Negative ion formation and evolution in atmospheric pressure corona discharges between point-to-plane electrodes with arbitrary configurations

Kanako Sekimoto[1] and Mitsuo Takayama[2]

[1]Atmospheric Environment Division, National Institute for Environmental Studies, Tsukuba, Japan

[2]Graduate School of Nanobioscience, Yokohama City University, Yokohama, Japan

Atmospheric pressure corona discharge has been used as an ionizer in a wide range of research and industrial fields such as environmental, analytical, and atmospheric sciences, and possibly even commercial electric appliances. Despite substantial progress of applications using corona discharge, the elementary process involved in ion formation occurring in an atmospheric pressure corona discharge are not yet well understood. It has been reported that negative ion formation is rather complex compared to that of positive ions, and therefore that it is difficult to regulate the reproducible formation of specific negative ion species.

The negative ion formation in corona discharge is attributed to various different reactions including electrons and common air constituents. Electron attachment reactions with N_2 and O_2 produce primary ions O^- and O_2^- and radicals N and O which are the precursors for the formation of neutral NO_x as discharge by-products. The primary ions move along the electric field lines between the electrodes. Simultaneously, they alter more stable ions through successive ion-molecule reactions with common air constituents and discharge by-products, referred to as "*ion evolution*". The progress of negative ion evolutions and resulting terminal ion formation are strongly dependent on the abundances of primary ions and neutral NO_x produced in the discharge area. It was noted here that the abundances of such ions and neutrals produced *via* the electron attachment reactions are regulated by the electron kinetic energy which is determined by the electric field strength at the electron accelerated position. Thus, it can be expected that the electric field strength and resulting kinetic energy govern the sequential progress of negative ion evolution.

Here we have studied the formation mechanism of negative ions on the basis of thermochemcial reactions to form various negative ions, electric field strength and the resulting electron kinetic energy, by using an atmospheric pressure DC corona discharge system coupled with mass spectrometers (JMS-LCmate reversed geometry double-focusing MS made by JEOL, and TSQ7000 triple-quadrupole MS made by Thermo Fisher Scientific)[1-3] and electric field calculation[2,3]. The experimental and theoretical results obtained suggested that the negative ion evolutions progress along field lines established between the point-to-plane electrodes with arbitrary configurations and that the resulting terminal ion formation on a given field line is attributable to the electric field strength on the needle tip surface where the field line arose. The NO_x^- and CO_x^- ions were dominantly produced on the field lines arising from the needle tip apex region with the highest electric field strength, while the field lines emanating from the tip peripheral regions with lower field strength resulted in the formation of the HO^- ion. Furthermore, these studies made it possible to regular and reproducibly generate various different negative ions originated from ambient air including HO^-, NO_x^- and CO_x^-, only by varying the electric field strength on the needle tip and resulting electron kinetic energy.

References

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