Retinal stimulator embedded with light-sensing function in distributed microchip architecture for subretinal implantation

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Introduction

Among several types of retinal implants, a sub-retinal implant [1], [2] is one of the most promising methods in terms of high-density stimulation and no requirement of an eye tracking system, which is required in the retinal prosthesis method with external imaging system, such as an epi-retinal implant [3].
We have already proposed distributed microchip architecture for retinal prosthesis to realize large number of electrodes, and demonstrated its fundamental operation *in vivo* by using a rabbit eye [4], [5]. In this presentation, we demonstrate a new type of retinal stimulator for subretinal implantation embedded light-sensing function in the distributed microchip architecture. Also the next generation chip with multi-site stimulation function has been developed.

Device structure and experimental results

A microchip has the same structure as in Ref. [4] except for embedded a light-sensing function in the chip as shown in Fig 1. A stimulus current is controlled by the light impinged on a microchip. When the light intensity reaches a threshold value of the inverter in Fig. 1, the stimulus current control switch is turned on, and the stimulus current flows into retinal cells.

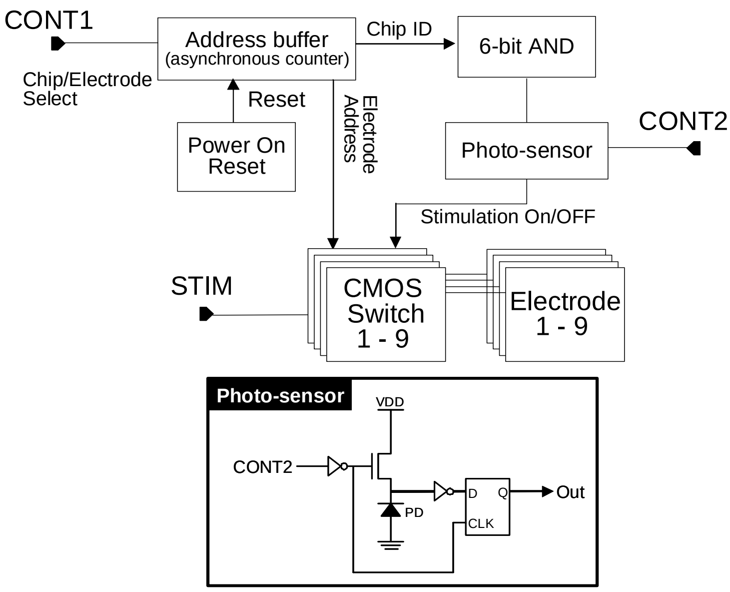

Figure 1: Block diagram of a microchip. Inset is photosensor circuits.

After the chip fabrication, nine Pt bumps were formed on Al metal pads of the chip for stimulus electrodes. The four microchips were assembled on a flexible polyimide substrate using a flip-chip bonding technology specially developed for this distributed architecture. Figure 2 shows the fabricated stimulator. It can be easily bend along the rabbit eye ball.

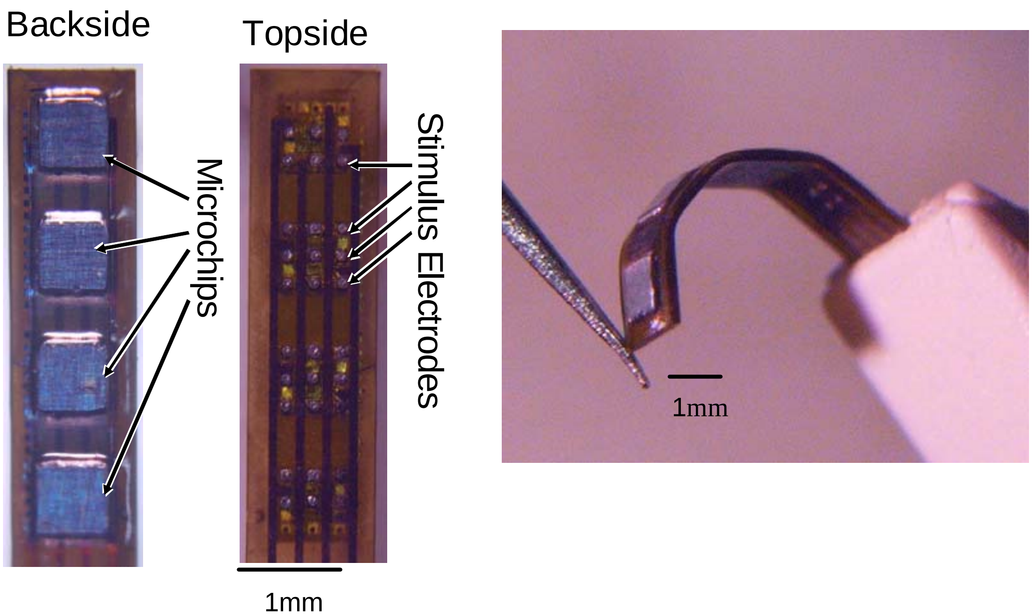

Figure 2: Photographs of the fabricated retinal stimulator. The left- and middle-side photos show the backside and topside view of the stimulator. The right-side photo demonstrates the mechanical flexibility of the stimulator.

The fabricated stimulator was implanted into a pocket formed in the sclera of a rabbit eye as shown in Fig. 3. Near infrared (NIR) LED array was illuminated on the eye where the stimulator was implanted. It is noted that NIR light cannot evokes photoreceptors and can penetrate the epithelium and some thickness of the sclera of a rabbit. EEP (electrical evoked potential) signal was measured through the screw electrodes set in a visual cortex. After implanting the stimulator, we confirmed that VEP (visual evoked potential) signal was not measured by NIR light used in this experiment before the measurement of EEP signal. When NIR light incidents on the eye, a clear EEP signal was obtained as shown in Fig. 4 and thus the stimulation of retinal cells were successfully demonstrated. The threshold of the stimulus current was about 100 µA, which is the same as in the previous experiment.

