COMPARISON OF GAS DISCHARGE FORMS PRODUCING OZONE

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ABSTRACT

The discharge forms in ozonizer models supplied by sine wave and impulse voltages of different slopes are investigated optically. Side-on shutter photographs, surface discharge and streak photographs are taken. The transition from single channels to homogeneous discharges is recorded and discussed.

1. INTRODUCTION

Ozone is produced in large extents in gas discharges with at least one electrode covered with a dielectric. Ozonizers can be built up as glass-glass or metal-glass configurations either with flat or with tubular electrodes. They are normally supplied by sine wave voltages with frequences up to several hundred cycles per second.

Recent investigations have indicated that the efficiency of ozone production may be increased by using impulse voltages. The high value of the reduced electric field E/p combined with impulse voltages influences the discharge mechanism and by that the ozone production.

The understanding of the discharge mechanism of ozonizers fed with sine wave and impulse voltages will be the first step to optimize ozone production.

2. EXPERIMENTAL

Two electrode configurations are built up to investigate the discharges in the gap as well as the creep discharges on dielectrical surfaces.

By using slightly curved electrodes (model A) it was possible to get single discharges at a fixed position. Flat electrodes are used to investigate the surface discharges on a plane glass plate and the degree of homogenity of discharges over a larger area (model B, Fig. 1).

Surface discharges could be recorded by pressing a high speed film covered with a thin glass layer of 0.15 mm thickness on the plane dielectric electrode.

The discharge models can be run either with frequences of 50 to 300 s^{-1} sine wave or by impulse voltages. Fig. 2 shows the electrical circuits.

By varying the charge voltage of C_s and the values of C_s, C_p and R_d (Fig. 2) it is possible to get different voltage slopes at the ozonizer. Risetimes of the voltage were up to 1 kV/ns.

Discharges with different time delays to breakdown t_d appear if square wave impulses with different overvoltages U_d are supplied to the ozonizer model. Different overvoltages are connected with different E/p values. Overvoltage and time delay depend on polarity.

If breakdown shall occur at a distinct E/p corresponding to a distinct U_d one can estimate the maximum risetime of voltage from the voltage time curve in Fig. 3.

With these test arrangements side on photographs of the discharges are taken with a fast image converter camera in streak and shutter mode. The maximum time resolution is 0.84 mm film/ns respective 50 ns. The camera is triggered by the discharge current because of the statistic time lag to breakdown of the discharge. As the camera and the trigger amplifier have a deadtime of about 50 ns an optical delay consisting of an image transmission length of 20 m is used. - All experiments are taken in atmospheric air.

3. MEASUREMENTS

Fig. 4a shows a shutter photograph of a single discharge taken with model A. The test-set is supplied with 50 s^{-1} sine wave voltage. The gap distance is 4 mm. A creep discharge is clearly detectable at the dielectric surface.

In comparison to this Fig. 4b shows a similar shutter photograph from the same model with the distinction that the test arrangement is supplied by an impulse voltage with 150 % overvoltage. In this case the gap distance is 2 mm. The discharge is voluminous and seems to be nearly homogenous.

Polarity dependent surface discharges are recorded on a photographic film put directly on the glass plate of model B. The air gap is 2 mm and the glass dielectric has a thickness of 1,1 mm.

With positive polarity at the dielectric electrode and with 50 s^{-1} sine wave voltage near the inception point only a few discharges appear (Fig. 5a). The diameter of each discharge pattern on the surface is about 7 mm.

Supplying model B with impulses of only 6 % overvoltage the character of the discharge begins to change. Several single discharges are combined to a larger luminous area (Fig. 5b). If the overvoltage is higher that 8 % only one nearly homogeneous glow covering the whole discharge area can be seen (Fig. 5c).

With negative polarity at the glass dielectric remarkably different positive surface discharges appear. At sine wave inception voltage only one discharge covering an area with nearly electrode diameter is recorded (Fig. 6a). The root of the channel discharge from the gap can clearly be seen (diameter 1 mm).

With pulsed discharges and overvoltages of 60 % several single discharges can still be distinguished but a spatial homogeneous discharge pattern appears at some places between the distinct surface discharges (Fig. 6b). In comparison with the opposite polarity discharges get nearly homogeneous only at much higher overvoltages of about 200 % (Fig. 6c).

