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Charge Transfer in Light Effect Under Visible Radiation in an Ozoniser Discharge

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ABSTRACT

Two fresh discharge vessels (1 and 2) of Siemen's ozoniser type having the same height but different surface-to-volume ratios have been fabricated by enclosing argon at 10 mm mercury. By immersing these in electrolytic solution and by subjecting these to a definite high 50 Hz ac voltage, the discharge count rates in dark $(C_f)_D$ and under light $(C_f)_L$ have been determined using a scaler held at different bias-voltages. The plot of the ratio $(C_{1f} / C_{2f})_D$ and $(C_{1f} / C_{2f})_L$ of discharge counts versus pulse height (bias-voltage) shows that this ratio for a constant potential of 3.5 kV (rms) is initially large in value, then rapidly decreases to a minimum. It is also observed that more is the surface-to-volume ratio, more is the magnitude of net effect of irradiation. Further, the pulse height analysis shows that the charge carried by the pulses to the electrodes (charge transfer) decreases under illumination. A possible mechanism to explain the net effect of the discharge current ratio in the light of pulse height measurements is discussed.

Keywords: Electromagnetic radiation, ozoniser discharge, light-effect pulse height, discharge count, charge transfer

1. INTRODUCTION

Considerable data on the effect of electromagnetic radiation on gas discharge has been accumulated in the past several years. Although different theories[1-5] have been putforth to explain the effect, the basic cause of its occurrence does not seem to have been fully understood yet. In all the earlier studies, the phenomenon has been studied in terms of a net change in the discharge current using different measuring devices such as galvanometers, oscilloscopes, etc, usually under ac excitation. The results obtained by various researchers vary rather largely. It may be so because the study under ac excitation becomes complex because it is governed by several factors such as amplitude, waveform and frequency of the applied potential, nature of current detector, gas pressure, nature of solid-gas interface, and electrical quantities, eg, the inter-electrode capacitance and spectral response of the source and detector[6], etc. Also, since the discharge mainly consists of discontinuous pulses, the current measurements may not be very meaningful. It is desirable to investigate the light-effect from the standpoint of the total charge transferred by the pulses in the discharge process.

2. EXPERIMENTAL PROCEDURE

2.1 Experimental Circuit

Argon at 10 mm mercury was filled in the annular region between two all-glass (quartz) unused tubes differing in dimension to form a Siemen's

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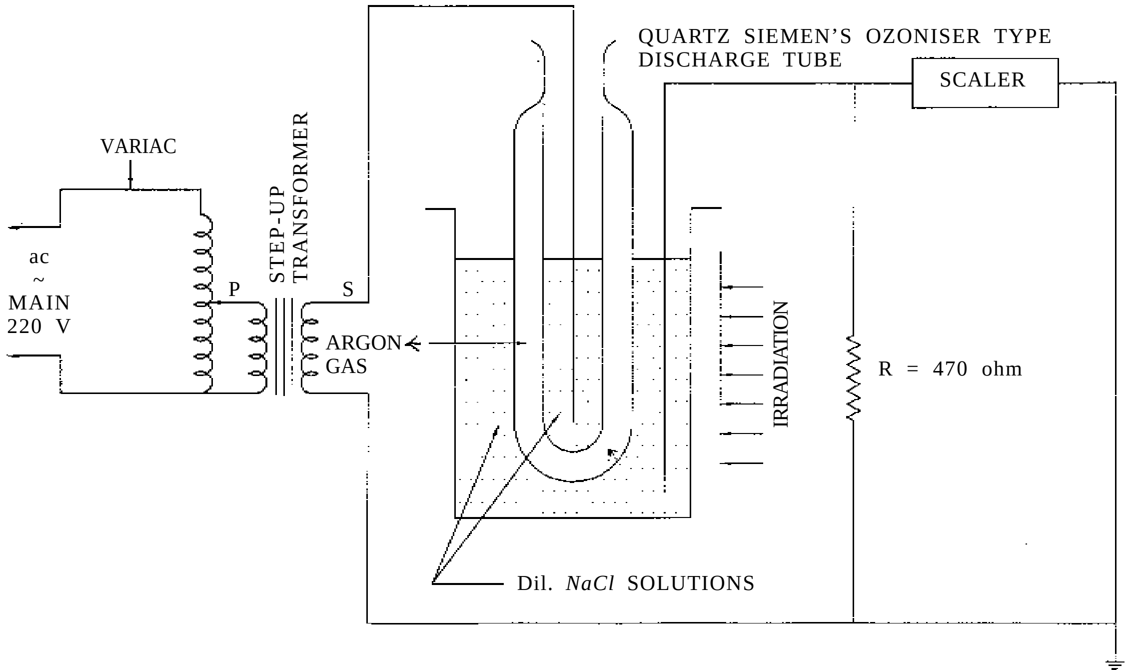

