PREFACE

Chitosan is a partially deacetylated derivative of chitin, a natural polysaccharide extracted from crustaceans, insects and certain fungi. Owing to its unique properties such as biodegradability, biocompatability, biological activity and capacity of forming polyelectrolyte complex with anionic polyelectrolytes, chitosan has been widely applied in the food and cosmetics industry, as well as the biomedical field in relation to tissue engineering, and the pharmaceutical industry relating to drug delivery. This book gathers current research from around the globe in the study of chitosan.

Chapter 1 - Interrelation between the structure and adsorption properties towards to water and nitrogen vapors and Ni, Cu and Ag cations of the chitosan samples modified by freeze-drying after precipitation with NaOH or Na_2CO_3 or drying in air, as well as cross-linking is studied. The investigations by IR spectroscopy, X-ray diffraction and pulsed NMR show the influence of the preliminary treatments on the supramolecular structure. The more ordered structure is observed in the freeze-dried samples of chitosan compared with the air-dried sample. The parameters of porous structure of the chitosan samples calculated from the isotherms of water vapors adsorption and the nitrogen vapors low temperature adsorption are compared. It is revealed that the isotherms of water vapors adsorption on the chitosan samples are more sensitive to the structural modification of polymers. The efficiency of different models based on the Flory-Huggins, Dubinin-Astakhov, and Dubinin-Serpinsky equations for fitting the experimental isotherms of water vapor adsorption is evaluated. The Dubinin-Serpinsky equitation 2 based on a model of two-stage localized adsorption of water molecules describes the experimental water vapor adsorption on the chitosan samples in the full range of relative pressures. In the range of small relative pressures, water molecules interact with chitosan polar groups which serve as the primary adsorption centers (PAC). Then, water molecules adsorbed on PAC become the secondary adsorption centers for further adsorption. As a result, at relatively high pressures the water clusters are formed. In the range of low water fillings of the chitosan adsorbents, the amount of primary adsorption centers can be evaluated by the comparative method.

The freeze-dried chitosan samples display the increased adsorption capacity towards to water and nitrogen vapors, as well as to metals cations. The cross-linking of the freeze-dried chitosan samples by glutaraldehyde reduces the adsorption capacity through the blockage of amino-groups. Cross-linking the chitosan films leads to the growth of adsorption capacities towards to water vapors. Thus, the analysis of the isotherms of water vapors adsorption

specifies that structural changes of the chitosan samples after freeze drying and cross-linking resulting in a growth of the amount of accessible adsorption centers.

The adsorption capacities and the rates of adsorption of metal cations as Ni, Cu and Ag onto the modified chitosan samples are examined. The Langmuir, Freundlich and Dubinin-Radushkevich adsorption models are used to describe the isotherms of metal cations adsorption. The kinetics experimental data properly correlate with the pseudo-first-order kinetic model. The modification of the chitosan structure by freeze-drying noticeably increases the adsorption capacities towards to metal cations. The adsorption capacity of the freeze-dried chitosan sample towards to nickel cations is as high as 4.5 mmol/g that is threefold higher than that of the air-dried chitosan sample.

The IR-VIS spectroscopic experiments performed for the copper cations adsorption on the chitosan samples at high adsorption values allowed to advance a probable model of copper-chitosan complex that is a "bridge" structure based on a binuclear copper complex which bounds two chitosan macromolecules, so that every Cu (II) cation of a pair is associated with one amino group in axial position which belongs to different chitosan chains.

Chapter 2 - Chitosan, a natural polysaccharide, and its derivatives are most important biomaterials because of their distinct physicochemical and biological properties such as biocompatibility, biodegradability, non-toxicity, antimicrobial and hemostatic properties. In addition, the existence of reactive functional groups in the chitosan molecule makes it also possible to tailor the chitosan material for many specific tissue engineering and hemorrhage control applications. In the first part of this chapter, we will focus on the properties of chitosan and various modifications to improve its properties to enhance drug delivery and tissue regeneration. The modification of chitosan will be introduced from two aspects: chemical and physical modifications, i.e. grafting with other small molecules or biomolecules and blending chitosan with other different biomaterials, respectively. The applications of chitosan, especially its derivatives in drug delivery and tissue regeneration targeting different organs, such as cartilage, bone, skin, blood vessel, nerve system and liver will be discussed. Current improvements of these different artificial substitutes (based on chitosan) in different organs by the authors and other researchers will be reviewed. In the second part of the chapter, we will review the development of chitosan-based biomaterials for hemorrhage control in trauma and surgical injuries. Both chemical and physical modifications of chitosan will be discussed. Finally, challenges and future directions to use chitosan as a biomaterial for tissue engineering and hemorrhage control will be elaborated.

