OZONIZER WITH SUPERIMPOSED DISCHARGE FOR INACTIVATION OF MICROORGANISMS

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The working characteristics of the sterilizer, which acts with use of ozone and ultrasonic cavitation, have been investigated. In this sterilizer the ozone is produced by ozone reactor with superposition of dielectric barrier discharge and surface discharge. The ozone concentration in sterilization bath was enhanced up to 10 mg/l owing to water temperature lowering to 15 °C with help of thermoelectric cooling module. The spectrometric researches of dielectric barrier discharge, surface discharge, and theirs combination have been accomplished. The experiments on bacteria sterilization in present sterilizer have shown that inactivation of Bacillus Cereus, E. coli, S. aurues takes 3…5 min, whereas the inactivation of spores requires 15 minutes.
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1. INTRODUCTION

At the present time the problem of low temperature sterilization is very actual. The ozone technologies with the use of the barrier glow discharge are one of the promising methods and a good alternative for the above-mentioned methods [1,2,3,4]. The expansion of the spheres of the application of ozone initiates new studies directed toward improvements in the characteristics of reactors for obtaining ozone. Different methods, connected with the pre-ionization in the main discharge, so-called dual discharges, also attract an attention [5]. The ozoniser with superposition of dielectric barrier discharge (DBD) and surface discharge seems as one of the most perspective.

Additional possibilities appear with generation of ultrasonic cavitation in ozonized media. In present work we investigated the low-temperature ozone sterilizer with ultrasonic cavitation.

2. EXPERIMENTAL APPARATUS AND METHOD

The ozone reactor with superposition of double barrier and surface discharges was used for ozone producing. The scheme of superposed discharge under atmospheric pressure is shown in Fig. 1. Dielectric barrier discharge was generated between two flat metallic electrodes (180×100 mm), which were coated with glass-enamel dielectric material, having a dielectric constant equal to 7 and a thickness of 0.2 mm. The high-voltage pulses were applied to these electrodes. The first of the electrodes for the surface discharge was composed of still strips of 2 mm width and was placed on the top glass-enamel surface. The second one was arranged on the bottom surface. The dielectric barrier discharge and the surface discharge have been excited by ac voltages of 8 and 4 kV respectively. The phase between applied voltages can be varied from 0 to 180°. Discharges were exited in dry air which after airflow controller flows through a 2.5 mm gap between electrodes. Parameters of these discharges were measured using ozone monitor, oscillograph, Rogowski coil and spectrometer. The data from these devices were processed by PC system with multifunctional plate input-output type L-Card L-783 (3MHz, 32 channels). The information system modules were based on C^{++}Builder-6.

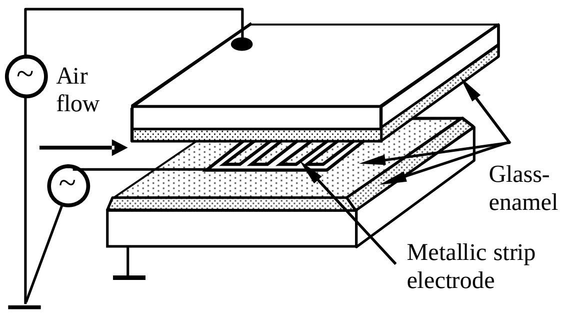

Fig. 1. Ozone reactor with superposition of barrier and surface discharges

3. RESULTS AND DISCUSSION

3.1. OZONE REACTOR CHARACTERISTICS

The ozone concentration at reactor output was measured for every of three possible regimes of its functioning: 1) surface discharge; 2) dielectric barrier discharge, and 3) the superposition of these discharges. The results presented in Fig. 2 shows that breakdown

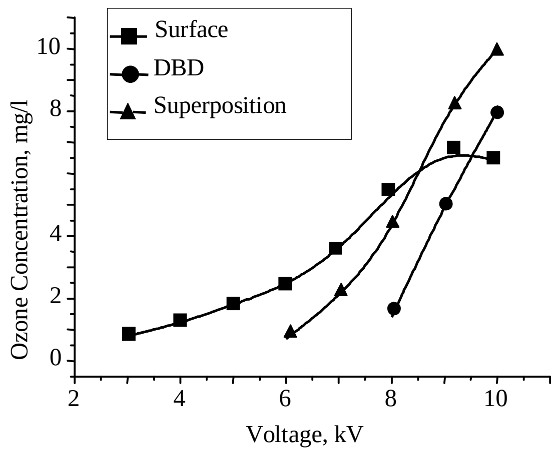

Fig. 2. Ozone generation characteristics of surface discharge, DBD and superimposed discharge

voltage required for the dielectric barrier discharge ignition is lower in combined discharge than in single barrier discharge (6 and 8 kV respectively). In addition, the ozone concentration is approximately 1.5 times greater in combined discharge than in DBD discharge.

The number of streamers, estimated by Rogowski coil, in superposed discharges is greater as compared to the singles DBD or surface ones. The maximal number of streamers is observed under the maximum phase shift, in 180°, between of voltages applied to the electrodes of surface and DBD discharges.

