Stem cells and TiO_2

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Size selective behavior of mesenchymal stem cells on ZrO_2 and TiO_2 nanotube arrays†

Sebastian Bauer,‡[a] Jung Park,‡[b] Josef Faltenbacher,[a] Steffen Berger,[a] Klaus von der Mark[b] and Patrik Schmuki*[a]

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This work reports on the behavior of mesenchymal stem cells on anodic ZrO_2 nanotube layers grown by a self-ordering process on zirconium with defined diameters between 10 and 50 nm. It is demonstrated that mesenchymal stem cells show a size-specific reaction to these nanoscale patterned surfaces. We compare the behavior on these ZrO_2 nanotubes to findings on TiO_2 nanotubes of different diameters. For both nanotube materials, TiO_2 and ZrO_2, cell adhesion and spreading are enhanced for nanotube diameters of ~15–30 nm, while a strong decay in cell activity is observed for diameters > 50 nm. Focal complex formation on adherent cells is selectively modulated by the specific nanoscale. Moreover, even if the surface chemistry of the nanotubes is completely modified with a dense AuPd coating onto the formed nanotube layers, or the length of the nanotubes is varied, the observed nano size effects still prevail. This demonstrates how strong the pure geometric diameter dependence in the range between 15 and 100 nm dominates over other possible effects on cell activity.

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Brief communication

Improved attachment of mesenchymal stem cells on super-hydrophobic TiO_2 nanotubes

Sebastian Bauer [a,1], Jung Park [b,1], Klaus von der Mark [b], Patrik Schmuki [a,*]

[a] *Department of Materials Science, WW4-LKO, Friedrich-Alexander-University of Erlangen-Nuremberg, Germany*
[b] *Department of Experimental Medicine I, Nikolaus Fiebiger-Center of Molecular Medicine, Germany*

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Abstract

Self-organized layers of vertically orientated TiO_2 nanotubes providing defined diameters ranging from 15 up to 100 nm were grown on titanium by anodic oxidation. These TiO_2 nanotube layers show super-hydrophilic behavior. After coating TiO_2 nanotube layers with a self-assembled monolayer (octadecylphosphonic acid) they showed a diameter-dependent wetting behavior ranging from hydrophobic ($108 \pm 2°$) up to super-hydrophobic ($167 \pm 2°$). Cell adhesion, spreading and growth of mesenchymal stem cells on the unmodified and modified nanotube layers were investigated and compared. We show that cell adhesion and proliferation are strongly affected in the super-hydrophobic range. Adsorption of extracellular matrix proteins as fibronectin, type I collagen and laminin, as well as bovine serum albumin, on the coated and uncoated surfaces showed a strong influence on wetting behavior and dependence on tube diameter.

Keywords: Titanium-dioxide nanotubes; Self assembled monolayers; Super-hydrophobic; Cell adhesion; Mesenchymal stem cells

Human mesenchymal stem cell adhesion and proliferation in response to ceramic chemistry and nanoscale topography

A. J. Dulgar-Tulloch,[1,2*] R. Bizios,[2,3] R. W. Siegel[1,2]**

[1]*Department of Materials Science and Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180*
[2]*Rensselaer Nanotechnology Center, Rensselaer Polytechnic Institute, Troy, NY 12180*
[3]*Department of Biomedical Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180*

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Abstract: Modification of the chemistry and surface topography of nanophase ceramics was used to provide biomaterial formulations designed to direct the adhesion and proliferation of human mesenchymal stem cells (HMSCs). HMSC adhesion was dependent upon both the substrate chemistry and grain size, but not on surface roughness or crystal phase. Specifically, cell adhesion on alumina and hydroxyapatite was significantly reduced on the 50 and 24 nm surfaces, as compared with the 1500 and 200 nm surfaces, but adhesion on titania substrates was independent of grain size. HMSC proliferation was minimal on the 50 and 24 nm substrates of any chemistry tested, and thus significantly lower than the densities observed on either the 1500 or 200 nm surfaces after 3 or more consecutive days of culture. Furthermore, HMSC proliferation was enhanced on the 200 nm substrates, compared with results obtained on the 1500 nm substrates after 7 or more days of culture. HMSC proliferation was independent of both substrate surface roughness and crystal phase. Rat osteoblast and fibroblast adhesion and proliferation exhibited similar trends to that of HMSCs on all substrates tested. These results demonstrated the potential of nanophase ceramic surfaces to modulate functions of HMSCs, which are pertinent to biomedical applications such as implant materials and devices. © 2008 Wiley Periodicals, Inc. J Biomed Mater Res 90A: 586–594, 2009

Key words: mesenchymal stem cell; nanophase; ceramic; cell adhesion; cell proliferation; grain size; material chemistry; material topography

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Stem cell attachment to layer-by-layer assembled TiO_2 nanoparticle thin films

Dinesh S. Kommireddy[a,1], Shashikanth M. Sriram[b], Yuri M. Lvov[a,c], David K. Mills[a,b,*]

[a]*Institute for Micromanufacturing, Louisiana Tech University, 911 Hergot Avenue, Ruston, LA 71272, USA*
[b]*School of Biological Sciences, Louisiana Tech University, 1 West Arizona, Ruston, LA 71272, USA*
[c]*Department of Chemistry, Louisiana Tech University, 1 West Arizona, Ruston, LA 71272, USA*

