Observation of Surface Change of Corona Discharge Wire

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Abstract

The stability and uniformity of corona discharge are significant in the electrophotographic process. The corona discharge is easily affected by the state of the wire surface and environment. The discharges were occurred at 1 hour, 3 hours, 10 hours and 20 hours. The morphology of the products grown on the wire surfaces was investigated. With an increase of the discharge time, the needle crystals, instead of the spots grow on the wire surfaces in the positive cases. On the other hand, a large amount of projections distribute on the wire surfaces non-uniformly, and some projections grow to cluster in the negative cases. By a long discharge time, a thin silicon oxide film grows to cover on the wire surfaces non-uniformly in both polarity cases. The growths of the products affected by the discharge current also are studied.

Introduction

It is well known that corona discharge devices are often used for supplying electrostatic charges with photoconductor and other materials in an electrophotographic process [1]. However, the wire electrodes of the corona discharge devices are degraded by the corona discharge. This degradation causes a non-uniform charge distribution on the photoconductor and affects a copy quality. The degradation of the wire electrodes results from the products grown on the wire surfaces. The products were identified as amorphous substances mainly consisting of silicon oxide. Nashimoto studied particularly the growths behavior of silicon oxide on the wire surfaces [2-7]. In all of those experiments, an atmospheric airflow was sent through the siloxane oil container, and supplied to the corona discharge area. Inside the electrophotographic copier, the siloxane vapor is generated by the silicone oil and/or silicone-related material. And it also has been reported that the accumulation of hydrocarbon on wire surface in negative case when atmosphere containing hydrocarbon vapor which is often used as a liquid developer [8, 9]. However, the products grown on the wire surfaces were also observed in the positive and negative corona discharge in the atmospheric airflow without containing siloxane vapor. The products were identified as consisting of oxygen and silicon at previous paper [10, 11]. The needles and films grew on the wire surfaces in the positive discharge, in the other hand, the projections and the thin films grew on the wire surfaces in the negative discharge. The products grown on the wire surface were induced by the strongly electrostatic field, caused by a small amount of silicon-related substances.

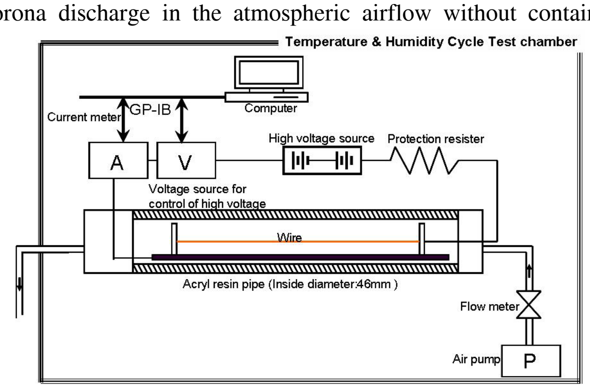


***Figure 1**. Schematic diagram of the experimental system.*

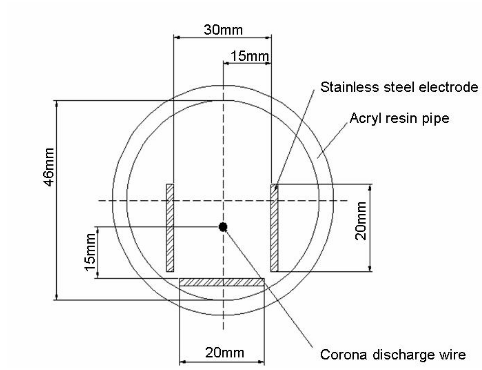


***Figure 2**. A cross section of equipment of corona discharge.*

In order to clarify the growth behavior and mechanism of the products, in this study, we compared the products grown by the positive corona discharge with the negative corona discharge. And the growth behaviors depended on the discharging time and discharging currents will be discussed. The applied voltage is controlled with time in order to maintain a constant corona current. After the corona discharge occurred, the morphology of the wire surfaces will be analyzed by scanning electron microscopy (SEM), and the chemical compositions of the wire surfaces are analyzed by energy dispersive X-ray spectrometry (DES).

