Photographic Action of High–Voltage Electric Discharge

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Photographic action of high-voltage electric discharge was studied applying direct current voltage of about 4000 to 9000 V with a configuration of two electrodes and a film in between. Photographic records of discharge for both positive and negative signs were obtained, and their densities as well as stretch or diameter of the developed image were measured under various exposure conditions. Positive discharge led to formation of Lichtenberg's figure, and in this case, stretch of image increased proportionally with an increase of the applied voltage. Negative discharge formed simply circular images, and their densities or diameters varied with complexity according to sensitive materials, applied voltages, electrode distances and exposure time. It is noticeable as an unusual behaviour that a resin coated photographic paper showed higher sensitivity towards negative discharge than a panchromatic or a orthochromatic film.

Introduction

Photographic technique has been hitherto used to study or to record electric discharge phenomenon[1,2], and more recently, much interest in Kirlian Photography using high-voltage electric discharge was taken by biologists, psychologists and other researchers[3]. The authors has previously reported a technique of high-voltage discharge photography and mentioned experimental conditions for image formation of Lichtenberg's figure and also showed some records of objects by electric discharge[4,5]. But, knowledge about photographic action of electric discharge on sensitive materials is not yet sufficient to discuss image formation from the standpoint of photographic science. In this paper, basic characteristics of sensitive materials towards action of high-voltage electric discharge will be reported.

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Experimental technique

Action of high-voltage electric discharge was recorded by an arrangement shown in Fig. 1. A rod electrode was placed above an aluminum plate electrode on which a piece of photographic material was layed with its emulsion side upwards. High-voltage of about 4000 to 9000 V (variable x (V)) was applied between two electrodes which were kept each

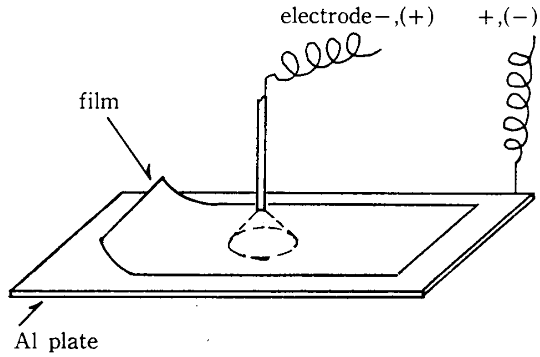


Fig. 1 An arrangement for electric discharge recording.

other with a definite distance (variable y(mm)). Exposure time varied from 1 to 100 s (variable z (s)). A voltage-multiplying rectifier circuit shown in Fig. 2 was used as a power source which supplied D. C. voltage of up to 10,000 volts. As sensitive materials, Neopan SS panchromatic sheet film, A 1 orthochromatic sheet film and Fujibro W P FM 3 resin coated paper were used, and after a definit time of exposure, they were developed with specified formulae to give final images.

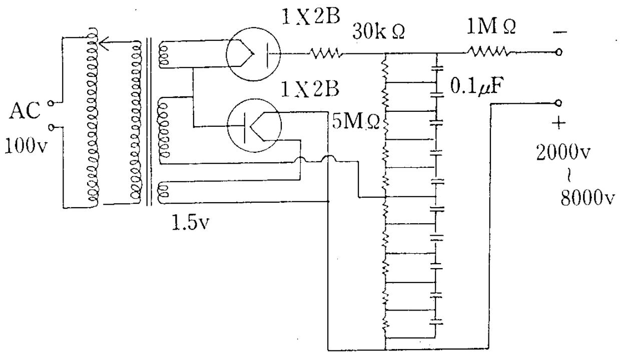


Fig. 2 A voltage-multiplying rectifier as a high-voltage source.

Results and discussion

Observation of discharge.

