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Commentary

Importance of Nanoporous Aluminium Oxide Membranes in Biomedical Applications

Annika Teuscher*

Department of Biomedical Engineering, UNC-Chapel Hill and North Carolina State University, North Carolina, USA

DESCRIPTION

Due to its biocompatibility, greater surface area, and ability to be customised with a variety of surface changes, nanoporous Anodic Aluminium Oxide (AAO) has gained importance in biomedical applications over the past several years. Pure aluminium is inexpensively anodized to create highly ordered, vertical nanochannels with well-controllable pore sizes, depths, and interpore distances, which self-assemble to produce AAO nanopores. AAO nanopores are good options for nanostructured substrates for cell-interface investigations because of their exceptional characteristics. This in-depth review highlights and presents a tabular summary of earlier studies on cell adhesion and proliferation on various AAO nanopore geometries and surface modifications. Future uses of nanoporous alumina membranes in biotechnology and medicine are also discussed, such as the use of nanoporous AAO as coculture substrates, immunoisolation devices, or implant modifications.

Current research on nanomaterials is rapidly moving into the area of nanoporous biointerfaces. Nanoporous Anodic Alumina Oxide (AAO) membranes have special qualities that have greatly aided the development of novel biomedical applications over the past several years. The family of self-organized, highly ordered, and biocompatible nanomaterials known as alumina membranes has regular pore size, homogeneous pore density, and high porosity on a large scale, which results in a greater surface area. Additionally, nanoporous AAO has the following properties: optical transparency, electrical insulation, chemical stability, bioinertness, and biocompatibility [1]. These exceptional qualities make AAO membranes useful for a wide range of biotechnology and medical applications, including biofiltration membranes, lipid bilayer support structures, biosensing devices, implant coatings, drug delivery systems with AAO capsules, and tissue engineering scaffolds. AAO nanopores are not always employed alone, but in addition they act as a popular template for other biocompatible nanostructures, like gold and platinum nanopillars [2]. AAO membranes have previously been used in a number of studies as neuronal cell culture substrates with the goal of creating sophisticated brain implants and sensing technology. Numerous studies have recently focused on the behaviour of osteoblasts and fibroblasts, two types of connective tissue cell types, in response to nanostructured AAO substrates. Since the early 1970s, when alumina ceramics were first used for hip implants, substantial research has been done on implant wear and fracture. AAO nanopores have grown in significance as a surface modification for bone implants during the past ten years, improving mechanical performance and enhancing osteoblastic cell ingrowth into the implant surface [3].

The other two basic tissue types are epithelial cells. Their spread and adherence to AAO nanopores have already attracted the attention of numerous surveys, which are summarised in this section. The cultivation of HEK293 human embryonic kidney cells is on extracellular matrix gel-coated AAO nanopores. The alumina holes were created on silicon substrates and had interpore lengths of 30 nm to 200 nm. The HEK293 cells were shown to attach and proliferate well on the alumina nanopores for up to 14 days in culture, along with typical electrophysiological performance.

Only a few teams have examined the development of muscle cells on nanoporous AAO membranes thus far. AAO substrates with diameters of 20 nm and 200 nm and how they affect Smooth Muscle Cells (SMCs) regarding cell morphology and cell proliferation, they discovered that the cellular response was dependent on the nanotopography, although cellular adhesion remained unaffected. On membranes with 20 nm pores, cell proliferation was found to be worse than on pores with a diameter of 200 nm. Additionally, the larger holes showed higher expression of genes related to the cell cycle, DNA replication, cell proliferation, and signal transduction pathways, showing that the physiological response of SMCs is highly dependent on the underlying nanopore shape [4].

The reaction of blood cells to alumina nanopores plays a critical role in the development of novel implant surfaces that reduce the inflammatory response of the human body. Recent studies addressing this particular cell-AAO interaction are discussed in

Correspondence to: Annika Teuscher, Department of Biomedical Engineering, UNC-Chapel Hill and North Carolina State University, North Carolina, USA, E-mail: annikateuscher@gmail.com

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this section. Prepatterning approaches on nanoporous alumina membranes were recently employed by several groups to enable spatially confined growth of microorganisms on AAO nanopores. Over the past years, nanoporous alumina membranes have been introduced into several drug delivery and immunoisolation applications. In 2002, biocapsules were produced from AAO to encapsulate molecules of different molecular weights. Molecular diffusion characteristics of the AAO capsules could be well controlled for the two model drugs fluorescein and FITC dextran by adjusting the pore size from 25 nm to 55 nm. It is possible to create nanoporous AAO membranes with highly repeatable geometries by employing an affordable and manageable etching method. AAO nanopores are remarkable possibilities for biomedical applications due to their exceptional material characteristics. Nanoporous AAO membranes have already been used in alumina biosensors, nanoporous biocapsules for drug delivery, and coculture substrates for tissue engineering [5].

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