Chapter 3 - Chitosan, a cationic polymer, is the N-deacetylated derivative of chitin, which is abundant in nature. Chitosan has drawn much attention because of its good biocompatibility, biodegradability, low toxicity, and ability to be fabricated into various forms in tissue engineering. Because of the interesting biological properties, the utilizations of chitosan have been sufficiently developed. To make a breakthrough for the exploiture, modification will be a key point. Here we described several modifications including gamma irradiation, blending with PEG, PHB, gelatin, butyl bromide, collagen, polycation materials, nano-hydroxyapatite, coupled with GRGDS peptide, and carboxymethylation. Then the effect of the different modifications on chitosan cell affinity and biocompatibility has been discussed. Tissue engineering has emerged as promising field to treat the loss or malfunction of a tissue. A scaffold in tissue engineering plays an important role in accommodating and stimulating new tissue growth. Chitosan is one the widely used natural polymers in tissue engineering. Here the authors also discussed the applications of chitosan with different forms

in tissue engineering including cartilage tissue, bone tissue, nerve tissue, vascular tissue, liver tissue, and skin tissue. All the descriptions have shown that the application of chitosan has a good prospect.

Chapter 4 - It is being realized that the performances of chitosans depend in most cases on their essential characteristic properties, such as the degree of acetylation and the average molecular weight. Crystalline polymorphic form, degree of crystallinity, polydispersity of molecular weight, zeta potential and other properties are also important. The selection of a certain chitosan for a particular application has consequences in terms of degree of efficacy, reproducibility of the results and suitability for scaling up in various areas such as pre-clinical tests, adoption for pharmaceutical formulations, environment protection. The requirements for reproducible quality of tailor-made chitosans become even more stringent when they are chemically or enzymatically modified.

Macrophages, fibroblasts and other human cells respond to the presence of chitosans in significantly different ways depending on their DA and MW, in terms of phenotypes, secretory repertoire, efficacy of their receptors, and final capacity to demonstrate superior biochemical significance compared to other polysaccharides. This is particularly true in wound healing, bone defect repair, control over inflammation, exertion of immune-stimulation, efficacy in drug delivery, anti-cholesterolemic capacity.

Chitosans are also antioxidants and antistress agents, capable to scavenge free radicals in a mammalian organism: this action too is controlled by DA and MW, chelating activity, and capacity to interact with biochemicals like nitric oxide, superoxide dismutase and glutathione peroxidase. Chitosans of proper chain size lend themselves to be targeted to a tumor, where they suppress the proliferation of tumor cells or at least reduce their viability; moreover they exert anti-metastatic action.

Chitosans are also active on the fungal and bacterial cells, and the selection of the proper size of the chitosans permits to optimize the results against pathogens, in consideration of the multiplicity of mechanisms of action of oligochitosans and partially hydrolyzed chitosans, using a combination of approaches, including in vitro assays, killing kinetics, cellular leakage measurement, membrane potential estimation, and electron microscopy, in addition to transcriptional response analysis.

This review includes concise but detailed well-assessed protocols for the preparation of oligochitosans and partially hydrolyzed chitosans, mainly by using sodium nitrite, sonication, hydrogen peroxide, electrolysis, and hydrolytic unspecific enzymes.

Chapter 5 - In this chapter thermal relaxation properties of chitosan neutralized and non-neutralized films will be reported as a function of water content using dynamical mechanical analysis and dielectric spectroscopy in the temperature range from 20 to 250°C. Three relaxation processes have been observed in different temperature and frequencies ranges. For the first time, the low frequency α-relaxation associated with the glass-rubber transition, which relate to a plasticizing effect of water, has been detected by this technique in both chitosan forms in the temperature range 20-70°C and for moisture contents between 0.5 to 10 wt %. On this basis, the glass transition temperature was estimated in the range 86-102°C which shifts to higher temperature with decreasing moisture content and the glass transition vanishes in a dry material. A second low frequency relaxation was observed from 80°C to the onset of thermal degradation (240°C) and identified as the sigma-relaxation often associated with the hopping motion of ions in the disordered structure of the biomaterial. This relaxation exhibits a normal Arrhenius-type temperature dependence with activation energy of 86-88