Figure 1. Circuitry for comparative measurement of discharge counts in different vessels filled with argon at *p*=10 mm mercury.

ozoniser-type system Fig. 1. The inner cylinder contained an electrolyte (a dilute solution of sodium chloride), while the outer cylinder was in contact with the identical electrolyte contained in a beaker. A metal wire dipping in the inner electrolyte was connected to the high tension terminal of a stepup transformer while the other identical wire dipping in the outer one was earthed through 470 Ω coupling resistance (*R*) connected in series. A counter scaler was directly connected across 470 ohm. A variac connected to [230 V (rms), 50 Hz] supply served to change the voltage applied to the primary of the high tension transformer. The voltage at the secondary (ie, applied voltage) was calculated from the knowledge of the stepup ratio (1:70) of the transformer and the voltage at the primary.

The discharge tube was activated to 3.5 kV(rms). The pulses developed across the coupling resistance *(R)* were fed to the scaler counter, which consisted of rectifier and a non-overload amplifier. The pulses of desired height were counted for 1 min applying a proper bias. The analysis or pulse height was carried out alternately in dark as well as under electromagnetic radiation.

The source of white light was a 15 W tungsten filament clear glass lamp operated on main supply and placed at 30 cm from a discharge tube. The radiation was allowed to fall on the outer cylinder of the ozoniser. Though the beam is parallel, its angle of incidence may vary due to the cylindrical shape of the ozoniser tube. In the present experiment, two fresh discharge tubes (systems) were used. The surface area-to-volume ratio of tube 1 was greater than that of the tube 2.

2.2 Methodology for Preparation of Fresh Tubes

Day-to-day operations of the experimental vessel, can tarnish the surfaces of glass walls. With this tarnished electrodes, it is not easy to obtain reproducible values of counts since the count rate is often intermittent, presumably due to local changes on surface of the glass walls. It is therefore necessary to remove the adsorption in layers from the surface of electrodes to obtain reproducible value of counts. The surfaces of the discharge tube were freed from the adsorbed gases by the following process. The discharge tube was heated in a heater box fitted with heater coils and then cooled slowly to the room temperature. The heating at 100^o C for 4 h wipes out its previous history[7]. Thus, the heating brings the condition of the tube near to that of the fresh one and such a tube is henceforth referred to as fresh tube using a subscript *f*.

3. RESULTS AND DISCUSSION

3.1 Charge Transferred in the Discharge Process

The area under the individual pulse in the discharge process can be considered as a quantity proportional to the charge transferred by the pulse. If N_i is the number of pulses of V_i volts occurring during time (t), the charge transferred by these will be proportional to N_iV_i. The total charge transferred, q, by all the pulses of varying amplitudes in the discharge process during the time (t), can be expressed by the relation.

$$q + K_1 \sum_{V=0}^{V=V_{max}} N_i V_i$$

where K_1 is the constant of proportionality.

Now, if N represents the number of pulses having amplitudes ≥ V then dN will be the number of pulses having amplitudes lying between V and $V+dV$ volts. Therefore, the charge transferred by these pulses will be VdN. Hence

$$\sum_{V=0}^{V=V_{max}} N_i V_i = \sum_{N=N_{max}}^{N=0} V.dN$$

since at $V = V_{max}$, $N = 0$ and $V = 0$, $N = N_{max}$

As mentioned earlier, in the measurements using the utility scaler, the counts correspond to the number of pulses of amplitudes equal to or greater than the value set on the discriminator bias. Hence, the area under the curve, counts/minute versus the discriminator bias, would represent a quantity proportional to the charge transferred in a minute between the dielectric electrodes of the tube.

