18pD1-5

Diagnosis of Fireball by Discharge on the Surface of the Water for Decomposition of Floating Particulate Matter

水放電を用いた火の玉プラズマの診断と浮遊粒子物質除去・分解実験

Keisuke Tanaka, Hideki Nakashima, Naoji Yamamoto, Ryosuke Kawashima and Taichi Morita
田中啓介，中島秀紀，山本直嗣，川島諒祐，森田太智

Department of Advanced Energy Engineering Science, The University of Kyushu, 6-1 Kasugakoen, Kasuga, Kyushu 816-8580,Japan
九州大学　先端エネルギー理工学専攻　〒816-8580　福岡県春日市春日公園6-1

In order to evaluate the possibility of decomposition and removal of PM2.5 by Fireball(FB), the plasma characteristic of FB is investigated. In this paper, electron temperature of FB is estimated using by emission spectroscopy, assuming thermal equiliblium. Estimated temperature of FB reaches 1.0×10^4 K at 400 μs after discharge and decrese with time, and it leaves 5.4×10^3 K at 3 ms. This would be enough high temperature to decompose PM2.5.

1. Introduction

PM2.5 removal devices are demanded in these days. There exist bag filters and electrical dust precipitators as PM2.5 removal devices, but a situation that the removal efficiency is low and disposal cost is high happens depending on the generation source of PM2.5. Moreover, the both devices are the devices of separating PM2.5, and have some disadvantages entailing a large amount of cost to disinfect the filters and having a risk of splashing PM2.5. In order to overcome these disadvantages, development of PM2.5 removal and decomposition devices is demanded.

Three ways of using FB[1] for removing and decomposition of PM2.5 are supposed. The first way is that PM2.5 is burned by high temperature of FB. Secondly, PM2.5 is expected to be condensed by the electrostatic force of OH radical and O radical generated by FB. Lastly, the oxidation power of the OH radical and O radical is supposed to decompose PM2.5. If the FB is applicable for removal and decomposition devices of PM2.5 by the ways described above, a large equipment and filters for separating PM2.5 are not needed. Therefore a removal cost and effort are significantly reduced and they are big advantages. However, FB is almost unknown so far therefore, elucidation of the physical mechanism is necessary.

In this paper, the emission spectroscopy is used to turn out which atoms burn out and the electron excitation temperature.

2. Experimental Setup and Conditions

An experimental setup used was the same as that described in the previous paper[2], and then the experimental system was stably operated under the conditions described in **Table.1.**. A schematic diagram of the electrode(anode) was submerged at the bottom of a glass container. Meanwhile, a rod electrode(cathode) insulated from the electrolyte by a boron pipe was placed at the center of container, and protruded a few millimeters above the solution surface.

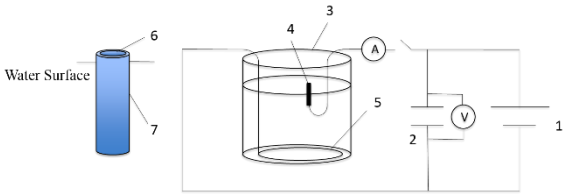

Fig.1. Setup for generatig FB

Table.1. Entire list of experimental condition

1	**Voltage　5.0 kV**
2	**Condenser　96 μF**
3	**PP Beaker**
4	**Cathode, rod**
5	**Anode :Cu,　Inner Diameter : 5 cm**
6	**Cathode,　Cu,　Diameter : 10 mm**
7	**Cathode,　B&N,　Diameter : 12 mm**
8	**Electrolyte : $NaHCO_3$**

Fig.2. shows a schematic of the emission spectroscopy experiment[3]. The FB emission is focused by the lens and transferred to the spectroscopy and photographed by the ICCD camera. The Photo Detector analyzes the emission intensity of FB and the emission time. And **Fig.3.** shows waveforms of the photo intensity and the discharge current.

