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Application of Reactive RF Magnetron Sputtering in customized Orthopedic Implants

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Extended Abstract

The biggest problem faced with the use of conventional metallic orthopedic implants is the low longevity (20-25 years) and the extended time for bone fixation (between 10-15 years). This is due to the low adhesion of bone cells (osteoblasts) and, consequently, low osteointegration, leading to the aseptic loss of approximately 25% of all titanium hip implants [1]. Nanomaterials are capable of simulating the dimensions of bone components, and, allow better cell adhesion, growth and differentiation, reduce fibrosis and implant encapsulation, and improve calcium deposition [2]. Furthermore, nanomaterials exhibits improved mechanical properties, biocompatibility, and antibacterial characteristics than microscale materials [2]. Because of this, researches around the world have been studying nanomaterials to improve prognostic of orthopedic implants surgeries. Additionally, the interest in customized implants obtained by additive manufacturing (AM) has increased as they give more flexibility to the implant design, also improving its implantation process and the patient recovery. Considering that AM uses microscale particles, this study aimed to develop and characterize nano-modified surfaces of customized titanium orthopedic implants by sputtering process. The samples were designed to have representative dimensions and both solid and trabeculate areas. They were obtained by additive manufacturing using Electron Beam Melting (EBM) technology, by Iconacy Orthopedic Implants Ind. e Com. de Prod. Médico Hosp. Ltda, a Brazilian company. We studied three types of film deposition: a. titanium; b. titanium carbide (TiC) and a c. gradient with the final layer entirely composed of carbon. The RF magnetron sputtering deposition [3] and characterization processes were carried out by Integrable Systems Laboratory, at the Polytechnic School at USP, department of Electronic System Engineering. Surface-modified and non-modified samples were characterized using macro and microscopic evaluation, and XRD analyzes. The implant samples with carbon (b. and c.) in film composition became yellow-dark, being more intense brown as longer as was the deposition time. Samples deposited with titanium did not change color compared to the non-modified samples. Electron microscopy revealed for all samples the characteristic surface of additive manufactured implants, which are constructed layer-by-layer. Trabeculate areas appeared to have less roughness than solid areas and samples deposited with carbon presented smoother deposit films compared to titanium only layer. The sample with gradient film (c) showed delamination-like structures that could detach from the implant after implantation. The release of metal ions or debris particles of an implant can cause osteolysis, inflammatory responses and other related limitations [2, 4]. XRD analyzed identified the phases and crystallographic orientations of the coating deposited on each sample, compared to a previous similar study [5], confirming that the deposition process was effective. Our study succeeded in developing an effective surface deposition process in customized implants by sputtering. The best results were obtained with films (a) titanium; (b) titanium carbide (TiC), being (c) gradient the less promisor in terms of implant performance and safety. Further characterization studies and biocompatibility tests need to be concluded, as well as validation protocols need to be developed and processes validated to confirm the safety of the proposed films.

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