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Research Article

Artificial Iris Surface Modification by Means of Carbon Film Deposition for Providing the Eye Diaphragm Loss Compensation

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Abstract

New medical products, materials and surgical procedures keep improving current health-care practices. Many of these innovations involve polymeric devices that must meet certain clinical and costs requirements. Chief among these pressures is the need for biocompatibility between the physiological environment and synthetic biomaterial surface. Carbon Film (CF) such as diamond-like, carbyne, carbyne-containing, carbon nanotubes; deposition for obtaining the materials with nanostructured surface (NSS) can improve synthetic material biocompatibility and biofunctionality.

The aim of our work was artificial iris creation and subsequent sufficient prosthetic replacement of a partial or complete loss of the natural iris diaphragm in eyes. For implantation artificial irises manufactured from polyethyleneterephtalate (PET), polytetrafluorethylene (PTFE) and polyvinilidenefluoride (PVDF) were used with their surface modification by CF deposition. Modification was carried out using CF deposition from directed ion-plasma flows of hydrocarbon vapors or by magnetron deposition.

Implanted iris prosthesis showed in all cases a stabile position. Iris prostheses which surface was modified by means of CF deposition after their implantations permitted the compensation of the native iris absence. NSS of artificial iris excluded fibrous tissue proliferation. Experimental eyes achieved the desired anatomic result.

Implantations of prosthetic iris devices manufactured from PET, PTFE, PVDF and covered by CF deposition showed the required results for eye diaphragm loss compensation. One of most convenient aspect of CF deposition technology is the potential for simultaneous surface modification and sterilization. Obligatory properties of artificial iris surface provided with CF deposition: the absence of toxicity, biocompatibility, and dispersed surface, certain adhesive and repelling for cells and the properties of chemical compounds can give a possibility of a successful application for this artificial substitute.

Keywords: Carbon Film (CF); Nanostructured Surface (NSS); Polytetrafluorethylene (PTFE)

Introduction

The medical needs for tissue and organ substitutes result from trauma, age-related diseases, degenerative conditions and end-stage organ failure [1]. In some suitable cases, organ or tissue loss could be treated by the transplantation of donor materials. But transplantation is severely limited by critical organ donor shortages and by difficulties in overcoming immune responses to transplants. In standard organ transplantation, a mismatch of tissue types necessitates lifelong immunosuppression, with its attendant problems of graft rejection and drug therapy costs. It is known that some donor organs and tissues could not be transplanted from one individual to another, such as the iris of the eye. A true solution to this massive problem can be found through perfect artificial substitute development [2]. In recent years a new field of science for obtaining different biomaterials has emerged as a powerful tool for the development of a novel set of tissue replacement parts and technologies. The use of synthetic materials in biomedical applications has increased dramatically during the past few decades [3-11]. Although most synthetic biomaterials have the physical –chemical properties that meet or even exceed those of natural tissue, they often result in a number of different physiological reactions. Among methodologies that have been considered and developed to alter the interactions of biomaterials with their biological environment, surface modification by means of CF deposition is discussed in the present paper.

The main features of materials and substances in the nanoscale range are defined not only by the reduction in structural element dimensions but also by the appearance of quantum dimensional effects, the wave nature of transient processes and the dominating role of interfaces. By changing the dimensions and the shape of nanostructures, novel functional characteristics of materials which sharply differ from the properties of bulk materials could be obtained. The choice of PET, PTFE and PVDF enables to explore a wide application of these polymers in biology and medicine, and also the possibility of providing a large range of new properties after modifying the surfaces of these polymers. The results of a study of prosthetic iris devices manufactured from NSS PET, PTFE, and PVDF by means of CF deposition, artificial irises characteristics, as well as possibilities for their implantation are presented in this work.

Materials and Methods

NSS on substituted polymers have been formed by treatment of their surface by ions of chemically active and noble gases and their mixtures (CF_4, Ar, O_2). Modification was carried out using two methods: by a deposition of CF_4 from directed ion-plasma flows of hydrocarbon vapors with 5-120 nm thickness and by magnetron deposition of highly dispersed films.

An atomic force microscope "FemtoScan" with a maximum scan square 10x10 μm has been used for the study of the surface structure. For every sample surface, photographs on different points have been obtained.

