Enhanced Antibacterial Titanium Surface Developed using Hydrothermal Treatment

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Statement of Purpose: Titanium (Ti) has been widely used for fabricating bone implants, implant screws, heart stents, and heart valves. However, the life span of these medical devices is limited due to failure attributed to inflammatory responses, thrombosis, and bacterial biofilm formation. Researchers have attempted to enhance the surface properties of these medical devices using several surface modification techniques such as heparin modification, anodization, plasma etching, shot peening, etc. Patients are also prescribed with antibiotics to tackle bacterial infection, but these medications have proven to fail after the biofilm formation[1]. Thus, there is a serious need to develop a surface with durable biocompatible response and antibacterial properties. Recently, nano surfaces have shown enhanced properties, when compared to non-textured surfaces[1]. In this study, we have fabricated unique hierarchical nanostructures surface on Ti using hydrothermal treatment and vapor-phase silanization.

Methods: Pure titanium (Grade 2) samples were polished, ultrasonically cleaned and later hydrothermally treated with sulfuric acid at 60 ºC for 8 hrs and they further were coated by vapor-phase silanization. Treated surfaces were characterized with goniometer, scanning electron microscopy, X-ray photo electron spectroscopy and X-ray diffraction. for surface morphology, surface chemistry and phase analysis. The modified surfaces further were incubated with bacteria for 6 hrs and 24 hrs. Surface bacterial properties were studied using gram positive (*Staphylococcus aureus*) and gram negative (*Escherichia coli*) for bacterial adhesion, inhibition and biofilm formation studies.

Results: The hydrothermal treatment led to etching in the surface and produced novel hierarchical surface features with micro level pyramid-like structures and these structures have nano level nanopores on them (Figure 1a). When the treated surface was further coated with the silane using vapor silanization technique, they were superhydrophobic (171°) when compared to the control (Figure 1c). The control Ti surface is hydrophilic in nature. This led to significantly low (almost zero) bacterial adhesion on all treated surface when compared to control (Figure 2). There was also no biofilm formation seen on the treated surfaces.

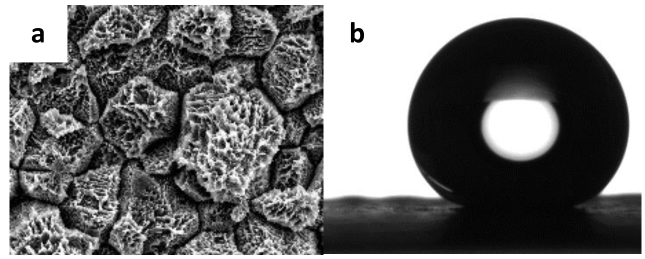

Figure 1: a) Surface morphology of the modified surface. **b)** Static apparent contact angle made by deionized water on the modified surface.

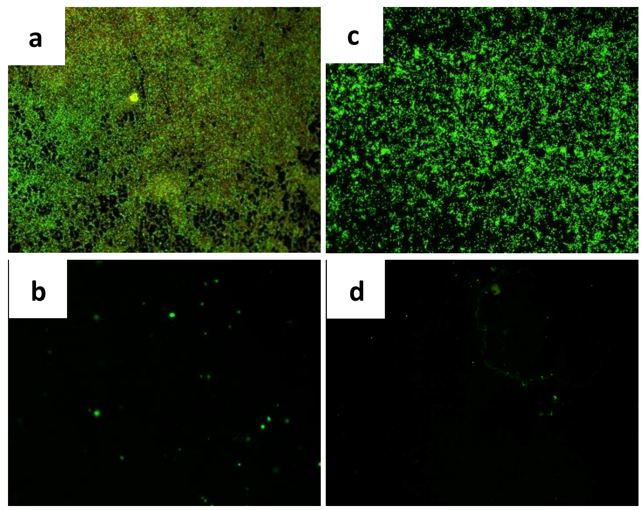

Figure 2: Florescence image was taken after surfaces were incubated in bacteria solution (concentration: 10^6/mL) for 24 hours. a) control surface with *S. aureus*. b) modified surface with *S. aureus*. c) control surface with *E. coli*. d) modified surface with *E. coli*.

Conclusions: The novel hierarchical structures produced using the hydrothermal technique were stable. After coating with silane, they were superhydrophobic and are highly antibacterial by restricting bacterial adhesion on the surface. This can improve the implant life and prevent other complication due to bacterial biofilm formation.

References:

1. Quinn, ISCIENCE (2020), S2589-0042(20)30942-1.