Study for Analyzing Unevenness of Negative Corona Discharge

Akinobu Morimitsu, Makoto Omodani, and Kenichiro Nakamura, and Yasusuke Takahashi
Department of Electro-Photo Optics, Faculty of Engineering, Tokai University
Hiratsuka, Kanagawa, Japan

Abstract

We have been studying the basis of the air flow effect which increases the uniformity and stability of negative corona discharge. The possibility that the stability of the negative corona is disturbed by some interruption for the flow of light to the surface of the wire electrode is investigated. Spectra distributions of the corona discharge in air atmosphere and in N_2 atmosphere are measured as a first step. Major peaks are seen in the ultraviolet band. Measured peak heights in negative corona discharge are found to be four times bigger, in air, than those in positive corona discharge. Almost all major peaks in air were confirmed to have the same wavelength as was measured under N_2. The measured difference in the spectrum distribution curves between positive and negative corona discharges indicates differences in the discharge mechanisms and a hint for analyzing the air flow effect in negative corona discharge.

Introduction

Corotron chargers are popular for realizing charging and transfer processes in electrophotography systems. A corotron with non-uniform charging characteristics often suffers degradation in output image quality. In general, negative corona discharge has more uneven discharging characteristics than positive corona[1].

It was recently reported that the uniformity[2,3] and stability[4,5] of negative corona discharge in a corotron can be improved by flowing air over the corotron's wire electrode. However, the reason for this air flow effect[6,7] has not been clarified yet: it seems to lie outside the conventional explanations of corona discharging mechanisms.

This research aims at clarifying the basis of this air flow effect by considering the differences in discharging mechanisms between positive and the negative corona discharge. We expect that this clarification will lead to a more detailed explanation of corona discharging mechanisms. The light emitted from sheath area surrounding the wire electrode is thought to contribute to the continuation of corona discharge[8].

In this paper, we focus on the role of light emission on the uniformity of corona discharge: we speculate that non-uniformity and instability result from some effect that blocks light transmission to the wire's surface by something produced in the discharging area[2,9]. This study analyzes the spectra of the lights emitted under negative and positive corona discharge: it is an important first step in confirming our speculation.

Experimental Method

Positive and negative discharge experiments were carried out both in air and N_2 gas atmosphere at 1 atm. Spectra of light emitted from the discharging area were measured in four cases. The N_2 gas atmosphere was chosen as the reference atmosphere.

An experimental apparatus is shown in Figure 1. A corotron discharger composed of a gilded tungsten wire electrode (diameter: 60 μm, effective length: 260 mm) and shield electrode made of stainless steel were used in the experiments. A 1.0 MΩ resistance was inserted in the circuit between the wire electrode and the power supply as protection against unexpected bursting discharge. Spectra were measured with a spectrophotometer (Otsuka Electronics, MCPD-1000 Photal) using measuring conditions shown in Table 1. The optical probe of the spectro-photometer was set 8.0 mm in front of the wire electrode.

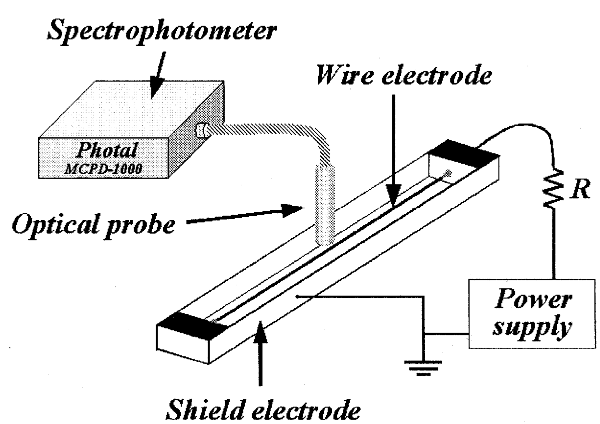

Figure 1. Experimental apparatus.

Table 1. Measuring conditions of the spectrophotometer.

