Sputtering and nanosurface modification of biomedical devices

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Abstract

The conjugation between optimal bulk performances with appropriate surface properties/characteristics in biomedical implantable devices is rarely achieved within the same material. The need occurs to modify the surface of such devices in order to obtain the suitable response from the biological environment.
One of the major concerns related with this type of approach is the stress developed in the interface bulk/coating due to the discrepancy of mechanical and chemical properties. In nature, these problems are controlled by gradually varying the material behavior through a structure, i.e, by bio-functional graded materials. Another biological approach also includes the development of hybrid organic/inorganic materials. The same strategies in tailoring biomaterials can be used.
In the last years the GNM has exploited different approaches for the modification, by r.f. magnetron sputtering, of biomedical materials just to name a few - vascular stents[1,2] and neural implants[3], By optimizing the deposition parameters allows to modify the surface topography, morphology and chemical functionality in order to achieve the desired performance. In this work it is briefly reported some of the developed research in the nanomedicine area.
In the modification of 316L stainless steel vascular stents the strategy was to chemically match the bulk and the coating material by a chemical graded thin film with a sub-micrometric thickness. The thin films were co-deposited from 316L stainless steel and poly(tetrafloroethylene) (PTFE) targets. The optimized procedure allowed to achieve a functionally graded thin film (2D-FGM) consisting of a metallic composition near the vascular stent and a polymeric material in the outmost surface. Conjugated with the gradual transition in chemical composition the thin films presented a nanocomposite structure (Figure 1). This solution allowed a very fast re endothelisation of the coated stent when compared to the uncoated one, suggesting that the problems of reestenose associated with implanted stents are reduced.
The study on the modification of surfaces with hybrid PTFE/Au thin films intended to address two distinctive but important problems. The first one related to ensuring the correct positioning of some implantable devices into the human body. The solution is to introduce in the coating, (nano)materials with high electronic density such as gold. The other problem is generic and related with all implantable devices: the rejection of the “foreign” materials by the human body. Although very complex and not fully understood this process begins with the adsorption of biological proteins that, due to the subsequent denaturation, trigger the rejection biological pathways. The use of a polymeric material is usually more favorable in preventing the loss of protein 3D conformation. The co-deposition of the two materials induced a hybrid nanocomposite structure. The developed surfaces permitted the adsorption of bovine serum albumin without protein denaturation (Figure 2).
Another line of research aims at the development of antimicrobial coatings for biomedical devices. In this area the development of thin films with hybrid organic/inorganic matrix doped with antimicrobial metals is being studied. The co-deposition of hydroxyapatite (HA) and PTFE doped with silver which, for selected deposition parameters, creating surfaces with an inhomogeneous phase distribution could be cited as an example. This feature appears to induce on the same surface the ability to, simultaneously, promote and inhibit the growth of selected bacterial strains (Figure 3).

References

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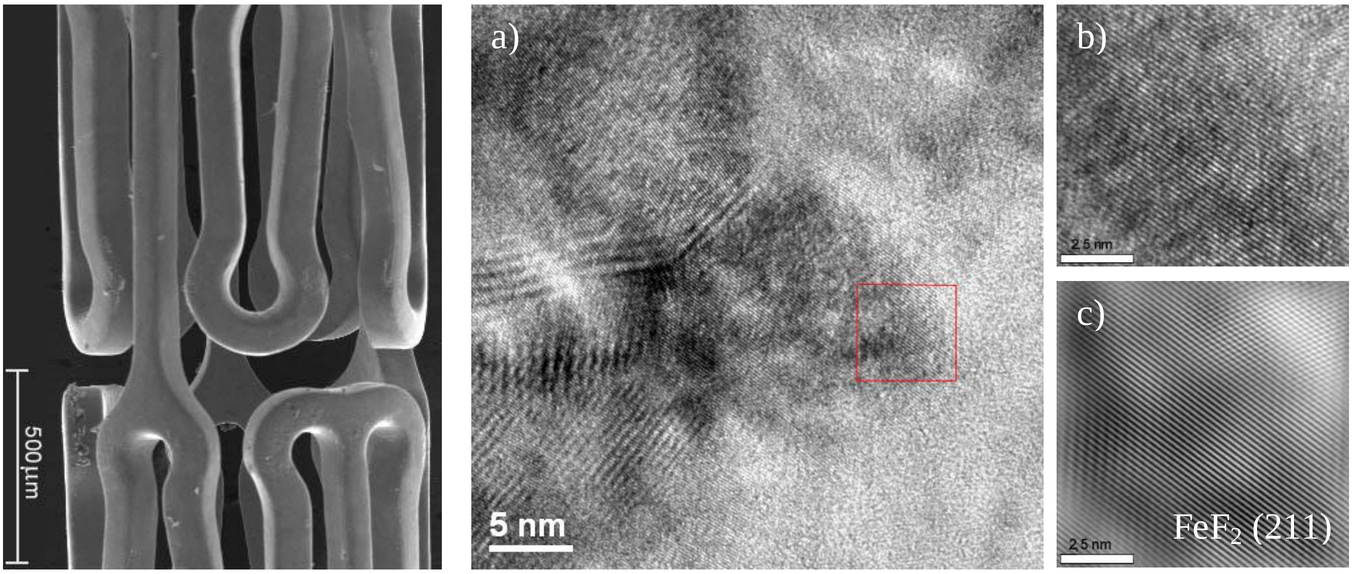

Figure 1 – Stainless steel vascular stent coated with a hybrid nanocomposite thin film of stainless steel PTFE. a) HR-TEM of a film with 11at.% of fluorine; b) HR-TEM of the selected area; c) Inverse discrete Fourier transform of (b) identifying iron fluoride nanocristallites within the amorphous matrix.