Experiment

A schematic diagram of the experimental system is shown in Figure 1. Corona discharges are generated by a non-uniform strong electric field that is induced near the wire in a wire-to-plane system [12] at atmospheric pressure. A cross section of equipment of corona discharge is shown in Figure 2. A gold-plated tungsten wire was used as the wire electrode. It had a plating thickness of 2 um, and was 60 um in diameter and 320 mm in length. The wire electrode is surrounded by three plate electrodes that are made of stainless steel and parallel to the wire electrode at a distance of 15 mm. The dimensions of the plate electrodes are 20 mm x350 mm. For both safety and sending airflow into the corona discharging area, the corona discharging device is assembled in a 46-mm-diameter acryl resin pipe. With the application of high voltage, a plasma sheath of corona discharge takes place just around the wire electrode due to the intense non-uniform electric field owing to the wire and plate electrodes system. The applied voltage is controlled

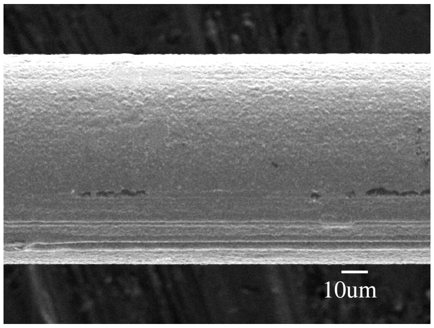


***Figure 3**.A SEM micrograph of original wire before discharge.*

by a computer program to maintain a constant current. The voltage, which is applied every 2 seconds, is saved to the memory of the computer. The discharging current is maintained at 0.1 mA, 0.5 mA or 0.8 mA in the measurements. The discharge is occurred at 1 hour, 3 hours, 10 hours or 20 hours. The products behaviors depended on discharging time and discharging currents are discussed. An atmospheric airflow is introduced at a 2.0 l/min flow rate by an air pump during the corona discharges. When an airflow is applied to the discharge area, the voltage for maintaining a constant discharge current decreases due to the blowing off of discharge suppression gas such as ozone [13]. It was shown experimentally that the voltage decrease is nearly constant at an airflow rate of 2.0 l/min. So the airflow was introduced at 2.0 l/min.

It is well known that the temperature and humidity are significant factors to affect the stability of corona discharge. Thus, the corona discharging device is placed inside a test chamber (DS-I DW made in Kato co.,Ltd.) which can control temperature and relative humidity to stabilize. The temperature can be set to a value between -10 degrees to 80 degrees. The temperature distribution inside the simulator is ±1.0 degree (no loading inside). And the relative humidity also can be set to a value between 30 to 95%. The distribution of relative humidity is ±3.0% (no loading inside). The temperature and relative humidity conditions in this study are controlled at 20 °C, 60% Relative Humidity (RH).

Results and discussions

Figure 3 shows the SEM micrograph of original wire before discharge occurred. A clean wire surface without any contamination was observed, considering the discharges were began in a good condition. After positive discharge for 1 hour, lots of spots grew on the wire anode surface as shown in the SEM micrograph of Figure 4(a). The discharge current was maintained constant at 0.5 mA. After positive discharge for 3 hours, the spots disappeared, and instead, a long and thin needle crystal grew on the wire anode surface as shown in Figure 4(b). By discharge of 10 hours, as observed in Figure 4(c), the wire anode surface was covered with the longer needle crystal than the above products as shown in Figure 4(b). For discharged 20 hours as observed in Figure 4(d), the radius of wire anode became bigger than the original wire as shown in Figure 3. All the surface of wire was covered with a thin film, and amounts of needle crystals grew on the film. In addition, there were some clusters modes consisting of needle crystals on the wire anode surface.

On the other hand, after negative discharge for 1 hour, 3 hours, 10 hours and 20 hours, the observations of wire cathode surface are shown in Figure 5, respectively. The discharge current was maintained constant at -0.5 mA at each measurement. After discharge for 1 hour, no any notable change was observed as shown in Figure 5(a). Some dilute spots were appeared on the wire cathode surface after discharge for 3 hours as shown in Figure

