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Surface construction and biocompatibility of polymeric used for cardiovascular medical device[○]

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Abstract

BACKGROUND: Biomaterials for the treatment of cardiovascular diseases must have anti-thrombotic, anti-biodegradability and anti-infective ability in the blood-contact condition.

OBJECTIVE: To investigate the biocompatibility, blood compatibility and cytocompatibility of new implantable (interfered) polymer material (surface) used in cardiovascular tissue engineering.

METHODS: The PubMed database and Wanfang database were retrieved for the related articles from 1967 to 2012 with the key words of "biocompatibility, blood compatibility, biomedical materials, biomedical polymer materials".

RESULTS AND CONCLUSION: The graft copolymer surface and a block copolymer surfactant that can be used as biological materials were in-depth analyzed through analyzing the design requirements of type, application, cardiovascular medical devices and implantable soft tissue substitutes of polymeric biomaterials used for cardiovascular medicine. The results showed that the difference between the surface and nomenclature will be reflected on many molecular layers that extended from the surface to the nomenclature, while the two main factors of surface energy and molecular motion determined the nomenclature/surface behavior including the nomenclature/surface difference and surface phase separation. If the understanding of the nomenclature/surface consisting difference should be taking into consideration, the other determinant should be added too, that was the crystallization behavior of each component. If the one of the components contained in the graft copolymer surface and a block copolymer surfactant had higher crystallinity, the other components will be squeezed out; crystallization could also hindered the motion and diffusion of molecules, and eventually, the incompatibility degree of two components of copolymers will affect the phase separation tendency in the nomenclature and surface layers.

Key Words: biomaterials; biomaterial review; polymeric biomaterials; biomedical polymer material; biocompatibility; blood compatibility; cell compatibility; graft copolymer surface; block copolymer surfactant

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INTRODUCTION

The biomaterials mainly refer to the base materials used in particularly the temporary or permanently implanted medical device.

The definition is: the natural or synthetic substances (non-drug) and complexes used as the overall system or part in treating, improving or replacing the human tissues, organs or body function in any time and with any manner^[1]. Among them, the main purpose of the blood contact materials used for cardiovascular medicine includes the application in the *in vitro* devices of blood transfusion and blood collection, vascular

interventional devices and permanently implanted device. Permanently implantable device, as a soft tissue substitute material, is mainly used in the improvement and regeneration of human soft tissue.

In practical applications, biomaterials include synthetic polymeric materials, metal materials, ceramic materials and natural macromolecular materials. Preparation and processing of biomaterials should primarily against its characteristics that closely contact with the bio-proteins, cells, tissues, organs or organ systems^[1-5]. The biomaterials can be long-term implanted into the human body (such as artificial heart

valves) or temporary intervention (such as intravenous catheters), the specific selection criteria depends on the specific application conditions. But all the biomaterials used in medical devices should meet the requirement that cannot cause any harmful effects on the living body, and the harmful effects include localized effects and systemic effects. In conclusion, the biomaterials must be non-toxic, non-carcinogenic, non-antigenic and non-mutagenic^[6]. The biomaterials used for cardiovascular medicine should have the anti-thrombus under blood contact conditions; in addition, the requirements that against biodegradability and anti-infections should be analyzed according to the specific conditions, such as the requirements of materials used for permanently implantable heart valves are significantly higher than those of the catheter materials used for intervention therapy. For the patients need to be treated with cardiopulmonary bypass treatment, the long-term and large-area contact between the blood and the medical devices may activates the physiological and compensatory immune system, thus resulting allergic reactions. Therefore, the requirements of corresponding device material are higher^[7-17].

