Electrochemical growth of coatings on metal alloys for local delivery of therapeutic agents

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Electrochemical surface treatments

Concept

Metallic materials are widely used in the fabrication of biomedical devices, such as intravascular stents and orthopedic or dental permanent implants. They require specific biocompatibility, customized mechanical properties and excellent corrosion and wear resistance. It is also possible to functionalize these devices by carrying out surface treatments giving them special properties. Surface treatments can create coatings that act as reservoirs for sustained local release of therapeutic agents to treat or prevent a variety of diseases, such as stent restenosis, implant associated infections or for the delivery of growth factors for tissue regeneration. This is a promising emerging field of biomedical research because implant-related infections remain among the leading reasons for prosthesis failure with high economical and social associated costs. Traditional drug administration methods may distribute drugs systemically, even though in many cases they are only needed at the implant site. Localized drug release from implants can minimize side effects and enhance treatment outcomes.

Scientific approach

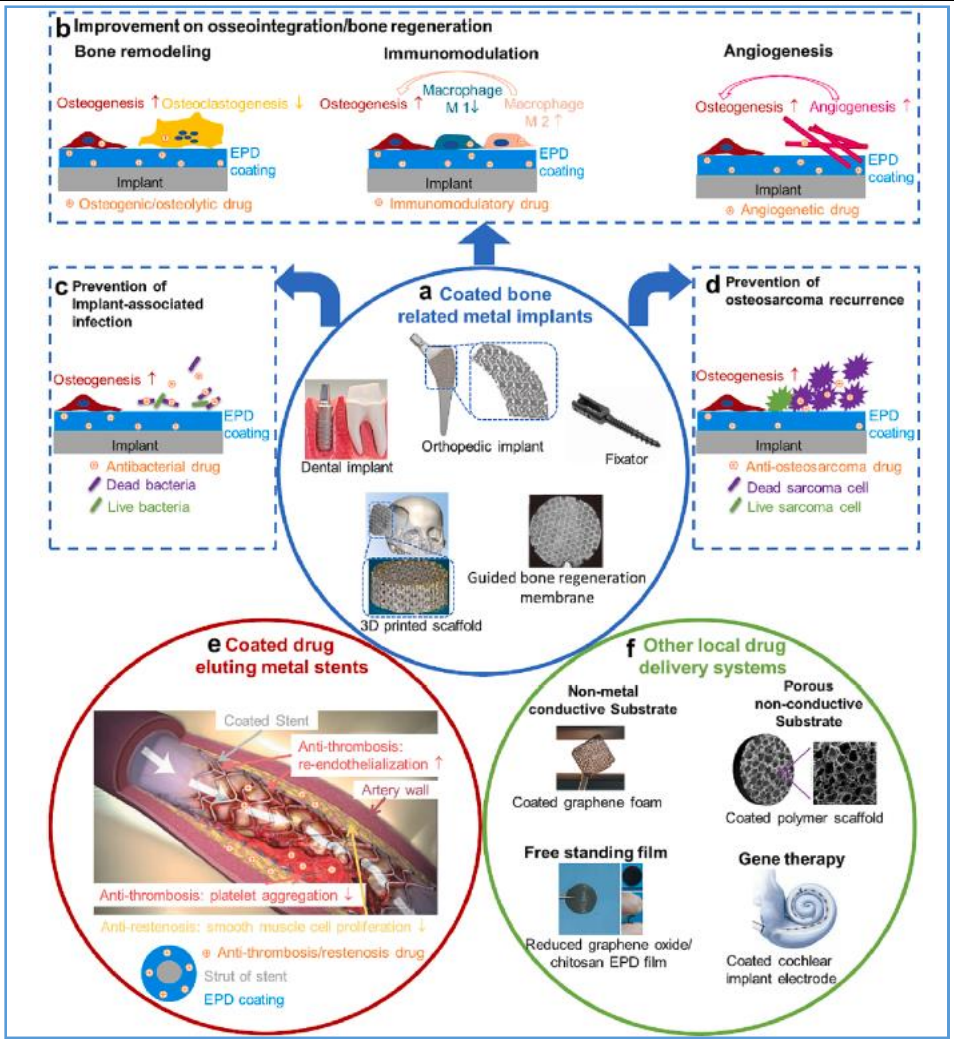
The PhD Project focuses on electrochemically growing therapeutic agent-delivering coatings on metal alloys, primarily titanium alloys. Ti4V6Al (TAV) is one of the most widely used alloys in the fabrication of permanent implants. Anodizing is an electrochemical process for metal surface modification that allows the growth of a stable oxide film on the surface of the metal of interest. This technique will be employed to create TiO_2 films on TAV, with variations in process parameters yielding different morphologies such as barrier, porous or nanostructured oxide film. Indeed, anodizing makes it possible to realize nanostructures that does not require an additional coating process and they will not delaminate from the surface, for example TiO_2 Nanotubes (TNTs). These show promise for local drug delivery due to their biocompatibility and ability to incorporate specific elements into their pores. The project involves adjusting process parameters to vary coating thickness and morphology, followed by electrochemical and biological characterizations to assess corrosion resistance and cytocompatibility, respectively. Drug release will be performed using immersion tests in fluids simulating the physiological environment.

