Fabrication and Manipulation of Titanium Nanotubes

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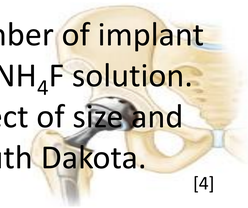
Motivation

While TiO_2 NTs are known to improve native tissue cell function (osteoblast), there is little understanding of the impact that TiO_2 NTs size/dimensions have on the macrophage polarization - a critical element of in vivo of osseointegration.

Abstract

Research in biocompatible coatings could potentially increase the longevity of implants, lessening the number of implant replacements. Ti/Ti_6Al_4V nanotubes were fabricated via anodic oxidation in 0.1 M ethylene glycol + 1.0 M NH_4F solution. Characterization of the microstructure was carried out using scanning electron microscopy (SEM). The effect of size and shape of nanotubes on macrophage polarization will be studied in collaboration with the University of South Dakota.



[4]

Background

- Expected lifetime of bone implant is 10-20 years [2].
- Titanium is commonly used orthopedic implant metal for great mechanical properties – strong, lightweight, bioinert [3].
- Why Nanostructures?
  - Material-host tissue interfaces governed by nanometric surface cues, Increases ability of bone to bond to implant surface.
- Improved osseointegration increases lifespan of implant and reduces number of revision surgeries.

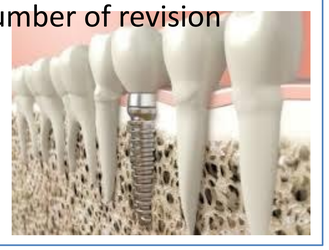


Figure 5: *Osseointegration of dental implant (image from Dental Implants Cohoes).*

Objectives

- Processing TiO_2 NTs via anodic oxidation.
- Altering dimensions by changing experimental variables.
- Microstructure characterization via SEM micrograph.
- Macrophage polarization (collected in collaboration with USD).

Materials and Methods

- Two electrode anodization cell- titanium anode and platinum cathode.
- Changing nanotube dimensions- tube diameter, lengths.
- Analyze biocompatibility of cells with altered nanotube surfaces.

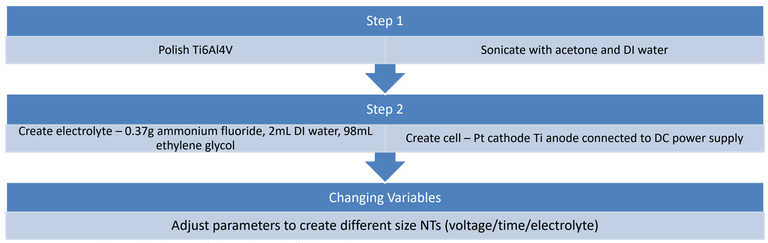


Figure 1: *General Experimental Overview*

Figure 2: *Blank Ti samples prepared for anodization.*

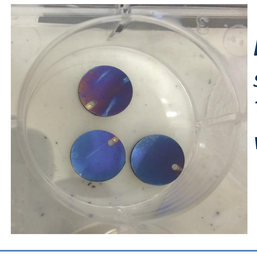


Figure 3: *Ti samples with TiO2 oxide layer with NTs.*

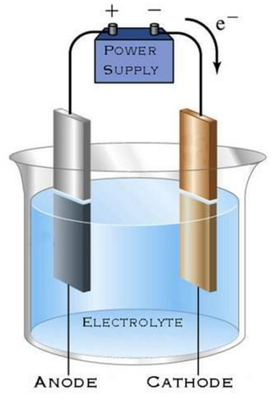


Figure 4: *Basic anodization cell (Image from Intech).*

Results

SEM Characterization

- NTs were characterized by a uniform tube diameter and vertically aligned (perpendicular to Ti substrate) nanotube length.

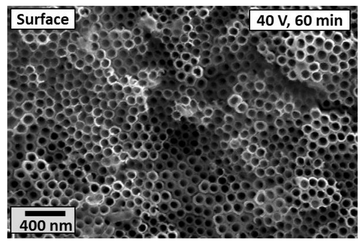


Figure 5: *SEM surface image of TiO_2 NTs processed at 40V for 60 min.*

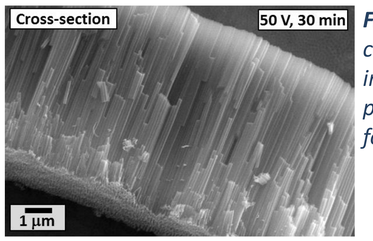
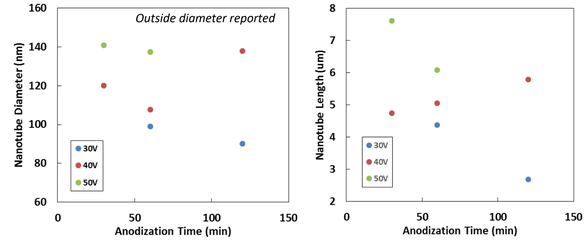


Figure 6: *SEM cross-sectional image of TiO_2 NTs processed at 50V for 30min.*

Nanotube Measurements



- In general, NT length increased with increasing anodization voltage.
- NT length was significantly influenced by anodization time (not expected).
- In general, NT diameter increased with increasing anodization voltage.
- NT diameter not significantly influenced by anodization time.
- *Note, all measurements obtained for a single replicate for each treatment. Additional replicates are needed to increase statistical significance.*

Conclusions

- TiO_2 NTs of varying length scales (tube diameter and length) were processed using NH_4F/ethylene glycol electrolyte.
- In general, tube diameter and length increased with increasing anodization voltage while anodization time had little affect on tube dimensions.
- Further process optimization is needed to gain increased control over tube dimensions.

Further Development

Develop process for producing TiO_2 NTs of various dimensions. There is a need to improve repeatability of fabrication process. In collaboration with USD, further determine relationships of macrophage polarization on altered titanium nanotube surfaces.

References

[1] Crawford, G., & Chawla, N. (n.d.). Porous hierarchical TiO2 nanostructures: Processing and microstructure relationships. Acta Materialia, 854-867.
[2] Wolford, M., Palso, K., & Bercovitz, A. (2015, February 12). Hospitalization for Total Hip Replacement Among Inpatients Aged 45 and Over: United States, 2000–2010. Retrieved July 12, 2015.
[3] Shrestha, Amin. (2013). Processing, Microstructure Characterization, and Adhesion Performance of TiO2 Nanotubes Coating for Ti Bone Implants.
[4] ©1995-2015 American Academy of Orthopedic Surgeons.

Acknowledgements

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