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Abstract

Surface topography is one of the most important factors influencing the attachment and spreading of cells. In the present study, layer-by-layer assembled titanium dioxide (TiO_2) nanoparticle thin films were chosen for attachment, proliferation and spreading studies on mouse mesenchymal stem cells (MSC). Increasing surface roughness was observed with increasing number of layer-by-layer assembled TiO_2 thin films. Four layer TiO_2 thin film showed higher number of attached cells than a one layer thin film and control surfaces. MSCs experienced no cytotoxic effects after culture on the TiO_2 coated substrates as observed from the cytotoxicity tests. Cell spreading, visualized with scanning electron microscopy, showed a faster rate of spreading on a rougher surface. Cells on a four-layer substrate, at 12 h showed complete spreading, where as most of the cells on a control surface and a one-layer surface, at 24 h, retained a rounded morphology. In conclusion, TiO_2 nanoparticle thin films were successfully assembled in alternation with polyelectrolytes and in-vitro studies with MSC showed an increase in the attachment and faster spreading of cells on rougher surfaces.

Keywords: Layer-by-layer assembly; Stem cells; Nanoparticles; Surface roughness; Surface modification; Titanium dioxide

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Nanosize and Vitality: TiO_2 Nanotube Diameter Directs Cell Fate

Jung Park,[†] Sebastian Bauer,[‡] Klaus von der Mark,[†] and Patrik Schmuki*,[‡]

Department of Experimental Medicine I, Nikolaus Fiebiger-Center of Molecular Medicine, Germany, and Department of Materials Science, Friedrich-Alexander-University of Erlangen-Nuremberg, Germany

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ABSTRACT

We generated, on titanium surfaces, self-assembled layers of vertically oriented TiO_2 nanotubes with defined diameters between 15 and 100 nm and show that adhesion, spreading, growth, and differentiation of mesenchymal stem cells are critically dependent on the tube diameter. A spacing less than 30 nm with a maximum at 15 nm provided an effective length scale for accelerated integrin clustering/focal contact formation and strongly enhances cellular activities compared to smooth TiO_2 surfaces. Cell adhesion and spreading were severely impaired on nanotube layers with a tube diameter larger than 50 nm, resulting in dramatically reduced cellular activity and a high extent of programmed cell death. Thus, on a TiO_2 nanotube surface, a lateral spacing geometry with openings of 30–50 nm represents a critical borderline for cell fate.

■ communications

Stem cells

TiO_2 Nanotube Surfaces: 15 nm—An Optimal Length Scale of Surface Topography for Cell Adhesion and Differentiation**

*Jung Park, Sebastian Bauer, Karl Andreas Schlegel, Friedrich W. Neukam, Klaus von der Mark, and Patrik Schmuki**

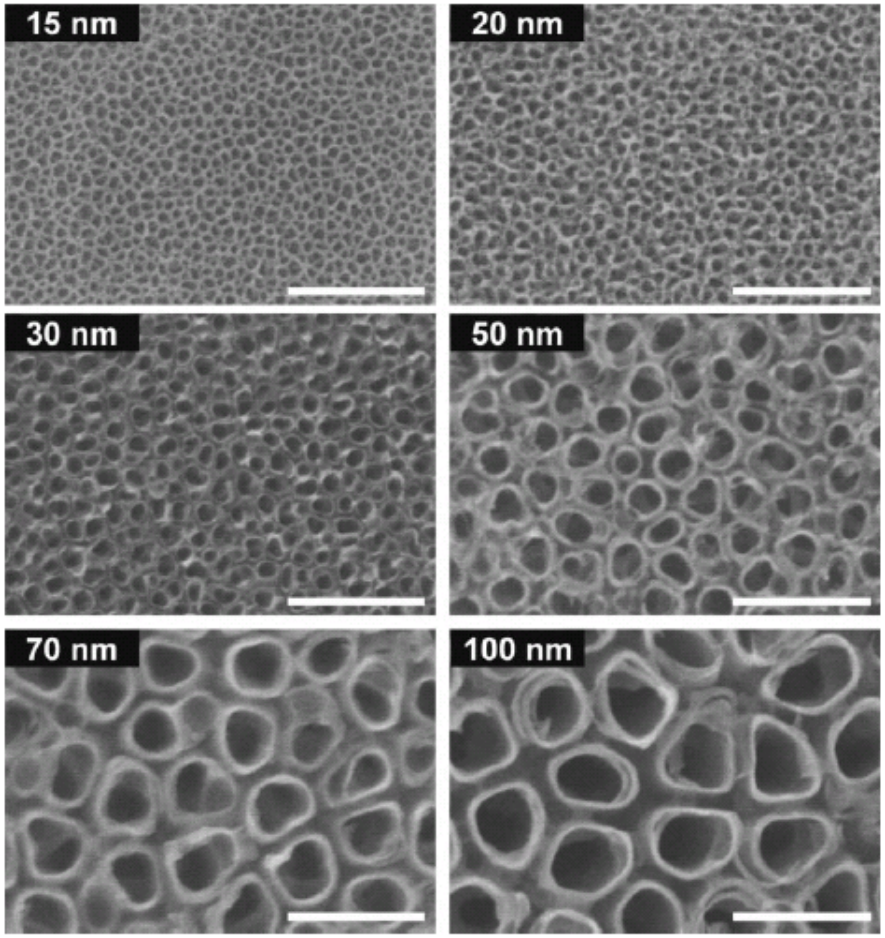

Figure 1. Top-view SEM images of self-assembled layers of vertically oriented TiO_2 nanotubes of six different diameters ranging between 15 and 100 nm formed in 1 M H_3PO_4 + 0.3 wt% HF at potentials between 1 and 20 V for 1 h. Scale bars: 200 nm.