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BIO-MEDICAL APPLICATIONS OF THE ELECTRON-BEAM PLASMA

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The main study objective is to experimentally prove the applicability and advantages of the electron-beam plasma for actual biological, pharmacological, and medical problems. The production of substances with novel biological and pharmacological properties and formation of supramolecular complexes "protein-drug agent" are considered as examples. Beam-plasma technologies for the production of novel composite materials for bio-medical applications are described as well.

The peculiarity of the techniques involved is as follows: the modification of biomacromolecules occurs in plasma generated by the electron-beam injection into various gases or aerosols containing the dispersed particles of powder to be treated. In the latter case so-called dusty plasma is generated. To study the generation and properties of pure and dusty electron beam plasmas the experimental units were specially designed [1]. Some of the laboratory set-ups were used as plasmachemical reactors that can be considered as prototypes of the technological equipment.

The beam plasma techniques of various chemical compounds and biomaterials modification (such as organic heterocyclic substances, fibrous and globular proteins, amino acids, polysaccharides and some others) were developed and a number of modern analytical methods were specially adjusted to study the structure and properties of the products obtained due to the beam-plasma treatment. The UV- and IR-spectroscopy, NMR, ion-exchange chromatography, exclusion chromatography, capillary electrophoresis, immunoelctrophoresis, and electrophoresis in polyacrylamide gel were applied to characterize properties, structure, and composition of the products. The comparative studies of the biological properties of native substances and products of their beam-plasma modification were carried out. The deceleration of the human platelet aggregation (both *in vitro* and *ex vivo* [2]) and the velocity of the bacteria breeding *in vitro* were chosen as the quantitative characteristics of the products biological activity.

The research confirmed the beam-plasma treatment to be highly efficient and controllable. The effective inhibitors of the human platelet aggregation were produced by means of the proteins treatment in the electron beam plasmas of oxygen, noble gases, and especially in the plasma of the water vapor. The native blood protein, fibrin-monomer, was used as original peptide and new peptides formed due to its plasmachemical modification were found to be active agents for the therapy of cardiovascular diseases and no subsidiary effects were observed in studies *ex vivo*.

When treated the substance is subjected to the combined action of a number of factors inherent to the electron beam plasma: reactions with active heavy plasma particles (atoms, ions and radicals), fast electrons bombardment, bremsstrahlung (X-ray) and UV irradiation. The

contribution of each above factor to the total effect of the new properties acquisition was determined. It was proved that all of them are responsible for the biomaterials modification but the plasmachemical processes predominate. The relationship between the plasma treatment duration and the products properties was found. The parameters of the electron beam (beam power, electron energy) and plasmagenerating medium (gas pressure and chemical composition), the reaction zone arrangement (plasma bulk shape and dimensions, powder distribution in the reaction zone, size of the powder particles) were optimized.

The methods of the computer simulation were developed to predict properties of pure and dusty electron beam plasmas under various conditions of the plasma generation and they were verified using available experimental data [3]. The concentrations of chemically active plasma particles, temperatures of the gaseous and powder components in the plasma, heat transfer between the plasma and solid state body (if it is inserted into the plasma) can be calculated in terms of the methods involved. The computer simulations were carried out to preliminary evaluate the optimal parameters of the powder treatment and surface modification of the solid bodies affected by the electron beam plasma. The latter problem was considered in the context of formation of biocompatible coatings on the dental and bone implants. The coatings of this kind were synthesized on titanium samples of a complicated shape. Our experiments showed the deposition and synthesis assisted by the electron beam plasma to be effective for the production of implants for surgery.

The dust-plasma structures in the RF glow discharge controlled by the electron beam were studied to experimentally prove the possibility of the supramolecular complexes formation on the basis of the biomaterials powders. For this purpose the novel method of plasma volume formation was realized. At the first stage the protein powder is injected into the gas discharge and forms a stable dust-plasma structure levitating over the RF-electrode; then the electron beam evaporates the target which contains a therapeutic agent. The vapor is activated by the electron beam plasma and deposited on the powder particles forming a supramolecular complex. Proteins and some other powders were used as the materials for dust-plasma structure while nitrogen, oxygen, noble gases, and gaseous hydrocarbons were used as plasma generating media. The possibility of supramolecular complexes formation was demonstrated in the following experiments:

1) condensation of some low molecular organic substances (acetylsalicylic acid) evaporated by a single pulse of the electron beam on carbon particles levitating in a plasma trap;

2) deposition of vapor of the sublimable substances (acetylsalicylic acid was used as the model compound) on the particles of bovine serum albumin powder;

3) deposition of the amorphous carbon or protein dust-plasma structure on the cloth.

The experiments showed that the beam-plasma reactors with reaction zone in the form of the dusty-plasma structures can be used to produce composite materials with combined pharmacological action (e.g. haemostatics with antimicrobial or regenerative properties) and to form supramolecular complexes for the addressed drug delivery.

Reference

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