For both positive and negative potential supply, phenomena accompanied by discharge around the rod electrode were observed in a darkroom. When negative potential of several thousands volts was applied to the rod electrode, merely a brightening spot was observed at a pointed end of the rod electrode. On the other hand, when positive potential was applied to the rod electrode, glow corona discharge was observed under a mild condition where no spark discharge occurred. A photographic record of positive discharge is illustrated in Fig. 3, which was taken by Neopan 400 (ISO 400) panchromatic film with an ex-

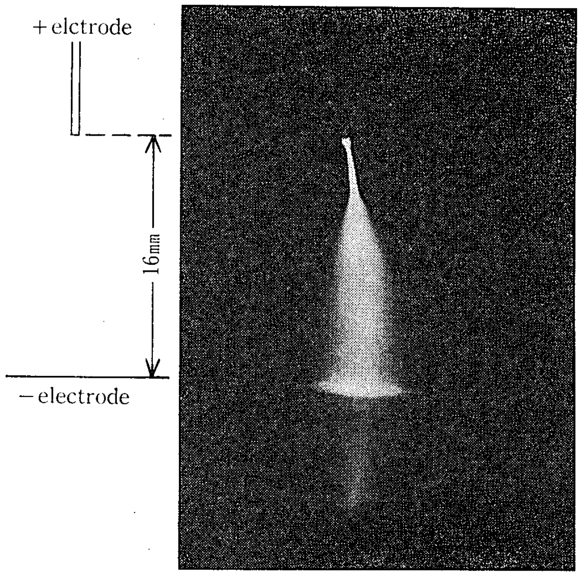
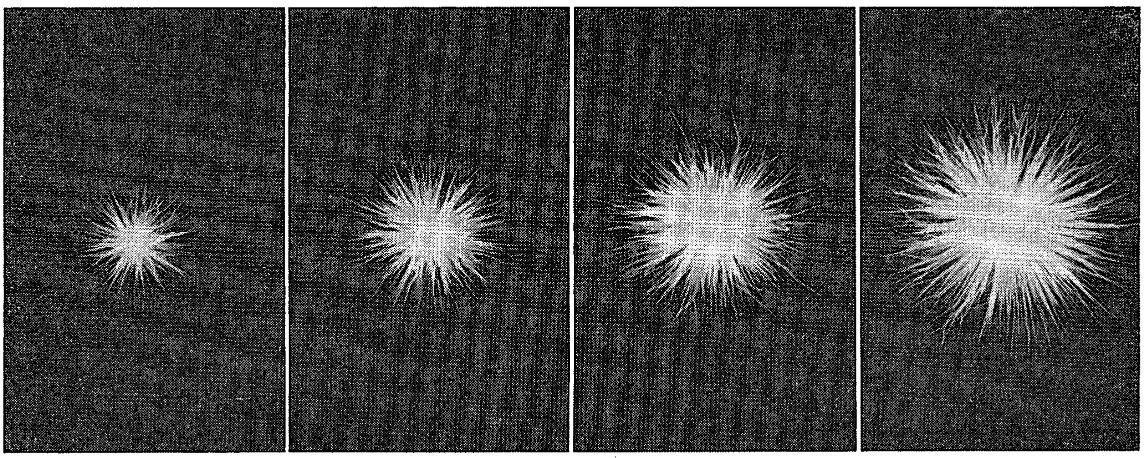


Fig. 3 A photogaph of corona discharge.



3400v 4200v 5200v 7200v

at 1mm,5s

Fig. 4 Relation between image stretch and electrode potential.

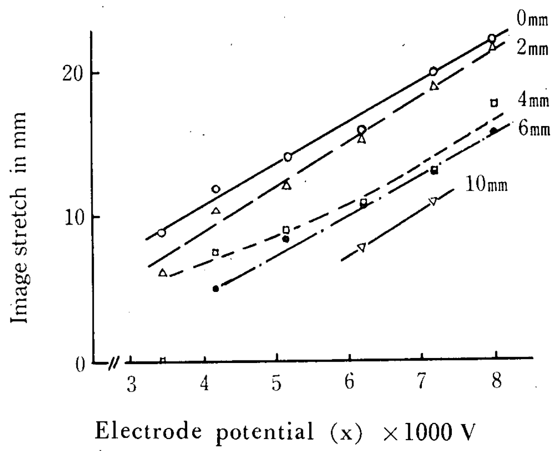


Fig. 5 Relation between image stretch and electrode potential.

