Corona Discharge Characteristics in Several Humidity Conditions and in Airflow Containing Siloxane Vapor

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Abstract

Corona discharge is affected by various factors such as vapors and so on. Humidity is familiar vapor and understanding its effect to corona discharge is important to realign stable condition. Siloxane is known as one of most influential vapors to corona discharge stability. On the condition of corona discharge in the atmosphere containing siloxane vapor, the voltage to maintain corona discharge current constant is monitored as a function of time. The increase of the voltage is observed when the siloxane vapor is sent to the discharge area and the decrease of the voltage is observed just after stopping siloxane vapor mixing. From the increase and the decrease of the voltage, main mechanisms of the voltage change are considered as wire degradation and discharge restraint by siloxane vapor itself in corona discharge.

Introduction

Corona discharge is widely used in electrophotographic process or others various fields [1, 2]. In the electrophotography, uniform electrostatic charging to the photoconductor is significant for keeping the good image quality. However, stability of corona discharge is influenced by various factors such as humidity and gases, and the influence leads to a deterioration of image quality. The corona discharge is took place by non-uniform strong electric field. Thus, humidity is an important factor to affect the corona discharge. It is considered that humidity alters wire surface state and restrains free electron generation.

The wire electrode is degraded in corona discharge. One of the wire degradations is identified as caused by siloxane vapor which is often used as silicone oil or silicone-related materials [3-9] and so on. It was considered that growths of silicon oxides on the wire electrode restrain the corona discharge in the case of positive discharge in these papers. However, it has not been clarified whether siloxane vapor effect the non-uniform charging distributions in both polarity case. Therefore, it is important to understand influence of siloxane vapor in order to clarify the degradation mechanisms of wire electrode.

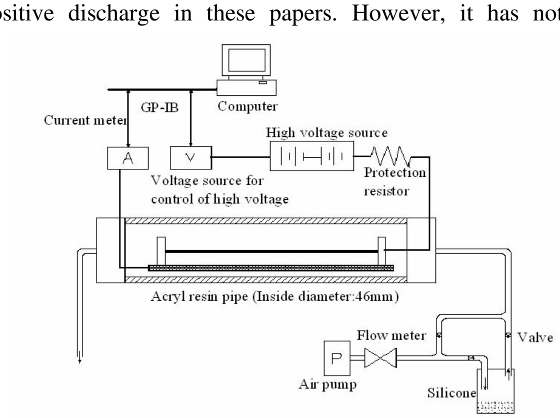

***Figure 1**. Schematic diagram of the experimental*

In the present study, we discussed the influence of both humidity and siloxane vapor. We compared with the applied voltage variations in different relative humidity, and analyzing the applied voltage change and degradations of wire electrodes when atmospheric airflow mixing siloxane vapor is supplied to corona discharge area. The applied voltage is made to change with time in order to maintain corona current constant. During the corona discharge, the behavior of the corona luminescence was observed. After the corona discharge, morphology and structure of the products on the wires were analyzed by SEM (Scanning Electron Microscopy), and the chemical components of the products on the wire electrode were analyzed by EDS (Energy dispersive X-ray Spectrometer).

Experimental

The schematic diagram of the experimental system is shown in Figure 1. Corona discharges are generated by non-uniform strong electric field which is induced by wire-to-plane electrode system at the atmospheric pressure. This system is called corotron [10]. A gold-coated tungsten wire which is 2µm in plating thickness, 60µm in diameter and 320mm in length is used as the wire electrode. The wire electrode is surrounded by three plate electrodes made of stainless steel which are parallel to the wire electrode at a distance of 15mm. Size of plate electrodes is 20mm×350mm. This corona discharging device is set up in an acryl resin pipe of 46mm diameter, for both safety and to send airflow to corona discharging area. With the application of a high voltage, a plasma sheath of corona discharge take place just around the wire electrode, due to the intense non-uniform electric field. The variation of applied voltage controlled by the program of the experimental computer to maintain constant current occurs. The applied voltage on every 2 second is saved to the memory of the experimental computer. The experimental system is set up in the temperature & humidity controlled room. The experimental temperature and humidity can be controlled through change the room setup. Atmospheric airflow was introduced at 2.0L/min flow rate by air pump during corona discharges.