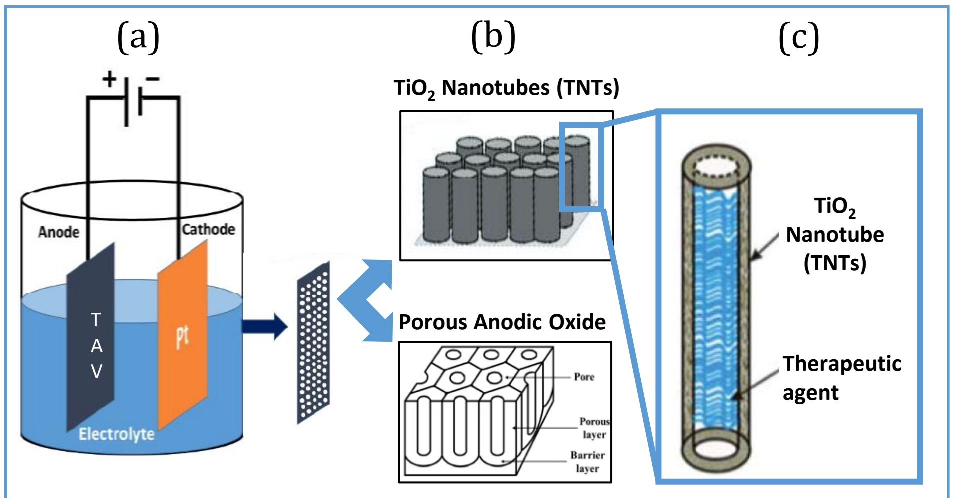
Research objectives

Tailoring the loading and release of drugs from implants is crucial for specific applications (cardiovascular, orthopedic or tissue engineering). Incorporating multiple therapeutic agents can address multiple medical issues. These studies aim to produce coated devices enhancing patients' quality of life. Analyzing and optimizing these systems is the focus of the PhD Project. Additionally, the process steps studied can be scaled up for industrial production and integrated into a process line.

Cheng et al., «Electrophoretic deposition of coatings for local delivery of therapeutic agents", Progress in Materials Science 136, 2023

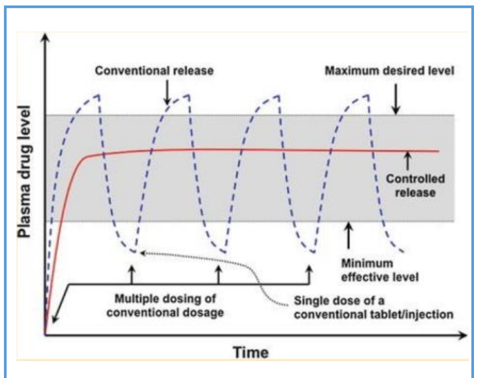
Shokuhfar et al., «Intercalation of anti-inflammatory drug molecules within TiO_2 nanotubes» RSC Advances, 2013





Schematic representation of: a) Synthesis of TiO_2 films on TAV via Anodizing, b) porous and nanostructured anodic oxide films and c) therapeutic agent loaded TNT

Industrial Anodizing line



Trend of drug concentration in tissues after intake