Streak photographs of a single event demonstrate the rapid development of the discharges. Fig. 7 is taken with a positive metal electrode and a 4 mm gap of model A. A cathode directed streamer is visible starting in the middle of the gap. The velocity increases towards the cathode. After the streamer has reached the cathode a transient glow bridges the gap and fades out after some ten ns /1/. The mean velocity of the first streamer is about $0.9 \cdot 10^8$ cm/s with 50 s^{-1} sine wave voltage supply and reaches values of $2.5 \cdot 10^8$ cm/s with impulses of 70 % overvoltage.

4. DISCUSSION AND RESULTS

The transition from single channels to homogeneous discharges can be understood if the number density of primary electrons and the electron diffusion in the heads of avalanches is taken into account. With rising E/p the number of avalanches starting from the cathode at the same time increases and the discharge becomes more homogeneous by overlapping of the heads of the avalanches /2/.

In the case of metalic cathodes (see Fig. 3 and 5) primary electrons are easier released from the surface than from dielectric cathodes (Fig. 6) so that lower overvoltages are sufficient to give enough primary electrons for homogeneous discharges /3/.

The surface discharge patterns resulting from negative respective positive charge accumulations on the dielectric surface are quite different. In the case of negative surface charges no roots of discharge channels at sine wave voltage supply can be detected. It may be concluded that the electron cloud is distributed homogeneously by electric repulsive forces immediately in front of the surface. - With the opposite polarity distinct surface discharge channels (Lichtenberg figures) are detected. The propagation velocity of this surface discharge is measured optically. It is of the order of $1.0 \cdot 10^8$ cm/s.

5. CONCLUSIONS

The discharge proceedings of sine wave respective impulse voltage supplied ozonizers are rather similar. Using impulse voltages the discharge becomes voluminous. With metal cathodes even at several percent overvoltage homogeneous discharges appear. The degree of homogenity depends on polarity and the value of the overvoltage. - In comparison to sine wave fed ozonizers the mean velocity of the first streamer rises with the value of the overvoltage. The reduced electrical field strength is enlarged promoting ozone production.

In sine wave voltage supplied ozonizers ozone is produced essentially in the first streamer. The E/p-value increases towards the cathode dramatically. In addition ozone is produced in creep discharges. The creep discharges are fed by charge carrier accumulations which arise from very fast events. That is why surface discharges act like impulse discharges.

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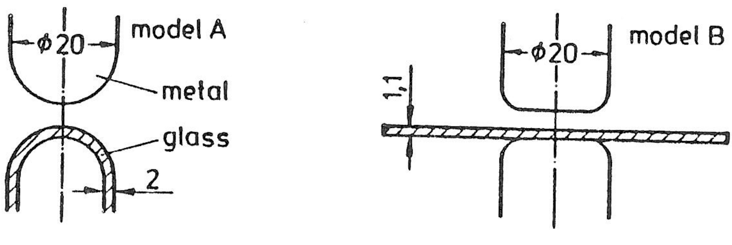

Figure 1: Electrode configurations for investigations of single discharges (model A) and surface discharges (model B)

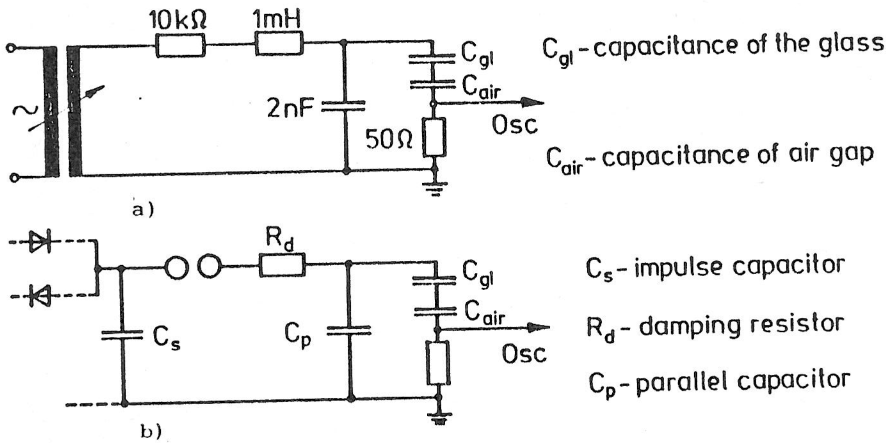

Figure 2: Electrical circuits for a) sine wave voltage and b) impulse voltage supply

