UDC 533.9

# DESIGN AND INVESTIGATION OF HF-OZONATORS

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In the present activity the ozonators with the time modulated power supplies and reactors (plate-type and tubular) operating on the base of surface barrier discharge are investigated. The measurements of the main specifications of the reactor at the average power level up to 50W were performed using spectroscopy diagnostic. The relationships of the output concentration of ozone on the temperature of the reactor, frequency and power of a source, air injection rates were obtained and discussed in detail. In addition, on the basis of the performed experiments the geometrical parameters of reactors were optimized. Some types of reactors and power supplies with the power up to 500W were designed. The prototypes of ozonators for medical purposes, agriculture and household applications have been manufactured.

## 1. INTRODUCTION

Ozone technologies are widely applied in different areas stimulating the further investigations of ozone generation processes. Thus, the development of generators alongside with power supplies of a new type for obtaining the optimal ozone yielding rates has become a problem of the highest importance. It is well known that different types of discharges are applied for ozone generation, which in its turn determine the following construction and power characteristics of ozonators. Our special attention has been paid to the problem of developing the ozonators on the base of glow barrier discharge with a pulsed power supply operating at different frequency ranges up to the super-high frequencies [1-3]. The efficiency of ozone yielding rate depends on different parameters, namely: the temperature in discharge, the geometry and shape of electrodes, the electrode material including a dielectric one, air flow rate, etc.

The surface barrier discharge is known to be among the most promising methods used for ozone generation [4]. By investigating such discharges a new and more efficient ozonators could be designed.

In the present paper different types of reactors of ac-current with power supply frequency from 1 to 50 kHz have been investigated. The high ozone concentration is obtained due to micro discharges with the duration of tens nanoseconds. The utilization of the time-modulated power supply allows to improve the ozone yielding rate more than 20% [5]. The measurements of ozone concentration for different reactors at the average power level of 50W were performed using spectroscopy diagnostic. The dependencies of the ozone yielding rate on different parameters such as: the temperature, the pulse frequency, air flow rate, applied voltage were obtained.

## 2. EXPERIMENT AND DIAGNOSTIC

The ozone generation process in a surface barrier discharge in air and at atmospheric pressure with and without time-modulated power supply was the subject of our investigation. A schematic diagram of the experiment is shown in Fig.1. Different types of reactors were used for ozone generation. In reactors, presented in Fig.2 (a, b), the air was fed through a discharge gap without limitations of the flow rate, whereas, in Fig.2(c) the air flow rate was limited by the dimensions of the internal dielectric tube and a wire mesh, which served as the internal electrode. The

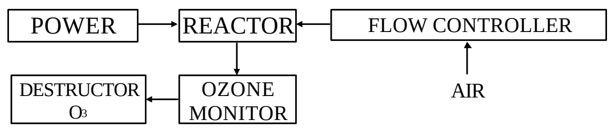



*Fig.1. Schematic diagram of the experiment*

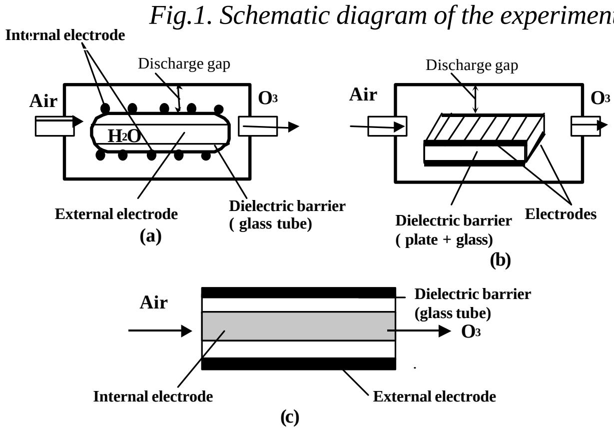
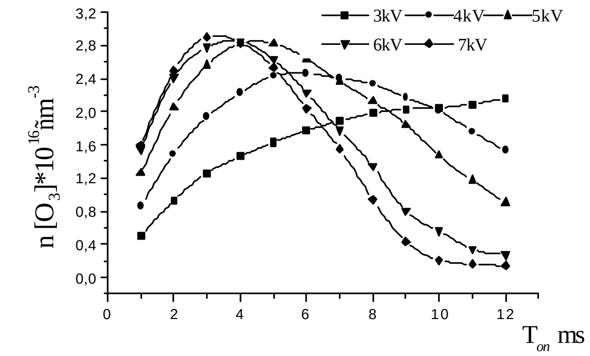



Fig.2.(a, b ,c) Discharge reactors

reactor dimensions were varying during the experiment.