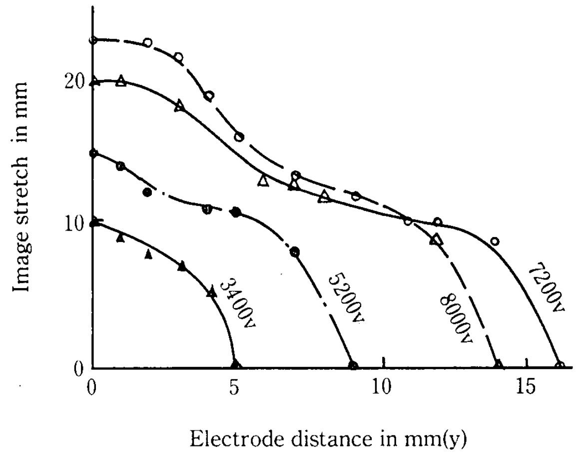


Fig. 6 Ralation between image stretch and electrode distance.

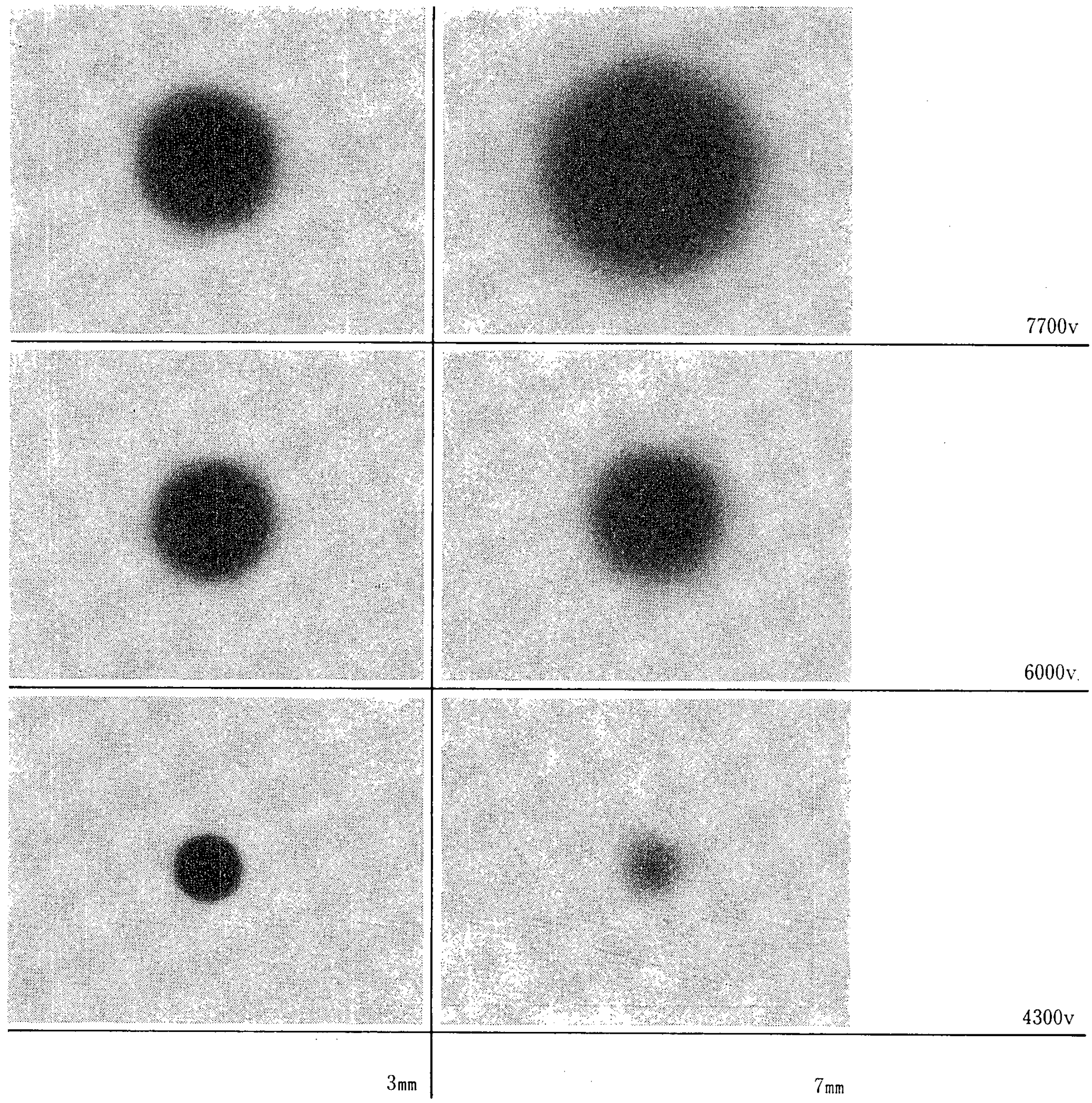


Fig. 7 Records of negative discharge.

posure of 3 min. In this case, a potential of 9300 V was applied between the electrodes having a distance of 16 mm long, and this condition gave a weak glow corona discharge which was almost invisible with naked eyes. As the photograph of Fig. 3 shows a fine shape of discharge, contribution of considerable extent of invisible radiation is suggested.

Lichtenberg's figure

