Hydrophobic Surface Functionalization via Ultrashort-Pulse Laser Texturing

Vieira, A.[1,2*], Grabon, W.A.[3], Adamiak, M.[4], de Rossi, W.[5], Batalha, G.F.[2]

[1)] SENAI São Paulo University Center (UniSENAI-SP), Brazil
[2)] São Paulo University (USP), Brazil
[3)] Rzeszów University of Technology, Poland
[4)] Silesian University of Technology Gliwice, Poland
[5)] Nuclear and Energy Research Institute (Ipen), Brazil
*Corresponding author: alexandrevieirax@gmail.com

Grade 2 Titanium alloy is applied in implantable devices, particularly in dental applications and fixation components. However, bacterial adhesion and biofilm formation remain significant challenges in ensuring long-term performance and increasing the success rate of these implants. In this context, this study aims to optimize laser processing parameters to produce nanostructured surfaces using ultrashort-pulse laser texturing. The resulting textures led to an increase in the surface contact angle from 71.8° to 121.6°, indicating enhanced hydrophobicity. These results demonstrate promising potential for surface functionalization and the mitigation of bacterial adhesion.

Keywords: Surface engineering, Ultrashort laser texturing, Hydrophobic surface, titanium alloy

1. Introduction

Grade 2 titanium alloy is a commercially pure titanium alloy extensively used in implantable medical devices, particularly in dental applications, due to its excellent corrosion resistance and favorable osseointegration behavior. Beyond dental implants, it is also employed in fixation systems and implantable components where its ductility offers mechanical and clinical advantages. Despite these benefits, the long-term success of titanium-based implants depends critically on their biological acceptance, as adverse responses may lead to implant rejection, prolonged recovery periods, and the need for additional surgical interventions.

Among the main causes of implant-related complications are bacterial adhesion and subsequent biofilm formation on implant surfaces. In recent years, surface functionalization strategies aimed at modifying surface–biological interactions have gained increasing attention as a means to mitigate these issues. In particular, the development of hydrophobic and nanostructured surfaces has shown strong potential to reduce bacterial adhesion. Within this context, ultrashort-pulse laser surface texturing has emerged as a promising and versatile technique for producing functionalized surfaces with controlled topographical features, contributing to improved implant performance [1].

2. Methodology

For surface texturing, primary consideration was given to the laser fluence and the pulse overlap rate in order to determine the ablation threshold, as described by the following equation (1):

$$F_{th}(N) = F_{th}(\infty) + [F_{th}(1) - F_{th}(\infty)]e^{-S(N-1)} \qquad (1)$$

For sample characterization, analyses were performed using white light interferometry to evaluate surface roughness and other surface parameters, as well as contact angle measurements to characterize the surface wettability properties.

3. Results

For comparison purposes, the results obtained from the textured surface (Figure 1b) were compared with those from a polished surface (Figure 1a), representative of the material surface prior to processing.

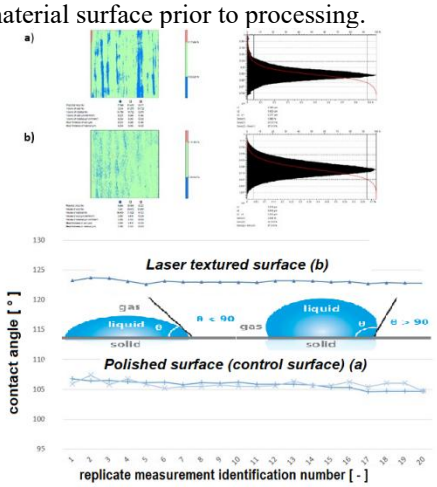

Figure 1: Contact angle measurement: Polished surface (control surface) (a) laser textured surface (b)

The laser texturing results demonstrated a promising increase in the contact angle, conferring hydrophobic properties to the surface. While the polished surface exhibited a contact angle of 71.8°, the textured surface showed a contact angle of 121.6°.

4. Conclusions

Ultrashort-pulse laser surface texturing is a promising process for imparting hydrophobic characteristics to surfaces, with the future objective of mitigating bacterial adhesion and biofilm formation on implantable devices.

5. References

[1] Uhlmann, E. et al., “Application of laser surface nanotexturing for the reduction of peri-implantitis on biomedical grade 5 Ti-6Al-4V dental abutments” Int. Soc. For Opt. & Phot., 2019, 109080A.