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Large scale electrode array based on distributed microchip architecture for retinal prosthesis

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1. Introduction

Several types of retinal prosthesis devices have been reported [1]-[5], while they have had a small number of electrodes so far. For realizing better vision using retinal prosthesis, over 1000 electrodes would be preferable. When increasing the number of electrodes, we are faced with the issue of interconnection between electrodes and external lead wires. It is noted that a Si-LSI chip with a large area size cannot be implanted directly, because a flexible substrate is required to bend itself along the eye ball when implanted.

To solve this issue, we have developed a new type of smart stimulator that consists of a number of LSI-based microchips distributed on a flexible substrate as shown in Fig. 1 [6], [7]. Each microchip has several stimulus electrodes, which can be externally controlled to turn on and off through an external control circuit. In addition to solving the interconnections issue, LSI-based stimulators offer several advantages such as signal processing. For implantation, the LSI-based stimulator should be thin and flexible to fit the eye and to avoid damaging tissue. However, silicon is rigid and thinning of the LSI chip increases the risk of breakage. To allow flexibility, we place several microchips on a substrate in a distributed manner.

In this paper, we propose a new structure to realize a large number electrode array with better extendibility and better sealing characteristics in biological environment compared with the previous one.

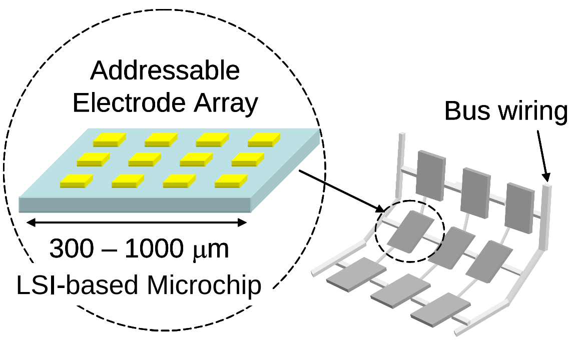

Fig.1: Schematic illustration of distributed microchip based stimulator.

2. Stimulator design

To enhance extendibility and reliability of the stimulator for large array size, we propose a new stimulator design, in which the microchips are placed on the backside of the flexible substrate, that is, flip-chip bonding. Figure 2 illustrates the comparison between two stimulators; the previous simulator places microchips on the flexible substrate, while the new one places them under the substrate. The stimulus electrodes are electrically connected with the microchips through micro via-holes. The microchips are connected to each other such that the column can be extended vertically, so that the stimulator can increase the number of microchip placed on it. All of the connection wires are placed on the backside of the substrate; no wire bonding is needed in the configuration and thus the new stimulator is more reliable.

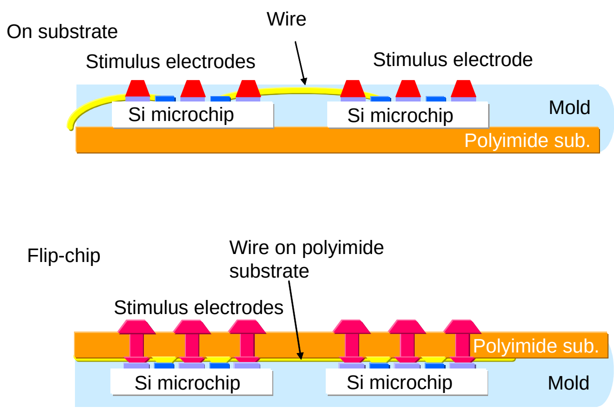

Fig. 2: Cross section of two types of stimulators.

3. Microchip design

The microchip has nine stimulation pads and four input lines including the power supply lines with a chip size of 600 μm x 600 μm. The layout and the block diagram are shown in Fig. 3. Each stimulation pad has unique 4-bit address to selectively activate the electrodes. The four input lines are Vdd, GND, CNTL, and STIM. Vdd and GND lines are used for power supply (5V and 0V DC). The control and stimulation can be achieved with only two lines; CNTL and STIM. One of the stimulation electrodes can be selected with the number of the pulses applied on the CNTL line. The microchip counts the pulses applied on the

CNTL line with 10-bit address buffer. The lower 4-bit for the address buffer is used for electrode selection, and the upper 6-bit is used for chip identification, as shown in Fig. 3. The microchip is fabricated in 0.35 µm standard CMOS technology with a high voltage option.

