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The Use of Atmospheric Non-Thermal Plasma in the Industries
マルチフェーズプラズマに期待する大気環境下 低温プラズマの産業応用

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Corona discharge is one of the methods to produce the non-thermal plasma. The corona discharge ionization has been mainly used for neutralization of the electrostatic charged objects in the manufacturing industries for the prevention of electrostatic discharge problems. The long-term stability of the capabilities is required for industrial applications to maintain the quality of the industrial products and to reduce the operating cost. In this paper, the recent development of the corona discharge ionizer is reviewed and applications of the ionizer in a variety of industries are described.

1. Introduction

Corona discharge is one of the methods to produce the non-thermal plasma under atmospheric pressure. The high concentration of air ion is generated by the corona discharge with low-power and high-voltage power supply. The corona discharge ionizer has been widely used to eliminate electrostatic charge on insulators in variety of manufacturing industries for the prevention of electrostatic discharge (ESD) problems [1].

In this paper, the recent development and industrial uses of the corona discharge ionizer are reviewed.

2. High Efficient Electrostatic Elimination

Generally, high speed electrostatic elimination and low offset voltage depended on the balance between amounts of positive and negative ions are required for performance of ionizer. The performance declines with deterioration of high voltage electrode caused by the dust attraction and the abrasion by the corona discharge. The discharge current that does not contribute to eliminate electrostatic charge reduces the efficiency of the electrostatic elimination and causes the electrode deterioration. The efficiency is affected by the waveform of the applied voltage. The optimization of applied voltage is important to achieve long-term stability in the performance. An intermittent pulse voltage AC power supply has been developed for high efficient electrostatic elimination [2].

Fig.1 shows typical waveform of the output voltage of the intermittent pulse voltage AC power supply. The voltage is generated by high voltage pulse transformer driven by a PWM inverter [2]. The timing, repetition rate and the amplitude of the each pulse are adjustable arbitrarily and optimized for the electrostatic elimination.

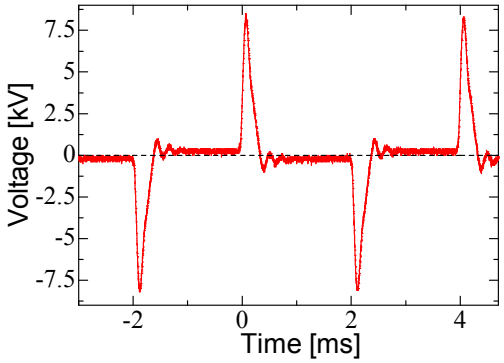

Fig.1. Typical waveform of AC power supply driven by PWM inverter.

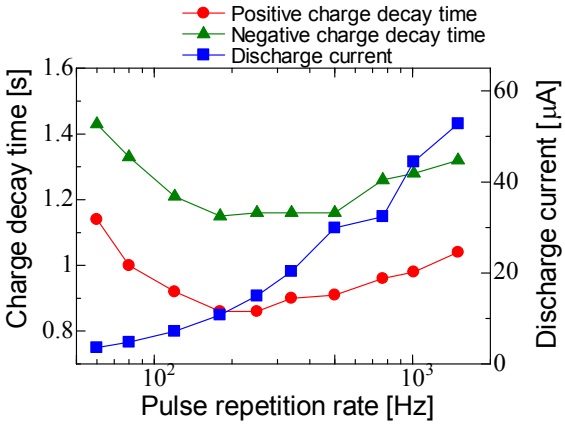

Fig.2. Static charge decay time and ozone concentration as a function of pulse repetition rate for various air velocities.

Fig. 2 shows the static charge decay time and discharge current as a function of pulse repetition rate. The charge decay time was measured using a charged plate monitor (Trek, Model158) having a

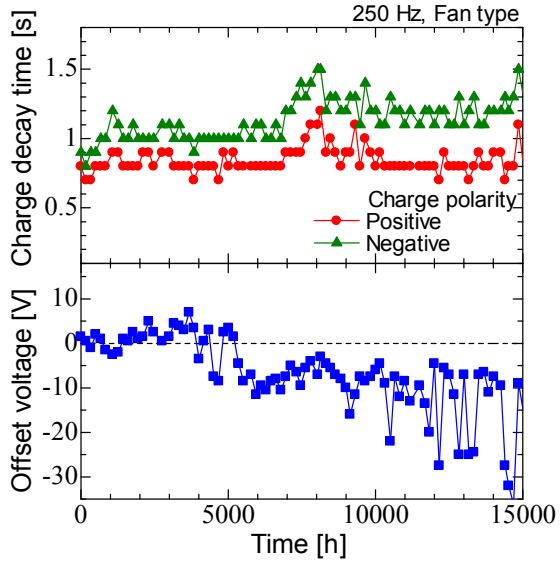

Fig.3. Time history of the charge decay time and the offset voltage of the electrostatic eliminator using the intermittent AC pulse.

capacitor of 20 pF. The pulse width is fixed at 290 us. The minimum value of charge decay time is obtained at the pulse repetition rate of 250 Hz. When the pulse repetition rate is less than 250 Hz, the concentration of the air ion decreases owing to the decrease of number of discharges. Above 250 Hz, the amount of ion reached to the charged plate monitor decreases by increase of the ion loss rate of ion-ion recombination [3]. The discharge current increases with increasing the pulse repetition rate. The result indicates that the efficiency for the electrostatic elimination decrease above the optimum pulse repetition rate.

Fig. 3 shows the time history of the charge decay time and the offset voltage of the electrostatic eliminator using the intermittent AC pulse. The decay time and the offset voltage are maintained for over 15,000 hour continuous operation, which is stabilized several times longer than that of conventional applied voltage type such as DC and commercial frequency AC.

3. Use of Ionizer

The ionizer has been mainly used in electronic device manufacturing processes within the offset voltage of several ten volts to prevent ESD event causes damage to the devices. Especially, a perfectly balanced ionizer with the offset voltage below 1~10 V has been required in the HDD manufacturing processes.

On the dust removal system, the electrostatic charged dust particles are neutralized by the ionizer to collect and transport under vacuum easily by reducing the electrostatic attracting force. The electrostatic elimination of the charged objects also contributes to reduce the risk of the dust attraction to the objects. The system has been used various processes such as film manufacturing, molding process and food process.

Corona discharge produced by the ionizer induces various chemical reactions, which is possible to treat the harmful gas with low-power and long-term stability [4]. The ethylene gas treatment system using the ionizers is investigated for the freshness preservation and rottenness prevention of fruit and vegetable in container transport [5]. The concentration of ethylene released from the fruits in a 20-feet container increased 7.5 ppm per a day and reached about 150 ppm after 20 days storage. The concentration is kept 7 ppm during 20 days and the fruit quality is maintained using the treatment system. This work was supported by Scientific technique research promotion program for agriculture, forestry, fisheries and food industry in 2011-2014 (No. 23059).

4. Conclusions

The recent development of the corona discharge ionizer for electrostatic removal and the industrial applications are described. The environmental air frequently contains the pollutions such as dust particle, moisture and harmful gas. The surface contamination of the ionizer by attracting the pollutions causes the decrease of the resistance between high voltage and ground terminals, which leads the performance degradation and the safety deterioration. The long term stability of the performance is required to maintain the quality of the products. Furthermore, short cleaning interval of the unit increases the operating cost. The stability and safety are affected by the structure of the electrodes and applied voltage waveform. It is recommended that the corona discharge system must be evaluated on the balance between the performance and the long-term stability.

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