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In situ Analysis of Discharge Sound and I-V Characteristic on Gliding Arc Discharge for Nano Particle Preparation

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Abstract

Electrical and sound characteristics of gliding arc have been taken to analyze and discuss the discharge mechanism, which is very complex due to the plasma non-uniformity in space and time. This work focuses on the relationship between discharge current and sound during gliding arc discharge. Measurement and analysis of waveforms of applied voltage, discharge current and discharge sound were carried out. New technique of optical wave microphone was introduced to observe generation of compressional wave after one pulsed discharge in air.

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1. Introduction

Plasma-chemical applications such as exhaust gas cleaning, organic compounds decomposition and nano-material production require high electron temperature, density and low gas temperature. However, no conventional thermal

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plasma or non-thermal plasma can satisfy these conditions simultaneously. One of the candidates to create mixture state of thermal and non-thermal plasma is gliding arc discharge [1-27]. The gliding arc discharge starts from arc at the shortest gap between two divergent electrodes and it glides along gas flow. The arc cannot maintain when the length of the arc exceeds its critical length and transition from thermal to non-thermal plasma occurs. When we observed the electrode temperature of the gliding arc discharge, we caught a strange phenomenon by a full flame image of thermography. Because a thermography is not a spectroscopy, it cannot measure temperature of gas or plasma. However, in discharge space, temperature distribution was measured. This meant that there were some nano materials which did black body radiation in discharge space. But it is very difficult to grab this directly. These processes are repeated periodically. Therefore, fundamental investigation especially on frequency analysis of discharges and system optimization for electrode material, geometry of electrodes, frequency of power supply, breakdown ignition system etc. are needed to make accurate control of the gliding arc discharge [28, 29].

In this study, we have focused on compressional wave generated by electric discharge because it includes information about discharge current and atmospheric condition around discharge [30]. A condenser microphone has been used to detect audible discharge sound wave, however it is impossible to set it close position to discharge electrodes where electric field is very strong. On the other hand, optical measurements such as beam deflection, Shadowgraph and Schlieren have been employed to avoid the above mentioned problem of a microphone. However, their sensitivity is relatively lower than that of a microphone, then it is recognized that they are useful especially to detect intense compressional wave like shock wave.

Here, we introduce a new optical method of an optical wave microphone [31, 32] which is expected to substitute for conventional microphones or optical methods mentioned above. The optical wave microphone is a unique technique which can detect compressional wave or change of density in gas medium or even in liquid medium with a probe laser, a Fourier lens and a detector. Because this technique is based on Fraunhofer diffraction between compressional wave and a probe laser, it is very useful to detect not only audible sound but also ultrasonic wave or shock wave without disturbing propagation of compressional wave and electric field in case of electric discharge. Now we consider that generated fine particles in a discharge space had strong causal association with a discharge sound. However, because a sound wave to occur by discharge phenomenon exceed far audible range, observation is difficult in a normal microphone.

In this paper, frequency properties on discharge current and discharge sound waveforms of gliding arc discharge and their relationship were analyzed by FFT (Fast Fourier Transform). Measurements of compressional wave, which is emitted by generation of discharge plasma in gliding arc and propagates in air, were carried out with a conventional microphone and an optical wave microphone.

2. Principle of optical wave microphone

Theoretical explanation of the optical wave microphone is as follows. When a probe laser beam crosses refractive index change such as sound wave at (x_0, y_0) , diffracted waves are generated and propagate with and in the penetrating beam through a Fourier optical lens and reach the observing detector which is set at Fraunhofer diffraction region or in the back focal plane (x_f, y_f) of the Fourier lens. The diffracted optical wave is homodyne-detected by using the penetrating optical wave as a local oscillating power. The optical wave distribution $u_w(x_f, y_f)$ at the detector position is shown in the next equation.

$$u_w(x_f, y_f) = \{i \exp(-2k_i f) / \lambda_i f \} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} u_w(x_0, y_0) T(x_0, y_0) \exp \{ik_i(x_0 x_f + y_0 y_f) / f\} dx_0 dy_0$$

Here,

$u_w(x_0, y_0)$: complex amplitude of laser at (x_0, y_0)

$T(x_0, y_0)$: phase modulation component by refractive index change

k_i : wave number of laser

λ_i : wave length of laser

f : focal length of Fourier lens

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