The power supplies of two types were developed. The first one is transistored, its characteristics are listed below:

| | |
|---|---|
| Output voltage- | 2,6-15 kV; |
| Converter power | 1000 W; |
| Modulation frequency | 2Hz-21 kHz; |
| $T_{on}$-$T_{off}$ | 1,05-5 |



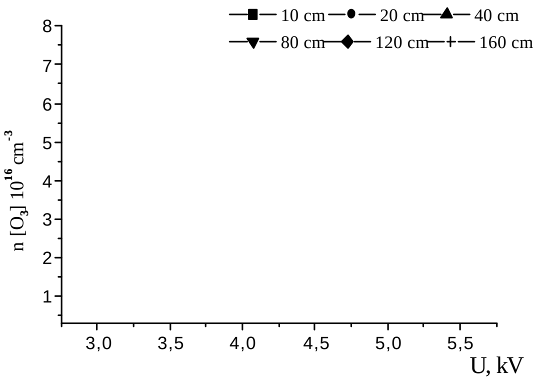
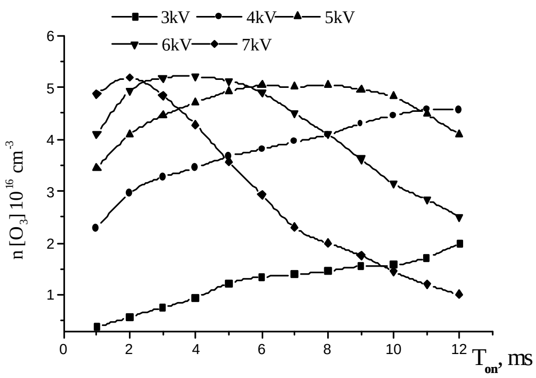




*Fig3. Dependence of ozone concentration on $T_{on}$ with different applied voltage. $T_{pulse}$=16ms, ,$L_{reactor}$=10cm, Q =0,8l/min, t°=const*

*Fig4. Dependence of [O3] concentration on applied voltage with different reactor lengths. Without time- modulation. Q =0,8l/min*



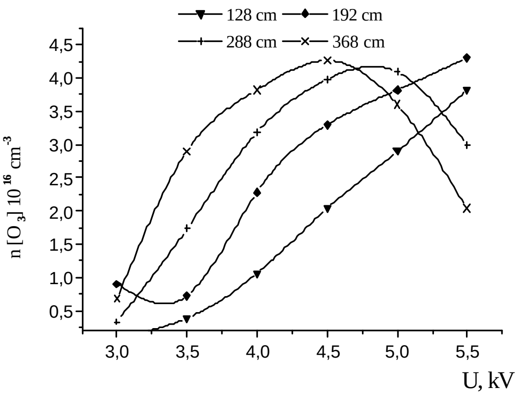
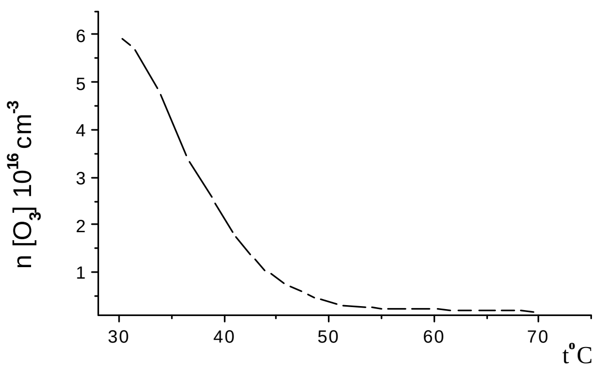




*Fig5. Dependence of ozone concentration on $T_{on}$ with different applied voltage. $T_{pulse}$=16ms,$L_{reactor}$=368cm, Q =0,8l/min, t°=const*

*Fig6. Dependence of [O3] on applied voltage with different reactor lengths. Without time-modulated signal and pulses. Q =0,8l/min*



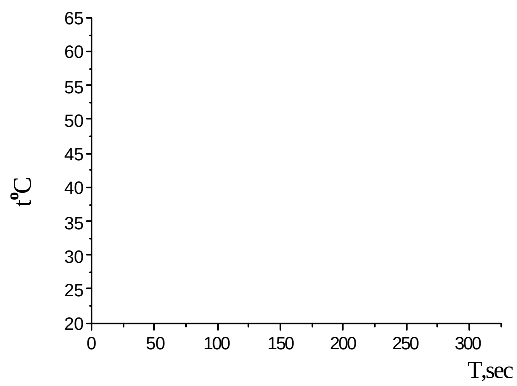




*Fig.7. Dependence of ozone concentration on the temperature of air in reactor.*

*Fig.8. Time dependence of the reactor temperature. Without cooling. Q =0,8l/min*

**TABLE 1 Improvements in n [Î$_3$] by Time-modulation of power supply**

I. F=0,8(l/min), L=10(cm)

| $P_w$ | System | $n[O_3]$ $*10^{16}cm^{-3}$ |
|---|---|---|
| 4 kW | C.W. | 3,6 |
| | Time-modulated | 4,5 |
| | C.W | 3,6 |
| 5 kW | Time-modulated | 5 |

II. F=0,8(l/min), L=386(cm)

| $P_w$ | System | $n[O_3]$ $*10^{16}cm^{-3}$ |
|---|---|---|
| 4 kW | C.W. | 1,9 |
| | Time-modulated | 2,5 |
| | C.W | 1,5 |
| 5 kW | Time-modulated | 2,9 |