The purpose of this study is to develop new implantable (interfered) polymer material (surface) used in cardiovascular tissue engineering, design and compound "ABA" type conjugate poly(ethylene oxide) monomethylene ether, and finally obtain series "CABAC" type block conjugate through fixing functional groups with specific functions on both sides by terminal hydroxyl group-reactivity, and then identify that this kind of block conjugate is non-toxic and have good *in vivo* histocompatibility. After determination of the safety of *in vivo* administration, the polyurethane materials were treated with surface modification by noumenon bending and surface coating method with the surface modifier of block conjugate. Then, the modified surface could be used for serum protein adsorption experiments, *in vitro* blood compatibility experiments and human endothelial cell compatibility test to detect the biocompatibility and cell compatibility of various corresponding modified surfaces.

DATA AND METHODS

Sources

The PubMed database and Wanfang database were retrieved for related articles from 1967 to 2012. The key words were "biocompatibility, blood compatibility, biomedical materials, biomedical polymer materials" in Chinese and English. A total of 191 articles were screened out.

Inclusion and exclusion criteria

Inclusion criteria

The articles related with the blood compatibility study of biomedical polymer materials: research of polymeric biomaterials and surface used for cardiovascular medicine were included. For the articles in the same field, those published recently or in the authorized journals were selected.

Exclusion criteria

The repetitive articles were eliminated.

Data extraction

A total of 191 articles were screened out, included 21 Chinese articles and 170 English articles. Among them, 102 articles that poorly correlated with the research purpose and with old and repetitive content were eliminated, and finally 89 articles were included for review.

Quality evaluation

The 87 articles that met the inclusion criteria were further analyzed. Literatures [1–35] discussed the type and application of polymeric biomaterials used for cardiovascular medicine, literatures [36–42] investigated the design requirements of cardiovascular medical devices and implantable soft tissue substitutes, and literatures [43–87] explored the graft copolymer surface and a block copolymer surface that could be used as biomaterials.

RESULTS

Type and application of polymeric biomaterials used for cardiovascular medicine

The type and application of polymeric biomaterials used for cardiovascular medicine showed ^[18-35].

Design requirements (parameters) of cardiovascular medical devices and implantable soft tissue substitutes

The design requirements based on the material angles should be considered from nine aspects (the first four aspects were mechanical properties) ^[36-42].

Strength

The materials used for large arteries, heart valves and vascular balloon molding required high strength, such as the engineering plastics and synthetic compounds; materials of intervention catheters, surgical suture and intravascular stent should have moderate intensity, mainly included plastics, elastomers and various bions-derived materials; non-load bearing and weak shear surface coating materials required lower strength,

the materials were mainly some biological macromolecules and hydrogels. In addition, the substrates of long-term interventional catheters and artificial blood vessels should had both strength and flexibility, the strength could ensure the completion of insert and torque actions, while the flexibility was intended to ensure not to damage the blood vessel wall and other bios tissues during the long-term application.

Compliance (adaptability)

The long-term interventional catheters, cardiac and vascular prostheses and artificial blood vessel materials required the compliance above average. Blood disorders usually occurred on the healing site of the arteries with relatively good compliance and the non-extendible grafts. The blood disorder could cause the changes in vascular permeability, and lead to anastomotic pseudoaneurysm intimal hyperplasia. Fiber shaping responses of elastomer were the reasons to the decreasing compliance of elastomer in the grafts within a certain time. On the other hand, even in the match compliance condition, there was a complex problem to be solved, that was the presence of excessive compliance region in the healing site, where there were likely to occur pseudoaneurysm.

Creep resistance

Creep resistance was used to measure the ability of the materials to maintain the shape and size under stress. The bios materials achieved the creep resistance through various forms of crosslinking. Among the synthetic materials, the cross-linked polymers (silicones) and multiphase block copolymers (polyurethane) also had good creep resistance; while the fluoropolymers, such as polytetrafluoroethylene, and uncrosslinked hydrogel had poor creep resistance.

Aging resistance

Aging resistance specifically referred to the ability of anti-progressive cracking of materials under critical stress and relaxation conditions. Most plastics had poor aging resistance, but polyether polyurethane elastomer had quite excellent aging resistance, and therefore widely used in cardiovascular medicine.

