5µm, and pitch ~8µm.

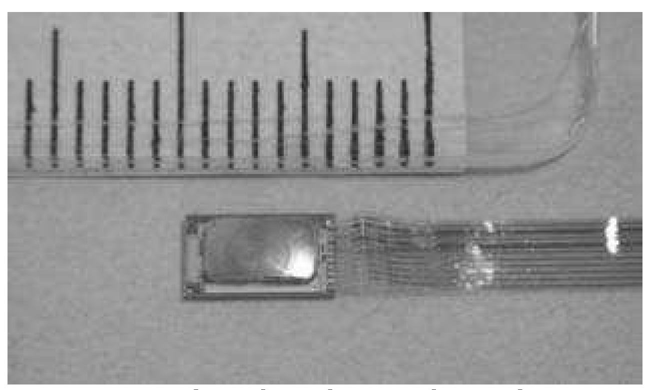
Figure 2 – Retinal prosthesis device with curved MWG on top, ready for final sealing of package. Scale is in 1 mm increments.

REFERENCES

[1] Scribner, D., et al, *Proc. IEEE 2003 Custom Integrated Circuits Conf.* (Cat. No.03CH37448), 517-20, 2003.

ACKNOWLEDGEMENTS

Work is sponsored by Dr. Leonard Buckley who manages the DARPA Neovision Program and Joel Davis, Office of Naval Research.