High-voltage positive discharge forms Lichtenberg's figures as shown in Fig. 4. The figures in Fig. 4 were recorded by Neopan SS panchromatic sheet film using various steps of voltage (x) from 3400 to 7200 V with electrode distance of 1 mm and exposure of 5 s. In this case, stretch of whiskerlike images

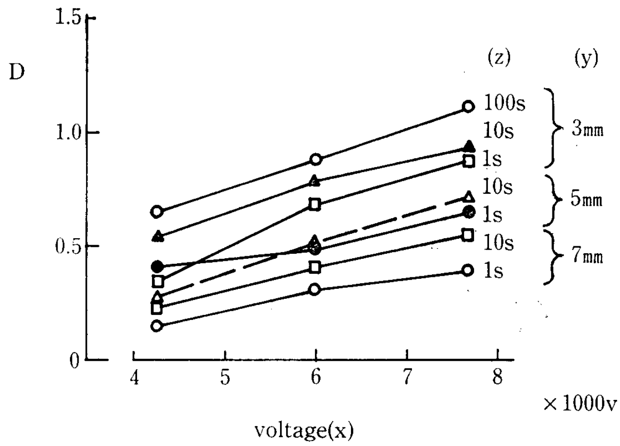


Fig. 8 a) Densities of records of negative discharge on Neopan SS Film at various voltage.

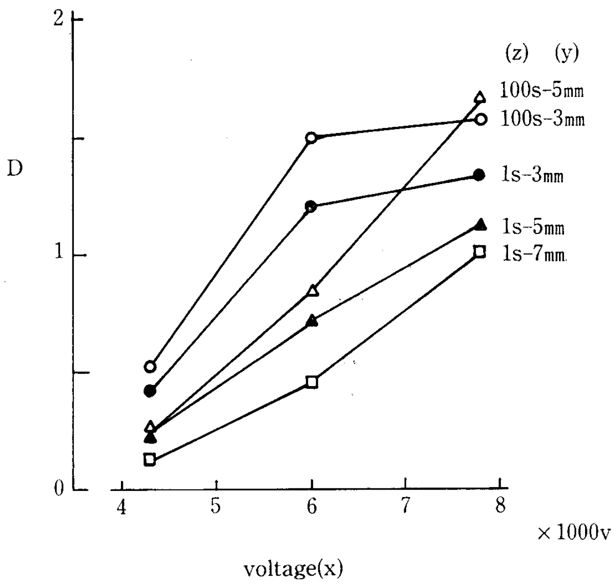


Fig. 8 b) Densities of records of negative discharge on A 1 Film at various voltages.