Smoothness

The surface smoothness of materials mainly reflected in the surface friction coefficient, which was essential for the interventional catheter, as the non-sufficiently smooth surface will seriously damaged the vessel wall. The surface smoothness of the materials were obtained mainly depend on the hydrogels or biopolymer surface coatings.

Water absorption

The strong water absorption of polymer material may easily lead adverse effects on the strength and creep resistance. The strength and other mechanical properties of nylon 6/6 were significantly reduced under moist conditions.

Biological stability

The biological stability of the materials could reflect the capabilities of resistance to degradation and maintaining *in situ* performance under application conditions. The forms that caused polymer degradation and performance loss reduction included hydrolysis, oxidation, hydrolysis, lipid deposition, swelling and calcification. Polyester polyurethane was easily hydrolyzed, polyether was easy to be oxidized, and the polyether polyurethane and silicone were prone to result in loss of material properties after absorbing esters substances. Calcification and digestion mainly occurs in the natural polymer materials and their derivatives under blood environment.

Biological activity

Biological activity mainly refers to the special material properties of some materials that are inherent and can participate in some bios reactions. For example, the bioactive coating materials can prevent blood coagulation or dissolute formed thrombus at the molecular level; negatively charged surfaces can eliminate the complement components on the interface; while the surface immobilized polypeptide or protein can promote the endothelial cell seeding and the bios soft tissue attachment on the surface of the materials.

Biological responsiveness

Biological responsiveness of the materials (such as inflammatory response and coagulation reaction) is an important indicator that should be considered in the biomaterial designing. The initial reaction of inflammatory response and coagulation response was originated in the interactions between proteins and cells on the surface of biomaterials. The chronic inflammatory response on the surface of biomaterials will lead to tissue fibrosis and long-term persistence of leukocytes on the inflammation sites, which can cause the necrosis of surrounding tissue and thus result in the failure of medical devices implantation. The implants suffered with environmental erosion, as well as the residual monomer, plasticizers, processing aids and degradation products in the materials may lead malignant allergic phenomena. Except for the coagulation and endogenous inflammatory response, pathogens as well as the endotoxin and body fragments will also lead to severe exogenous inflammatory responses, and the thrombus structure on

the surface of biomaterials may also be the lesions of pathogen infection. In addition, angioplasty-caused intimal hyperplasia reaction will largely limit the application of small-diameter artificial blood vessels.

Graft copolymer surface/block copolymer surfactant that can be used as biomaterials

Compose of homopolymers and random copolymers are relatively homogeneous. Due to the influence of surface orientation effects, oxidation and pollution, chemical properties and the nomenclature properties on the outermost layer of the materials are essentially different. However, for the graft copolymers and block copolymers, the difference between the surface and the nomenclature will be reflected in many molecular layers that extending from the surface to the nomenclature^[43-48]. The two main factors determined the nomenclature/surface behavior including nomenclature/surface difference and surface phase separation, namely surface energy and molecular motion.

Any interface tends to reach the state with the lowest interface energy, therefore, if there exists more than one component in one system, the component that lead to the lowest interface energy will be shifted to the surface as far as possible. Therefore, the polymer/air interface, the minimum surface energy components (or lowest surface energy functional groups) will be enriched in the interface layer. While in polymer/water interface, the maximum polar components and functional groups will be shifted to the interface to the maximum extent. The movement degree of the polymer molecules is directly related to the realization or not of the lowest interfacial energy mentioned above, if the molecular motion is limited, the energy minimization process of surface structure will be frozen in place. Thus, melting, dissolving solvent, heating above T_g and plasticizing treatment will contribute to realize the thermodynamically stable state to the maximum extent. If taking the difference of nomenclature-surface composition into consideration, another additional determinant should be added, namely crystallization behavior of each component. If one of the components in the graft copolymer or block copolymer containing a relatively high crystallinity, the other components will be squeezed out, thus resulting in the surface regionalization. Crystalline can hinder the molecular motion and diffusion. Finally, the incompatible degree of the two components of copolymers will affect phase separation tendency in the nomenclature and surface layer.

