CONTROL OF THE BIOLOGICAL RESPONSE TO METALLIC BIOMATERIALS THROUGH APPLICATION OF THE DLC COATINGS WITH DOPANTS

Dorota Bociąga[1]*, Anna Olejnik[1], Krzysztof Jastrzębski[1], Anna Jędrzejczak[1], Lidia Świątek[1], Jacek Grabarczyk[1], Anna Sobczyk-Guzenda[2], Marta Kamińska[3], Witold Jakubowski[3], Piotr Komorowski[3], Piotr Niedzielski[1]

[1] Division of Biomedical Engineering and Functional Materials, Institute of Materials Science and Engineering, Lodz University of Technology, Poland
[2] Division of Coatings Engineering and Non-metallic Materials, Institute of Materials Science and Engineering, Lodz University of Technology, Poland
[3] Division of Biophysics, Institute of Materials Science and Engineering, Lodz University of Technology, Poland
*e-mail: dorota.bociaga@p.lodz.pl

[Engineering of Biomaterials 138 (2016) 94]

Introduction

Increasing market of implants and medical devices enhances nowadays the diversification of products that support surgical outcome more successfully [1]. Currently, two groups of materials the most of implants are made of, are metals and polymers. The commonly applied metallic implants possess relatively poor surface properties caused by the lack of total chemical stability in human body environment [2]. One of the most extensively researched solutions include the application of diamond-like carbon (DLC) coatings, which exhibit a combination of highly desirable properties in the context of biomedical applications [3]. Different properties of synthetized carbon coatings can be further improved by the incorporation of different elements into the carbon matrix [4]. As far as orthopaedic and cardiovascular implants are concerned, one of the most promising dopants is silicon (Si), which not only favours the proliferation of endothelial cells, but also acts as an antithrombogenic agent. In the case of orthopaedic implants the enhancement of the osseointegration process is highly desirable in order to assure the proper bone-healing, what may be achieved by the addition of either titanium (Ti) or silicon. In the case of implantation procedure, in general, the antibacterial properties are very important. Addition of silver can fulfil this requirement [5].

Materials and Methods

In this work the DLC coatings with Si and Ag dopants were have been manufactured on two commonly applied metallic biomaterials (AISI 316 LVM steel and Ti6Al7Nb alloy) using two methods: RF PACVD and magnetron sputtering. The surface characteristics involved the analysis of surface morphology (SEM), chemical composition and structure (XPS, FTIR) as well as surface wettability and surface free energy. The biological assessment of the deposited coatings was based on two complementary cell proliferation and viability assays (LIVE/DEAD and XTT test) performed on two different cell lines, i.e. endothelial cells line EA.hy926 and osteoblast-like cells line Saos-2. The bactericidal activity was assessed using E. coli. The obtained results allowed to check the influence of both dopants on the biological response towards the modified carbon coatings as well as to correlate the obtained results with the surface properties of the investigated coatings.

Results and Discussion

According to the literature, the increasing concentration of Si is associated with lower number of adhering platelets and decreased platelet activation level, and hence higher hoemocompatibility [6]. At the same time, Si favours the attachment of human endothelial cells and does not induce cytotoxicity [7]. Our investigations showed that dopant has to be incorporated at proper rate to induce positive reaction in biological meaning constituting a safe implant with designed properties. Too high amount of Si does not improve the hoemocompatibility and depending on the methods and substrate, the rate of Si as well as Ag element has to be individually adjusted.

Conclusions

The obtained results demonstrated that the incorporation of Ag and Si dopants (at proper ratio) allows to obtain coatings of good biocompatibility and high antibacterial properties, what makes them a good materials for medical application.

Acknowledgments

This research has been supported by the National Centre for Research and Development under the grant no. LIDER/040/707/L-4/12/NCBR/2013 entitled „MOBIOMED: Modified BIOmaterials – MEDicine future" and grant no. M-ERA.NET/2012/02/2014 entitled "CarLa – Ag/Si doped carbon layer for bio-medical application".

References

[1] Analysis of the Global Orthopedic Implant Market. Fost & Sullivan (2014).
[2] Y. Okazaki, E. Gotoh, T. Manabe, K. Kobayashi, Comparison of metal concentrations in rat tibia tissues with various metallic implants, Biomaterials 25(28), 5913-5920 (2004).
[3] R. Hauert, K. Thorwarth, G. Thorwarth, An overview on diamond-like carbon coatings in medical applications, Surface and Coatings Technology 233, 119–130 (2013).
[4] R. Hauert, A review of modified DLC coatings for biological applications, Diamond and Related Materials 12, 583–589 (2003).
4) S.E. Ong, S. Zhang, H. Du, H.C. Too, K.N. Aung, Influence of silicon concentration on the haemocompatibility of amorphous carbon, Biomaterials 28, 4033–4038 (2007).
[5] D. Bociąga, W. Jakubowski, P. Komorowski, A. Sobczyk-Guzenda, A. Jędrzejczak, D. Batory, A. Olejnik Surface characterization and biological evaluation of silver-incorporated DLC coatings fabricated by hybrid RF PACVD/MS method, Mater. Sci. Eng. C 63 462-474 (2016).
[6] S.E. Ong, S. Zhang, H. Du, H.C. Too, K.N. Aung, Influence of silicon concentration on the haemocompatibility of amorphous carbon, Biomaterials 28, 4033–4038 (2007).
[7] A.A. Ogwu, T.I. Okpalugo, N. Ali, P.D. Maguire, J.A. McLaughlin, Endothelial cell growth on silicon modified hydrogenated amorphous carbon thin films, Journal of Biomedical Materials Research Part B: Applied Biomaterials 85(1), 105-113 (2008).