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Radical-functionalized plasma polymer films: Multi-functional interfaces for bone implant applications

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A large number of orthopaedic surgeries fail due to poor bone integration or biofilm formation; leading into revision surgeries in extreme cases. In 2016, there were more than 400,000 knee and hip replacement surgeries undertaken in Germany alone, with the estimated price of about EUR 6000 per replacement. Application of bio-functionalized coatings on bone implantable devices is a promising approach to drive rapid bone-implant integration and to eliminate infection, dramatically reducing the need for revision surgeries. Here we report the development of highly reactive and stable, radical-functionalized plasma polymer (RFPP) films for bone implants using a combination of plasma polymerization and plasma immersion ion implantation. A custom-made plasma polymerization reactor consisting of a radio frequency (RF) electrode and a pulsed voltage source connected to the titanium substrate was utilized to deposit RFPP films from mixtures of argon, acetylene, and nitrogen gases. We provide new insights into the role of energetic ion bombardment on the growth mechanisms of plasma polymers by measuring the hydrogen content of the films using elastic recoil detection analysis. Nano-indentation and nano-scratch tests, as well as stability studies in simulated body fluid (SBF) at 37^{o}C suggested a strong correlation between the degree of energetic ion bombardment and physico-chemical stability of the coatings. The effectiveness of RFPP films to regulate osseointegration is confirmed by covalent attachment of fibronectin followed by quantifying primary osteoblast attachment, spreading, and proliferation. The bio-functionalized interfaces enhanced the interaction of primary osteoblasts, suggesting the bioactive presentation of fibronectin and the potential to improve bone cell interactions with implants treated in this manner. The RFPP films functionalized with antimicrobial peptides Mel4 and caspofungin prevented biofilm infection caused by S. aureus and C. albicans, respectively. Deposition of RFPP films via this technique holds great promise for the fabrication of modern real-world biomaterials, in particular bone implantable devices such as hip prosthesis and dental implants.

Keywords
Plasma polymerization
Bone implants