DEVELOPMENT OF A LARGE-AREA AND SPHERICAL ARRAY OF POLYMERIC PHOTOVOLTAIC PIXELS FOR ARTIFICIAL VISION

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ABSTRACT

We developed a large-area epiretinal prosthesis based on organic electronic materials embedded into a stretchable matrix. High-density photovoltaic pixels were designed to provide artificial vision up to 45 ° of visual field thanks to a transparent and spherical substrate. The prosthesis can withstand rolling and injection into the eye through a small scleral cut. To manufacture such implants, standard microfabrication techniques were adapted to soft, temperature- and solvent-sensitive materials.

KEYWORDS: Organic photovoltaics, wide-field retinal implant, high-density, curved substrate, microfabrication

INTRODUCTION

Retinal implants have demonstrated to restore a limited, but useful, form of artificial vision [1]. Even though various technical difficulties have been overcome, some challenges yet remain unfulfilled, such as fabricating a prosthesis with a high number of electrodes distributed over a large and curved surface area to maximize not only the resolution but also the restored visual field. Electrically addressed stimulating electrodes would require a vast number of tracks, inevitably resulting in large and unsafe trans-scleral connecting cables. Moreover, the substrate materials used for available implants are stiff and flat, preventing an extensive and homogeneous contact of the stimulating pixels with the retinal tissue [2].

To overcome these issues, we developed a spherical epiretinal prosthesis made of organic electronic materials fabricated onto a stretchable substrate [3]. To stimulate the retinal ganglion cells, high-density photovoltaic pixels have been designed to transduce projected light into electrical signals, avoiding the need for connecting cables and thus allowing to place a high number of electrodes. To cover a wide retinal surface, a soft and transparent substrate was molded to obtain a large-area and curved pixels array. Finally, the procedure to implant these large devices is inspired by intra-ocular lenses placement and the prosthesis is conceived to withstand rolling and injection into the eyeball through a minimal scleral cut.

EXPERIMENTAL

In this paper, we introduce a new generation of wireless implants and the manufacturing challenges that require standard microfabrication techniques adapted to soft, temperature- and solvent-sensitive materials (main steps of the process flow presented in Fig. 1A). The patterning of the photovoltaic pixels is performed without the use of solvents. Furthermore, the mechanical challenge of shaping a two-dimensional array into a spherical one (Fig. 1B) requires a hybrid stiff-soft architecture in order to avoid pixels breaking (as shown in Fig. 1C).

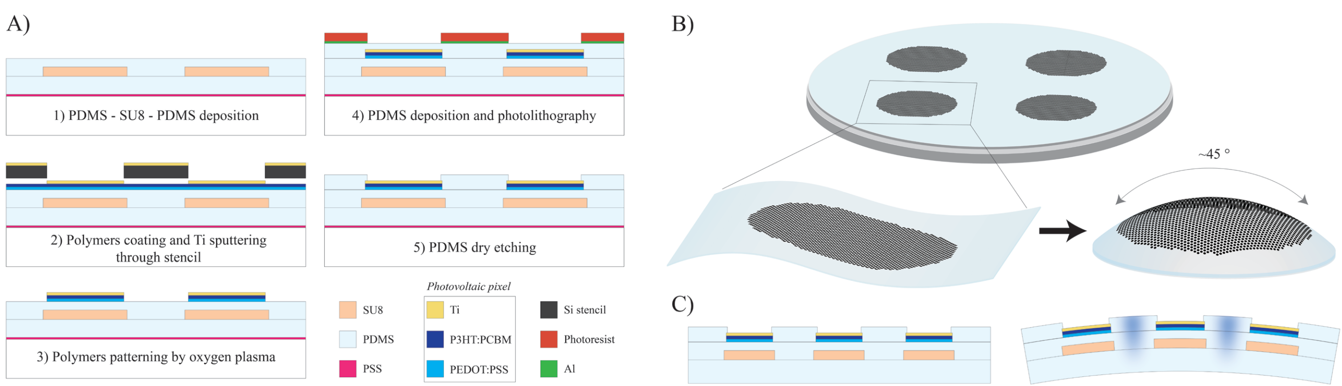

Figure 1: Main steps of the process flow (A) and array moulding into spherical shape (B). (C) Schematics of strain distributions within the array when shaped (shaded dark-blue regions represent zones subjected to higher strain).