Corona discharge in different relative humidity

The corona discharge takes place in air and ions, and discharge is easily affected by surroundings factors. We discussed the relative humidity influence in both corona polarity cases. Each corona discharge measurement was took place 3 hours. Temperature is 20～. The relative humidity conditions are shown in Table 1. Depending the applied voltage change maintain the discharge current constant (0.5mA) on time in both corona

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Table 1 Relative humidity conditions

Time	0~60Min	60~120Min	120~180Min
Humidity	30%	50%	70%

Table 2 Airflow conditions

Time / Condition	0～30 Min	30～60 Min	60～180 Min
a	Airflow		
b	Airflow	Airflow containing siloxane vapor	Airflow
c	Airflow	Airflow containing siloxane vapor	

polarity cases. The current at 0.5mA is bigger than the current of usually used in electrophotographic copiers.

Corona discharge in airflow mixing siloxane vapor

When airflow contains siloxane vapor, atmospheric airflow was sent through the siloxane container and then into corona discharging area. The siloxane vapor was supplied from commercially available silicone oil (KF-96L-2CS made in Shin-Etsu Chemical.co.,Ltd). Vapor pressure of siloxane was estimated to be approximately 0.8Torr at 20 ℃. Each corona discharge measurement was carried out at 20 ℃, 50%RH for 3 hours. The airflow conditions are shown in Table 2.

During negative corona discharge, it was observed that the luminescence of the wire electrode was not uniform in air containing siloxane vapor, a few glowing spots were found on wire electrode surface. After discharging, both negative and positive corona discharge, products growing on the wire electrode were found.

Results and discussion

The variations of the applied voltage which depends on voltage to maintain discharge current constant on time with relative humidity conditions are shown in Figure 2. In positive

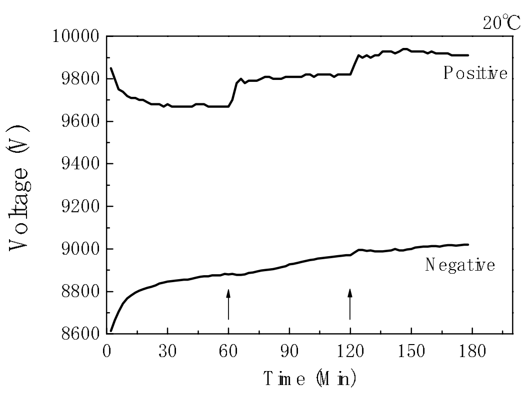

***Figure 2**. Dependence of voltage to maintain constant discharge current on time with relative humidity conditions of Table 1.*

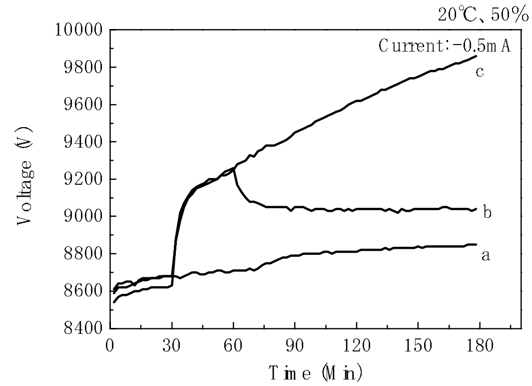

***Figure 3**. Dependence of voltage to maintain constant discharge current on time with three airflow conditions of Table 2 in negative*

case, the applied voltage obviously increased when relative humidity increases. Shahin (1966) studied the ion species for N_2, O_2 and air, with controls placed on the water content of these gases [11]. He found that $(H_2O)_nH^+$ ion clusters dominated the positive corona. As relative humidity increases, n becomes bigger, and ion mobility is restrained, thus applied voltage which depends on voltage to maintain discharge current constant on time increased. That is, corona discharge is restrained. Another, in negative case, the applied voltage finely changes when relative humidity increases. It is considered that hydrate products on the wire surface and affects trigger electrons release.

We also discussed the influence of siloxane vapor to corona discharge. The variations of the applied voltage which depends on voltage to maintain discharge current at -0.5mA constant on time with three airflow conditions of Table 2 in negative case are shown in Figure 3. In condition a, the airflow is sent to discharge area for 3 hours, the variation of the applied voltage is shown in Figure 2a. The applied voltage was approximately constant in airflow sending for 3 hours negative corona discharge. The corona discharge is promoted by airflow [12, 13, 14]. Because of the active gases such as O_3 and NO_x are blown away form the discharge area by airflow sending. In condition b, airflow mixing siloxane vapor was sent between 30~60 minutes to the discharge area. The applied voltage increased about 400V rapidly just after siloxane vapor mixed to discharge area. That is, the corona discharging is restrained by siloxane mixing. Then, the applied voltage increased slowly approximately 200V in the siloxane

