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Aligned Carbon Nanotube-Based Flexible Gel Substrates for Engineering Biohybrid Tissue Actuators

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Abstract

Muscle-based biohybrid actuators have generated significant interest as the future of biorobotics but so far they move without having much control over their actuation behavior. Integration of microelectrodes into the backbone of these systems may enable guidance during their motion and allow precise control over these actuators with specific activation patterns. Here, this challenge is addressed by developing aligned carbon nanotube (CNT) forest microelectrode arrays and incorporating them into scaffolds for cell stimulation. Aligned CNTs are successfully embedded into flexible and biocompatible hydrogels exhibiting excellent anisotropic electrical conductivity. Bioactuators are then engineered by culturing cardiomyocytes on the CNT microelectrode-integrated hydrogel constructs. The resulting cardiac tissue shows homogeneous cell organization with improved cell-to-cell coupling and maturation, which is directly related to the contractile force of muscle tissue. This centimeter-scale bioactuator has excellent mechanical integrity, embedded microelectrodes, and is capable of spontaneous actuation behavior. Furthermore, it is demonstrated that a biohybrid machine can be controlled by an external electrical field provided by the integrated CNT microelectrode arrays. In addition, due to the anisotropic electrical conductivity of the electrodes provided by aligned CNTs, significantly different excitation thresholds are observed in different configurations such as the ones with electrical fields applied in directions parallel versus perpendicular to the CNT alignment.

Keywords

Author Keywords: bioactuators; carbon nanotubes; cardiac tissue engineering; hybrid hydrogels; microelectrode arrays

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