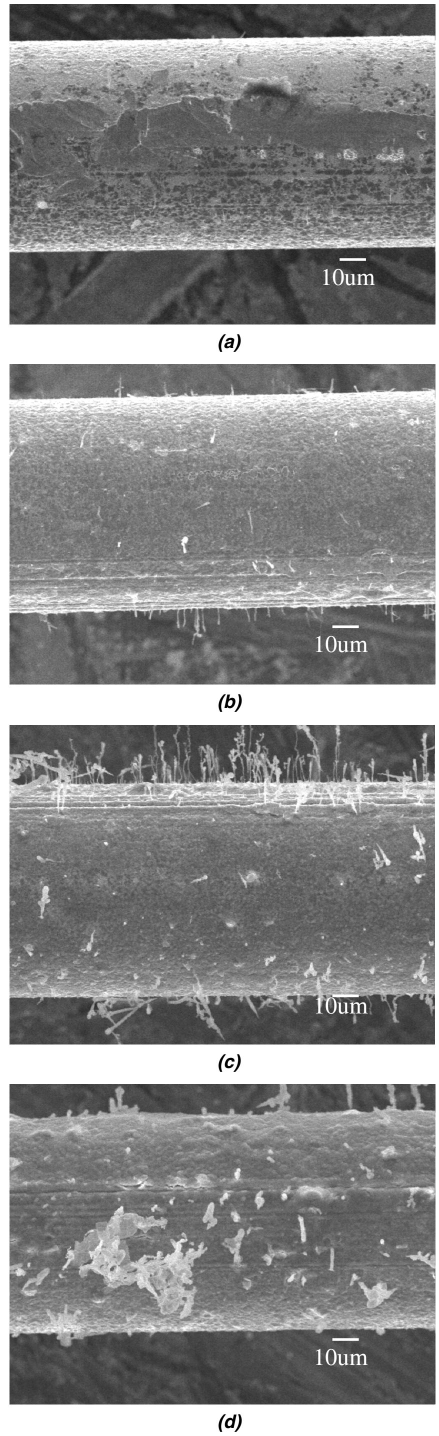
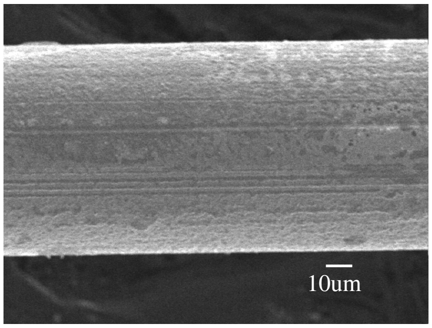
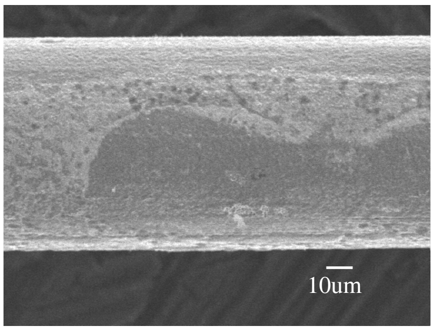


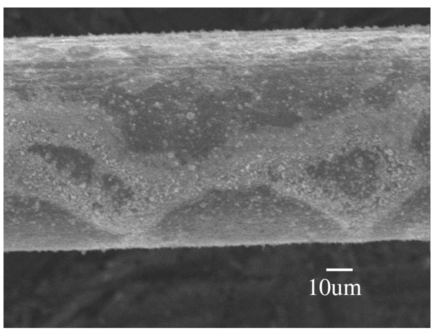
***Figure 4**. SEM micrographs of the wire anodes, the discharge current was required constant at 0.5 mA, the discharge time was (a) 1 hour, (b) 3 hours, (c) 10 hours, (d) 20 hours.*



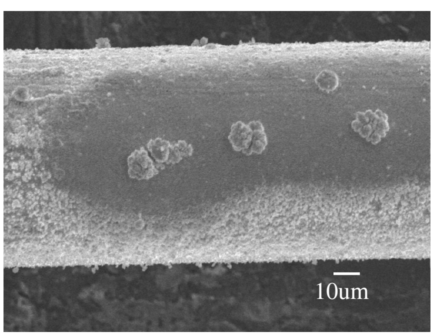
(a)



(b)



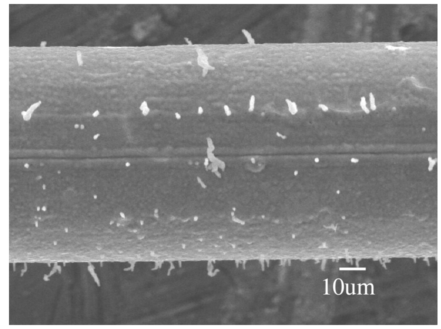
(c)



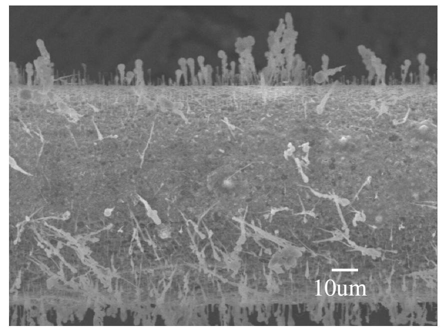
(d)

***Figure 5**. SEM micrographs of the wire cathodes, the discharge current was required constant at -0.5 mA, the discharge time was (a) 1 hour, (b) 3 hours, (c) 10 hours, (d) 20 hours.*

5(b). After discharge for 10 hours, as shown in Figure 5(c), the boundaries of the spots became clearer and larger than the above growths as shown in Figure 5(b), and a large amount of small projection began to grow, and distributed on the wire surface non-uniformly. By discharge of 20 hours, as shown in Figure 5(d),