kJ/mol and it is independent of water content. The non-neutralized chitosan possess higher ion mobility than the neutralized one as determined by the frequency location of the σ-relaxation. A high frequency (10^4 -10^8 Hz) secondary β-relaxation in neutralized and non-neutralized chitosan, related to side group motions by means of the glucosidic linkage is observed in the temperature range 20-120°C and moisture contents less than 3 wt % with Arrhenius activation energy of 46.0-48.5 kJ/mol. In the films with higher moisture contents this relaxation is not well resolved due to a superposition of two relaxation processes: beta and beta wet relaxations that merge into one common β-relaxation process.

Chapter 6 - Chitin and chitosan have been receiving great attention as a novel functional material for their excellent biological properties such as biodegradation, immunological, antioxidant and antibacterial activities. However, its use has been scarcely developed due to its high molecular weight, which causes poor water solubility and high viscosity of the solutions. Compared with ordinary chitosan, chitosan oligomers have much improved water-solubility and some special biological functions due to the high absorption rate at the intestinal level, thus permitting its entrance in blood circulation and distribution all over the body. The potential application of chitin and chitosan, and respective oligomers, is multidimensional and it has been found in food and nutrition, biotechnology, material science, drug delivery, agriculture and environmental protection, and recently gene therapy too. In the realm of this chapter, we will focus on some biological activities attributed to those molecules, such as, antimicrobial and antifungal activities, wound healing, antioxidant, anti-inflammatory, anti-carcinogenic and anti-coagulant.

Chapter 7 - Chitosan has been exploited in promising drug delivery systems to release drugs in the target place, at the appropriate time and dosage, improving their bioavailability and, consequently, the therapeutic efficiency. On top of that, also allows the protection, control and release of biotech drugs such as peptides, genes, vaccines, antigens as well as synthetic drugs, which are highly limited to cross biological barriers and reach the target site, without collateral damage. Besides being easily manipulated, chitosan has important features, which make it unique. Its hydrosolubility and positive charge enable negative interactions with charged polymers, macromolecules, and polyanions when in contact with aqueous environment. Its exceptional biological properties such as mucoadhesiveness, permeation-enhancing effect across biological surfaces, biocompatibility and non-toxicity/non-antigenic make it useful for transmucosal drug delivery, improving absorption of the paracellular route. However, a better and future application of chitosan as therapeutic agent clearly depends on the design of appropriate carriers. As revised in this chapter, chitosan has been used in preparing films, beads, intragastric floating tablets, microparticles and nanoparticles for applications in the pharmaceutical field, surgeries and bone restructuring. Controlled drug delivery technology represents one of the borders of science, which involves a multidisciplinary scientific approach, contributing to human health care. Chitosan, with all its chemical and biological multipotential emerged as a promising solution for different conditions and medical applications, overcoming common problems of other drug carriers. As also described in this chapter, several clinical trials involving chitosan-based delivery systems are on the roll to explore in clinical the advantages of this exceptional material.

Chapter 8 - This chapter deals with a novel method of chemical modification of polysaccharides, in particular solid-state synthesis of chitosan and its composites with biocompatible synthetic polymers. The technique is based on a variety of chemical and

physical transformations at conditions of plastic flow, which are realized in polymeric solids at pressure and shear deformation. The extrusion in the solid state is one of the most environmentally friendly methods of polysaccharide modification, since it does not require the presence of any catalysts, initiators, as well as organic solvents. It is desirable for biomedical applications, as it allows avoiding toxic remains over final composite materials. At the same time it provides numerous possibilities to circumvent many processing obstacles typical for preparation of natural polymers-based hybrid materials and to achieve better results compared to those of reactions in a melt or in a solution. Compared with traditional methods for design and manufacture of hybrid polysaccharide-based materials, solid-state reactive blending is a relatively simple, cost effective, and convenient way to improve the composite properties. In particular, grafting of polyester moieties onto chitosan chains was found to occur under selected deformation conditions. These polymeric materials demonstrate an amphiphilic behavior with dispersion propensity in organic solvents and could be promising for various biomedical applications. Microfibers containing chitosan up to 40% can be obtained by electrospinning of these dispersions. A uniform structure of the obtained polylactide/chitosan materials is confirmed by improved mechanical properties of films as compared with a model molten system with the same composition. Also it was shown recently that chitosan-g-poly(vinyl alcohol) copolymers can be produced by simultaneous alkaline solid-state deacetylation of chitin and poly(vinyl acetate) in an extruder. The main feature of these co-polymeric systems is solubility in neutral water at low and moderate temperatures. The obtained graft-copolymers possess excellent ability to stabilize nano-scale particles of both organic-inorganic origins. The dependence of chemical composition, morphologies and macroscopic properties on the ratios of co-extruded components as well as on the processing conditions is discussed.

