Nanotechnology-derived catheters for reduced inflammation and infection

Luting Liu and Thomas J. Webster
Department of Chemical Engineering, Northeastern University, Boston, MA

Statement of Purpose:

Polydimethylsiloxane (PDMS) has been used for short- and long-term catheters. However, PDMS shunt tubing has been scrutinized recently because of their extremely high failure rates (such as their use to treat hydrocephalus). While there are many reasons why PDMS shunt systems fail, one is tissue occlusion of the ventricular catheter, most often caused by macrophages. Infection is also problematic. Nevertheless, few attempts have been made to detect and to manipulate shunt catheter inflammation and infection. It is hypothesized that nanotextured and nanotubular surfaces can be carefully manipulated to inhibit immune cell (specifically, macrophages) and bacteria responses. The objective of this study was to create PDMS molds of titanium (Ti) anodized to possess nanotubes and test inflammatory and bacteria responses on such substrates. Previous studies have determined decreased inflammation and bacteria growth on anodized compared to unanodized Ti [1,2].

Methods:

The detailed protocol for preparing anodized nanotubular titanium was previously published[1,2]. Briefly, 99.2% pure titanium sheets were cut into 1cm×1cm squares using a shear cutter and cleaned with acetone, 70% ethanol, and deionized water. The samples were etched for 1min with a solution of 1.5% by weight nitric acid and 1.5% by weight hydrofluoric acid to remove the thin oxidized layer that spontaneously forms on the Ti surface in the presence of air. A cleaned Ti sample was used as an anode, while a high purity platinum sheet served as a cathode. Both were immersed in an electrolyte solution consisting of 1.5% by weight hydrofluoric acid in a Teflon beaker. The surface of the etched Ti was placed next to the platinum sheet at a distance of around 1cm. The anodization system (shown in Figure 1) subjected standard Ti to 20V for 10min to create nanotubular Ti. The samples were rinsed with large amounts of deionized water immediately after anodization, samples were air dried, and sterilized under ultraviolet light for 3 hours.

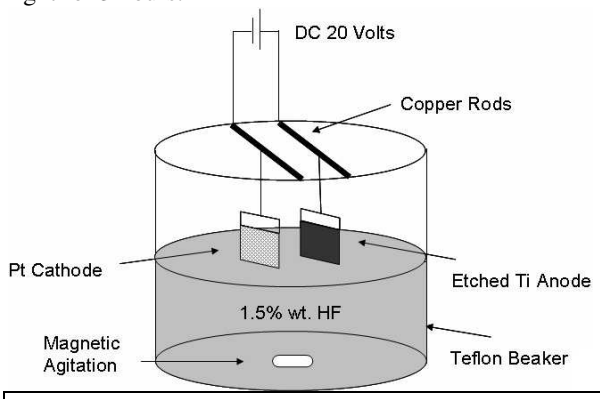

Figure 1. The anodization process. 20V DC was applied for 10min in 1.5 wt% hydrofluoric acid to modify the Ti surface to process nanotubes.

Next, the PDMS monomer and cross-linking agents were mixed at 10:1 (weight ratios) by a mechanical stirrer for 15min and was placed in a vacuum chamber for 30min to remove air bubbles. The mixture was cast onto the nanotubular Ti master mold and then was placed into a vacuum chamber for another 1h to remove the bubbles on the patterned interface and the PDMS slurry. To improve the ability to remove the PDMS from the Ti, a platinum film was sputtered onto the top surface of the PDMS template. After coating, the PDMS slurry was poured onto the PDMS template and placed in a vacuum chamber for 5h. The desired PDMS replica was cured at 60℃ for 2h and then removed from the PDMS template using a razor blade. Samples were characterized using standard SEM, AFM, and XPS analysis. Standard cell culture assays were also completed using macrophages and bacteria as purchased from ATCC. All experiments were completed in triplicate and repeated at least three times.

Results:

As expected, nano-sized tubes were distributed uniformly on the Ti surface after anodization (Figure 2). The uniform pores, as observed by scanning electron microscopy, were estimated to have a diameter of 50-60nm and a depth of 200nm. After pouring the PDMS slurry onto the surface of the nanotubular Ti and peeling off the first PDMS template, a nanopatterned structure was observed. In addition, the PDMS replica showed exactly the same nanotubular features as anodized Ti. Cellular results will also be presented.

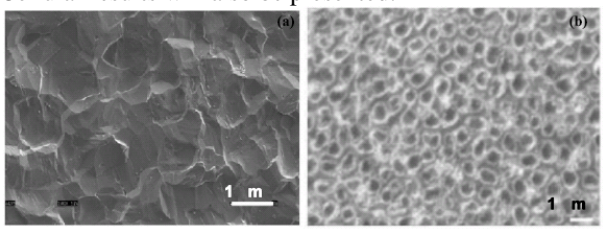

Figure 2. SEM micrographs of: (a) unanodized Ti and (b) anodized Ti.

Conclusions:

A PDMS template obtained from anodized nanotubular Ti was achieved and demonstrated a promising ability to inhibit macrophage and bacteria functions.

Acknowledgements:

The authors would like to thank Northeastern University for funding.

References:

[1] Rajyalakshmi A. International Journal of Nanomedicine. 2011;6:1765-1771.
[2] Puckett S., et al. Biomaterials. 2010; 31(4): 706-713.