Graft copolymer surface

Most of the researches on the graft copolymer surface

focused on the characterization of polymer branch presented on the surface. The testing methods are mainly the surface infrared spectroscopy^[49-52], contact angle and X-ray photoelectron spectroscopy^[52-54].

X-ray photoelectron spectroscopy is the common method to characterize the existence of surface grafting and quantitatively test the surface content, with the example of low density polyethylene grafted with poly(2-hydroxyethyl methacrylate). In view of the low grafting rate, the hydrometer method has been unable to provide accurate measurements, while XPS is able to meet the requirements^[54-56].

The principle of minimum interfacial energy has a very important manifestation in the graft copolymer system. When testing the silicone rubber of radiation grafting hydrogels by XPS photoelectron spectroscopy under hydration state ($-160\text{ }^\circ\text{C}$), the corresponding graft tile peak will be reflected on the Si peak^[57]. While after sample dehydration (*in situ* processing to make the sample temperature increase to the room temperature in the X-ray photoelectron spectroscopy devices), there is almost no spectral peaks of graft components. As the sampling depth of X-ray photoelectron spectroscopy was about 100 Å, we can find that the detected surface structure reconstruction is based on the multilayer molecular scale. Similar surface chemistry changes can be found in comb copolymer containing pro-hydrophobic segments, such as the poly(2-hydroxyethyl methacrylate)^[58]. Due to the different nature of the interface during annealing, its pro-hydrophobicity can be significantly adjusted. For example, if annealing on Teflon or in air, the hydrophobic surface could be obtained; if annealing on the polarity Mylar surface, the water infiltration surface will be obtained. Many literatures have reported the changes in surface chemistry caused by interfacial properties and environmental factors^[57, 59-63]. The driving force of such changes was initially thought to be based on the energy changing, that is the decreasing surface energy. However, recent studies showed the dilution effect of nomenclature based on entropy change properties on the surface functional groups could be considered as the driving force to the chemical changes above, and then acted on some certain solution system. For example, characterized with polyethylene exposed to N₂RF-induced plasma coupling system by X-ray photoelectron spectroscopy will find that the surface content of nitrogen containing functional groups was reduced due to the presence of solvent, and the reason was the presence of solvent destructed the hydrogen bonds between chains. And for hydrogen bonds, the

non-covalently bonded crosslink form, can reduce the movement of molecules, and thus limiting the surface functional groups to diffuse to the noumenon.

In some recent experiments on radiation grafting, two different monomers were grafted on the same substrate simultaneously, thus getting in-depth observation on the complex surface systems^[64]. In the experiments, hydroxyethylmethacrylate and poly(2-hydroxyethylmethacrylate) were grafted on low-density polyethylene surface with irradiation method. The products of the experiments were characterized with X-ray photoelectron spectroscopy, and the results showed the hydroxyethylmethacrylate firstly, and then the poly(2-hydroxyethylmethacrylate), which strongly determined the nature of the product surface. Indicating that no matter the copolymerization product obtained by simple solution, or the "normal" graft copolymerization product, the surface of the products was not the balance system. Studies on the surface area of a single compound were carried out based on the idea above.

The surface grafted sample with radio frequency plasma deposition has aroused widespread interest due to its unique chemical properties. The in-depth characterization indicates that the unique chemical properties are derived from atomic sequences rearrangement, namely that the monomer molecules can split into several charged radical fragments in the plasma environment. The rearrangement of these fragments in the radio frequency plasma reactor and the deposition based on any surface can be achieved by a complex behavior. The conduction of this behavior is determined by the monomer concentration, plasma radiation intensity, accurate stoichiometric reaction and the presence of second component with accelerating or delaying reactions, as well as the ratio of surface etching rate to surface deposition rate. There are many reports on the preparation and properties of plasma-derived membrane^[65-67]. The key of plasma-derived membrane is the significant boundaries exit in its component regions: graft chain-substrate interface, the commonly interface between plasma-derived membrane and the substrate, and the thickness is just about few molecules in terms of many such systems. It is different from the graft copolymer surface prepared with chemistry and radiation technology, as for the graft copolymer surface prepared with chemistry and radiation technology, the interface between the graft and noumenon has a few hundred to several thousand angstroms of gradient range^[68-69].