Chapter 9 - Chitosan (CHIT), a non-toxic, biocompatible, and biodegradable natural polymer finds tremendous commercial application in its native and modified form. In the recent years, considerable efforts have been devoted to fabricate CHIT based smart materials with adopting attractive approaches, for examples, the ability to alter texture in a controlled mode via external stimulus including stress, electric or magnetic fields, temperature, moisture and pH. In the chapter, we have discussed the recent studies of the preparation of CHIT based smart materials from their various perspectives with put their special attention in the field of medical diagnostic and treatments. The modifications are illustrated basically on the stimuli-responsive CHIT as molecular device materials, biomimetic materials, hybrid-type composite materials, functionalised polymers, supermolecular systems, information- and energy-transfer materials, environmentally friendly materials, *etc.* at synergetic levels along their striking applications in both strategic and civil sectors.

Chapter 10 - Chitosan is a linear aminopolysaccharide obtained from the alkaline deacetylation of chitin. Chitosan is both biocompatible and biodegradable, making it an attractive material for use in drug delivery, gene delivery, cell culture, and tissue engineering applications. The achievement of predictable and reproducible release of an active agent into a specific environment over an extended period of time has significant advantage. A number of biodegradable polymers are potentially useful for this purpose, including synthetic as well as natural substances. Because chitosan is a swellable polymer with properties that can be tailored by varying the degree of deacetylation and molecular weight, it has been extensively investigated for use as a retardant polymer in matrix tablet formulations. The purpose of this review is to take a close look at the applications of chitosan IPNs and copolymers in

controlled drug release. Based upon the present research and available products, some new and futuristic approaches in this area are thoroughly discussed.

Chapter 11 - The interest for finding better materials with the objective to use them as implants, has led to search in the mixture of natural polymers for a source to satisfy this necessity. This chapter presents the information about the synthesis, characterization, and some applications of hydrogels based in the chemical reaction between the hybrid, natural-synthetic, Chitosan-g-Glycidyl Methacrylate (CTS-g-GMA), of cationic nature, with water-soluble anionic polymers, such as Xanthan gum (X) and Hyaluronic acid (HA). The formed polyelectrolyte complexes, due to electrostatic attraction between the polymers, have improved properties when compared to hybrid CTS-g-GMA, which provides a wide range of applications in the biomedical field. All materials have been characterized by different analytical techniques such as infrared spectroscopy (FTIR), X-ray diffraction (XRD), thermal analysis (DSC and TGA), and the results were compared to the precursor materials (chitosan, X, HA, and CTS-g-GMA). Due to the HA nature, the film obtained from this reaction has been assessed for use as a patch for wound healing; whereas the properties showed by the hydrogels obtained from the reaction with X, make them very promising for applications in the treatment of recovery of spinal cord injuries. Cell culture was performed in all materials; different cell types were seeded and the viability has been quantified by the DNA (proliferation) assay, over several time intervals. The analysis showed satisfactory results of the (CTS-g-GMA)-X when compared to pure chitosan. Peroxide and interleukin-1β (IL-1β) assays have been performed to analyze the inflammatory response caused by biomaterials. Results show a moderate inflammatory response of our hydrogels when compared to raw chitosan. The implant of the hydrogels [(CTS-g-GMA)-X] in Wistar rats was performed after injuring the spinal cord by a laminectomy. The somatosensory evoked potentials (SEP) obtained by electric stimulation onto peripheral nerves were registered in the corresponding central nervous system areas, showing a successful recovery after 30 days of the implant. The results are promising and strongly support the future use of these hydrogels as scaffolds for tissue engineering and recovering.

