Development of a Foldable and Photovoltaic Wide-Field Epiretinal Prosthesis

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***Abstract*— With more than 30 million blind people worldwide, retinal prostheses have become a valuable option for vision restoration that – although limited – demonstrated to be clinically useful. Retinal prostheses available nowadays either commercially or in clinical studies still fail to fulfill the requirements of visual acuity and visual field to overcome legal blindness. We developed a novel high-density and wide-field epiretinal prosthesis based on organic photovoltaic materials able to induce retinal ganglion cells activation upon illumination. The implant is inspired by intraocular lenses, allowing the placement of more than 10’000 pixels distributed over an area corresponding to 45 degrees of visual field.**

I. Introduction

Age-related macular degeneration and retinitis pigmentosa are among the most frequent and incurable retinal diseases that can lead to blindness [1]. Epiretinal prostheses, placed in contact with the retinal ganglion cell (RGC) layer, bypass the degenerated photoreceptors stimulating the ganglion cells by locally altering the electric potential in correspondence to the desired phosphene location [2].

In this work, a photovoltaic strategy has been chosen to deliver visual information: upon illumination, the pixels can generate a photovoltage able to activate the neurons located nearby. Light of a specific wavelength can therefore be projected onto the implant and power the selected electrodes. This allows the pixels to lay freestanding and with high density on the prosthesis. The implant is designed to be folded and injected into the eye as for intraocular lenses, consenting the pixels to be distributed over a large area and covering a wide-angle of visual field, without being constrained by the minimal scleral incision needed for implantation.

II. Results

We developed a foldable prosthesis that self-opens once injected into the eye, covering an active area of about 45 degrees of visual field. The shape of the implant is spherical in order to accommodate the retina and allow a tight contact of the electrodes to the RGCs. The pixels, embedded in an elastomeric matrix, are based on organic electronic materials, which offer simple processing capability, biocompatibility, and a wide range of wavelength sensitivity. These photovoltaic pixels are composed by PEDOT:PSS, P3HT:PCBM (565 nm peak sensitivity) or PCPDTBT:PCBM (730 nm peak sensitivity), and Ti as cathodic contact (Fig. 1). The implant was successfully fabricated with 80 µm or 60 µm pixel diameters and a total number of pixels higher than 10’000 (79 pixels per mm^{-2}) or 18’000 (149 pixels per mm^{-2}), respectively. Shaping the electrode array requires stretching of the matrix; therefore, each electrode was mechanically protected thanks to the incorporation of a rigid disc out of SU-8 within the elastomer. These platforms protect the pixels from excessive stresses also during folding and injection into the eyeball.

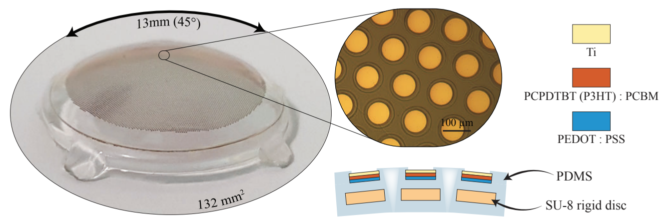

Figure 1. Photograph of a prototype with 80 µm pixels with a micrograph showing the integrity of the array after spherical shaping and its schematic cross-section highlighting the structure and the materials.

The photovoltaic materials have proved to stimulate RGCs in explanted, blind, mice retinas [3] and generate up to -3.5 V mm^{-2} and -50 µA mm^{-2} for a light intensity 50 % lower than the ophthalmic safety limits [4]. Interestingly, the photovoltage transient decay can be engineered to have higher time constants by using crosslinking additives within the anodic electrode. Slower voltage decays can be used for inducing a more network-mediated RGC response with respect to fast, squared-shaped stimuli [5].

III. Conclusion

These preliminary results demonstrate the possibility of restoring vision with a large visual field and a relatively high acuity using a soft, curved, and freestanding implant. The stimulating pixels are composed of organic photovoltaic materials that can be tuned to respond to different light wavelengths.

References

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