One of the stimulation electrodes is selected according to the value in the lower 4 bits of the address buffer. The 6-bits address space for microchips enables to control arbitrary number of microchips (up to 64) with only one set of input lines. Consequently, the multi-chip stimulation device platform can configure 64-chip device with 576 stimulation electrodes. To ensure the flexibility, the microchip array is assembled in 1000 - 1200 µm pitch. The area of 64-chip device is estimated to be approximately 58 - 80 mm^2 and could cover the important part of the human retina.

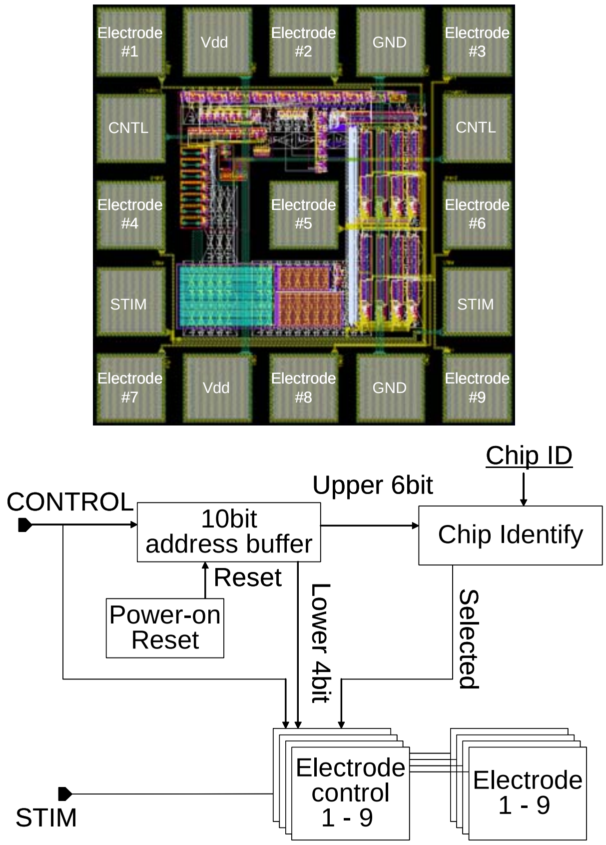

Fig. 3: The layout and block diagram of the microchip.

4. Fabrication of the stimulator

We design and fabricate an arrayed microchip in one die. The fabrication process is as follows. First of all, grooves to separate each microchip are formed on the die. Connection bumps for flip-chip bonding are formed on the pads of the microchips. We use gold ball bump as the connection bumps. Then the die is bonded onto the backside of the flexible patterned substrate with flip-chip bonding technique. Bump electrodes are formed on the top of the flexible substrate. Then, the bottom of the die is grinded as to separate each microchip completely. The separated microchips are molded with molding material and backing film.

Fig. 4 shows a fabricated stimulator in which Si dummy wafers with the size of the microchips are assembled with the fabrication process mentioned above. The stimulator shows acceptable thickness (approximately 250µm), and enough flexibility to fit eyes of the human. The optimization of the fabrication process for the CMOS microchips is now undergoing, and will be presented at the conference with the performance of the assembled thin and flexible stimulation device.

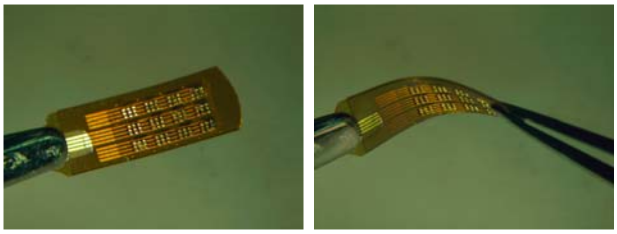

Fig. 4: Fabricated stimulator. It can be bent easily.

5. Conclusions

We have proposed and fabricated a flip-chip type stimulator for a large number of stimulation in STS. It could ensure the extendibility and reliability. In the fabricated device, up to 576 simulation electrodes can be realized. The fabricated stimulator will be tested to operate in a saline solution.

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