Chapter 12 - The fundamental electrical and magnetic interactions between iron ions and biomaterials were investigated using an experimental approach, ^{57}Fe Mössbauer spectroscopy, and ab initio computational methods. A conventional spin-Hamiltonian approach adopted for the data analysis of the Mössbauer data showed that the metal ion in the Fe-chitosan complex is in the high-spin ferric state and that it has an internal magnetic field of approximately 440 kG, at the nucleus. The magnitude of the internal field arises from the predominant Fermi-contact interaction of the high-spin ferric species with N/O ligands. Based on the analysis of the experimental data, a scheme for the Fe-chitosan complex has been proposed. Similar analyses of spectral data were performed for other biomaterials such as glucose, cellobiose, and glucosamine. Studies pertaining to metal ion interaction with monomers such as glucosamine, glucose, and chondritin sulfate indicate that the oxidation state of the metal ion does depend on the pH of the reaction medium. Stability of any oxidation state is attributed to the presence or absence of a glycosidic linkage between sugar units.

To further probe the geometry, energy, and details of bonding of these Fe complexes, density functional theory (DFT) computations were performed, using Becke's three-parameter functionals with Lee Yang-Parr's correlation correction (B3LYP), together with the largest suitable basis sets available in the Gaussian quantum mechanical program. Four

hexa-coordinated iron compounds were studied: (a) Complex 1 - Fe(II) with β-D-glucopyranose (glucose); (b) Complex 2 - Fe(II) with amino-2-deoxy-β-D-glucose chitosamine (glucosamine); (c) Complex 3 - Fe(II) with protonated glucosamine; and (d) Complex 4 - Fe(III) with protonated glucosamine. In all four cases, the iron atom was coordinated to oxygen atoms of two water molecules placed on an axial position. In addition, the iron atom was coordinated to two hydroxyl oxygen atoms of two glucose molecules in Complex 1, to two hydroxyl oxygen atoms of two protonated glucosamine molecules in Complexes 3 and 4, and with one hydroxyl oxygen and one amine nitrogen from two glucosamine molecules in Complex 2. In all four complexes, the two monosaccharides were rotated with respect to each other by 180°, both around the axis perpendicular to the molecular plane and around the molecular plane. Complex 1 was studied with low and high-spin electron configurations, whereas Complexes 2 and 3 were studied only with high-spin configurations. Predictions of Mössbauer chemical isomer shifts (δ_{Fe}) and electric quadrupole interaction (ΔE_Q) for these four complexes were obtained from standard curves based on experimental values.

Chapter 13 - Chitosan, a natural based nontoxic cationic polysaccharide polymer obtained by alkaline deacetylation of chitin, presents excellent properties such as biodegradability, antibacterial and wound-healing activity and immunological properties. These properties make chitosan a good candidate for the development of conventional and novel drug delivery systems. Chitosan has been used as a polymer for a controlled delivery system, gene delivery, scaffold, haemostatic action in wound healing, cell culture and cosmetic applications. Chitosan has become the focus of major interest in recent years because it has applications in not only the drug industry but also the agriculture, textile and paper industries. On the other hand, use of this biopolymer as a pharmaceutical excipient by different dose and for a number of applications is not new, but it still appears to be present in marketed drugs. The development of new delivery systems for controlled release of drugs is one of the most interesting areas of research in the pharmaceutical sciences. Nano and microparticles can be used for controlled release of different biological substances and drugs such as plasmids, hormones, peptide and proteins, antibiotics and vaccines. In this field, chitosan particular systems and chitosan matrixes, prepared by using different methods, can be used for encapsulating the drugs. Moreover, there has been interest in the chemical modification and PEGylated chitosan in order to improve its solubility and applications. Representatives of these novel chitosan modified polymers are carboxymethyl chitosan, thiolated chitosan, succinate and phthalate of chitosan salts and trimethyl-chitosan. The main chemical modifications of chitosan that have been proposed in the literature are reviewed in this chapter. Furthermore, recent studies suggested that chitosan and its derivatives are promising candidates as a supporting material for tissue engineering applications owing to their porous structure, gel forming properties, ease of chemical modification, high affinity to in vivo macromolecules. In general, this review provides an overview of using chitosan in pharmaceutical and biomedical applications.