It may be mentioned here that the present investigation is governed by many factors[6]. Hence, to eliminate their effects, the ratio of count rates of two fresh tubes (C_{1f}/C_{2f}) has been investigated. It has been found that under irradiation from 15 W incandescent glass bulb in the first fresh tube, the pulses (counts/min) of heights < 15 V increase in number (the positive effect), whereas those having heights >15 V decrease considerably in number (the negative effect) to approach zero which amounts to almost the complete suppression of the discharge counts. The result is similar to the previous finding[8,9]. However, pulses of height > 35 V increase only slightly in number in tube 1 and displays a point of inversion (Fig. 2).

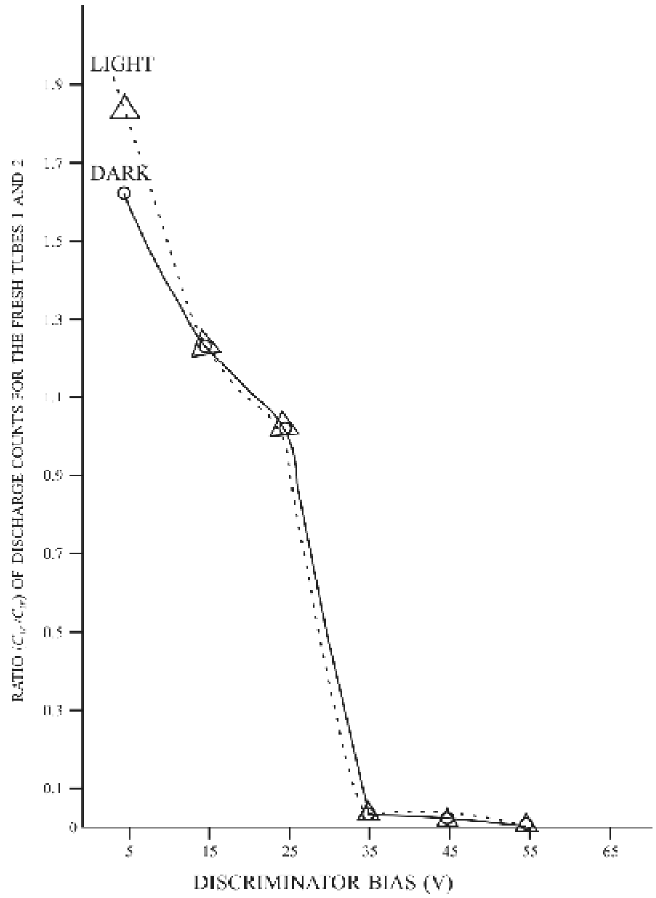

Figure 2. Ratio (C_{1f} / C_{2f}) of discharge counts for the fresh tubes 1 and 2 filled with argon at p = 10 mm mercury as a function of bias-voltage.

3.2 Electrical Discharge in Argon before and after Irradiation

The characteristics of volume ozoniser based on the bias, variation of discharge counts before and after visible radiation, have been taken 3.5 kV (rms). Sets were obtained in two different tubes.

From these observations, the charge transferred per minute (in arbitrary units) was calculated for each set, using the method described earlier. Two interesting conclusions have been drawn which embrace both the positive and negative effects:

(a) The influence of irradiation is to cause a net decrease in the charge transferred per minute.

(b) The parallel nature of the curves in the plot of charge transferred against the applied voltage shows that the reduction in charge transferred is independent of the applied potential within the potential-range studied. It is interesting to note that a similar trend was observed for different optical filters[10].

3.3 Pulse Height Variation of the Discharge Current Ratio

Figure 2 compares the change in the ratio (C_{1f}/C_{2f}) of discharge counts for sizes of discharge tube 1 over tube 2 before and after the radiation during the period of discharge for argon. From the figure, the following observations has been made.