Gram-positive Staphylococcus aureus ATCC 29213 and Gram-negative Pseudomonas aeruginosa ATCC 27853 have been used for the antimicrobial activity study. For this purpose 3-4 colonies of microorganisms cultured in 18-20 hours have been suspended in 3 ml of saline solution. The suspension had a turbidity standard of 0, 5 according to the McFarland scale ($1,5 \cdot 10^8$ cfu/ml). The base suspension was then diluted in saline solution serum dilutions until the concentration was 15 cfu/ml.

NSS polymers foils were cut into fragments of size 15x15 μm. The fragment of substrate was put into a tube with liquid nutrition medium for control of the sterility of the coatings. Muller-Hinton Bovril was used as a nutrition media. From every tube with different concentration 25 μl of suspension was extracted using a pipette and were deposited on separate fragments of the polymer substrate with NSS for control of the growth of the culture.

Such infected fragments were incubated in wet media with a thermostat at 37ºC for 2 hours. After incubation, all fragments were put into tubes with 4 ml of nutrition media again incubated in the thermostat at 37ºC for 48 hours. Antibacterial activity was estimated by the appearance of visible growth in tubes with nutrition media after 48 hours.

After positive results had been obtained from investigations of CF treated PET, PTFE, PVDF toxicity (the investigation results are described in details in [15], antimicrobial activity that polymers were chosen as initial materials for artificial irises manufacturing.

Artificial iris substitutes were designed from NSS PET, PTFE, PVDF foils (dispersed polymer surface treated by means of α-C:H (100 nm) deposition). The thickness of obtained iris prosthesis was 0,15-0,25 mm, its diameter varied between 11.0 and 12.0 mm, and artificial iris diaphragm diameter of 3,5-4,5 mm.

The swine model was used for experimental investigations. Iris prostheses were implanted into the anterior chamber of experimental animals' eyes.

Results

Study of antimicrobial activity

In all the experiments, as well as the control samples for growth of cultures, control of sterility of samples was also provided. Experimental results of antimicrobial activity study are presented in Table (1). In tubes with polymer samples without CF coatings growth of microorganisms in all the dilutions was observed, which demonstrated high turbidity of the media. The absence of a CF antimicrobial effect in relation to Pseudomonas aerugenosa in some samples may be explained by the fact that this microorganism is more resistant to the influence of different aggressive factors compared with Staphylococcus aureus. Of greater interest are results demonstrating the CF coatings antimicrobial activity to Pseudomonas aerugenosa in samples 11-16. Sample 15 has suppressed the growth even at concentration of microorganisms of 10^4 cfu/ml. Samples 14 and 15 which have suppressed the growth of both types of microorganisms are of most interest.

Analysis of Table (1) has shown that maximum CF antibacterial activity was observed for samples with the maximum relief (ratio of real surface to geometrical one is about ~ 100). A comparison between the results from the study of surface charge and careful analysis of Table (1) data show that the interaction between NSS and microorganisms may depend upon two mechanisms.

One of them is connected with an electrostatic interaction and a sample of this type is shown in Figure 1 where the real surface was increased by a factor 5-8 and the charge was 1-5 μC/m^2. The second mechanism is connected with the dispersion parameters of NSS, a sample of this type is shown in Figure 2 where the value of the real surface was increased by factor about ~100.

