ANNOTATION

to the dissertation work of Ainur Kairatbekovna Akildinova
" Application of barrier discharge plasma for modification of functional dielectric and biological materials", submitted for the degree of Doctor of Philosophy (PhD) in the specialty "6D072300-Technical Physics"

General description of work. The dissertation work is devoted to the study of barrier discharge plasma and its application for the modification of functional dielectric and biological materials.

Relevance of the topic.

A dielectric barrier discharge (DBD) is a discharge that is ignited in a narrow gas gap between flat or coaxial electrodes, one or both of which is covered with a dielectric. A feature of this type of discharge is that it is generated at atmospheric pressure and in room conditions, without the need for massive vacuum equipment. This makes it preferable to use a dielectric barrier discharge to generate atmospheric pressure plasma in such areas where it is necessary to cover and treat large areas and materials. Another advantage of the dielectric barrier discharge is the production of a low-temperature, so-called "cold" atmospheric pressure plasma. Atmospheric pressure plasma generated by a dielectric barrier discharge has been widely studied in recent years, which is associated with its application in many fields, for example, in medicine, agriculture, water purification, surface treatment of various materials and in nanotechnology.

One of the types of discharge generating low-temperature atmospheric pressure plasma is dielectric barrier discharge. Depending on the configuration of the electrodes, there are several types of dielectric barrier discharge: volume dielectric barrier discharge, surface dielectric barrier discharge. There is also an intermediate type of DBD, the so-called dielectric coplanar surface barrier discharge. It is based on the use of equipment with metallic electrodes on the dielectric surface in the form of a series of parallel strips. The main advantage of using this type of discharge is that the plasma can be generated directly in the air (no need for additional working gases) and cover very large volumes. Low-temperature atmospheric pressure plasma is of great interest because it does not require special bulky vacuum equipment and is easy to obtain.

The technological application of the dielectric barrier discharge is very extensive. The use of this type of discharge in nanotechnology, medicine, and agroindustry can be particularly distinguished, which is associated with the possibility of processing heat-sensitive samples, such as polymers, nanomaterials, and biological organisms.

The development of agro-industry in the world is associated with new technologies necessary for growing and storing crops. As you know, protection from diseases and pests, stimulation of seed growth is an important part of the technology of growing crops. Pre-sowing treatment of seeds is one of the most important elements of the technology of growing agricultural crops, which makes it possible to increase their germination and protect them from pests. In addition,

pre-sowing seed treatment prevents the emergence and spread of a number of diseases during the growth and development of plants. At present, the role of physical methods of pre-sowing seed treatment is increasing, which is due to the urgent need to obtain environmentally friendly products and reduce the pesticide load.

One of the promising physical methods of seed pre-sowing treatment is treatment with low-temperature atmospheric pressure plasma. Plasma treatment is an alternative to chemical seed pretreatment and provides an environmentally friendly method of eliminating seed pests. A wide range of plasma sources such as radiofrequency discharges, bulk dielectric barrier discharge (DBD), dielectric coplanar surface barrier discharge (DCSBD), etc. are used for seed treatment. Nowadays a number of scientists out of numerous kinds of physical methods of seed pre-sowing treatment distinguish treatment of agricultural seeds by dielectric barrier discharge plasma as this type of discharge is generated at atmospheric pressure, possesses high biological activity of plasma and gas-kinetic temperature about 300 K, which enables to eliminate thermal effect during treatment of agricultural seeds with plasma of this discharge. In this case, non-ionizing radiation of low energy and numerous reactive particles, including reactive oxygen and nitrogen forms generated by plasma, can be used to cause desirable changes in a wide range of development of physiological processes in plants, increasing seed resistance to stress and disease, changing the structure of the seed layer, increasing the permeability of the seed layer and stimulating seed germination.

According to researches of some scientists, dielectric coplanar surface barrier discharge plasma can influence germination of agricultural crops seeds in the following ways: seed disinfection by deactivation of harmful microorganisms and bacteria, which can significantly improve sowing quality, introducing changes in the seed surface structure, increasing hydrophilicity, thus contributing to water absorption by seeds; changing chemical composition of treated samples by introducing radicals; stimulating seed growth by in Plant organisms produce special substances called enzymes or enzymes. These substances have the ability to induce and accelerate chemical reactions occurring in living organisms. Scientists study one type of enzyme, called catalase, because it breaks down peroxides to form molecular oxygen, that is, it breaks down peroxides that are harmful to the body, thereby protecting the body from external disorders. There are also several types of enzymes that catalyze hydrolysis reactions, otherwise known as hydrolases. These include the enzyme alpha-amylase, which hydrolyzes starch to form dextrins and maltose, which affects the further growth of plants.

The idea of this work is to study dielectric barrier discharge plasma at atmospheric pressure as applied to the technology of dielectric and biological materials modification, by studying the dynamics of macroparticles, the biological response of samples to plasma exposure, studying the disinfecting properties and the effect on the wettability of grains.

Dissertation work was carried out in accordance with the plans of fundamental research works: "Development of scientific and technological bases for increasing plant growth and yield of grain crops with the use of cold

atmospheric pressure plasma treatment" 2018-2020, cipher IRN AR05134280, "Investigation of the properties and influence of atmospheric pressure cold plasma on the surface of materials ". 2015-2017, cipher 3220/GF4.

The goal of the work is to study the properties of atmospheric pressure gas-discharge plasma as applied to the technology of seed pre-sowing treatment of grain crops and flow water treatment technology for various applications.

