STUDIES OF AN AIR DISCHARGE IN A GAP WITH DIELECTRIC ON THE ELECTRODE

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ABSTRACT

The aim of the work is to correlate the ozone formation with the conditions of the discharge development in a gap with dielectric on the electrode. Experimentally and theoretically is found that the ozone synthesis depends on the electric field in the gap, this field being formed not only by the external source but by the charges on the dielectric as well.

INTRODUCTION

Our previous studies of the discharge were carried out on an ozonizer model that consisted of an air gap with a dielectric on the electrode. The increse of the frequency of the applied voltage leads to a marked decrease of the discharge current impulse amplitude and a decrease of the ozone formation. For air such marked change of the current amplitudes and the ozone concentration is seen for a critical frequency f= 1000-1500 Hz. These experimental results were presented to the ISH-79 in Milan [1].
The discription of the model and the measurments as well as the experimental results are given in [1]. The width of the air gap was 1,5-2,5 mm, the dielectric used were glass tubes, organic glass or a layer of glass ceramic put on one of the electrodes. Depending on the material of the dielectric its layer was 1,1-2,5 mm thick.
As in [1] there is no analysis of experimental results the aim of the present work was to fulfill this shortcoming.

2. EXPERIMENTAL

In our subsequent work 2 the dust figure method was used for detection of the charges left on the dielectric surface after a discharge in the air gap. The experiments have shown that if the voltage is applied for a long time there is seen a change in the character of the dust figure pattern when the critical value of the frequency is reached. The traces of individual discharges begin to mix giving an indefinite picture. When the frequency exeeds 2000-2500 Hz no charge at all is seen in the whole central part of the dust figure.
The measurments have shown that the sensibility of the dust figure method for our conditions is such that a charge having density more than $3,4.10^{-9}$ Coulomb/cm^2 can be detected on the surface. It means that the charge on the "blank" parts of the

dust figure is less than the above value. Previous measurments have shown that for each individual discharge (for instance for d.c. voltage) a charge is left on the dielectric surface having density 5-10 times higher: $1,5 - 3,5.10^{-8}$ Coulomb/cm² . Thus it is seen that with frequency rise the distinct pattern of the charge distribution disappears and its value begins to be less by an order. The ozone concentration decreases simultaneously. The same dependence of the impulse current amplitude and the ozone concentration on the surface conditions of the dielectric was reported before [3]. If small spots of half-conducting material ($\rho_s = 10^6$ Ohm) are placed on the surface of the dielectric having $\rho_s > 10^{14}$ Ohm, the mean value of the current decrease and the ozone concentration is 2 times less (fig. 1).

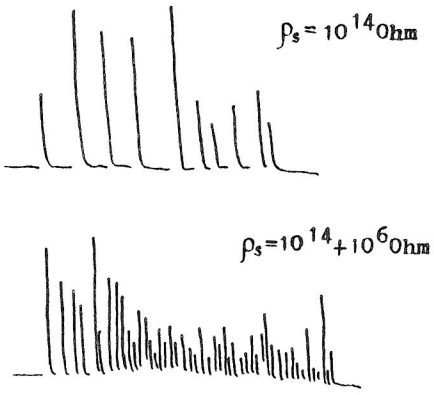

Fig.1
Oscillograms of current impulses

If a resistance is put into the discharge cercuit its value varying from 20 to $6,9.10^6$ Ohm a change is seen both in the impulse current and in the ozone concentration (fig.2). As a result it may be said that by a change in the discharge circuit an optimum value of the ozone concentration is reached.

It must be noted that the thermodynamical conditions of the gas in the discharge area was the same in all our experiments. The gas cooling prevented the ozone destruction.

3. DISCUSSION

The analyse of the experimental results permit to suppose that in all cases (when the frequency or the surface resistivity are varied, or the discharge current is limited) there is a a change in the conditions of the discharge development in the gas gap. As a result the ozone concentration is changed.

Indeed: the discharge in the gap involve processes in gas and on the dielectric surface [2]. In a whole these procrsses create a charge that is left on the dielectric surface and that influence the electric field in the air gap at the moment when a new discharge starts in the next half-period of the applied voltage. Each value of the electric field intensity define a certain value of the discharge current. A change in the field strength leads to a change in the intensity of the ionization processes in the gas, a change in the energy distribution of the electrons and - as a result - a change in the ozone concentration.

It seems that not only the amplitude but the duration of the current impulse governs the ozone formation. Using a measuring circuit with a constant $\tau < 5$ ns and an oscillograph with the

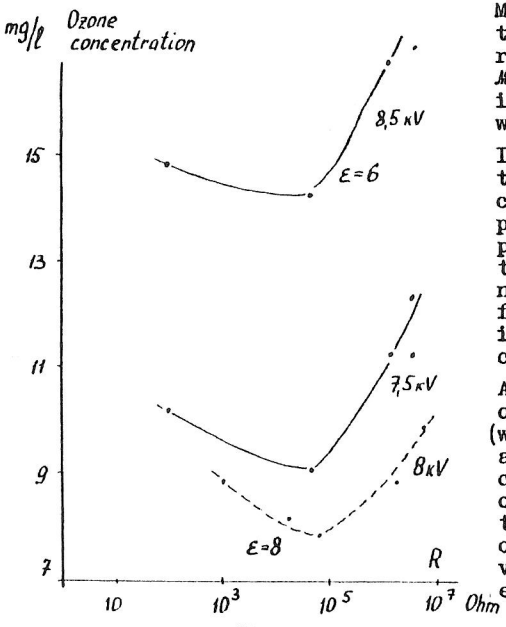

Fig.2
The influence of current limiting resistance on the ozone concentration

frequency band up to 2 MHz it was found that the duration of the current impulse is 0,5-1 Ms, the front of the impulse being shorter with lower amplitude.