Sampling time	10 sec
Number of scanning passes	10 times
Measured wavelength	220-800 nm
Slit width	0.2 mm
Resolution	6.0 nm

A constant-current power supply was used to ensure constant discharge current. Voltage values were 9.0 kV (7.3 kV) and -7.5 kV (-3.5 kV) for positive and negative discharge in air (N_2 gas), respectively. The discharge experiments in N_2 gas were performed in a 48 liter closed case.

Experimental Results

Figure 2 plots measured spectra in air for positive and negative corona discharge. The vertical axis values are normalized using the maximum peak height in negative discharge in air. Main peak wavelengths are listed in Table 2.

Significant major peaks exist in the ultraviolet band, while only very weak lights from the wire electrode can be visually observed even in a dark room. Peak heights under negative discharge are about four times higher than those under positive discharge. Major peaks are observed at the same wavelengths in both positive and negative discharge.

Figure 3 plots measured spectra under corona discharge in N_2 atmosphere. Wavelengths of major peaks are also shown in Table 2. Vertical axis values are also normalized using the maximum peak height under negative discharge in air. Wavelengths of the spectrum peaks of positive and negative corona discharge under N_2 are the same as those under air within the band of over 300 nm; several peaks that are not seen in Figure 2 are observed in the band from 200 nm to 300 nm in Figure 3.

It is noted in Table 2 that each four major peaks (1~4) have identical wavelengths in positive and negative corona discharge under air and N_2. The main peaks in Figure 3 are far higher than those in Figure 2. Relative values of maximum peak strengths under air and N_2 are listed in Table 3.

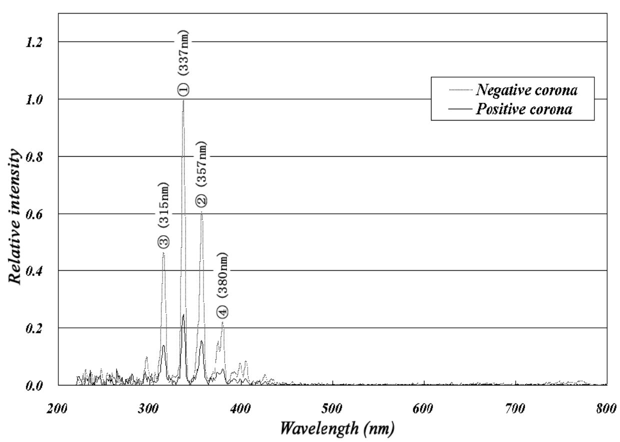

Figure 2. Measured spectrum of corona discharge in air.

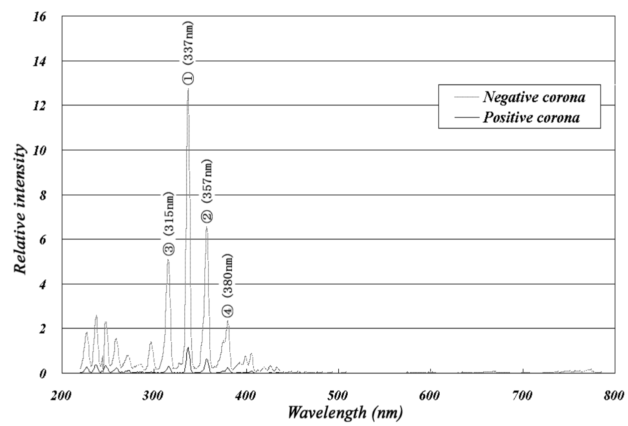

Figure 3. Measured spectrum of corona discharge in N_2.

Table 2. Spectrum peak wavelength in air and N_2.

Order of peak heights	Wavelength (nm)				Note
	Air		N_2		
	Positive	Negative	Positive	Negative	
④	380				Identical peaks in air and N_2
②	357				
①	337				
③	315				
	–		271		Other peaks
	–		259		
	–		248		
	–		237		
	–		226		

Table 3. Relative values of maximum peak strength.

	Negative	Positive
N_2	(13)	1.2
Air	1	0.25

Discussion

Major peaks in the spectrum were observed in the ultraviolet band, so intensity could not be discerned visually. It is noted that negative corona discharge yields more intense light emission than positive corona discharge. This observation supports the conventional explanation that light emission significantly contributes to the establishment of constant discharge in the negative corona discharge.