Transmission electron microscopy and scanning

electron microscopy can also get a lot of interesting information. The ultrathin section transmission electron microscopy image of the graft copolymer section can be used to characterize the morphology of graft chain and the substrate interface, as well as the morphology of surface region of the materials. In the preparation process of transmission electron microscopy samples, cutting, staining and other processing methods can increase the potential for introduction of human operation error. In addition, for the hydrogel graft, more human operation error may be introduced during the sample detection progress under dry state. For transmission electron microscopy, the sample surface shrinkage will be caused by dehydration process during sample preparation, and this may change the inherent morphology of the sample, so it is difficult to obtain the required information directly. There are two kinds of technologies that can help the transmission electron microscope to achieve the surface morphology differences under dry and wet state and characterize the relationship. First, the optical stereoscopic microscope can be used to detect the hydrogel graft chain in water, and if the observed morphology has large-scale characteristics ($> 10 \mu\text{m}$), the overall appearance of the optical microscope photograph has a direct reference significance to the result of scanning electron microscope. Second, wet graft copolymer samples can treated with *in situ* hardening treatment after frozen by liquid nitrogen, and then the water-containing samples can be observed under transmission electron microscope directly. In addition, drying treatment of hydrogel critical point can be expected to maintain the surface morphology of graft copolymers. However, during critical point drying treatment, the introduction used to replace the aqueous solvent will bring morphology changes that similar to the dehydration, and this is because of swelling-deswelling process. The similar results obtained by two different analysis methods have been determined with the morphological images, and finding that the differences between wet and dry graft surfaces is mainly depend on the scale of the surface protrusions, rather than other general natures, and this is related with the initiation grafting rate. The in-depth study on this issue is undergoing. Application of high resolution scanning electron microscope can directly contribute to better access the information on the polymer surface morphology^[70]. Application of Lanthanum-boron compound cathode electron gun can make the analysis depth of scanning electron microscope to extend to 30 \AA , and meantime, the potential damage to the sample surface is obvious, and more serious to the samples with large surface

unevenness. Radiographic inspection can lead to the introduction of artificial illusion, so the detection should be rapid and short in time to decrease the radiographic inspection.

Block copolymer surfactant

Phase separation, or micro-structural phenomenon is widespread in the block copolymer materials. The driving force of this kind of phase separation is based on the nature of entropy changes and energy. In recent years, the researches in this field have achieved development^[43-44, 71], but there is less development in the researches of the surface characteristics of this kind of materials.

Transmission electron microscope is used to observe the surface morphology of block copolymer surfactant, and mainly focus on the surface phase separation. For the stained polymer film, the main information of surface morphology is obtained mainly depends on the scanning electron microscope and transmission electron microscope. The information obtained with transmission electron microscope make from the staining sheet is important for the understanding the nomenclature morphology of block copolymer, especially the block copolymer in the region has phase separation^[43,72]. Duplication method is very useful in the preparation of transmission electron microscope sample, and it can be used to further identify the X-ray photoelectron spectroscopy conclusions^[73]. For the electron microscopy analysis of multiphase polymer systems, scattered electron microscope can be used to improve the contrast, but should pay attention to avoid introducing artificial illusion^[74].

In the analysis of block copolymer surfactant with remarkable texture and cracking plane, such as osmium stained polystyrene/polybutadiene blends, using the backscattered electron analysis generated from accelerated electron flow with different energy can observe the microdomains situation in the surface area. Moreover, the analysis depth is controllable. The penetration and sampling depth obtained under 35 kV accelerating voltage are larger than that obtained under 15 kV accelerating voltage, and the sampling depth can be decreased to 100Å. Although the result was obtained from the testing of blend, but it is suitable for the research of copolymer.

