Nanostructured Antibacterial Films by Ionized Jet Deposition: An Overview

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Infection is among the main complications connected to orthopaedic and dental implants and show important cross-relations with osteointegration. To address infection, functionalization of the biointerface by nanostructured metal-based coatings is a promising approach, as it permits to tackle bacteria without pushing towards the development of resistant bacterial strains. To this aim, metals can be used alone, or incorporated in calcium phosphates, to promote osseointegration. Together with composition, the morphological characteristics of the coatings are important, to avoid cracking and obtain a tuned release, both avoiding cytotoxicity.

Here, we propose the use of silver, copper and zinc-based nanostructured coatings, obtained by Ionized Jet Deposition. Films morphological (FEG-SEM, AFM) and compositional (EDS, XRD) characteristics are studied, and correlated to their antibacterial efficacy (inhibition of planktonic growth, of bacterial adhesion to the substrate and of biofilm formation, *E. coli*, *S. aureus*, *E. faecalis*, *P. aeruginosa*). The latter are studied by a specifically developed evaluation setup, based on the Calgary Biofilm Device.

Deposition of metal-doped calcium phosphates coatings (Ag-TCP) is also shown, demonstrating the feasibility to deposit complex materials while preserving their stoichiometry. Stability and antibacterial efficacy of the coatings is demonstrated and absence of cytotoxicity (reduction of cells viability or capability to differentiate) is studied on mesenchymal stem cells (MSCs).

Finally we show that the coatings can be deposited onto heat-sensitive substrates, including electrospun patches (Poly(L-lactic acid) - PLLA, Nylon – PA, medical grade polyester polyurethane - PU), without causing damage.

Our results show that silver films are composed by metallic silver, while oxides are obtained starting from copper and zinc targets. All films have a nanostructured surface morphology, where the size, shape and dimensions of the aggregates that compose them, as well as their thickness, strongly depend on the characteristics of the deposition target. All films are non-cytotoxic

Antibacterial efficacy of the films is strain- and metal- dependent, with silver being more efficient against Gram negative strains, and copper and zinc against Gram positive ones. In addition, the different metals impact differently on the different growth mechanisms of bacteria. The thickness and surface morphology of the films, both being dependent on deposition duration are also crucial in determining bacterial response to the coatings. After proper optimization, all films show high antibacterial efficacy, in terms of inhibition of planktonic growth, bacterial adhesion and biofilm formation.

Composite films preserve the composition of the target, although crystallinity is significantly reduced. Silver doping is also preserved, although its presence is reduced compared to the target. Even in the absence of thermal treatments the stability of the films is over 14 days in simulated medium. Silver-TCP films show high antibacterial efficacy and are non-cytotoxic.

Results show that the proposed films are promising for antibacterial functionalization of orthopaedic and dental implants.