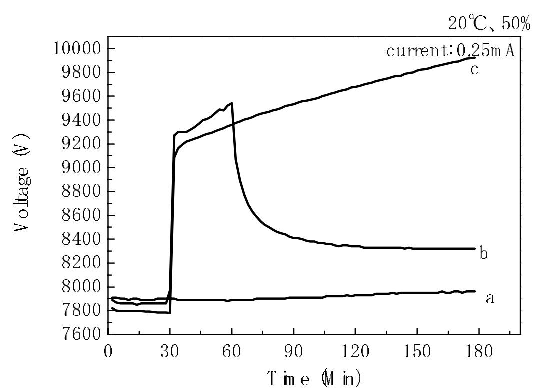

***Figure 4**. Dependence of voltage to maintain constant discharge current on time with three airflow conditions of Table 2 in positive*

vapor mixing period. Decrease of the voltage of about 200V was observed just after stopping the siloxane vapor mixing. The decreased voltage was higher compared with the original voltage before mixing siloxane vapor. In the condition c, airflow mixing siloxane vapor was sent to discharge area continuously starting from 30 minutes of discharging. It was the same as condition b in between 30~60 minutes. After that, applied voltage increased slowly.

The variations of the applied voltage which depends on voltage to maintain discharge current at 0.25mA constant on time with three airflow conditions of Table 2 in positive case are shown in Figure 4. In the condition a, the discharge is stable in airflow sending. The influence was as same as that in negative discharge, positive discharge is also promoted by airflow sending. In the condition b, the applied voltage increased 1300V rapidly when siloxane vapor is mixing. The applied voltage decreased 800V just after stopping siloxane vapor mixing. The decreased voltage was also higher compared with the original voltage before mixing the siloxane vapor. In condition c, the applied voltage increased rapidly just after siloxane vapor mixing. After that, applied voltage increased very slowly till the last.

The applied voltage rapidly increases when airflow mixing siloxane vapor is supplied to corona discharge area, and the applied voltage rapidly decreases as stopping siloxane mixing in the both polarity cases. That is, the corona discharge is restrained when siloxane mixing. When stopping the siloxane mixing, a portion of restraint of discharge is reduced. Since the voltage change, it is understood that the corona discharge is restrained by siloxane itself. The main suppression mechanisms of siloxane itself of corona discharge are estimated to the restraint of primary ionization in negative case [15], and the absorption of UV radiation in positive case.

Stopping the siloxane vapor mixing, the decreased voltage was higher compared to the original voltage before mixing the siloxane vapor. The products growing on the wire surface are restrained the discharge continually in negative or positive case. Electrons release primary mechanism of negative discharge is considered that energetic positive ions bombard the wire cathode, more trigger electrons are created to repeat the ionization burst, and negative corona discharge is lent to self-sustaining discharge. The electron generation depends on wire cathode surface chemistry, especially is the surface is contaminated, oxidized or is reactive to the impinging gas. The growth causes different secondary ionization coefficient (γ) along the wire. The electron generation is restrained. Therefore, the applied voltage was not returning to the original voltage in the negative case. When siloxane mixing continuously, the applied voltage increased continuously is due to the growth of the accumulation of siloxane on wire. In positive case, it has been clarified that the radius of the wire anode and the thickness of growth layer increase with the growth time (or discharge time). Also, the applied voltage increases with the growth time of products and with the apparent wire anode radius or the apparent thickness of the growth. Thus, the restraint mechanism of growth is estimated that may be caused by the increase in wire anode radius and/or the voltage drop across the grown layer. When airflow mixing siloxane is supplied to corona discharge area continuously, the applied voltage increases with the apparent wire anode radius or the apparent thickness of the growth [7]. The increase of voltage is very slow. The increase of applied voltage in positive case is slower than that in negative case.

In the discharging period, the luminescence in positive case is uniform than that in negative case. When siloxane vapor blended to corona discharge area, a few glowing spots appeared on the wire cathode surface. The glowing spots are seems look like move on the wire surface. The movement of the glowing spots is due to products grew non-uniformly on the wire surface, and peeled off the wire by vibration and airflow. The vibration of wire cathode is caused by positive ion bombardment.

