DLC COATING DOPED BY SPECIFIED ELEMENTS AS A BIOMATERIAL DESIGNED FOR INDIVIDUAL PATIENT NEEDS

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Abstract

Currently, there are more and more new materials (nanomaterials) proposed for biological and medical applications. They are, among other things, the effect of surface modification. One of the most frequently used techniques, fairly widespread, is plasmo-chemical method of diamond-like carbon (DLC) coating fabrication. There is many alterations of them, nevertheless all are characterized by short duration of the process and its economics. The final result does not require additional finishing treatments and the required coating properties can be controlled and obtained by selecting appropriate process parameters. Good mechanical and tribological properties, high corrosion resistance and its tolerance by biological systems have been documented in the literature. However, given the very wide range of applications of biomaterials found over time that the properties of carbon coatings are not always sufficient. The research conducting by scientific centres around the world have shown, however, that surface properties can be controlled by introducing specified elements into the DLC layer. Each of these added elements causes some properties change. Taking into consideration that we are dealing with biomaterials – the materials which are used in very harsh and demanding environment of a living organism, which also have a strong intra-individual variability, the solution in the form of material designed adequately to the needs of the individual patient is even more attractive and desirable. The DLC coatings doped by silver fulfilling constitute an innovative materials for biomedical application and are the subject of our investigations.

Keywords: *carbon coating, doped DLC, biomaterial, biocompatibility, implant.*

Introduction

Every year, around the world about 100,000 artificial heart valves, 200,000 pacemakers and 1 million orthopedic implants are implanted. In 2010 only in England and Wales 166,000 hip and knee replacement surgeries were conducted showing the increase in comparison to 114,497 in 2009 and 109,825 in 2008 [1]. This phenomenon is due to the use of biomaterials social demand increase from 8% to 15%. The growth factors are: aging population, increased public awareness, shorter biomaterial approval process to the market and increase of the application area. Also the fact that people, from the very beginning of their life, have lack of physical activities, for many hours a day stay in sitting position and have very bad nutritional habits.

Many hours sitting position combined with a poor diet and a strong stress factors lead to the formation of cardiovascular diseases, dysfunction of the skeletal, muscular and nervous systems. As a result of that there is the still growing demand for biomedical engineering and biotechnology products, which are designed to fight the above mentioned side effects. Also, it is necessary to remember that specific personal conditions (e.g. allergies, congenital dysfunction, etc.) or to the needs generated by aesthetic medicine (e.g. implants manufactured for plastic surgery) also affect the needs, requirements and biomaterials market demands.

The achievements of scientists in the production of synthetic biomaterials and the development of surgical techniques in the middle of the last century, are a response to the need to implant while achievements in this field broadened the possibilities of using biomaterials as implants and medical instruments. That was manifested in explosive development of biomedical engineering and medical devices. It is estimated that the healthcare market in this area is currently worth more than $ 300 billion and is expected to grow by 20% per year [2]. According to the European Market for Orthopedic Trauma Devices the value of the European market of external and internal fixation of bone fractures by 2016 will reach nearly 600 million euros [3].

However, not all implants are "accepted" by the recipient. A dozen or so percent are rejected by the body. The reasons for this are various: bacterial infections, allergies, metalosis and others. Taking into account the good of the patient and the economic performance of global health, organizations and research centres had set very high criteria of biomaterials biocompatibility. In order to meet these requirements, scientists from all over the world are trying to improve their physico-chemical, mechanical and biotolerance, the effect of which is to minimize the risk of postoperative complications and the need for reoperation.

Materials and methods

In principle, it is known that biomaterials come into direct contact with the biological environment. They must therefore have adequate biocompatibility so as not to interfere with the physiological functions of the human body, which is very sensitive and hard on the implant forming foreign body. In addition, as for example biomaterials for hard tissue regeneration, they should not only be biologically inert to the surrounding cells, tissues and fluids of the body, but also have the appropriate mechanical properties. Items being implanted into the human body cannot release toxic and carcinogenic elements. Since the surface of the biomaterial is in direct contact with the biological environment, so that the surface properties largely determine the possibility of their use in medicine. For this reason, in most cases, modification/functionalization of the surface condition is considered as a sine qua non of good biocompatibility. One of the most effective methods to improve the surface properties is the surface layer onto the biomaterial constituting bioinert material, resistant to corrosion, with satisfactory biocompatibility.

Carbon coatings were produced using a hybrid RF PACVD/MS method and silver ions were incorporated into carbon matrix. The processes consist of followed stages: synthesis of nanocomposite carbon (CVD) doped titanium coatings (PVD) [4] and next stage carbon (CVD) and silver deposition (PVD) or Ag ion implantation into carbon coating.

The aim of this study was the evaluation of influence of silver onto the surface morphology and biological properties of nanocomposite DLC coatings. For this purpose, samples with DLC doped by Ag ions were tested in live/dead test using two cell strains: human endothelial cells (Ea.hy 926) and osteoblasts-like cells (Saos-2). For testing bactericidal activity of the coatings, an exponential growth phase of E. coli strain DH5 α was used as a model microorganism. In order to evaluate the surface condition and estimate its physicochemical properties in connection with biological results, the structure and morphology were investigated using scanning electron microscopy (SEM), surface characteristics were determined using atomic force microscopy (AFM) and chemical composition of coatings were tested using X-Ray photoelectron spectroscopy (XPS).

Results and discussions

The results assigned the carbon layers doped with silver as a material showing the antibacterial properties. Simultaneously, the material having come into contact with live cells of higher organisms requires high biocompatibility, i.e. insignificant for both cytotoxicity and possibly low-cell responses observed by changes in metabolism which result from contact with the surface.

Conclusions

DLC coatings being manufactured by the RF/MS RF-PACVD method modified by silver ions implantation enables to obtain biomaterial which limits the growth of bacteria and at the same time has a limited impact to the human cells.

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