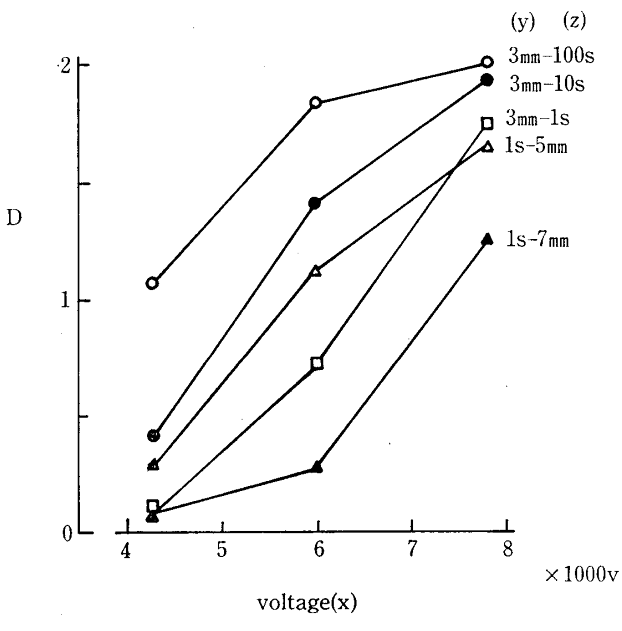


Fig. 8 c) Densities of records on WP Paper at various voltages.

varies with applied voltage (x) and with electrode distance (y). Fig. 5 shows a relation between the stretch of image and voltage (x), and a linear relation is found between them. Dependence of the stretch of image on electrode distance (y) is shown in Fig. 6, and here, a simple relation is not found. This result suggests a complicated nature of action of electric discharge onto sensitive emulsion.

Records of negative discharge

Records of negative electric discharge were studied in detail, using three kinds of sensitive material under various exposure conditions. Fig. 7 shows an example of record for negative discharge which gives circular blackening on exposed sensitive materials after development. The figures in Fig. 7 were recorded by a resin coated paper with voltage (x) of 4300, 6000 and 7700 V, at electrode distance (y) of 3 or 7 mm long respectively. In order to estimate the photographic action of discharge, maximum densities of developed images were measured by MacBeth densitometer and then diameters of circular images were determined.

Results of density measurements are shown in Fig. 8 to Fig. 10. A relation between image densities and applied voltage is given in Fig. 8; a) for Neopan SS panchromatic film, b) for A 1 orthochromatic film and c) for a resin coated Fujibro W P FM 3 paper. In these figures, the conditions of exposure including applied voltage (x), electrode distance (y) and exposure time (z) are denoted in each plot. The results of Fig. 8 show that image densities generally increase when applied voltage becomes higher, but the relation between density and voltage does not always vary linearly. Comparing figures of a), b) and c) each other, densities of the records on a panchromatic film are generally low and those on a resin coated paper are highest. Response of sensitive material like these is unusual, because photographic emulsion of panchromatic film is usually the most sensitive in ordinary use and that of resin coated paper has only thousandth or less sensitivity of panchromatic emulsion. To explain this abnormal behaviour of sensitive material towards electric discharge, some interaction or sensitizing action of pig-