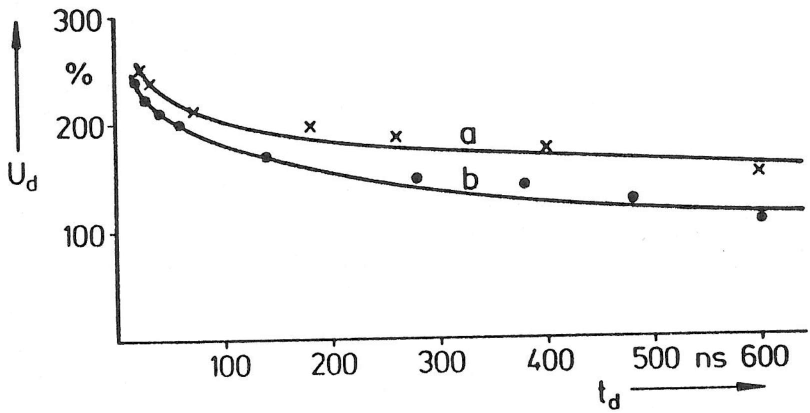

Figure 3: Voltage time curves of model B (a) positive and b) negative metal electrode

a) b)

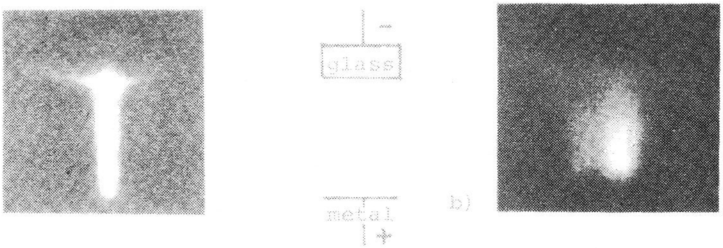

Figure 4: Shutter photographs of single discharges
a) sine wave, b) impulse voltage

a) b) c)

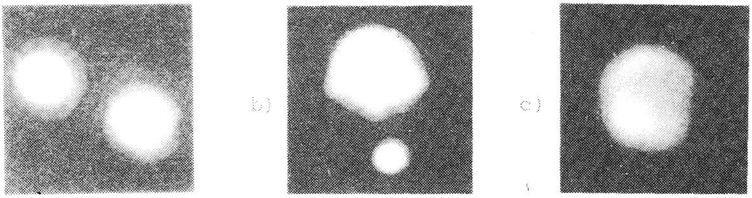

Figure 5: Negative surface discharge patterns
a) sine wave inception voltage, b) impulses of 6 % and c) of 8 % overvoltage

a) b) c)

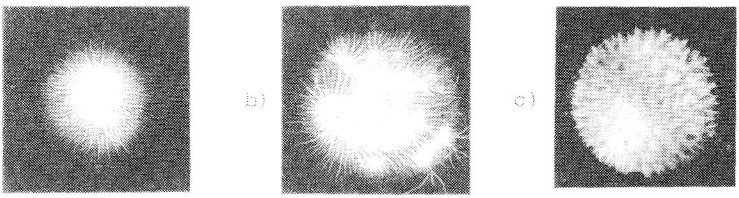

Figure 6: Positive surface discharges
a) sine wave inception voltage, b) impulses of 60 % and c) of 180 % overvoltage

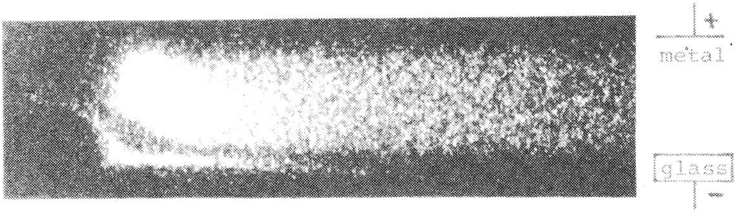

Figure 7: Streak photograph (positive metal-, negative glass-electrode, sine wave voltage, 4 mm/ns)