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PROCESSES OF IMPULSE BREAKDOWN IN N$_2$-O$_2$ GAS MIXTURES AND IN AIR AT LOW PRESSURE

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INTRODUCTION: The impulse breakdown processes were observed for N$_2$-O$_2$ gas mixtures and for dry air at low pressure by an image converter camera. The results of time-resolved photographs are presented and the influence of the electro-negative gas O$_2$ on the breakdown process is discussed.

EXPERIMENTAL CONDITIONS: The tested electrode arrangement was a needle point (1mm tungsten rod with hemi-spherical cap) to plane (16cm brass) gap 8 cm long and was installed in a Pyrex glass cylinder of 18cm diameter and 45 cm in length. A positive impulse voltage, 1.6~150 kV, with breakdown probability between 20% and 80% was applied to the point. The gas pressure reduced to 20°C was kept at 15 torr. The gases used in the gas mixtures indicated by the oxygen content $P_0$% were 99.995% pure for both N$_2$ and O$_2$. Dry air was also used for comparing the results with those obtained in the gas mixtures.

RESULTS AND DISCUSSION: A) Breakdown Process. The breakdown process can be divided into two types each with three phases of discharge. As the initial phase of the process, the first corona streamer (FCS), the ionizing wave (IW), secondary mid-gap streamers (cathode directed streamer (CDS) and anode directed streamer (ADS)) and the diffused luminous wave (DLW) occur in a sequence and is independent of the oxygen content. After the DLW reaches the anode glow (AG) in front of the anode, the intermediate phase of the process starts. In this phase, a positive column forms and develops from anode to cathode with the growth of discharge current. The transient positive column consists of a diffused positive column (DPC) and a filamentary positive column (FPC). However, this phase of discharge can be divided into two distinct types of the transient glow, as shown in Fig.1(a). In the first type, for the range between $P_0$ = 0% and 9%, no cathode streamers (CS)/1/ appear. The second type is as follows; for the range between $P_0$ = 10% and 100%, a series of the CS advancing from the negative glow (NG) to the DPC appear. Furthermore, the breakdown process for $P_0$ = 21% shown in Fig.1(a) becomes very similar to the one in air as shown in Fig.1(b), and the mean frequency ($f_w$) of the CS increases from about 20kHz to 300kHz with the oxygen content in the range 10~100%, as shown in Fig.2. As the final phase of the process, the DPC reaches the NG, the discharge current increases rapidly and the transient glow changes into the transient arc without a Faraday dark space (FDS). In short, two types of the breakdown process in the N$_2$-O$_2$ gas mixtures may be illustrated schematically as shown in Fig.3.

B) Negative Glow and Transient Positive Column. Fig. 4(a) and (b) show the current density $J_N$, in the NG and $J_p$, in the positive column obtained as a ratio of the discharge current, I, to the luminous cross section which was measured in the framing photograph. $I$-$J_N$ characteristics and the values of $J_p$ are approximately the same as those of dc glow discharge. On the other hand, the current density of the DPC in the range 0.05~2 A/cm$^2$ and the FPC in the range 2~30 A/cm$^2$ is the same as that of the positive column in dc glow discharge and the arc column in dc arc, respectively/2/. According to a spectroscopic study, 1st and 2nd positive band systems of N$_2$ are strong in...
(a) The breakdown process for Po = 0–9 % (Type I)
(b) The breakdown process for Po = 10–100 % (Type II)
(c) Framing picture of the figure (b)

Fig. 3 Conceptual figures of the breakdown processes in N₂–O₂ gas mixtures

(a) Negative glow  (b) Positive column at the distance 1 cm from anode

Fig. 4 Discharge current versus current density in the negative glow and the positive column

(a) N₂ 1st pos. band  (9–6)  (b) N₂ 2nd pos. band (0–0)  
(c) N₂ 1st neg. band  (0–0)

Fig. 5 Relative intensity of N₂ and N₂ band spectra for various discharge phases at Po = 21 %