We should note that short wavelength light tends to be easily scattered and absorbed. The short wavelength lights, which are emitted from the corona discharge area, would be scattered or absorbed strongly if there were some gas barrier between the light source and the wire's surface.

It is very likely that gases such as ozone, which will be produced in the corona discharge area, act as the barrier for those ultraviolet lights. This barrier can be expected to interrupt constancy of negative corona discharge, and thus is the reason for discharge instability and non-uniformity. Flowing air through the discharging area can be expected to flush the discharging area and so improve the uniformity of corona discharge.

The fact that the observed spectra under N_2 gas is almost identical to that under air, indicates that N_2 gas significantly contributes to the light emission effect in corona discharge. It was confirmed that the common highest peak (337 nm) in positive and negative corona discharge under air and N_2, correspond to the principal peak in the transition spectrum[10] for the N_2 molecule. The observed spectra showed that the light emission phenomenon is stronger under N_2 gas than air. These results indicate that the discharge phenomena under N_2 gas can be taken as a good reference for that under air.

We are now planning to continue this study to reveal the relation between light emission and discharge stability, which is expected to yield a more detailed understanding of the corona discharging mechanism.

Conclusion

(1) Measured spectrum distribution of the luminescence in corona discharge under air shows that the major peaks in the spectrum lie in the ultraviolet band, not in the visible band.
(2) In air, peak heights of the spectra in negative corona discharge are four times higher than those in positive corona discharge.
(3) It is estimated that the N_2 molecule greatly contributes to the light emission of corona discharge in air.
(4) The difference in light emission intensity between positive and negative corona discharge is considered to reflect the impact of the light emission effect on the continuous discharge mechanism.

We speculate that gas created within the discharge region accumulates and interrupts the flow of light to the surface of the wire electrode, this disturbs the continuous discharging mechanism which relies on the excitation providing by the arriving light. The air flow effect, which increases the uniformity of negative corona discharge, is understood to flush the offending gas from the discharging region.

Reference

1. N. Yamazaki: Journal of the Institute of Electrostatics Japan, vol.12, No.6, pp.418-425 (1988) [in Japanese].
2. A. Kasugai et al.: "Air Flow Effect on Corona Discharge Characteristics", Japan Hardcopy '96, pp.137-140 (1996) [in Japanese].
3. M. Omodani et al.: "Ion Flow Printing", Proceedings of ICPS '98, pp.113-117 (1998).
4. A. Morimitu, M. Omodani, K. Nakamura: "Mutual influence between positive and negative corona discharge", Extend abstracts (The 59th Autumn Meeting 1998); The Japan Society of Applied Physics No.1, p.111 (1998) [in Japanese].
5. A. Morimitu, M. Omodani: "The Influence of Airflow on the Negative Corona Discharge", Proceedings of 1998 Annual Meeting of The Institute of Electrostatics Japan, pp.247- 250 (1998) [in Japanese].
6. A. Morimitsu, M. Omodani, K. Nakamura: "Analysis of air flow effect to negative corona discharge", Extend abstracts (The 60th Autumn Meeting 1999); The Japan Society of Applied Physics No.1, p.79 (1999) [in Japanese].
7. A. Morimitu, M. Omodani: "Influences of temperature, humidity, and airflow in the negative corona discharge", Proceedings of 1999 Annual Meeting of The Institute of Electrostatics Japan, pp.291- 294 (1999) [in Japanese].
8. Edgar M. Williams: The Physics & Technology of Xerographic Processes, International Business Machines Co. (1984), pp.41-52.
9. A. Morimitu, M. Omodani, K. Nakamura, Y. Takahashi: "An analysis of spectrum distribution for emitted light in corona discharge.", Proceedings of 2000 Annual Meeting of The Institute of Electrostatics Japan, pp.17-18 (2000) [in Japanese].
10. The Chemical Society of Japan, Chemical handbook basic edition 2, Maruzen Co.Ltd., pp.602-605 (1993) [in Japanese].

Biography

Akinobu Morimitsu was born in 1976. He received his B.S. degree in 1999 from Tokai University. He is expected to receive his M.S. degree from Graduate School of Tokai University in 2001.He is now engaged in a study of corona discharge at Tokai University.