(a)

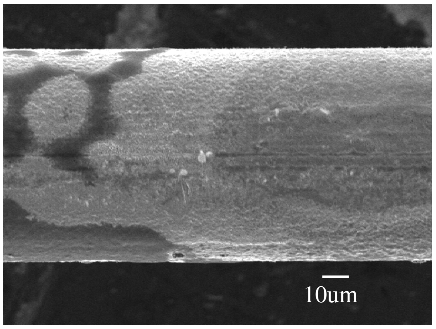


(b)

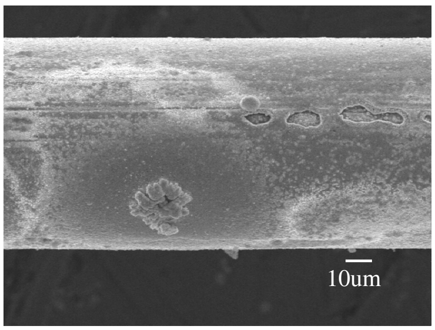
***Figure 6**. SEM micrographs of the wire anodes, the discharge current was maintained constant at (a) 0.1 mA, (d) 0.8 mA, the discharge time was 20 hours.*

also, the surface of wire was covered with a thin film, and a large amount of projections grew on the film. Especially, some projections grew to cluster on the film were observed.

The products grown on the wire surfaces grew up by discharge time increasing on the positive and negative discharge cases. It is interesting for compared the products grown by positive discharge with those by negative discharge. There shows different morphology and structure of products between positive discharges and negative discharges. In the positive discharge case, after a livelong discharge time, a large amount of needle crystals grew on the wire surfaces. However, in the negative discharge case, some clustered projections grown on the wire surfaces were observed. As described in previous paper [10, 11], the compositions of the products grown on the wire surfaces were obtained consisting of silicon oxide in the positive and negative discharges. The silicon-related molecules are dissociated and oxidized through electron collisions in the plasma area. Silicon oxide species produces by the plasma oxidation would be charged positively/negatively because of an electron impact ionization or would come to be in a polarized state under a strong electric field. These species are neutralized and condense into a deposit on the wire surface in the positive or negative discharge. At initial growth stage, some dilute spots are formed and grow to the film in the both polarity discharge cases. At next stage, the morphology of the products transit from a spot to a needle crystal in the positive discharge case. In contrast, the boundaries of the spots became clearer and larger in the negative discharge case, and a large amount of projections grew on the wire surface. By the increase of the discharge time, the thickness of the film increases and the needle crystals grow more and longer in the positive discharge case. On the other hand, the thickness of the



(a)



(b)

***Figure 7**. SEM micrographs of the wire cathodes, the discharge current was maintained constant at (a) -0.1 mA, （d） -0.8 mA, the discharge time was 20 hours.*

film increases and some projections grew to cluster in the negative discharge case. The differences of the morphology of the projections between positive and negative discharges are considered resulted from the ascription of the discharge.

After positive discharge for 20 hours, the discharge current was maintained constant at 0.1 mA and 0.8 mA respectively, the SEM micrographs of the wire surfaces are shown in Figure 6(a) and Figure 6(b),respectively. Comparing with the discharge current required constant at 0.5 mA as shown in Figure 4(d), the growth of needle crystals is promoted by discharge current increasing. Especially, the discharge current required constant at 0.8 mA, a fairly large amount of needle crystals grew on the wire surface. The needle crystal is long and thin, and has a round thick tip and a thin root. The products grown on the wire surfaces almost conductive projections of silicon oxide generate intense electric fields around their tips. These fields may generate localized electron avalanches and causes the growth of the products. At negative discharge cases, the SEM micrographs of the wire surfaces are shown in Figure 7(a) and Figure 7(b), respectively. The growth of the clustered projections and films were more promoted at bigger discharge current case.

Conclusions

The products grown on the wire surfaces were observed in atmospheric air in both polarity cases. The morphology of the products has been discussed in this study. With an increase of the discharge time, the needle crystals, instead of the spots grow on the wire surfaces in the positive cases. On the other hand, a large amount of projections distribute on the wire surfaces non-uniformly, and some projections grow to cluster in the negative cases. By a long discharge time, a thin silicon oxide film grows to cover on the wire surfaces non-uniformly in both polarity cases. And the growth of the products is promoted by the increase of the discharge current in the positive and negative case. It is considered that conductive of products of silicon oxide generate intense electric fields around their tips and cause the growth of products.

Acknowledgement

The authors would like to express his sincere thanks to Prof. Hara of Nippon Institute of Technology for his advices on Temperature & Humidity Cycle Test Chamber.

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