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Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Zhang, Y., Petersen, F. H., Abbaspourmani, A., Petersen, P. M., & Ou, Y. (2023). *Novel nanostructured antimicrobial surface for dental implant applications*. Abstract from 48th International Conference on Micro and Nano Engineering, Leuven, Belgium.

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Novel nanostructured antimicrobial surface for dental implant applications

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Since Dr. Per-Ingvar Brånemark implanted the first oral implant in a human in 1965, the use of implantology in dentistry has been providing dentists with a unique opportunity to replace missing teeth [1,2]. Currently, inflammation in the surrounding tissue and loss of this bony integration over time is a great concern in dental implantology. Peri-implantitis is an inflammatory disease where a bacterial biofilm on the implant surface leads to inflammation and marginal bone loss. A clinical picture of this is illustrated on Figure 1. This type of chronic low-grade inflammation has been associated with several chronic diseases including type II diabetes and cardiovascular disease [3]. According to research, 45% of all the patients with dental implant presented with peri-implantitis in 9 years [4].

Traditional treatment by using systemic antibiotics usually works on the top layer of bacterial biofilm and this leads to the bacteria's development of antibiotic resistance over prolonged period of use. The mechanical cleaning is complicated by difficult access to the full surface on modern implants that are rough on microscale for optimized osseointegration. This missing surface disinfection from available treatments often results in recurrence of peri-implantitis and even failure of dental implants. In the last decade, nanostructured antimicrobial surfaces have attracted a significant attention due to their ability of killing bacteria physically through contact killing mechanism [5]. Bio-inspired sharp nanostructures can rupture the bacteria cell membrane and thereby prevent the adhesion and formation of bacterial biofilm on the material surface [6].

In this work, we report a new nanofabrication method that can fabricate nanostructures uniformly on dental implant surfaces, which is a big challenge today since most nanofabrication methods for this application only work on plane 2D surfaces. The developed method consists of a nanopatterning process to form a mask layer and a wet etching process to form the surface nanostructures [7]. The method has been developed on commercially pure Titanium (Ti) samples, which is the most commonly used material today for dental implant. Figure 2 shows the fabricated nanostructures on the Ti surface with an average size of 41 nm and height of 46 nm. To investigate the antimicrobial effect of the nanostructured surface, a biofilm formation test of *Staphylococcus aureus* was conducted on the Ti samples with nanostructured surface and plane surface as reference, respectively. Test units were stored at ambient temperature for 4 days and then the content of microorganisms in inoculum was analyzed and counted. Figure 3 shows the number of colony-forming units (CFU) of the *Staphylococcus aureus* counted on both plane and nanostructured Ti surfaces. It is seen that, by introducing surface nanostructures, the average number of *Staphylococcus aureus* biofilm that attached to the Ti surface was reduced by more than 99%.

In conclusion, we presented a nanofabrication method to form surface nanostructures on the commercially pure Ti material. The fabricated surface nanostructures exhibit an excellent antimicrobial effect with the ability of reducing *Staphylococcus aureus* biofilm formed on the Ti surface by more than 99%. It suggests that the nanostructured antimicrobial surface could be an effective method to lower the bacterial infections in dental implants. The proposed method can also be used as an universal solution for other prosthetic implants.

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Figure 1. Clinical picture of peri-implantitis after surgical access (photo courtesy of Dr. Tore Tranberg Lefolii, University of Copenhagen).

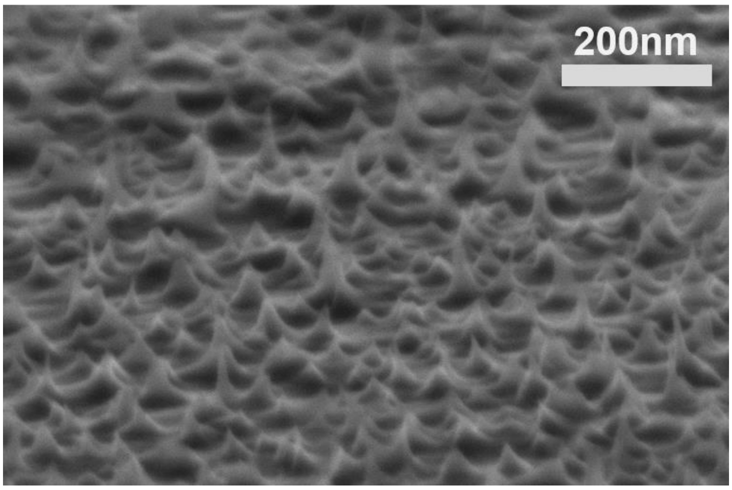

Figure 2. Scanning electron microscope (SEM) image of nanostructured antimicrobial Ti surface.

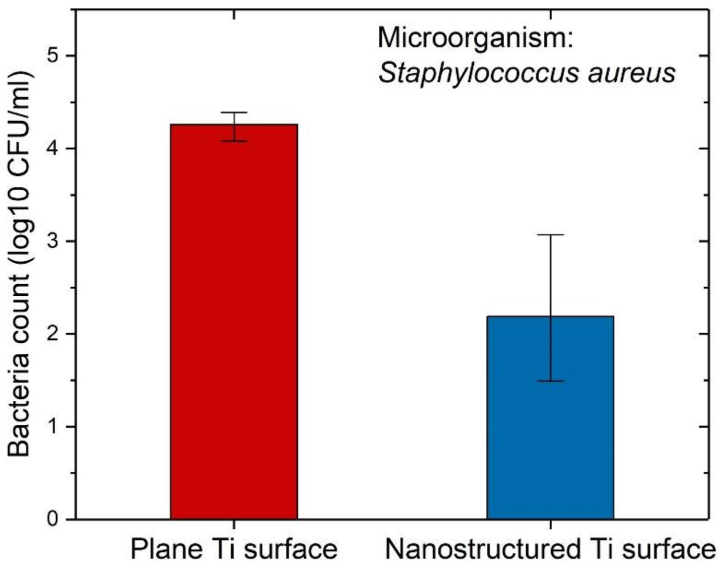

Figure 3. Colony-forming units (CFU/mL) of the *Staphylococcus aureus* on plane Ti surface and nanostructured Ti surface.