Electrochemical deposition of functional bioactive calcium phosphate coatings on the TiAlNb implant alloy

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Increased life expectancy and rising expectations regarding quality of life have underscored the growing significance of implant materials, with metals emerging as the predominant choice [1,2]. Titanium and its alloys, particularly prominent in dentistry and orthopaedics, owe dominance to their favourable physical, chemical, and mechanical properties. TiAlNb alloy represents good alternative to TiAlV alloy since it contains non-harmful Nb instead of cytotoxic V. Although exhibiting good biocompatibility and good corrosion resistance based on spontaneous formation of TiO_2 oxide layer on its surface [2,3], the titanium alloy is classified as bioinert material [1,4].
Hence, the calcium phosphate-based (CaP) materials are employed as coating agents on titanium-based implants due to their good osteoconductive properties based on resemblance to the human bone [5]. CaP coatings promote bone apposition and osseointegration ensuring the structural integrity and continuity of implant material with the surrounding bone [3,4]. Among various techniques that can be employed for CaP coatings production, electrochemical deposition garnered significant attention due to its distinct advantages over conventional methods [3,4,6,7]. By adjusting process parameters, such as temperature and voltage, one can precisely control the thickness, composition, and microstructure of the deposited coating. However, synthesizing CaPs with controllable crystal shape and structural characteristics remains a major challenge due to significant variations in chemical composition, crystallization kinetics, phase stability, and dissolution behaviour among different CaPs.
In this work, the CaP coatings were electrochemically deposited on the TiAlNb alloy. The corrosion behaviour of the unmodified and the CaP-coated titanium alloy was examined *in situ* in simulated physiological solution, Hanks' solution, under *in vitro* conditions of real implant applications, using electrochemical impedance spectroscopy (EIS). The electrochemical behaviour and corrosion parameters were also investigated by linear polarization measurements (the LPR method and the Tafel extrapolation method). The morphology, microstructure and chemical composition of the electrodeposited CaP coating were characterized by scanning electron microscopy, energy dispersive X-ray spectroscopy (EDS) and attenuated total reflection Fourier-transform infrared spectroscopy (ATR-FTIR). The focus of this work was to optimize the electrodeposition conditions to form the compact functional CaP coating that improves corrosion resistance of the underlying titanium alloy while contributing to enhanced biocompatibility and bioactivity. *In situ* investigations carried out under *in vitro* conditions provide useful information and further insight towards the understanding of the electrodeposition mechanism and implant surface functionalization.

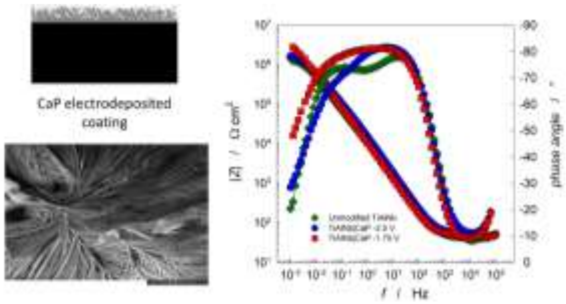

Figure 1. The SEM image of electrodeposited CaP coating presented with Bode plots of the unmodified and the CaP-coated TiAlNb alloy recorded in Hank's solution at open circuit potential.

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References:

1. M. Kaur, K. Singh, *Mater. Sci. Eng. C* **102** (2019) 844-862. https://doi:10.1016/j.msec.2019.04.064
2. N. Eliaz, *Materials* **12** (2019) 407-49. https://doi.org/10.3390/ma12030407
3. A. Gao, R. Hang, L. Bai, B. Tang, P.K Chu, *Electrochim. Acta* **271** (2018) 699-718. https://doi.org/10.1016/j.elecacta.2018.03.180
4. N. Eliaz, N. Metoki, *Materials* **10** (2017) 334. https://doi.org./10.3390/ma10040334
5. S.V. Dorozhkin, *Mater. Sci. Eng. C* **55** (2015) 272–326. https://doi.org/10.1016/j.msec.2015.05.033
6. J. Katić, S. Krivačić, Ž. Petrović, D. Mikić, M. Marciuš, *Coatings* **13** (2023) 640. https://doi.org/10.3390/coatings13030640
7. R. Drevet, J. Fauré, H. Benhayoune, *Coatings* **13** (2023) 1091. https://doi.org/10.3390/coatings13061091