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3D conjugated polymer-based vertical structures for bioelectronic devices

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In the last decades bioelectronic devices have been employed for both sensing cellular electrical activity and stimulation to modulate specific cellular functionalities. The interface between cells and devices is crucial for an effective cell–device coupling. In fact, cells might be physically decoupled from the sensing electrodes by a cleft that forms at the adhesion sites between the plasma membrane and the surface of the material. For this reason, recent approaches have focused on engineering the interface with 2.5-3D architectures. Non-planar substrates, i.e. vertical protrusions such as pillars, cones and mushroom-shaped structures, have demonstrated to improve the coupling between the biological system and the device, reducing the aforementioned cleft.(1)

In bioelectronic devices, the conductive polymer poly(3,4-ethylenedioxythiophene):poly (styrene sulfonate) (PEDOT:PSS), has gained an increasing attention due to its properties such as flexibility, high transparency, conductivity, biocompatibility and great thermal and environmental stability.(2) Moreover, PEDOT:PSS shows mechanical properties that are similar to those of biological tissues (i.e. low Young's modulus)(3) and its conduction mechanism, based on both electrons and ions mobility, provides a promising electrical interface with cells for sensing and stimulation. Thanks to these properties, PEDOT:PSS has been employed in many bioelectronic applications.(4) However, engineering a surface with 2.5-3D features is still a challenge because the current methods by which it is possible to achieve these features require long procedures and they cannot provide high resolution and complex structures.(5)

To this aim, we present an approach for the fabrication of 3D conjugated polymer-based structures for cell sensing and stimulation. The realization of the 3D structures is performed by two-photon-polymerization (2PP) lithography, in which a pulsed laser that has a wavelength of 780 nm is focused in a confined volume spot, cross-linking the ip-dip photoresist. The non-conductive structures are then coated with a conductive thin layer of ITO or gold. Then, the substrate is coated with a layer of PEDOT:PSS obtained via cyclic voltammetry electrodeposition. The resulting 3D structures has been characterized by electron microscopy and electrochemical measurements (cyclic voltammetry and electrochemical impedance spectroscopy). Finally, biocompatibility assays have been carried out with neuronal cells and the local adhesion processes to the 3D structures have been characterized by means of optical and electron microscopy.

The proposed approach will lead to the realization of electrodes that will exhibit entirely organic 3D features and will be used for cells and tissues sensing and stimulation. Such electrodes can also find applications in biomedical devices as implants, probes and epidermal devices in which soft, flexible and conductive materials are required.

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