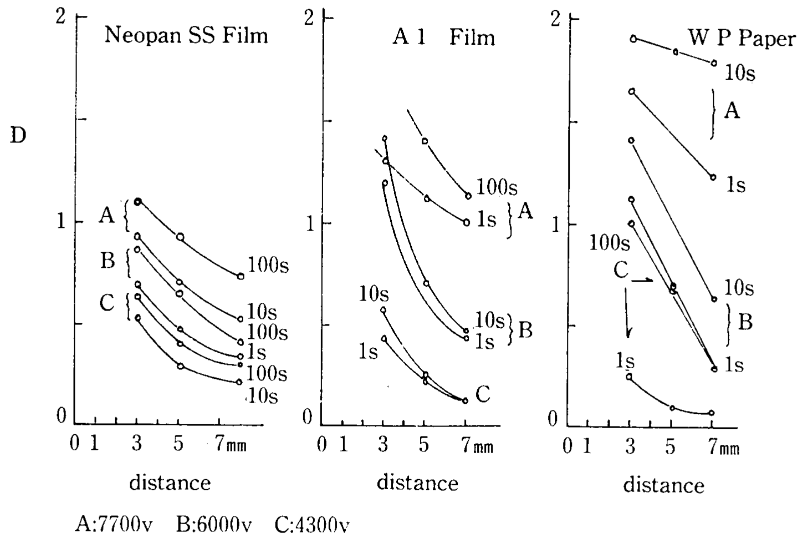


Fig. 9 Densities of records of negative discharge at various electrode distances.

ment or fluorescent brightening agent in a resin coated paper shuld be considered and further studies are needed.

Dependence of image densities on electrode distance (y) is shown in Fig. 9, where data are arranged for each sensitive material separately. The results show that the action of discharge decreases with an increase of the electrode distance, and this tendency is quite reasonable considering the dependence of electric field strength on electrode distance. As to the third variable (z), exposure time, tests were made at 1, 10 and 100 seconds. Fig. 10 shows the result for a resin coated paper and the plots likely give characteristic curves in time-scale exposure.

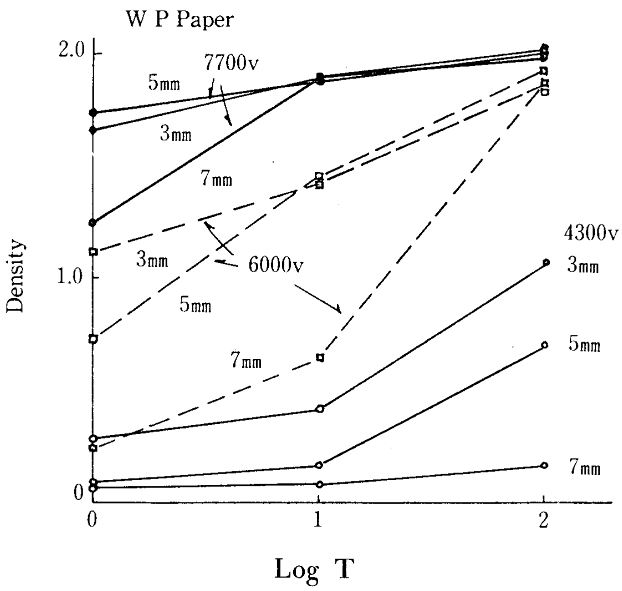


Fig. 10 Relation between densities and time of exposure.

Finally, diameter of circular images formed by exposure to negative discharge was measured. The diameter of developed image depends also on the condition of exposure, and in the case of a resin coated paper, its dependence is shown in Fig. 11. In Fig. 11, an increase of the diameter of developed image is indicated

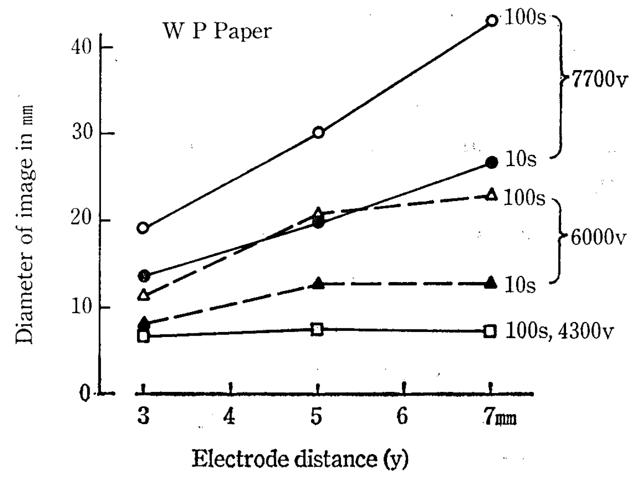


Fig. 11 Stretch of images formed by negative discharge at various voltage, exposure time and distances.