RESULTS

The fabricated implants embed more than 10'000 photovoltaic pixels distributed over a surface area of 132 mm^2 and covering a visual field of about 45 °, much wider than other devices so far (i.e., 5 – 20 ° [4, 5]). The pixels of 80 or 60 µm in diameter are composed by *poly(3,4-ethylene dioxythiophene):poly(styrene sulfonate)* (PEDOT:PSS), a semiconducting blend – *poly(3-hexylthiophene):phenyl-C61-butyric acid methyl ester* (P3HT:PCBM) – and titanium cathode (Ti). They are fabricated within a stretchable membrane of *poly(dimethylsiloxane)* (PDMS). The moulding and bonding of the PDMS-based photovoltaic array are performed by injection moulding and UV curing to a soft and transparent thiol-ene-epoxy thermoset [6]. In Fig. 2 an example of the curved photovoltaic array is presented (A), together with the photovoltaic responses of current and voltage upon illumination of the pixels (B), and the evoked activity in a retinal ganglion cell stimulated by a pixel of the implant under a 10-ms light pulse (C).

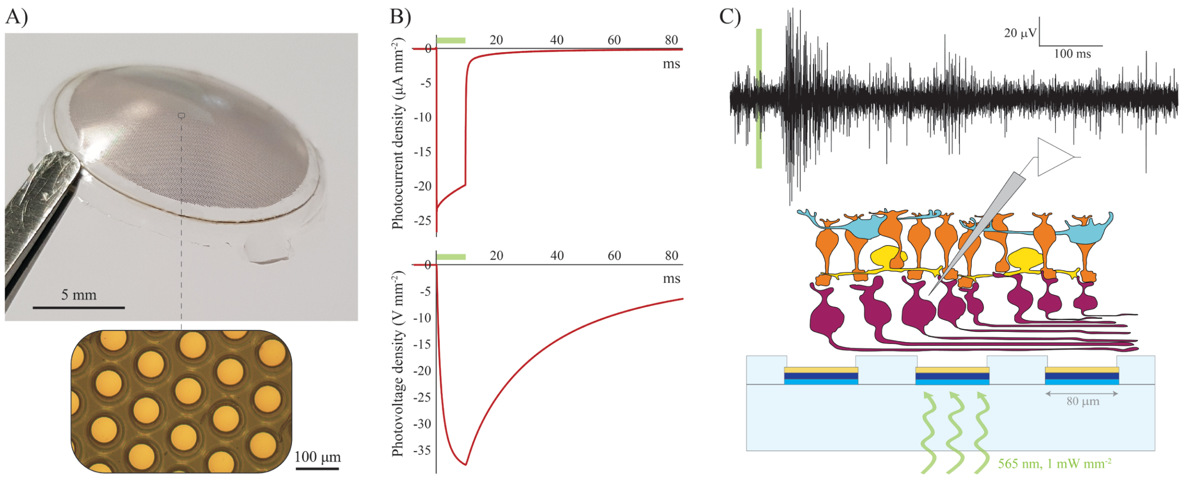

Figure 2: (A) Photograph and micrograph of a prototype (60 µm pixels). (B) Photovoltaic responses of PEDOT:PSS / P3HT:PCBM / Ti pixels upon 10-ms light pulse (565 nm, 1 mW mm^{-2}). (C) Example of in-vitro raw responses from a blind mouse (Rd10) retinal ganglion cell stimulated with single-pixel illumination as sketched (10 ms, 565 nm, 1 mW mm^{-2}).

CONCLUSION

These results demonstrate how organic, soft, and stretchable materials can be adapted to build a high-resolution and wide-field epiretinal prosthesis. Conjugated polymers can be selected according to the wavelength sensitivity of the projected light, opening a broad choice of materials and increasing the number of applications in the field of bioelectronic interfaces.

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