X-ray photoelectron spectroscopy has considered being the tool with particular value in the research of surface properties of block copolymer. The advantages of X-ray photoelectron spectroscopy in the research is

the surface properties (the research subjects are set in 10–100 Å on the surface top), preparation requirements of minimum amount of test specimen, material non-destructive depth sampling capability, and the ability to obtain rich-chemical information. The one of the earliest researches on X-ray photoelectron spectroscopy of block copolymer is the research on polydimethylsiloxane/polystyrene-AB type copolymer surface^[75-81]. Under all kinds of conditions, the instant surfaces are almost entirely constituted by pure polydimethylsiloxane. The observation of shake-up satellite peaks ($\pi \rightarrow \pi^*$ transfer) in the spectra of polystyrene C-1s X-ray photoelectron spectroscopy showed that the thickness of polydimethylsiloxane surface film is about 13–40 Å, and strongly influenced with nature of the casting solvent. After that, variable-angle X-ray photoelectron spectroscopy technique is also used in the research of same polymer system with lower molecular weight, but the results are totally different with those in the researches of the silane coating dominated polymer system with higher molecular weight. In addition, in the surface research of X-ray photoelectron spectroscopy of polycarbonate/polydimethylsiloxane copolymer, the concentration on the surface of polydimethylsiloxane segments is identified. And the study is also performed on polycarbonate/polysulfone copolymer systems. We can obtain the same conclusion that surface properties of block copolymer are greatly determined by the lower surface energy polymeric component in the copolymer system.

Except for the X-ray photoelectron spectroscopy, other methods can be used to characterize the surface migration and content of polydimethylsiloxane graft copolymer, such as the contact angle method^[79,80-82]. Sessile drop method was used for surface construction of styrene-dimethyl siloxane block copolymer prepared with toluene solution containing polystyrene^[82]. The surface tension testing showed that the exits of polystyrene-polydimethylsiloxane-polystyrene “ABA” block copolymers can significantly reduce the surface energy of the original polystyrene, and that may be caused by surface enrichment of silane block copolymer^[83].

Polyether-polystyrene block copolymer is used to study the surface/nomenclature difference. Transmission electron microscopy characterization of tetrahydrofuran/polystyrene copolymer fibers containing tetrahydrofuran that prepared with the chloroform solvent showed the tetrahydrofuran was covered with polystyrene^[84]. With the increasing of polystyrene content, the lamellar

morphology on the surface of polytetrahydrofuran was gradually observed, this is because of the presence of high content of tetrahydrofuran can make the crystalline of polytetrahydrofuran components to reject polystyrene component, and this crystalline behavior become the driving force for the covering of polytetrahydrofuran surface with polystyrene. Contact angle method and the reverse gas chromatography were used to characterize the complex phase separation exists in the system. And reverse gas chromatography is suitable for the surface research of methyl methacrylate-methacrylic acid ester block copolymer.

Variable-angle X-ray photoelectron spectroscopy technique was used to study the polyoxyethylene-polystyrene diblock or triblock copolymers^[73, 85-87]. The data showed the polystyrene component surface enrichment in two systems, as well as the discrete micro-composition of surface polystyrene and polyoxyethylene, and the electrical interaction and mutual mixing of polyoxyethylene and polystyrene has been confirmed. The interaction with the oxygen-ether bond may lead to the changes of morphology and strength of shake-up satellite peak of polystyrene aromatic ring. And from this, the AB and ABA similar structure observed in the blend system of polyoxyethylene and polystyrene can be explained. X-ray photoelectron spectroscopy surface analysis can be used to analyze the polystyrene/poly(-ethenyl pyrimidinyl) block copolymer. There is no electrical interactions and phase separation between two aromatic functional groups of the polystyrene/poly(-ethenyl pyrimidinyl) block copolymer. But the electrical effects above can be displayed by the random copolymer of styrene and 2-vinylpyrimidine, and can be correspondingly explained by the aromatic ring steric effects (larger in random copolymer and smaller in block copolymer) and electrical effects (compatibility).