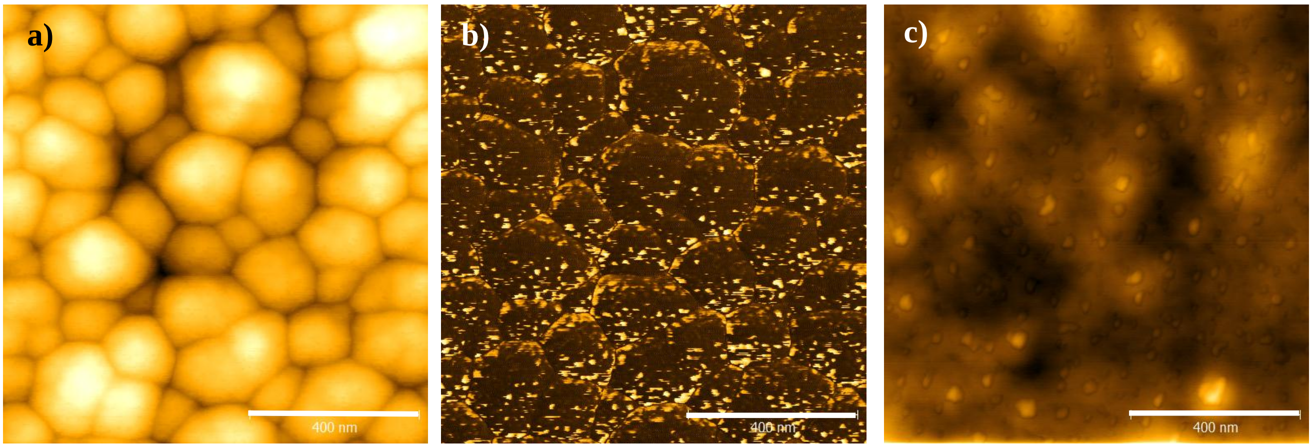

Figure 2 – AFM characterization of a PTFE/Au nanocomposite thin film. As deposited topographic (a) and phase images (b) and after BSA immobilization c) topographic image. (bar = 400nm).

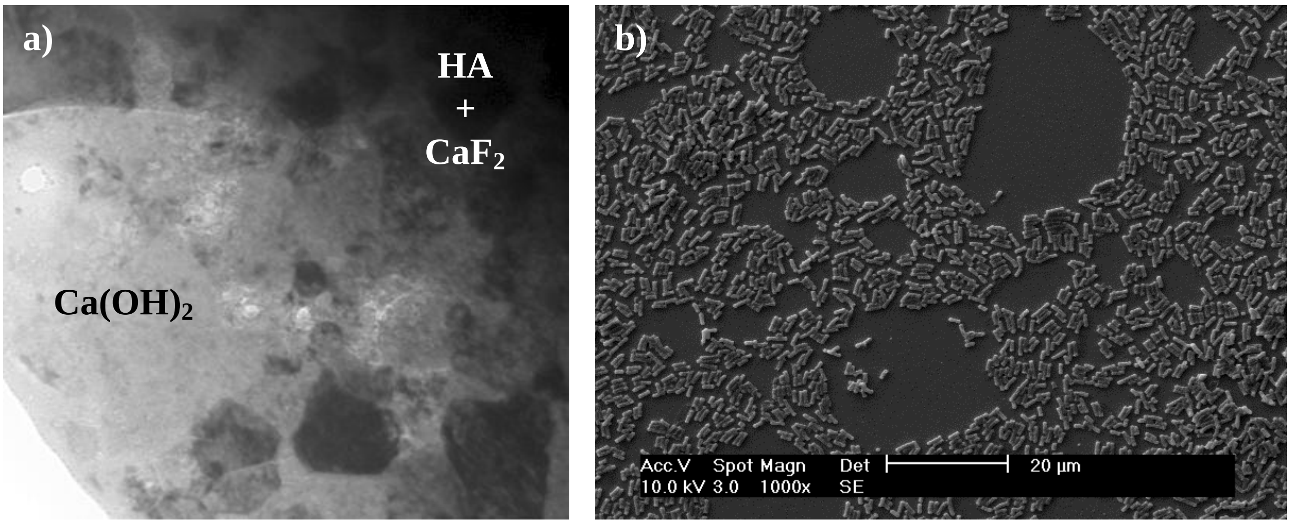

Figure 3 – a) TEM bright field image of an inhomogeneous phase distribution of a PTFE/HA/Ag hybrid thin film; b) SEM image of *Bacillus cereus* after 24h incubation on the same surface.