Chapter 14 - In this chapter, the availability of chitosan was systematically investigated for removal of bisphenol A (BPA, 2,2-bis(hydroxyphenyl)propane) through the tyrosinase-catalyzed quinone oxidation. First, the process parameters, such as the hydrogen peroxide (H2O2)-to-BPA ratio, pH value, temperature, and tyrosinase dose, were discussed in detail for the enzymatic quinone oxidation of BPA. Tyrosinase-catalyzed quinone oxidation of BPA was found to be effectively enhanced by adding H2O2, and the optimum conditions for BPA

at 0.3 mM were determined to be pH 7.0 and 40°C in the presence of H2O2 at 0.3 mM ([H2O2]/[BPA]=1.0). Removal of BPA from aqueous solutions was accomplished by adsorption of enzymatically generated quinone derivatives on chitosan beads. The use of chitosan in the form of porous beads was found to be more effective than that in the form of powders and solutions because heterogeneous removal of BPA with chitosan beads was much faster than homogeneous removal of BPA with chitosan solutions, and quinone conversion for the heterogeneous system with chitosan beads was a little higher than that for the heterogeneous system with chitosan powders. The removal efficiency was enhanced by increasing the amount of chitosan beads dispersed in the BPA solutions and BPA was completely removed by quinone adsorption in the presence of chitosan beads more than 0.10 cm^3/cm^3. In addition, a variety of bisphenol derivatives were completely or effectively removed by the procedure constructed in this study, although the enzyme dose and/or the amount of chitosan beads were further increased as necessary for some of the bisphenol derivatives used.

Chapter 15 - Over the past 40 years a greater attention has been focused on development of controlled and sustained drug delivery systems. The goals in designing these systems are to reduce the frequency of dosing or to increase effectiveness of the drug by localization at the site of the action, decreasing the dose required or providing uniform drug delivery. Polymers have been the keys to the great majority to design biomaterials for drug delivery systems. Chitosan, a natural biopolymer, has been extensively used for its potential in the development of biomaterials due to the polymeric cationic character and gel and film forming properties.

Hydrogels preformed by chemical cross-linking or physical interactions form three-dimensional, hydrophilic, polymeric networks capable of imbibing large amounts of water or biological fluid. The association of magnetic nanoparticles, which could be controlled by an exterior magnetic field and have dimensions to facilitate their penetration in cells/tissues, with hydrogel type biopolymeric shells confer them compatibility and the capacity to retain and deliver bioactive substances.

In this chapter we present a synthesis of our works, from the last 5 years, in this domain of chitosan usage for synthesis of biomaterials suitable in obtaining of drug delivery systems. In our works we used mainly chitosan with slight addition of hyaluronic acid for obtaining biomaterials with controlled properties. Chitosan and hyaluronic acid are two natural biopolymers with similar structure and special biological characteristics, easily to process in porous scaffolds, films/pellicles and beads. They are biocompatible, biodegradable, promote cell migration and cell adhesion and electrostatic interact, having a great potential in the development of drug delivery systems and in tissue engineering.

In a first stage, we obtained biopolymeric pellicles by casting method using mixtures of chitosan and hyaluronic acid solutions. Chitosan/hyaluronic acid pellicles crosslinked with sodium citrate could be used for enzymes immobilization on the surface or by entrapping in the polymer network. The pellicles with immobilized enzymes are stable during several months and could be used multiple times without a notable decrease of the immobilized enzymatic activity. The ultrastructure of simple chitosan pellicles, chitosan/hyaluronic acid pellicles and enzymes immobilized on chitosan/hyaluronic acid pellicles were examined by confocal scanning laser microscopy.

More recently, in other works, we developed a new system based on magnetic nanoparticles covered in a layer-by-layer technique with a biocompatible hydrogel from chitosan and hyaluronic acid capable of vectoring support for biologic active agents (L-

asparaginase, protease inhibitor, e.g.). Characterization of size and morphology of the obtained hydrogel-magnetic nanoparticles with entrapped L-asparaginase/protease inhibitor was made using dynamic light scattering method, transmission electron microscopy and confocal microscopy.

The structure of magnetic nanoparticles coated with hydrogel was characterized by Fourier transformed infrared spectroscopy. The biocompatibility of nanoparticles was evaluated and also the interactions with microorganisms.

The characteristics of developed pellicles and nanocomposite materials made them suitable to be used for medical or biotechnological purposes.