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Nanoscale Topography of Anodic TiO_2 Nanostructures Is Crucial for Cell–Surface Interactions

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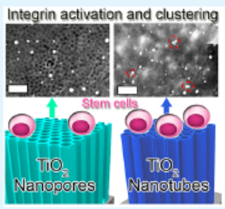
ABSTRACT: Anodic titanium dioxide (TiO_2) nanostructures, i.e., obtained by electrochemical anodization, have excellent control over the nanoscale morphology and have been extensively investigated in biomedical applications owing to their sub-100 nm nanoscale topography range and beneficial effects on biocompatibility and cell interactions. Herein, we obtain TiO_2 nanopores (NPs) and nanotubes (NTs) with similar morphologies, namely, 15 nm diameter and 500 nm length, and investigate their characteristics and impact on stem cell adhesion. We show that the transition of TiO_2 NPs to NTs occurs via a pore/wall splitting mechanism and the removal of the fluoride-rich layer. Furthermore, in contrast to the case of NPs, we observe increased cell adhesion and proliferation on nanotubes. The enhanced mesenchymal stem cell adhesion/proliferation seems to be related to a 3-fold increase in activated integrin clustering, as confirmed by immunogold labeling with β1 integrin antibody on the nanostructured layers. Moreover, computations of the electric field and surface charge density show increased values at the inner and outer sharp edges of the top surfaces of the NTs, which in turn can influence cell adhesion by increasing the bridging interactions mediated by proteins and molecules in the environment. Collectively, our results indicate that the nanoscale surface architecture of the lateral spacing topography can greatly influence stem cell adhesion on substrates for biomedical applications.



KEYWORDS: *TiO2 nanotubes, TiO2 nanopores, anodization, surface topography, stem cells, integrin*

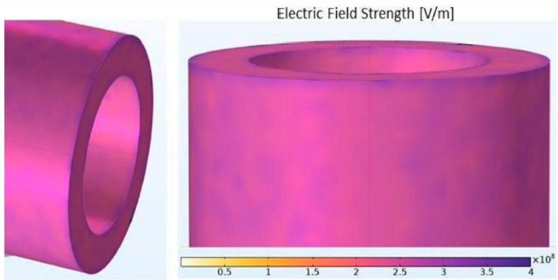


Figure 6. Calculated electric field distribution on the TiO_2 NTs surface in contact with the electrolyte solution. The model parameters were a bulk electrolyte concentration of 150 mmol/L and an electric potential of 110 mV.

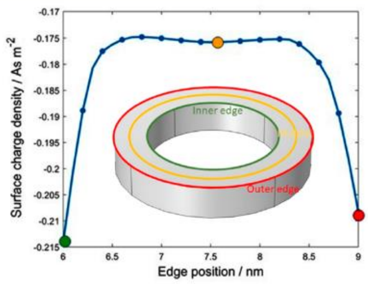


Figure 7. A schematic of the position of the inner edge, middle, and outer edge on the top NTs surface and the corresponding surface charge density as a function of the position on the wall rim (the inner edge, middle, and outer edge are denoted by dots in green, yellow, and red, respectively). The values of the model parameters are the same as those shown in Figure 6.