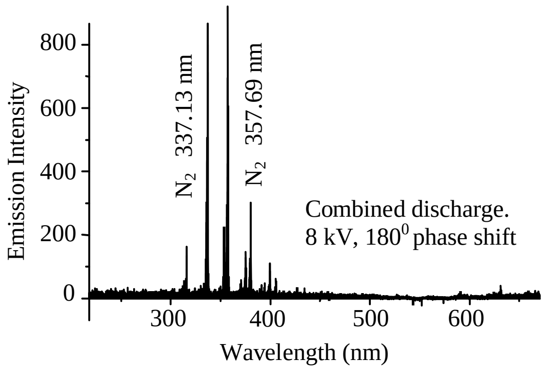

Fig. 3. Emission intensity for lines of N_2.in combined discharges under voltage of 8 kV and a phase shift in 180° between of voltages applied to the electrodes of surface and DBD discharges

Spectroscopic measurements, which were carried out on spectrometer SL40-2-3648USB, have shown the changes in concentration of nitrogen in dependence on parameters of discharges that was exited in pure air at one atmosphere and room temperature. Fig. 3 shows the emission spectra obtained over the wavelength range of 200…800 nm from surface and DBD combined discharges under phase shift in 180° between of voltages applied to surface and DBD discharges. The spectral lines intensity of nitrogen is maximal at phase shift in 180° that corresponds to the maximum electric field strength in the discharge gap of the reactor and connected with increasing the discharge power. The lines intensity in combined discharge under 180° phase shift between the applied voltages is substantially larger than in all others cases. The growth in ozone concentration is a consequence of the major intensity of combined discharge as compared with surface and DBD discharges.

3.2. OPERATING MODES OF THE STERILIZER

The functional diagram of sterilizer is shown in Fig. 4. From reactor an ozone-air mixture goes to the ultrasonic bath filled with distilled water. The ultrasonic source generates ultrasonic cavitations that enable the penetration of ozonized water into cavitations that enables the penetration of ozonized water into cavities and gaps of sterilized instruments and performance of theirs presterilization treatment. Water is cooling by thermoelectric cooler. The work of ozone reactor, ultrasonic source and thermoelectric cooler is headed by microprocessor. It is well known that ozone solubility strongly depends on water temperature. The considerable enhancement of ozone concentration and effectiveness of the sterilization may be provided by periodic switching and turning off of the ultrasonic source. When the water temperature is decreased to the lower designated limit, the ultrasonic source starts to operate, providing a cavitations that, in turn, causes water heating. When the water temperature reaches the upper of these designated limits, the ultrasonic source stops operating and water temperature drops. Fig. 5 shows the operating mode of sterilizer, when the upper setting temperature have been chosen at 15^0C, and lower level of temperature was 14^0 C. The initial water and air temperatures was 19 ^{0}C, the rate of air flow through the reactor was maintained near 0.2 l/min. The reactor yielded at these conditions the ozone concentration of 36 mg/l in air and near 10 mg/l in water.

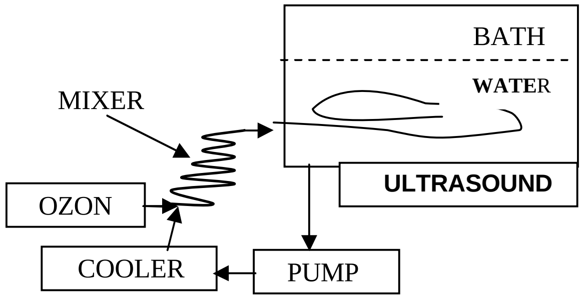

Fig. 4. Block diagram of sterilizer with a cooling module

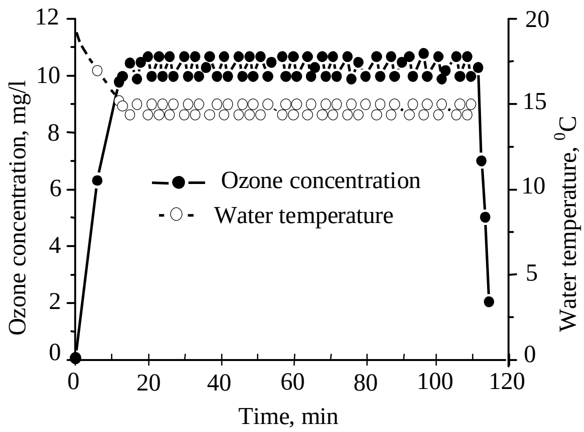

Fig. 5. Time dependence of ozone concentration under maintaining of water temperature between 14 and 15 ^{0}C

3.3. BACTERICIDAL INFLUENCE OF STERILIZER ON THE TEST-CULTURES OF MICROORGANISM

Experiments on the bacteria inactivation were carried out in ozonized distilled water. The following test-cultures of microorganism have been studied:

1. E. coli 055 K59 №3912/41, the Staphylococci aureus ATCC №25923, Pseudomonas aeruginoza 27/99 seeded on meat-peptone broth (MPB), as well as Cl.Oedematiens 198 and B. cereus № 8035 seeded on this medium.
2. Test-cultures seeded on the agar endo, 6, 5 % salt agar and meat-peptone agar (MPA) with 1% glucose. In the smears it is established 70…80% of spore culture Cl. Oedematiens 198 and B. cereus №8035. On the endo agar it is seen the increase of the colonies of dark-cherry color with the metallic luster. On the salt agar it is seen the growing of colonies of gray-white color. On MPA the colonies of blue-green color increased.

