Impact of Atmospheric Fine Particles on Equivalent Ionic Mobility in Direct Current Corona Discharge

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Abstract

An investigation into the impact of atmospheric fine particles on the ionic mobility is presented. A measurement apparatus was designed using direct current corona discharge at room temperature. Positive and negative ionic mobilities were extracted from the electric field and ion current density measured in the apparatus. With the presence of fine particles, equivalent ionic mobility was found to decrease exponentially with the mass concentration of the fine particles. Distributions of the electric field and space charge density, and the contributions to the charge density from small ions and charged fine particles were also calculated.

1 Introduction

Ionic mobility is a significant parameter to reveal the physical linkage between ionization processes and movement characteristics of diverse ions in an electric field. Particularly, atmospheric ionic mobility is utilized to establish the models of gas discharges and to calculate the electric field distribution of high voltage direct current (HVDC) transmission lines when corona discharge occurs [1]. The electric field of the lines and ions in air is known as the ionized field or ion flow field [2-3]. Fine particles with diameters less than 10 μm or even less than 2.5 μm will be charged in the ionized field and make the ionized field problem more complex.

In this paper, the impact of fine particles on positive and negative ion mobilities in air was investigated through both measurements and calculations. Fine particles were generated from burning incense. The electric field strength and ion current density at ground level were measured. The distributions of the electric field and space charge density were calculated by Poisson's equation and current continuity equation. The relationship between mass concentration of atmospheric fine particles and ionic mobility was achieved.

2 Measurement Principles and Apparatus

Equivalent ionic mobility was investigated in parallel electrodes in an enclosed indoor laboratory. The schematic diagram of the measurement apparatus is illustrated in Fig. 1. The top layer was a corona wire net to generate small ions by corona discharges of the wires. The second layer was a stainless steel mesh plate. The bottom layer was an aluminium grounded plate with a circular cavity in the center for the position of a DC field probe. A uniform ionized field was generated between the mesh plate and the grounded plate with controllable ion current density filled through the mesh plate. Incense particles were charged to form large ions between the electrodes. Based on the electromagnetic theory, the ionic mobility can be calculated by [3]

$$E_g^{\,3} - \left(E_g^{\,2} - \frac{2Jh_2}{e_{ap}K_{ep}} \right)^{\frac{3}{2}} = \frac{3JU_2}{e_{ap}K_{ep}} \tag{1}$$

where E_g and J are the magnitudes of the ionized field strength and ion current density on the grounded plate, respectively, $V \cdot m^{-1}$ and $A \cdot m^{-2}$; K_{ep} is the equivalent ionic mobility, $m^2 \cdot V^{-1} \cdot s^{-1}$;

U_2 is the voltage applied between the mesh plate and the grounded plate, V; h_2 is the distance between the two electrodes, m; ε_{ap} is the air permittivity with fine particles, $F \cdot m^{-1}$.

The electric field strength and ion current density were measured by the field mill and Wilson plate, respectively [1]. Fine particles were generated by the burning incense. Mass concentration, diameter distribution, image and element composition of the incense particles were also measured by a laser dust monitor (LD-5C), a particle counter (Fluke 985), and a scanning electron microscope (SEM, FEI Quanta 200F), as shown in Fig. 2. According to Eq. (1), measurement results of E_g and J on the ground level can be utilized to obtain the equivalent ionic mobility. Details of measurement principles and apparatus will be discussed in the full paper.

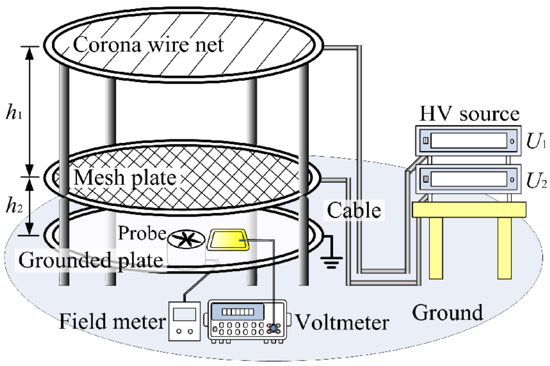

Figure 1: Measurement apparatus

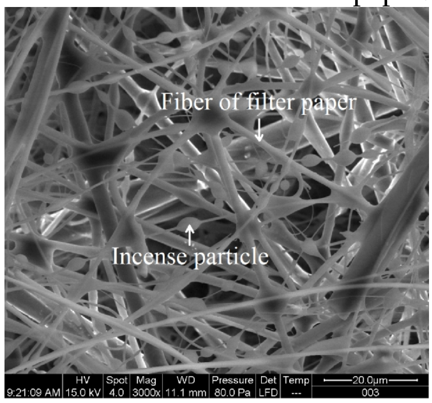

Figure 2: SEM image

3 Results

When corona discharge occurred on the corona wires, the ion current density increased with the applied voltage U_1. Under a certain mass concentration m_c of the incense particles, the ionized field E_g on the grounded plate increased proportionally with the ion current density J. In addition, distributions of the ionized field and space charge density along the vertical coordinate z between the mesh plate and the grounded plated were also obtained when m_c was from $5\,\mu g \cdot m^{-3}$ (clean air) to $598\,\mu g \cdot m^{-3}$ (serious contamination). The distortion extent of E_g, namely the curve slope of E_g - z graph, increased with m_c of the fine particles. Lastly, it was found that equivalent positive and negative ionic mobilities both decreased exponentially with the mass concentration of the particles. The results will be analyzed in detail in the full paper.

4 Conclusion

The impact of fine particles on atmospheric ion mobility was investigated. It was revealed that positive and negative ionic mobilities both decreased exponentially with the mass concentration of the incense particles. Distributions of the ionized field and charge density were also obtained under various particle mass concentrations.

Acknowledgements

This work was supported in part by the National Natural Science Foundation of China (No. 51907041).

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