Advanced surface analysis of Ti-based anodized material coated with a biodegradable polymer for potential application as a drug-eluting orthopaedic implant

Katja Andrina Kravanja[1], Matjaž Finšgar[2], Željko Knez[1], Luka Suhadolnik[3], Marjan Bele[4], Uroš Maver[5], Maša Knez Marevci[1]

[1] *Laboratory for Separation Processes and Product Design, Faculty of Chemistry and Chemical Engineering, University of Maribor, Maribor, Slovenia*

[2] *Laboratory of Analytical Chemistry and Industrial Analysis, Faculty of Chemistry and Chemical Engineering, University of Maribor, Maribor, Slovenia*

[3] *Department for nanostructured materials, Institut Jožef Stefan, Ljubljana, Slovenia*

[4] *Department of Materials Chemistry, National Institute of Chemistry, Ljubljana, Slovenia*

[5] *Institute of Biomedical Sciences, Faculty of Medicine, University of Maribor, Maribor, Slovenia*

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Abstract

Biocompatibility, excellent mechanical durability, low corrosion rate, and cost-effectiveness make Ti-based materials promising for biomedical applications, especially for the fabrication of implantable orthopaedic devices [1]. However, persistent implant failures associated with poor osteointegration, infection, and inflammation push for its targeted functionalisation. Due to this, the development of bioactive coatings and surface modifications of Ti-based implants has gained increasing interest in recent years. The formation of titania nanotubes (TNTs) by anodizing the Ti surface has been shown to increase bioactivity by enhancing the adhesion of osteoblast cells to its nano-topographic surface. Furthermore, it enables the delivery of drugs incorporated into the hollow structure of TNTs to the local site after implantation in a controlled manner [2,3].

This work aimed to fabricate the drug-eluting anodized Ti surface coated with a biodegradable and biocompatible polymeric coating to achieve controlled release of the incorporated (model) drug. Proper characterisation of the as-prepared materials is crucial to ensure suitability for potential application as orthopaedic implants. The evaluation of the chemical structure, interactions, and morphology of the surface of the newly designed materials is an essential first step that may contribute to further improvements and facilitation of the biological response by adjusting the chemical composition and surface structure. For this purpose, advanced surface analysis of the anodized and polymer-coated surface was performed using tandem time-of-flight secondary ion mass spectrometry (ToF-SIMS), X-ray photoelectron spectroscopy (XPS), atomic force microscopy (AFM), and 3D profilometry. The information about the surface and in-depth distribution of the multicomponent system and its interactions was successfully obtained by 3D imaging using gas cluster ion beam (GCIB) for both systems, ToF-SIMS and XPS, allowing effective sputtering and leaving the chemical structure intact. For the latter, ToF-SIMS was particularly useful in obtaining information on crystal formation of the active ingredients within the coatings. This technique enables the determination of molecular-specific signals characteristic for coating constituents. Using angle-resolved XPS, layered structures were examined non-destructively (without sputtering). Agglomeration of the active substances was investigated in detail using AFM. In addition, AFM was also used to investigate the influence of the coating dissolution in situ. 3D profilometry allowed large scale study of the coating and determination of substrate roughness.

References

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