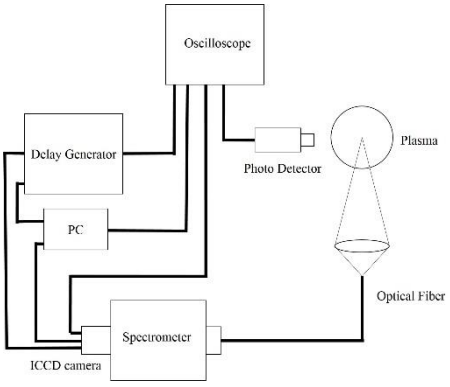

Fig.2. A setup of the spectroscopy experiment

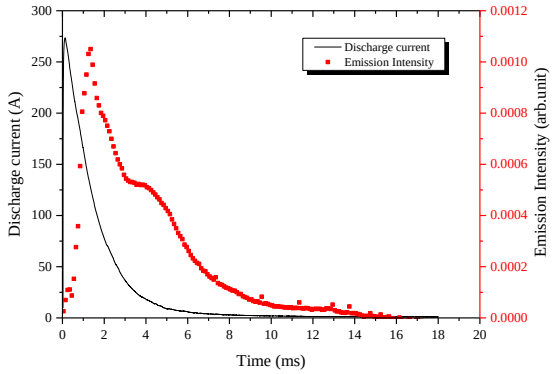

Fig.3. Waveforms of discharge current and emission intensity

Fig.3. presents that the discharge is almost finished at t=10 ms but the emission still continues at 16 ms. The physical mechanism of which the plasma continues without energy injection hasn't turned out yet and the characteristic is a phenomenon peculiar to FB.

Fig.4. shows the result of FB emission at t=1.0 ms. The emission of Cu atoms used as cathode, Na and H atoms used as electrolyte were observed. From the emission spectral lines of Cu atoms, the information of the electron excitation temperature T_{ex} can be inferred using the Boltzmann plot method with the assumption that the local thermal equilibrium was achieved. The equation can be expressed as

$$\ln\left(\frac{\varepsilon_{ji}\lambda_{ji}}{A_{ji}g_i}\right) = -\frac{E_i}{k_B T_{ex}} + \ln K \qquad (1)$$

where A_{ji}, E_i, ε_{ji}, g_i, λ_{ji}, k_B, and K, respectively, represent the transition probability, the upper level energy, the emission coefficient of the spectral line, the upper statistical weight, the wavelength of the spectral line, Boltzmann's constant and a generally constant. For that equation, T_{ex} was estimated from the six spectral lines of Cu atoms (**Table.2.**).

As a result, **Fig.5**. presents the time-variant T_{ex} and the electron excitation temperature falls with time and leave 5.4×10^3 K at 3000 μs. This temperature should be enough high to decompose PM2.5.

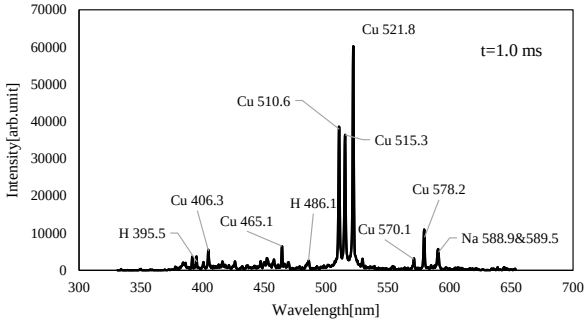

Fig.4. Spectral lines from 300 to 700 nm at t=1.0 ms

Table.2. Spectral line data for Cu atom

	λ(nm)	$A_{ji}(10^5 s^{-1})$	E_i(eV)	g_i
Cu I	406.2641	210	3.82	6
	510.5541	20	3.82	4
	515.3235	600	6.19	4
	521.8202	750	6.19	6
	570.024	2.4	6.19	4
	578.2132	16.5	7.74	2

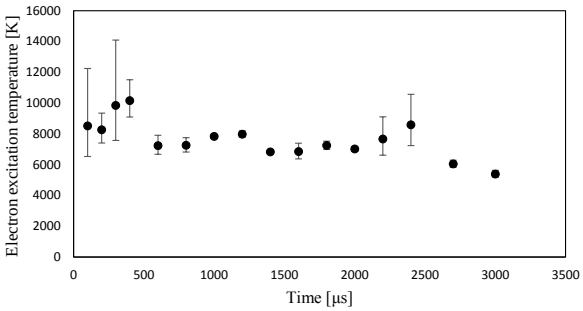

Fig.5. Time variation of T_{ex}

5. References

[1]: Y. Sakawa, Plasma and Fusion Research. Volume1,039,"Fireball Generation in a Water Discharge"(2006)
[2]:N. Hayashi,IEEJ Trans EEE, Vol4, No.5"(2009)
[3]: K. Shimamura, J,Appl.Phys, 084910(2011)