Micro-photodiode arrays as artificial retina implant

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This paper describes a photoelectric device that is intended to serve as a replacement for degenerated photoreceptor cells in the retina. The device is a kind of silicon based micro-photodiode arrays. The final implant devices were approximately 100 μm in thickness and ranged in diameter from 2.5 to 3.5 mm. The individual photodiode subunits on the device is approximately 250 × 250 (μm) and the isolated channel between these subunits is about 50-μm width. The implant feasibility of device was tested in vivo and in vitro. The results show that the device has good biocompatibility. When it was implanted into rabbits and powered by light, visual evoked potential (VEP) can be induced.

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Some retinal disorders such as retinitis pigmentosa (RP) and age-related macular degeneration will result in the progressive loss of vision for gradual loss of the retinal photoreceptor cell layer. The main function of the photoreceptor cells is to convert the incident light signals from the pupil into electric signals and convey the signals to the rest visual cells. Without photoreceptor cells, the chin is broken and the visual sense is lost. There are currently no therapies to restore vision to patients blinded by photoreceptor degeneration. Based on the fact that a proper electrical stimulation on the remaining retina can cause visual sensations or phosphenes[1], many researchers developed a prosthesis that could be directly implanted into the retina[2]. There are two kinds of retinal implant under development: epiretinal[3,4] and subretinal[5,6]. Epiretinal implant is to attach a stimulation electrode array to the inner retinal membrane. The visual signals transmitting to the electrode array come from a camera and have been processed by a computer which simulates the function of the retina. Subretinal device is a photodiode array that simulates the normal function of the photoreceptor cells. When the photodiode is implanted into subretinal space, the lost function of light-to-current conversion of degenerated photoreceptor is resumed and evokes the rest visual nerve cells with the photocurrent. We developed a kind of silicon based photodiode array and tested its character with animal.

Silicon is suit for fabricating photodiode at visible light or infrared band and is a kind of biocompatible material. Biocompatible is a required character for implant device. It means that the implant and the surrounding in the body should not influence each other, at least, on function. Biocompatible experiment[7] shows that silicon based photodiode array is compatible in vitro and in vivo during a two-week-long period.

The implant device is fabricated with silicon arts and crafts. Figure 1 shows both the face and rear of the implant device on the left, and on the right is the micrograph of the face. The devices are approximately 100 μm in thickness and ranged in diameter from 2.5 to 3 mm. The individual photodiode (PD) unite on the chip is approximately 250 × 250 (μm) and the isolated channel between these subunits is about 50 μm wide. A gold electrode is produced to collect the photocurrent and transmit the photocurrent to the adjacent nerve cells when it was implanted. The rest area of the unit can absorb incident light and generate photocurrent. If each PD in the array can generate current and evoke phosphenes corresponding to the power of incident light, a pattern vision will be sensed by the implant acceptor.

Before a pattern vision is generated, one must assure the PD array can arose visual evoked potential (VEP) or electroretinogram (ERG). Rabbits were chosen to test the chips. To establish a RP sufferer model, photoreceptor cells on the subretinal of the rabbit were destroyed by injecting medicine. Under anesthesia, the chip was placed via a sclerostomy and a retinotomy in the subretinal space in the right eye of the rabbit, the left eye was left as contrast. A white light beam send by laser emitter diode (LED) was projected from outside of the eye through the pupil and focused on a local area on eyeground. To evoke a VEP effectively, the light was modulated to form a 200-ms-wide pulse with a repeat frequency about 1 Hz. To present, fifty rabbits at different age stages were tested. A typical VEP of rabbit under above condition was showed in Fig. 2. The grid on both figures is 6.2 μV/vertical division and 100 ms/horizontal division. The VEP on the top of the figure is recorded from the right eye, in which the PD array chip was implant. The one on the bottom is from the control eye. The P^+ point of

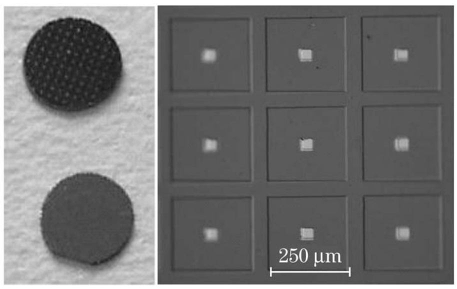

Fig. 1. Micro photodiode array consisting of individual photodiodes.

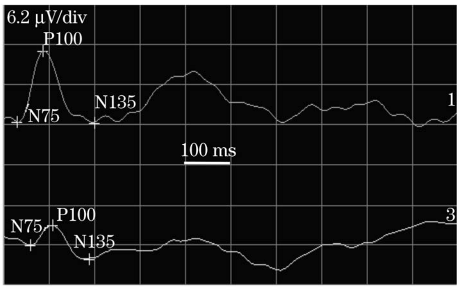

Fig. 2. Typical visual evoked potential (VEP) of the RP rabbit. The upper one is from a implanted eye and the bottom one is from the control eye.

VEP from the implanted eye is apparently higher than the contrast eye. Another different is the P^+ point on top appears earlier than the one on bottom. It shows the implant device improves a RP eye's sensitization.

In conclusion, we developed a micro photodiode array and implanted it into rabbits' eye to test the device. The test results show that the device improves a RP eye's sensitization.

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