3. The isolated colonies were seeded on MPB and MPA.
4. The plasma-coagulation reaction is positive with the staphylococcal culture.
5. Daily cultures E. coli, Staphylococcus aureus, Pseudomonas aeruginoza and seven-day spore culture Cl. Oedematiens were placed into sterilization camera and processed by ozone and ultrasound over the time of 90 minutes. The control samples have been taken from the sterilization water bath after 1, 3, 5, 10, 20, 30, 60, 90 minutes for a microbiological analysis. During these time intervals the ozone concentration increased from 0 to the values indicated in second column of the Table.

Time-kill assay for some bacteries

Test - culture	Conc. O_3 in water From 0 mg/l to:	Water temper. from 0° C to:	Time-kill assay (min)
E. coli	1.8	19	2
Staphylococcus aureus	1.8	19	2
Pseudomonas aeruginoza	6	17.5	5
Cl.Oedematiens 198	8.5	16.25	10
B. cereus № 8035	10	15	15

It have been found that the complete inactivation of E. coli and Staphylococcus aureus is realized under small ozone concentration and demands no more than 2 minutes. Meanwhile, the most persistent micro organisms – spores B. cereus № 8035, takes 15 minutes during which the ozone concentration in water rises from 0 to 10 mg/l, and the temperature reduces from 19 to 15 ^{0}C.

CONCLUSIONS

The low-temperature sterilizers used for disinfection and sterilization in water has been developed and investigated. The combined action of ozone and ultrasonic cavitations in aqueous medium makes it possible to achieve effective cleaning of the articles of complex form with internal cavities and possibilities of the inactivation of microorganisms on tools of complex configuration.

Physical principles grounded in the sterilization process allowed applying such devices in industry and for everyday purposes, for instance: medical tools, biotechnology, microelectronics, food industry, automobile construction, household devices, etc.

The output ozone concentration from the reactor of 30 mg/l provided the ozone concentration in a sterilization bath (2.5 and 0.5 liters) of order 10 mg/l. This concentration was obtained due to a specially designed water cooling module.

The ozonizer with superposition of double barrier and surface discharges has been proposed as an alternative to double discharge-type generators. Two high-voltage pulsed power supplies of 10 and 20 W have been used in such an ozonizer equipped with three parallel electrodes (central, surface, and outer one).

The phase between applied voltages was varied from 0° to 180°. An increase of the phase displacement in the main discharge leads to an increase in the output concentration of ozone and nitric components in the consequence of an increase of the field strength in the reactor

The breakdown voltage in the superimposed discharge occurs with the smaller applied voltage as compared to DBD (6 and 8 kV, respectively).

The output ozone concentration increases with increasing the discharge power. An increase of the main discharge gap from 1.5 to 2.5 mm allows increasing the output ozone concentration.

ACKNOWLEDGEMENTS

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ОЗОНАТОР НА ОСНОВЕ СОВМЕСТНОГО РАЗРЯДА ДЛЯ ИНАКТИВАЦИИ МИКРООРГАНИЗМОВ

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Исследованы рабочие характеристики стерилизатора, в котором используется совместное действие озона и ультразвуковой кавитации. Озон вырабатывается в генераторе озона с суперпозицией диэлектрического барьерного и поверхностного разрядов. Концентрация озона в стерилизационной ванне – до 10 мг/л при температуре воды 15 °С. Выполнены спектрометрические исследования диэлектрического барьерного разряда, поверхностного разряда и их комбинации. Проведенные эксперименты по уничтожению бактерий показали, что инактивация Bacillus Cereus, E. coli, S. aurues занимает 3…5 мин, а для уничтожения спор требуется 15 мин.

ОЗОНАТОР НА ОСНОВІ СУМІСНОГО РОЗРЯДУ ДЛЯ ІНАКТИВАЦІЇ МІКРООРГАНІЗМІВ

В.С. Таран, О.Г. Чечельницький, В.В. Красний, О.М. Швець

Досліджено робочі характеристики стерилізатора, у якому використовується спільна дія озону й ультразвукової кавітації. Озон виробляється в генераторі озону із суперпозицією діелектричного бар'єрного і поверхневого розрядів. Концентрація озону в стерилізаційній ванні – до 10 мг/л при температурі води 15 °С. Виконано спектрометричні дослідження діелектричного бар'єрного розряду, поверхневого розряду і їхньої комбінації. Проведені експерименти по знищенню бактерій показали, що інактивація Bacillus Cereus, E. coli, S. aurues займає 3…5 хв., а для знищення спор потрібно 15 хв.