If it is assumed that the amplitude of each current impulse corresponds to the electronic part of the current, i.e. the intensity of the ionization processes, then for the more powerful impulses there must be created more electrons.

As is shown in [4] the ozone formation process (when free electrons are available) needs 1-10microseconds and depends on the impulse form of the applied voltage. In our case the applied voltage is formed by the external source, by the net charge and by the charge on the dielectric surface. The current impulse being less means that the time of the presence of the electrons in the gap is less and may not be sufficient for the formation of the ozone.

But it is only one side of the problem. On the other side, the experiments show that there are processes (the cause of which is yet not known) that lead to a decrease of the current with frequency rise or with a decrease of the equivalent value of surface resistivity.

The main reaction that leads to the formation of ozone is the dissociation of the oxigen molecule. In our earlier work [5] we have found that the maximum probability of the oxigen dissociation process lies in the 4,5 - 12 eV energy range and falls rapidly if the electron energy exeeds 12 eV. It means that to have more ozone, such an electron energy distribution must be formed that gives maximum part of electrons with energy in the range of 4,5 - 12 eV.

On fig.3 there are shown some calculated curves corresponding to the "tail" part of the electron distribution function in oxigen. The calculation method used [5] describes the "tail" of the distribution function as

$$\varphi(W) = \frac{P}{\lambda_0 E/p} \exp\left(-\frac{pW - p_d W_d}{\lambda_0 E/p}\right), \qquad (1)$$

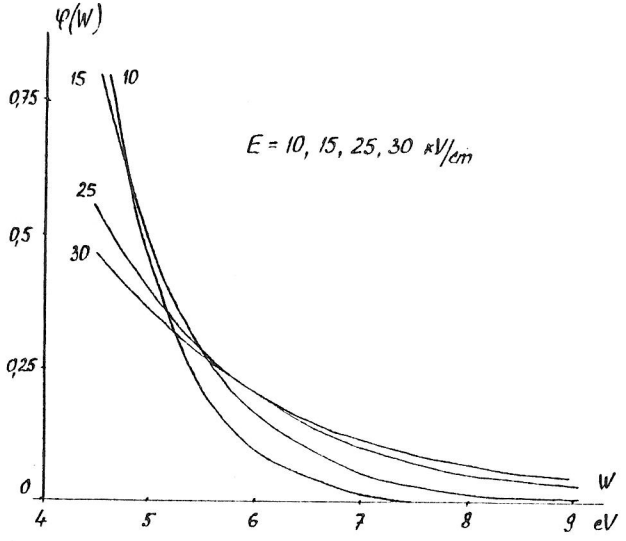

Fig.3
The energy distribution function in oxigen for different values of electric field

where $P = P_e + P_d$ is the sum probability of the electron energy losses on the elastic collisions and collisions with dissociation of oxigen molecule; λ_o - is the mean free path; and W_d -the dissociation energy. Equation (1) is valid only for energies higher than 4,5 eV and less than 12 eV, that is when there are no ionization processes.

From (1) it is easy to calculate the quantity of electrons with energy in 4,5-12 eVrange

$$A = \int_{W=4,5eV}^{W=12eV} \varphi(W)\, dW.$$

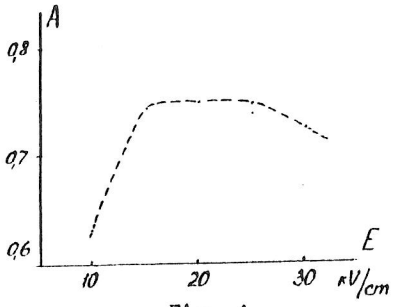

Fig. 4
Dependence of integral on the electrical field

The dependence of A on the electric field strength is presented on fig.4. It is clearly seen that there are optimum values of the field intensity corresponding to the maximum probability of oxigen dissociation. These optimum values were found to be 20 - 25 kV/cm. If the external field (formed by an external source) is the same but the field of the charges on the dielectric begins to vary because of the varying charge density then then there appear less electrons with

efficiency for dissociation and less is the ozone concentration So a decrease or increase of the current impulses must lead to a decrease in the ozone production.

The cause of the variation in the density of the charges left on the dielectric may be different: it may be the change in the surface resistivity of the dielectric; the limiting of the discharge current; the change in the dielectric characteristics (its thickness, its ε value etc) or some processes in gas preventing the net charge to come to the dielectric surface.

4. CONCLUSION

1. The rate of the ozone production is governed mostly by the intensity of ionization processes that is characterised by the impulse current amplitude and by the dissociation process as a result of collisions with electrons of a certain energy.
2. The amplitude of the current impulses is under the influence of the surface processes that depend on the ε value of the dielectric and on the development of the surface discharges.
3. For each kind of dielectric, each length of the gas gap, each gas and the frequency of the applied voltage there is an optimum value of discharge current that corresponds to an optimum value of the ozone produced in the discharge. This optimum current may reached in an electric field of a certain value. For oxigen this value is 20 - 25 kV/cm.
4. The field that governs the discharge processes is formed not only by the applied voltage but by charge on the dielectric surface. The amount of this charge in its turn depend on some processes connected with frequency rize. The nature of this connection must be the aim of future studies.

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