In order to achieve this goal, the following **tasks** must be accomplished:

– study electrical and optical properties, microdischarge structure of the barrier discharge plasma; study dynamics and interaction of separate spherical macroparticles, functional dielectric and biological materials with the surface barrier discharge plasma;

– analyze the influence of barrier discharge plasma on biological materials, particularly on seeding qualities, activity of hydrolysis ferment alpha-amylase of wheat grains and its application in technology of pre-sowing treatment of seeds;

– study the effect of barrier discharge plasma treatment on contamination by bacteria and microscopic fungi of wheat seeds; study the effect of atmospheric pressure plasma on the characteristics of flowing water.

The objects of the study are surface barrier discharge plasma at atmospheric pressure and functional dielectric, biological materials.

The subject of the study is static and dynamic volt-ampere characteristics of the dielectric coplanar surface barrier discharge, emission spectra of the discharge, the structure of DCSBD, the effect of atmospheric pressure plasma treatment on the dynamics of macroparticles of functional dielectric materials, the effect on biological materials, in particular on seeds and their germination, biochemical composition and on disinfection of the seed surface.

Research methods. For solving the problems necessary to achieve the goal, the following methods were used: methods of optical diagnostics of plasma, such as optical emission spectroscopy, methods for diagnosing the electrical characteristics of the discharge, methods for diagnosing the surface characteristics of crop samples, including electron microscopy, measuring the wettability of samples by contact angle measurements; methods for measuring the percentage of germination, growth parameters, a method for measuring constant mass by using an analytical balance; methods of analysis of biochemical properties of samples of agricultural crops.

The novelty of the work. The novelty and originality of the work lies in the fact that for the first time in it

- interaction of individual spherical macroparticles of different functional dielectric materials with microdischarge channels of surface discharge and their dynamics in the process of particles movement across the surface of discharge cell were studied, and it was suggested that there is an electrohydrodynamic effect which can cause effective transfer of long-lived reactive oxygen and nitrogen forms (RONS) due to gas flow enhancement;

- the influence of atmospheric pressure gas-discharge plasma on biological materials, particularly on the activity of the enzyme alpha-amylase in wheat seeds

at the early stage of germination has been studied and the relationship between the time of plasma treatment, alpha-amylase activity and biometric parameters of seedlings has been analyzed with regard to the technology of pre-sowing treatment; the relationship between the improvement of biometric parameters of seedlings due to biochemical changes in seeds due to the effect of active nitrogen forms and plasma oxygen was shown;

- it was demonstrated that the optimal time of plasma treatment for maximum seed germination does not correlate with the necessary treatment time for complete destruction of pathogens on their surface.

Scientific and practical significance of the work. The results obtained in the dissertation work are valuable for the development of low-temperature plasma physics and the use of low-temperature atmospheric pressure plasma in the agricultural industry. The results obtained may be useful for processing, cleaning and modifying the surface of biological materials, processing and improving the properties of agricultural crops. The results on studying the interaction of spherical macroparticles and surface discharge plasma may be useful not only from the fundamental point of view to determine the mechanisms of charging and action of electric and gravitational forces in atmospheric pressure plasma but also from the point of view of practical application for diagnostics of plasma properties, treatment of dispersed and powdered materials by means of dielectric barrier discharges. The results on the study of biochemical response of grain are very valuable for further deep understanding of the processes occurring in the interaction of cold atmospheric pressure plasma and seeds of crops, optimization and improvement of seed pre-sowing treatment technology. The data obtained in the study of flowing water treatment by atmospheric pressure plasma will be useful for scaling the technology of plasma activation of water, application in the development of sources of natural fertilizers and plant growth stimulators, the use of plasma-activated media on the water basis in plasma medicine and disposal of waste water contaminated with particularly persistent poisonous substances and chemical pollutants.

Provisions made for the defense:

1. With the inclusion of the barrier discharge plasma, the acceleration of the movement of macroparticles along the inclined surface of the installation at a power of 260 W decreased at an inclination angle of 5° by 36-47%, 10° by 13-30%, 15° by 2-6%, 20° by 3 -9% depending on the particulate material.

2. Treatment of wheat seeds with barrier discharge plasma for 5-15 s at 260 W leads to 20% increase of seed germination due to increased activity of hydrolysis enzyme alpha-amylase up to 1.0 mmE - mg-1 protein due to active influence of reactive oxygen and nitrogen forms.

3. Exposure to barrier discharge plasma at a power of 260 W on wheat seeds for up to 300 s increases the wettability of the grain surface and reduces the number of pathogenic fungi and bacteria.

The author's personal contribution lies in the fact that a significant amount of the work performed, including the development, assembly, adjustment and modernization of experimental facilities, the selection of a research method, the

conduct of experiments and the analysis of the data obtained, were performed by the author independently. The setting of tasks and discussion of the results were carried out jointly with the supervisors.

Reliability and validity of the results obtained

The dissertation work used well-known and proven experimental methods, such as methods for studying the electrical properties of plasma (current and voltage oscillography), optical diagnostic methods (optical emission spectroscopy, high-speed photography). Also, the reliability and validity of the results obtained are confirmed by publications in foreign journals with a high impact factor and in publications recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, and in the proceedings of international scientific conferences near and far abroad.

Publications. Based on the materials of the dissertation work, 14 printed works were published: 3 in journals from the List of the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan for the publication of the main results of the dissertation for the PhD degree and 3 articles in foreign journals with an impact factor included in the international information resource Web of Science (Clarivate Analytics , USA) and Scopus (Elsevier, the Netherlands); 7 papers in the proceedings of international scientific conferences and 1 innovation patent.

The volume and structure of the dissertation. The dissertation work consists of an introduction, 3 sections, a conclusion and a list of references from 141 titles, contains 93 pages of basic computer text, including 50 figures and 10 tables.