when electrode distance increased. This tendency is oppsite to that observed in the case of image formation by positive discharge (Lichtenberg's figure). This result suggests a difference of image forming mechanism between

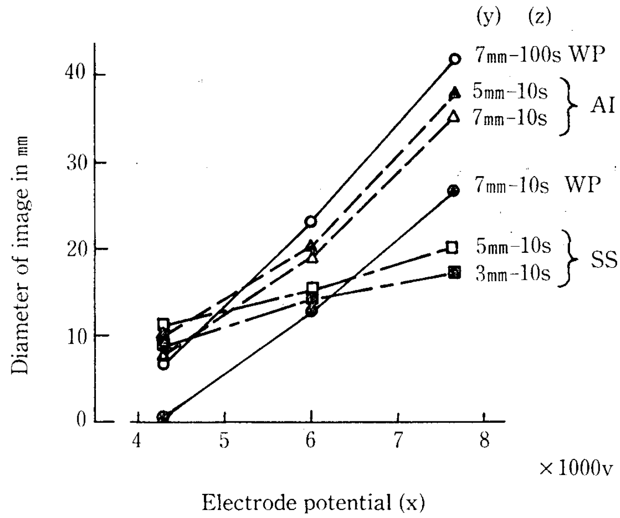


Fig. 12 Stretch of images formed by negative discharge on various types of sensitive materials.

negative and positive discharge. A relation between the diameter of image and applied voltage is shown in Fig. 12, and here, the relation is nearly proportional.

From the masurements of diameter of circular images, a limiting line of radiation or other sources, if any, exerting photographic action could be determined geometrically for each electrode distance. The limiting lines are illustrated in Fig. 13; a section including the rod electrode is represented in upper part, and a plan at the surface of sensitive material is shown in lower part. It is clear that the direction of action of discharge extends on the surface of sensitive material with a wide angle which depends on applied voltage: the direction of action is kept constant at a definite voltage, even electrode distance is changed, and the direction of action becomes more oblique when higher voltage is supplied.

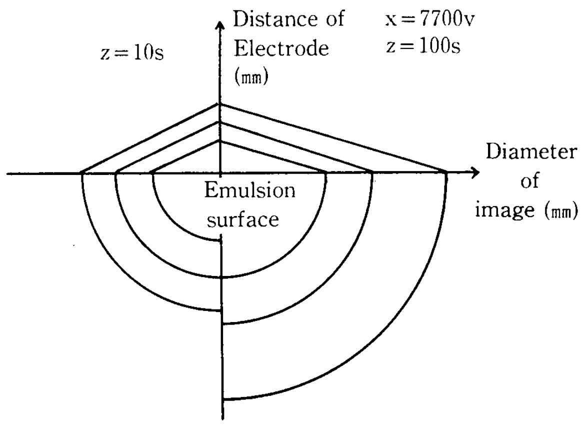


Fig. 13 Direction and limiting line of radiative energies.

To understand what kind of energy source contributes to the image formation by way of electric discharge is a problem of significance in these studies. According to our observation, the photographic action of discharge onto a sensitive material was neither restrained nor weakened by inserting a thin polyvinyl chloride film between the rod electrode and a sensitive surface, but interrupted by inserting a black pigmented film. Thus, the action of discharge seems to have radiative nature rather than corpuscular one such as an action of electrons or ions.

Conclusions

Photographic action of high-voltage electric discharge was studied and basic concept on the general behaviour of sensitive material towards discharge was obtained.

1. Positive discharge forms Lichtenberg's figure, and the higher the applied voltage, the longer the stretch of whiskerlike image. The stretch of image decreases with an increase of electrode distance under the fixed voltage.

2. Negative discharge forms circular blackening after development.

a) Under the fixed exposure condition, density of image is the highest for a resin coated paper, medium for an orthochromatic film and the lowest for a panchromatic film.

b) Density of the image increases with an increase of the applied voltage.

c) Diameter of the image increases with an increase of electrode distance under the fixed voltage.

d) Direction of the action of discharge extends with a wide angle which depends on the applied voltage and also on the electrode distance.

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