After negative corona discharge, the wire cathode of measurement (b) was observed by SEM (JEOL: JSM-5310), the SEM photos are shown in Figure 5, and Figure 6 shows result of component analysis of EDS (JEOL: JED-2410). Film was grown non-uniformly on the wire cathode surface caused by negative

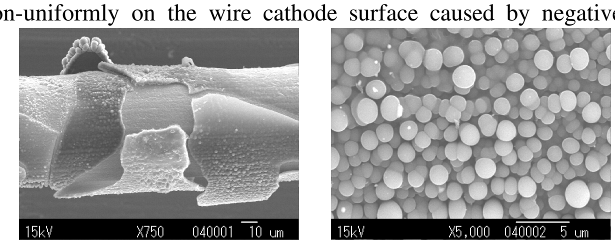

***Figure 5**. SEM photos of wire cathode (b).*

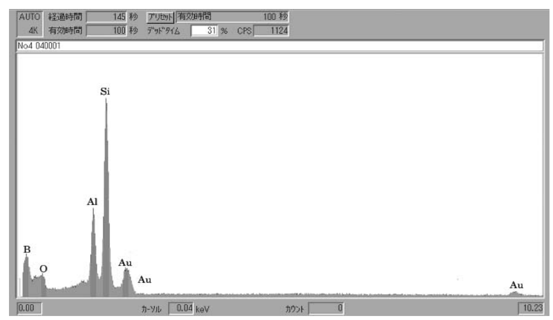

***Figure 6**. Results of EDS of wire cathode (b).*

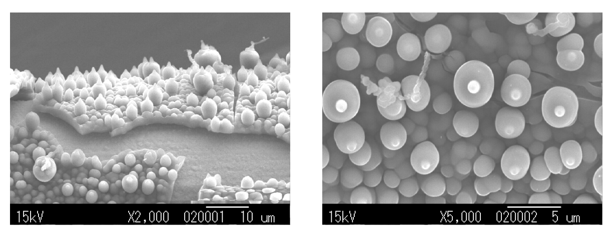

***Figure 7**. SEM photos of wire anode (b).*

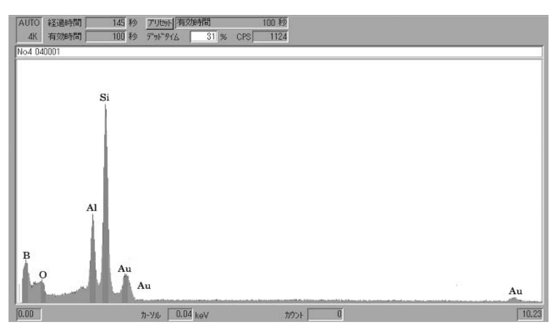

***Figure 8**. Results of EDS of wire anode (b).*

discharge. Silicium and oxygen were detected as components of products by EDS analysis. Aluminum and B which shows carbon in this EDS, were also detected by EDS. Aluminum was a component of SEM stage, the surface of wire was coated by carbon, in order to observe wire by SEM or EDS for a long time. Because the growth contains silicium and oxygen, it was thought that the product may be is silicon oxide. Another, the SEM photos of the wire anode of measurement (b) and results of component analysis by EDS were shown in Figure 7 and Figure 8, respectively. The products also grew on the wire anode surface. In previous papers [16, 17], the products merely grew on the wire cathode in negative case when airflow containing hydrocarbon which is often used as developing agent in electrophotographic copier is supplied to the corona discharge area. These decomposed and undecomposed hydrocarbon molecules would be charged merely negatively through electron collisions. However, in airflow containing siloxane case, the decomposed and undecomposed siloxane molecules would be charged negatively and/or positively, because of the electron impact ionization or would come to be in a polarized state under a strong electric field. Those decomposed and undecomposed siloxane molecules are neutralized and condense into a deposit on the surface of the wire electrodes.

Conclusions

The applied voltage increases when relative humidity increases in both polarity cases. It is consider that ion mobility is restrained by H_2O molecules in positive case, and hydrate products produced on the wire surface affects trigger electrons release in negative case.

Siloxane vapor mixing to corona discharge area is investigated in the positive and negative corona discharge. The vapor is mixed in the period of 30 minute after just air flow during 30 minutes and the voltage change to maintain corona current constant is monitored. It is found that the voltage increase when the siloxane vapor is mixed and the voltage decrease when the mixing is stopped. It is considered that these voltage changes are due to two mechanisms such as the growth of sedimentation of decomposed siloxane and corona discharge restraint by siloxane itself. It is found that the sedimentation occurs on both corona polarity cases, compared with the sedimentation only on the negative corona in case of hydrocarbon vapor. It is considered due to the siloxane decomposition to positive and negative ions at the corona discharge area.

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