№	Polymer/ deposition Conditions	Indicator m/o	Innoculation dose (cfu/ml)				
			10^5	10^4	10^3	10^2	10
1	PTFE: 1. treated CF_4	*Ps. aerug.*	+	+	+	+	±
	2. α-C:H (50 nm)	*S. aureus*	+	+	±	–	–
2	PTFE, smooth	*Ps. aerug.*	+	+	+	+	+
	1. α-C:H (50 nm)	*S. aureus*	+	+	+	+	+
	PTFE: 1. treated CF_4	*Ps. aerug.*	+	+	+	±	±
3	2. α-C:H (100 nm)	*S. aureus*	+	+	–	–	–
4	PTFE, smooth	*Ps. aerug.*	+	+	+	+	+
	1.α-C:H (100 nm)	*S. aureus*	+	+	+	–	–
5	PET: 1. treated CF_4	*Ps. aerug.*	+	+	+	+	+
	2. α-C:H (50 nm)	*S. aureus*	+	+	+	+	+
6	PET, smooth	*Ps. aerug.*	+	+	+	+	+
	1. α-C:H (50 nm)	*S. aureus*	+	+	+	+	+
7	PET: 1.treated CF_4	*Ps. aerug.*	+	+	+	+	+
	2. α-C:H (100 nm)	*S. aureus*	+	+	+	–	–
8	PET, smooth	*Ps. aerug.*	+	+	+	+	+
	1.α-C:H (100 nm)	*S. aureus*	+	+	+	+	–
9	PVDF: 1. treated CF_4	*Ps. aerug.*	+	+	+	+	±
	2. α-C:H (50 nm)	*S. aureus*	+	–	–	–	–
10	PVDF, smooth	*Ps. aerug.*	+	+	+	+	+
	1. α-C:H (50 nm)	*S. aureus*	+	–	–	–	–
11	PVDF: 1.treated CF_4	*Ps. aerug.*	+	+	+	–	–
	2. α-C:H (100 nm)	*S. aureus*	+	–	–	–	–
12	PVDF, smooth	*Ps. aerug.*	+	+	±	–	–
	1. α-C:H (100 nm)	*S. aureus*	+	–	–	–	–
13	PTFE(relief): 1. treated CF_4 2. α-C:H (100 nm)	*Ps. aerug.*	+	+	±	–	–

14	PTFE(relief), 1. α-C:H (100 nm)	Ps. aerug	+	+	–	–	–
15	PVDF(relief): 1. treated CF_4 2. α-C:H (100 nm)	*Ps. aerug.*	+	–	–	–	–
16	PVDF(relief), 1. α-C:H (100 nm)	*Ps. aerug.*	+	±	–	–	–

Table 1: Antimicrobial properties of samples.

Investigations on experimental animals

Insertions of iris prostheses were performed in the eyes of 6 swine: right eye – experimental, left eye- control, at 2 artificial iris of every polymer variety. The mean follow-up time for the experimental animals was 3-5 months. The prosthesis showed in all cases a stable position. All the eyes of experimental animals achieved the desired anatomic result. The quality of the graft by clinical examination, using slit lamp microscopy was evaluated as positive, without any complications. NSS of artificial iris excluded fibrous tissue proliferation.

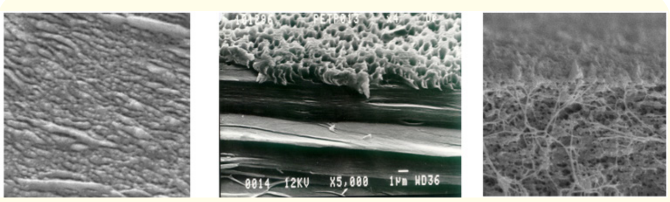

Figure 1: PTFE after treatment (etching).

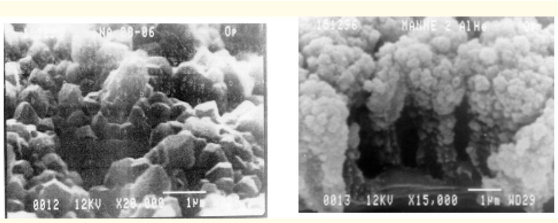

Figure 2: Microphotograph of super porous NSS.

Discussion and Conclusions

Materials with nanostructured surface are a separate class synthetic nanostructured materials. NSS is very desirable on the surface of implant, because artificial substitutes that come in contact with humeral liquids require special surface treatments to enhance biocompatibility [12-14]. The experimental study carried out on polymers with NSS formed by ion-plasma methods have shown that the degree of dispersion of the surface and the methods of its modification defines its surface characteristics and effectiveness, in particular, antimicrobial activity [15,16].

NSS surface modification by means of CF deposition using ion-plasma processes has been developed to attain specific surface properties [15]. The unique surface modification that can be achieved by using the plasma film deposition process results from the effects of the photons and active species in the plasma; these react with surfaces in certain depths without changing the bulk properties of the substrate material. Processing parameters, such as gas types, treatment power, treatment time and operating pressure, can be varied by the user and system parameters. Ion-plasma deposition process can change surface energies. Certain film deposition can modify almost any kind of substrate geometry. The most important feature is the ability of the CF treated surface to function, which chemical surface treatment cannot offer.