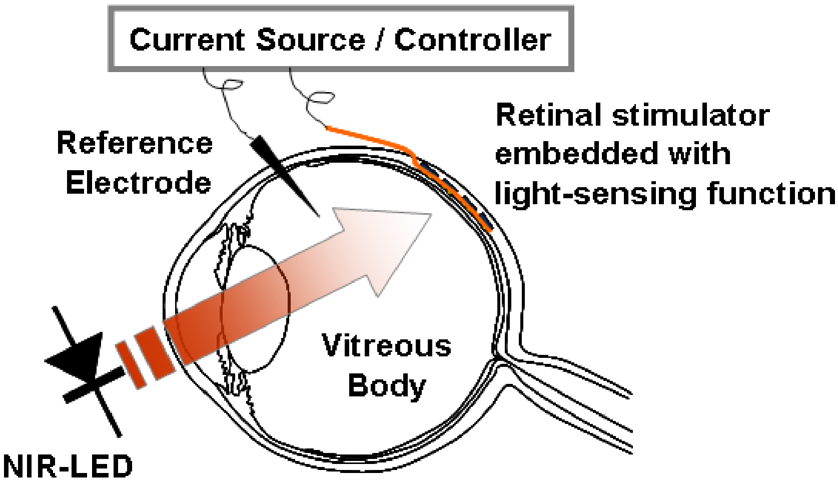

Figure 3: Experimental setup of light-controlled retinal stimulation.

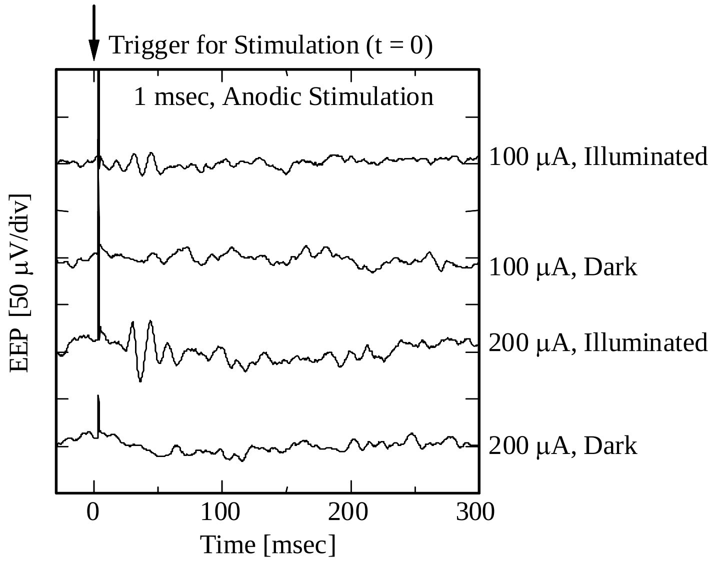

Figure 4: EEP signals of the implanted stimulator. NIR-LED emitted around 950 nm is used for the illumination source. The current value indicates the input current value to STIM node of the microchip. The stimulus current can flow only if the NIR light is illuminated on the chip. It is noted that only when the NIR light is illuminated, EEP signals were obtained.

In the microchip described above, only one stimulation site is activated. We have developed the next generation chip with multi-site stimulation, where a current source is integrated. In the microchip, the metal wire lines are utilized for the inter-chip connection, so that we can shrink the chip size in 200 µm square as shown in Fig. 5. We are now planning to implant the multi-site stimulation device into a rabbit eye.

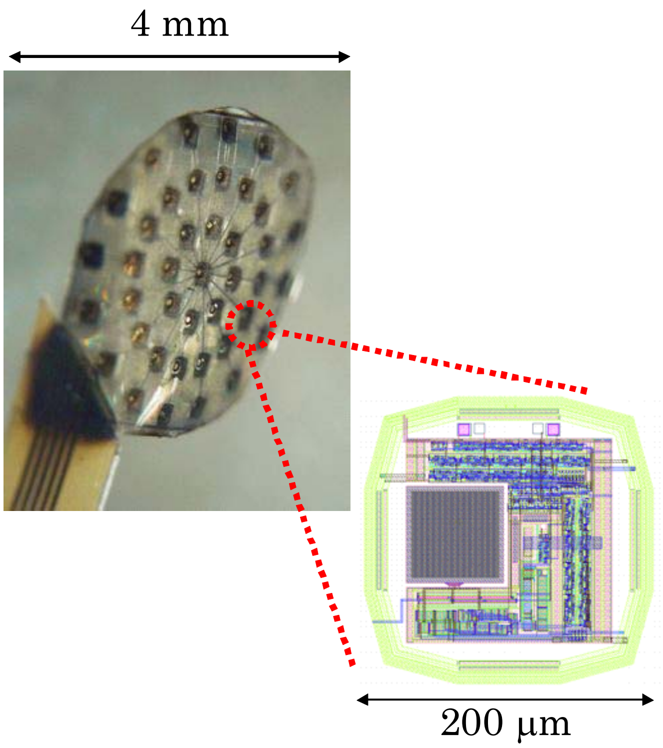

Figure 5: The multi-site stimulator. 97 microchips are placed on a parylene substrate. Each microchip is connected through Al wire lines. In the microchip with a size of 200 µm x 200 µm, a current source, a photo-senor, control circuits, and a stimulus pad are integrated.

Conclusion

We designed and fabricated the retinal stimulator embedded light-sensing function in the distributed microchip architecture, and successfully demonstrated EEP signal by using the stimulator implanted in a rabbit eye. Also the next generation chip with multi-site stimulation is demonstrated.

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