coatings

Editorial

Emerging Nanocomposite and Nanoarchitectonic Coatings for Biomedical Engineering

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Anti-bacterial, low-friction, superhydrophobic, and hydrophilic coatings are widely demanded in biomedical engineering for non-implantable and implantable devices, such as surgical tools, tubes, wires, rubber seals, and stents. Currently, the commercial coatings are majorly composed of a single functional material, e.g., PTFE coatings for surgical wires, parylene coatings for medical-grade silicone rubbers, PFA coatings for medical glass; these coatings can endow medical devices with additional functions such as low friction, anti-adhesiveness, and impact resistance, as the undesirable interactions between the biological tissue and the medical device are minimized. However, this strategy might not be operable for the design and fabrication of emerging implantable biomedical devices in constructing the tissue–electronics interface, where intensive interactions in the interface formed by the surface cells of the tissue and the surface molecules of the device exist. Nanotechnologies, i.e., nanocomposites and nanoarchitectonic coatings, can play an important role in constructing small-dimension, highly integrated, multifunctional coatings for achieving highly efficient tissue–electronics interfacing.

In the existing tissue–electronics interfaces, the brain–electronics interface might be the most complicated and intriguing one, as it may help understand the origins of intelligence and promote the development of biologically based artificial intelligence. Over decades, a wide variety of techniques and processes have been reported to demonstrate the effect of nanocomposite coatings on the performance of commercially available metal-based neural electrodes [1]. It has been widely observed that the formation of functional nanostructures on the surface of the neural electrodes can significantly improve their charge storage capacity, electrochemical impedance, and long-term stability. In 2006, the pioneer work by M. R. Abidian and D. C. Martin et al. demonstrated how the formation of the nanocomposite coating containing PEDOT-coated porous PLGA nanofibers on the conductive sites of a Michigan neural microelectrode can endow the neural microelectrode with the function of controlled drug release [2]. Upon removing the PLGA nanofiber cores, the nanocomposite coating can be transformed into a new 3D nanoarchitecture composed of PEDOT nanotubes, and a higher charge storage capacity and lower impedance can be obtained for the neural microelectrode. Moreover, the 3D porous network formed by the PEDOT nanotubes can accomplish the motions of contraction and expansion under the control of an applied voltage. In the following work published in 2009, M. R. Abidian and D. C. Martin introduced a soft alginate hydrogel coating on the surface of the neural microelectrode, which can promote the formation of PEDOT inside the hydrogel matrix and form a 3D multifunctional nanocomposite coating with the PEDOT-coated PLGA nanofibers [3]. The 3D multifunctional hydrogel-coated neural microelectrode showed a two-orders-of-magnitude increase in charge carrier density and a two-orders-of-magnitude decrease in impedance. Afterwards, in 2010, Abidian et al. proposed that coatings composed of randomly oriented conducting polymer nanotubes (PPy, PEDOT) can significantly improve the long-term functionalities of the neural microelectrodes, in terms of structural stability and the rate of in vitro neurite growth, compared to the structureless conducting polymer thin films [4]. Furthermore, in 2013, E. Castagnola et al. reported that the utilization of human fibrin hydrogel coatings on the PEDOT/CNT-nanocomposite-coated micro-electrocorticography (ECoG) arrays can create an electrically transparent, mechanically stable, and biocompatible protective layer to avoid direct contact of the brain to the nanocomposite-coated ECoG arrays [5]. The results of the in vivo signal recording tests in the rat somatosensory cortex showed that the human fibrin hydrogel and PEDOT/CNT-nanocomposite-coated ECoG arrays obtained a sensitivity and detection limit close to the PEDOT/CNT-nanocomposite-coated arrays, while the nanocomposite-coated arrays showed a conductivity two-orders-of-magnitude higher than the uncoated arrays at 100 Hz.

Besides the nanocomposites, nanoarchitectonics also showed their application potential in biomedical engineering, e.g., magnetic resonance imaging, photothermal therapy, nanomachines, and cell sheet technology [6]. Recently, A. Diaz-Alvarez et al. developed neuromorphic nanowire networks using randomly self-assembled silver nanowires. The neuron synapses were simulated by coating the Ag nanowires with polyvinylpyrrolidone, forming abundant atomic switches in the junctions among the nanowires [7]. The Ag nanowire network can be transformed into a high conductance state by applying a voltage bias above a threshold, which can be used to study artificial neural networks. These examples show how nanocomposite and nanoarchitectonic coatings can enhance the functionalities of the biomedical devices. As the nanocomposite and nanoarchitectonic coatings have become a long-lasting research focus in the science community, multicomponent, multidimensional, and multifunctional materials and devices with new configurations, new applications, and new intelligence can continue to be generated.

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