CF treated surface charge characteristics can assist the adhesion features or impart repulsion for chemical compounds, proteins, cells from interface through created active functional groups. Surface ammonia plasma treatment, for example, allows the enabling of covalent immobilization of cell-binding peptides derived from the extra cellular matrix proteins: fibrinogen, fibronectin, laminin, and the grafted peptides can provide an adequate matrix for the following cell migration.

Obligatory properties provided with CF deposition: the absence of toxicity, biocompatibility, and dispersed surface can give the possibility for the creation of artificial substitutes and their successful application. That is why artificial iris with NSS implantation could provide eye diaphragm compensation anatomically and avoids fibrous tissue proliferation developing, which subsequently causes of eye hydro-, hemodynamic disorders leading to severe complications, as glaucoma, uveitis till eye ball atrophy.

This is the first graphic example in eye surgery when the artificial iris manufactured from NSS polymer has been successfully applied.

The obtained results point the way to novel approaches in the creation of biologically active systems by means of NSS formation which could be a biological solution to tissue damage, loss or end stage organ failure compensation.

Bibliography

1. Langer R and Vacanti JP. "Tissue engineering". *Journal of Science* 260 (1933): 920-925.
2. Mohammad A Heidaran. "Tissue Engineering; Review article". *Iranian Biomed Journal* 4 (2000): 1-5.
3. Sundmacher R., *et al*. "Black-diaphragm intraocular lens for correction of aniridia". *Journal of Ophthalmic Surgery* 25 (1994): 180-185.
4. Reinhard T., *et al*. "Irisblenden-IOL bei traumtischer aniridie". *Klin Monatsbl Augenheilkd* 205 (1994): 196-200.
5. Sundmacher R., *et al*. "Black diaphragm intraocular lens in congenital aniridia". *German Journal of Ophthalmology* 3 (1994): 197-201.
6. Thompson CG., *et al*. "Implantation of a black diaphragm intraocular lens for traumatic aniridia". *Journal of Cataract and Refractive Surgery* 25 (1999): 808-813.
7. Tanzer DJ and Smith RE. "Black iris-diaphragm intraocular lens for aniridia and aphakia". *Journal of Cataract and Refractive Surgery* 25 (1999): 1548-1551.
8. Osher RH and Burk SE. "Cataract surgery combined with implantation of an artificial iris". *Journal of Cataract and Refractive Surgery* 25 (1999): 1540-1547.
9. Reinhard T., *et al*. "Black diaphragm aniridia intraocular lens for congenital aniridia: long-term follow-up". *Journal of Cataract and Refractive Surgery* 26 (2000): 375-381.
10. Burk SE., *et al*. "Prosthetic iris implantation for congenital, traumatic, or functional iris deficiencies". *Journal of Cataract and Refractive Surgery* 27 (2001): 1732-1740.
11. Mavrikakis I and Hickman Casey JM. "Phacoemulsification and endocapsular implantation of an artificial iris intraocular lens in traumatic cataract and aniridia". *Journal of Cataract and Refractive Surgery* 28 (2002): 1088-1091.
12. IH Loh and DM Hudson. "Polymerization Process", U.S. Patent, no. 5 (1995): 447,799.
13. MS Sheu., *et al*. "Biomaterials Surface Modification Using Plasma Gas Discharge Processes", in Encyclopedic Handbook of Biomaterials and Bioengineering, Part A. Materials, edited by DL Wise, D.J.Trantolo, D.E. Altobelli, M.J. Yaszemski, J.D.Gresser and E.R. Schwartz, Marcer Dekker, New York 1 (1995): 865-894.
14. BD Ratner., *et al*. "Plasma Deposition and Treatment for Biomedical Applications," in Plasma Deposition, Treatment and Etching of Polymers, edited by R. d'Agostino, Academic Press, San Diego, CA, 463-516; (1990).
15. VM Elinson., *et al*. "Barrier properties of carbon films deposited on polymer-based devices in aggressive environments". *Diamond and Related Materials* 8 (1999): 2103-2109.
16. PT Jacobs and SM Lin. "Hydrogen Peroxide Plasma Sterilization System". U.S. Patent, 4,643,876 and 4,756,882 (1987).