The solid and broken curves show both the positive and negative effects of irradiation and it varies instantaneously and reversibly due to irradiation in the range + (0.208 – 0.001) for bias–voltages of 5-55 V.

3.4 Effect of Irradiation and Potential Gradient

Below the breakdown potential (V_g), ie at applied potentials $V < V_g$, the field gradient in the discharge space is linearly variant with the distance separating the two electrodes, cathode and anode, used[11]. It is different with a marked gradient near the wire-in–cylinder-type vessels used by other workers[12]. This potential distribution in the discharge space is of great importance in determining the magnitude of the effect. The potential gradient controls the actual number of electrons produced in an avalanche due to an initiating electron generated by any secondary process, from low-tension electrode or in the gas phase. That is, the potential gradient determines the amplitude of the pulses. Thus, it was instructive

Table 1. Pulse height spectrum of the ratio of discharge counts for tube 1*f* to that for tube 2*f* for a constant potential

Bias-voltage (V)	Ratio of counts* in dark $(C_{1f}/C_{2f})_D$	Ratio of counts* in light $(C_{1f}/C_{2f})_L$	$\Delta(C_{1f}/C_{2f})$
15	1.246	1.230	− 0.016
25	1.160	1.155	− 0.005
35	0.024	0.024	0.000
45	0.016	0.022	+ 0.006
55	0.007	0.008	+ 0.001

* Annular surface coated with *NaCl* in H_2O solution. Pressure of argon in the tubes 1 & 2:10 mm mercury, system-temperature: 27° C, frequency of ac supply: 50 Hz, potential employed to the system: 3.5 kV(rms), and source of irradiation: 15 W, 230 V glass bulb

to consider from the results in Table 1 that on irradiation by incandescent lamp of 15 W, the pulses of shorter (≤ 15 V) amplitudes showed the positive effect + $\Delta(C_{1f}/C_{2f})$, of irradiation while those of longer (> 15 V) amplitudes showed the negative effect, and pulses of amplitudes > 35 V were enhanced.

Further, in the absence of external irradiation, an electron formed in the gas phase acquires energy due to the potential gradient. Then it starts ionization by collision after travelling a fixed distance away from the low-tension electrode in the potential gradient. The number of electrons produced in the avalanches which determines the pulse height [*cf*.–$D(C_{1f}/C_{2f})$] is governed fundamentally by potential gradient. The observations that under light are initiated + $\Delta(C_{1f}/C_{2f})$ of the same height (bias) as of those produced in dark. It suggests that the electrons initiate under light. It causes ionization by impact roughly from the same point to give approximately the same number of electrons. It constitutes the increased ratio (C_{1f}/C_{2f}) of discharge counts. It could occur only when the potential distribution between the low-tension and high-tension electrodes was unaltered by the external radiation.

4. CONCLUSION

Two fresh discharge tubes, denoted by the subscripts 1*f* and 2*f* of symbol C, containing welldried and purified argon at 10 mm mercury were selected for this investigation. Using these tubes separately and with an operating voltage of 3.5 k V (rms), the measurement of discharge counts before and after the irradiation at different voltages of bias was taken. Then ratio of discharge counts (C_{1f}/C_{2f}) with and without irradiation for the fresh vessels $1f$ and $2f$ were measured. Their difference gives the net effect, $\Delta(C_{1f}/C_{2f})$, of irradiation. The effect occurs in all parts of the visible spectra (from ultraviolet to the red-end of the spectrum), which can neither dissociate nor ionize the molecules. The lower values of bias show an increase in number $+\Delta(C_{1f}/C_{2f})$, while the bias between 5 V and 35 V shows diminishing number $-\Delta(C_{1f}/C_{2f})$ and for biases > 35 V, the amplitudes are completely enhanced. Reversal $+\Delta(C_{1f}/C_{2f}) \leftarrow\rightarrow$® $-\Delta(C_{1f}/C_{2f})$ with bias–voltage suggests the simultaneous occurrence of $+\Delta(C_{1f}/C_{2f})$ and $-\Delta(C_{1f}/C_{2f})$. These variations and reversals may probably be applied to the net charge transferred and the results of net charge transfer are to be shown nearly the similar. These variations may be attributed to the larger surface area-to-volume ratio of the tube 1.

