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Cell patterning via linker-free protein functionalization of an organic conducting polymer (polypyrrole) electrode

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ABSTRACT

The interaction of proteins and cells with polymers is critical to their use in scientific and medical applications. In this study, plasma immersion ion implantation (PIII) was used to modify the surface of the conducting polymer, polypyrrole, which possesses electrical properties. PIII treatment enabled persistent, covalent binding of the cell adhesive protein, tropoelastin, without employing chemical linking molecules. In contrast tropoelastin was readily eluted from the untreated surface. Through this differential persistence of binding, surface bound tropoelastin supported cell adhesion and spreading on the PIII treated but not the untreated polypyrrole surface. The application of a steel shadow mask during PIII treatment allowed for spatial definition of tropoelastin exclusively to PIII treated regions. The general applicability of this approach to other extracellular matrix proteins was illustrated using collagen I, which displayed similar results to tropoelastin but required extended washing conditions. This approach allowed fine patterning of cell adhesion and spreading to tropoelastin and collagen, specifically on PIII treated polypyrrole regions. We therefore present a methodology to alter the functionality of polypyrrole surfaces, generating surfaces that can spatially control cellular interactions through protein functionalization with the potential for electrical stimulation.

1. Introduction

For bioassays synthetic polymers require many facets such as biocompatibility, mechanical properties, ease of manufacture, and electrical insulation or conductivity. Organic conducting polymer materials are relatively new to the area of tissue engineering but already show excellent promise as biomaterials due to their biocompatibility, bio-function, and electrical and mechanical stimulatory features [1]. Dopant ions are incorporated during synthesis of the polymer and the movement of these dopant ions compensate for charge imbalances during voltage application. These dopants can be a bioactive species for applications involving the electrically controlled release of growth factors or drugs [2–4], for example on cochlear implant electrodes [5]. For mechanical stimulation of cells, the polymer can be actuated through the reversible movement of the dopant ions and accompanying aqueous medium, which causes expansion and contraction of the polymer [6,7]. One such conducting polymer, polypyrrole, has shown to be an efficacious material for supporting the growth and differentiation of numerous cell types such as endothelial, skeletal muscle, nerve and fibroblasts [2,6,8–10].

Cells in vivo are surrounded by extracellular matrix (ECM) proteins, which provide vital cues for many biological functions such as cell adhesion, migration and proliferation, tissue organization, wound repair, development, and host immune responses [11]. Therefore immobilization of such ECM proteins to polymers has been proposed for an improved biological activity. Simple physisorption is most commonly used to endow polymers with the biological activities of ECM proteins [12]. Physisorption is dependent upon the polymer surface characteristics including surface chemistry, wettability [13], energy and topography [12]. This physisorption can result in variable extents of attachment, persistence and conformational stability [14,15], which is often difficult to predict. Covalent protein–polymer interactions offer

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