CONCLUSIONS AND OUTLOOK

For a long time, we paid more attention on the modification of material surface to solve the biocompatibility of the materials. For example, in the study of the development of hemocompatibility materials, we focused on the surface molecular design of the material to improve the pro-sulfur water of the materials, introduce charged groups and load bioactive substances, and thus minimize the formation of thrombus to improve the blood compatibility of materials. However, because of the exposure to the body fluids, organic molecules, enzymes, free radicals, cells and other factors, the materials in the biological system have complex

biological environment, and improvement of hemocompatibility caused by the surface modification methods is limited.

Interaction between the blend components and characterization of surface conformation detected with attenuated total reflection fourier transformed infrared spectroscopy, X-ray photoelectron spectroscopy and contact angle method showed the ammonia hydrogen bond association exists in between modifier M(S)PEO and substrate PEU, and the association was established between the MDI segment in the central of modifier molecules and PEU hard segment, bases on this, the blending hydrogen bond graft model can be established; surface modification of blend-coating method was realized based on the amphiphilic nature of the modifier molecule and the high-elastic properties of substrate PEU, and completed through the spontaneous migration and enrichment from modifier molecule to blend membrane surface; the orientation and power of the spontaneous migration are determined by low surface energy tends and pro-hydrophobic of amphiphilic modifier molecules, and then the self migrating surface enrichment model of modifier in the blend system can be established, and the "ontology compensation mechanism of limited surface modifier losing" can be proposed based on this. And then the feasibility and stability of surface modification of blend-coating method can be confirmed, thus to establish this simple and effective modification method. In addition, the content of modifier end groups in surface layers with different depths is measured with variable-angle X-ray photoelectron spectroscopy, and the effect of the interaction between end groups and PEO bridging with different sizes on the surface construction was explored. Finally, the typical "PEO ring conformation" model of short-chain M(S)PEO modifiers can be established on the water phase interface. Compared with ontology blend system, the surface coating system can enhance the poor compatibility power between modifier and substrate, and weaken the kinetic resistance of "self migrating surface enrichment".

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心血管医疗装置的聚合物表面构建及生物相容性[○]

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文章亮点:

从强度、依从性(顺应性)、抗蠕变性、抗老化性、光滑性、吸水性、生物稳定性、生物活性及生物响应性, 9 个方面论述了心血管医疗器件及可植入性软组织替代物的设计要求。

关键词:

生物材料; 生物材料综述; 聚合物生物材料; 生物医用聚合物材料; 生物相容性; 血液相容性; 细胞相容性; 接枝共聚物表面; 嵌段共聚物表面

摘要

背景: 用于心血管医疗的生物材料在血液接触性条件下必须具有抗血栓性、对抗生物降解性与抗感染性。

目的: 考察用于心血管组织工程的新型植(介)入型聚合物材料(表面)的生物相容性、血液相容性和细胞相容性。

方法与结论: 检索 1967 至 2012 年 PubMed 数据库及万方数据库。检索词为“biocompatibility, blood compatibility, biomedical materials, biomedical polymer materials; 生物相容性材料, 血液相容性材料, 生物医用材料, 医用高分子材料”。

结果与结论: 深入研究了可用作生物材料的接枝共聚物表面和嵌段共聚物表面, 发现表面与本体的差别将体现在从表面向本体延伸的很多层分子上, 而两种主要因素决定了其包括本体/表面差异及表面相分离在内的本体/表面行为, 即表面能和分子运动性。如果考虑到对本体-表面的组成差异的理解, 则还必须追加另以附加决定因素, 即各组分的结晶行为。如果接枝共聚物或嵌段共聚物中所含的组分之一具有相对较高的结晶性, 则另一组分将被挤榨出去, 结果导致表面的分区化; 结晶也阻碍分子的运动及扩散, 最终共聚物两组分的不相容程度将影响本体及表面层中的相分离趋势。

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学术术语: 材料的生物活性-主要是指某些材料所固有的、可参与某些生物反应的特殊材料性质。

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