A few researchers have reported that even an extremely faint ultraviolet ray (such as reflection from the wall of a room, the intensity of which is too faint to be measured) is enough to stop an intermittent visible discharge and the discharge starts again as soon as the irradiation from outside is cutoff. This phenomenal truth may probably be applied as a sensitive detector of radiation, which can convert, with high efficiency, a variation in the external radiation to a variation in the current, and may find useful applications in high-voltage network. The production of light effect in discharge tubes by external nuclear radiations[13] and the recent finding of the occurrence of negative light effect by internal nuclear irradiation[14] [eg, by the addition of radio-iodine (^{131}I) to iodine vapour under discharge] can be useful in the field of nuclear engineering and technology.

REFERENCES

1. Pimpale, S.G. Comparison of hysteresis and anti-hysteresis in potential variation of a time effect on the ratio of discharge counts in different gases at a definite low pressure subjected to corona discharges. *In* Contemporary science and technology, edited by R.P. Singh. Allied Publishers (Delhi), 1996. GP-30.

2. Pimpale, S.G. Influence of surface resistivity on the time dependence variation of counts in air subjected to electrodeless discharge. *In* Contemporary science and technology, edited by A. K. Gwal. Allied Publishers (Delhi), 1998. pp. 415-18.

3. Pimpale, Sushama S. & Pimpale, S.G. Effect of external irradiation on the leakage time constant in a sleeve discharge and the associated light effect. *In* 9th International Symposium on the Science and Technology of Light Sources, 12-16 August 2001, Cornell University, New York, USA, pp.103.

4. Pimpale, Sushama S. Effect of charge fluctuation on current pulses and instability in a plasma produced in admixture of gases subjected to dc corona discharge. *Ind. J. Pure Appl. Phys.*, 2001, **39,** 155-58.

5. Khan, M. & Bhattacharya, A. Design, fabrication and characterisation of a capacitatively-coupled RF discharge plasma system. *Ind. J. Phys.*, 2003, **77B** (3), 323-26.

6. Pimpale, S.G. & Pimpale, Sushama S. Production of the relative effect of irradiation in hydrogen under silent electric discharge. *In* XIIth National Symposium on Plasma Science & Technology, Gandhinagar, 2-5 December 1997, PPA-55.

7. Navaneeth, G.N. & Mande, C. Studies on dc discharges between metal-glass electrodes. *In* Proceedings of the All Indian Symposium on Recent Developments in Gas Discharge Phenomena, *Nagpur Univ. Sci. J.*, 1971, **2**, 36.

8. Pimpale, S.G. Pulse height spectral studies of ozoniser discharges in argon at a moderate pressure and the associated Joshi effect. *Def. Sci. J.*, 1976, **26** (4), 157-60.

9. Pimpale, S. G. Studies of pulse height distribution and associated charge transfer in argon under field due to constant pulsating potential. *In* 10th National Symposium on Plasma Science & Technology, Varanasi, 1995. GP-25.

10. Mande, C. & Kanitkar, P.L. A study of charge transfer in the Joshi effect. *Nagpur Univ. Sci. J.*, 1970, **1**(1), 62-68.

11. Khosla, B.D. & Ramaiah, N.A. Oscilloscopic studies of Joshi effect and secondary processes in a low frequency electric discharge. *J. Phys. Soc.*, 1955, **10**(2), 1069.

12. Venugopalan, M. Photosensitivity of electrical discharges in gases. *Nagpur Univ. Sci. J.*, 1970, **1**(1), 22-32.

13. Venugopalan, M. Influence of x-rays and γ-rays on the discharge current in chlorine under ozoniser excitation. *Nuovo Cimento***,** 1965, **B40**, 375.

14. Arnikar, H.J. & Nene, M.G. Suppression of the discharge in iodine vapour due to radio-iodine (^{131}I). *J. Elect. Cont.*, 1963, **14**, 389-92.

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