Understanding the Biological Impact of Nanoengineered Surfaces

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ABSTRACT

Two model nanoengineered surfaces, a nanopatterned block copoloymer (BCP) film and a polymer nanofiber surface, were utilized to investigate the affect that nanofeatures have on protein adsorption. Scanning electron microscopy (SEM) and atomic force microscopy (AFM) were used to characterize the topography of the surfaces. Protein adsorption was quantified using a bicinchoninic acid (BCA) based assay. Future work will focus on investigating the mechanisms and dynamics of adsorption on surfaces with nanoscale features. This data will provide a better understanding of how these surfaces will react in the body.

Keywords: Nanoengineered surface, nanoscale, nanotechnology, protein adsorption

1 INTRODUCTION

There is a growing trend in the medical device industry to manipulate the surface topography of a device with nanoscale features (nanoengineered surface) in order to promote advantageous biological responses such as better tissue integration/growth [1]. Due to the considerable growth in the field it is imperative that the scientific and regulatory community develop an understanding of this technology, specifically how such nanoscale features influence biological response. This understanding and knowledge is crucial for the development of novel materials with enhanced properties yet is also equally important for the proper assessment of the safety and efficacy of these new materials to better protect the public health. Experimentation was conducted on two types of surfaces with nanoscale features (nanopatterned BCP film and polymer nanofiber surface) to gain a better understanding of the biocompatibility of these surfaces.

2 METHODS

2.1 Nanopatterned BCP Films

Poly(styrene)-*block*-poly(1,2-butadiene) (PS/PB) BCPs were modified with amide (boc group), anionic, and cationic functional groups using thiol-ene photochemistry. After purification and drying, the polymers were dissolved at 0.5 wt% in suitable solvents, or co-solvent mixtures. The polymer solutions were then spin-coated at 2000 rpm onto parylene coated glass cover slips for characterization and testing. The polymer films were imaged using an Asylum MFP-3D atomic force microscope.

2.2 Polymer Nanofibers

Polymer (85:15 poly(lactic-co-glycolic acid) (PLGA), MW~70-100 kDa) nanofibers of various sizes were created using an electrospinning process. A 25 wt% polymer polymer solution, in a co-solvent mixture which contained 80% dichloromethane and 20% dimethylformamide by volume, was used. The nanofibers were deposited on circular polystyrene inserts for subsequent testing. Characterization of the nanofibers was completed using scanning electron microscopy (SEM) and and atomic force microscopy (AFM).

2.3 Protein Adsorption

As stated earlier the modified BCP films were dissolved at 0.5 wt% in suitable solvents, or co-solvent mixtures, and spin-coated on parylene coated glass cover slips for protein adsorption studies. Polymer nanofibers were deposited on circular polystyrene inserts which were subsequently used for protein adsorption studies.

The nanoengineered surfaces were subjected to various protein solutions (either single protein solutions or media (10% fetal bovine serum) consisting of a composite mix of proteins). Protein adsorption was characterized utizing a Thermo Scientific Micro BCA Protein Assay Kit.

3. RESULTS

3.1 Nanopatterned BCP Films

The PB portion within the PS/PB BCP was functionalized with various moieties to yield thin film polymers. These polymer films were termed "nanopatterned" since due to the microphase separation of the polymer the charges were patterned in the nanoscale domain. Figure 1 below is an AFM image of a carboxylic acid-modified PS/PB BCP. The carboyxlic acid is confined to the PB domain of the polymer which occurs in a regular pattern (~60 nm across) throughout the film. The result is a polymer film which contains a homogenous, sequential pattern of electrostatic charge (negative charge) in a physiological (pH~7) environment.

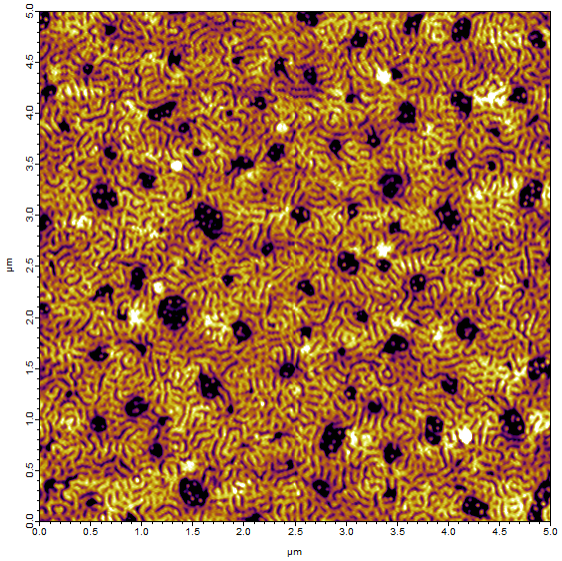

Figure 1. AFM image of a carboxylic acid-modified BCP. The carboxylic acid moiety is localized to the polybutadiene block of the BCP reuslting in a sequential patterning of negative charge in a physiological environment.

3.2 Polymer Nanofibers

Various sizes of PLGA nanofibers were obtained using electrospinning. SEM and AFM were used to characterize the nanofibers. Figure 2 and 3 below are representative images (AFM and SEM) of the nanofibers under experimental study.

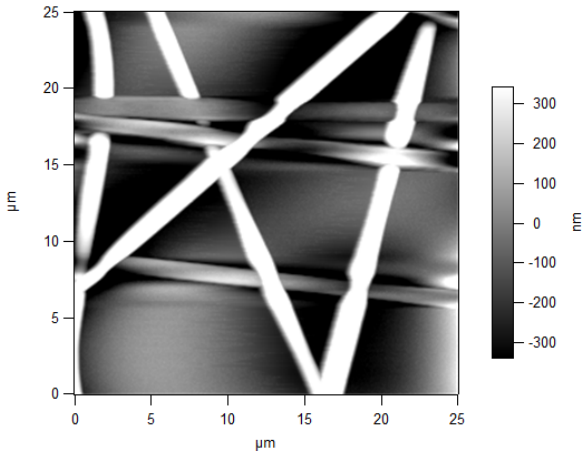

Figure 2. Representative AFM image of PLGA nanofibers

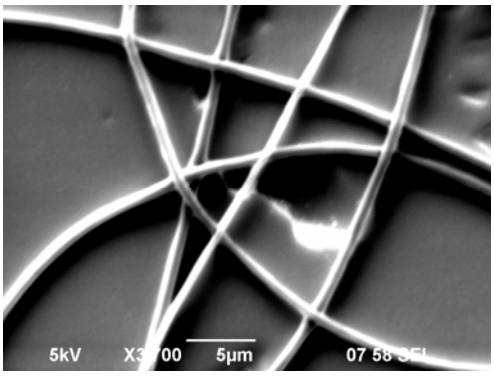

Figure 3. Representative SEM image of PLGA nanofibers.

3.3 Protein Adsoprtion

When exposed to 10% fetal bovine serum (FBS) under static conditions it was found that the nanopatterned surfaces adsorbed similar protein amounts to the controls. This finding was consistent with earlier findings where protein adsorption under static conditions was quantified using a quartz crystal microbalance.

Concurrent experiments were conducted to look at adsorption of individual proteins onto polymer nanofiber surfaces. Results of this experimentation showed that the polymer nanofiber surfaces adsorb less protein compared to a flat polystyrene surface (control). Further experimentation is under way to investigate the mechanisms and dynamics of protein adsorption on surfaces with nanoscale features. This data will provide a

better understanding of how these surfaces will react in the body.

REFERENCES

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