Variation of a power supply frequency -10-50 kHz

The second type of the power supply, being thyristor one, was applied in a small-power ozonators:

| | |
|---|---|
| Output voltage | 3 - 8 kV; |
| Power | 20 W; |
| Generator frequency | 25 kHz, |
| Pulse duration | 12 ms, |
| Duration leading edge | 200 nsec. |

The ozone concentration was determined by chemical and spectroscopic methods. In particular, the changing in ozone concentration was measured using the absorption method in absorption band with ë=253.7. A photoelectric multiplier and a monochromator served as detectors. The error in determining the ozone concentration was 10E+14 due to a low-frequency drift of the photoelectric multiplier.

From the reactor outlet, the ozone was fed to a gas cuvette, whereas the air flow rate injected through the reactor was controlled by a gas rate-of-flow indicator. The air temperature was controlled by the thermal converter and mercurial thermometer.

$O_3$ is produced in short time after the discharge – on by the dissociation process of $O_2$ to O. The life-time of O (10 nsec) is much shorter than that of $O_3$ (more than several minutes depending on the circumstances), leading to the fact that there exists time difference between $O_3$ production and decomposition. Introduction of time – modulated power-supply with an appropriate $T_{off}$ can be effective for improving n [$O_3$]. One can predict that the $O_3$ production decreases with T, whereas $O_3$ dissociation increases, a fact which works to the disadvantage of high $P_w$ in the discharge space and to requirement of a cooling system for practical uses of $O_3$ production by discharges. Time-modulation (on-off modulation) of the power supply would be one possible way to reduce $P_w$, to achieve n[$O_3$] identical to the case of CW power supply.

Dependence of ozone concentration on different voltage applied, for reactor 10 cm in length using time-modulation is shown in Fig.3.

Fig.4. shows the dependence of ozone concentration on different voltage applied at a constant frequency of a power supply with different reactor length (10,20, 40,80, 120,160 cm)

Analyzing the represented dependencies one can conclude that:

a). when applying the time-modulated pulse it is possible to increase its amplitude decreasing the pulse duration.. This lead to increase of [O3] concentration and allows to decrease a power consumption. Therefore, the efficiency is higher in this case. (See Tab.1.(I)).

b). for reactor with 10cm in length and with applied voltage of 4 and 5 kV, n[$O_3$] is higher for time-modulated power supply.

c). the increase in power leads to improvement of the ozone yielding rate when applying $T_{on}$–$T_{off}$ modulation.

d). the increase of the reactor length also provides increasing of the ozone yielding rate. Moreover, when increasing the reactor length, the maximal ozone concentration could be attained at lower voltage (which is selected optimally for every reactor length). n[$O_3$] have a tendency to decrease with the following increase in voltage.

One can draw an analogy when considering the dependencies presented in Fig.5,6 Tab.1 (II).

It should be noticed that, in this case, the increase of the reactor length took place in a parallel way unlike the case shown in Fig. 3-4. In so doing, a sequential increasing of the reactor length provides an essential increase of n[$O_3$] as compared with a parallel one. The dependence of ozone concentration on the air temperature in reactor and time-dependence on the reactor temperature without application of the cooling systems are presented in Fig.7,8 respectively. The obtained dependencies were found to be very helpful for the optimization of the ozone producing devices.

## 3. CONCLUSIONS

Experiments were performed with different reactors applied in a surface barrier discharge using a time-modulated power supply.

We summarize the obtained results as follows:

1. The ozone yielding rate increases more than 15% with the use of a time-modulated power supply as compared with conventional continuos-wave one. $T_{on}$-$T_{off}$ time, for optimal ozone outlet, is strongly dependent on the reactor construction.
2. The optimal conditions for ozone generation considering the reactor geometry, applied voltage, time-modulation and the air flow rate were obtained
3. Two types of the power supplies with a power up to 1 kW were designed. Pilot models of ozonators used for different purposes have been constructed.

## References


[1] V.V. Lunin, M.P. Popovich et.al.//J. Physical chemistry Moscow: MSU,(1998) p.480

[2] R.A. Ahmedzhanov, et.al. Investigation of the ozone production process in nanosecond SHF-discharge in air and oxygen //J. Tech. Phys.**Vol.66**,(1997),pp.9-17.

[3] V.S.Taran, O.M. Shvets, E.N. Babich. A selection of practical application of the HF-discharge for plasma technologies // J. Prob. of Atomic. Science and Technology, **Vol. 3(3),3(4),** (1999), pp.276-279

[4] S. Masuda. et. al. Ceramic-based ozonizer // Proc. IEEE JAS, Toronto, Canada (1985), p.1353

[5] O. Kazuyuki, et. al. Improvements of ozone yielding rate in atmospheric pressure barrier discharge using a time-modulated power supply // Proc.IEEE Transaction on plasma science, **Vol.(27)6**, (1999), pp.1582-1586