Measurement of negative ion mobility in ultra high purity O_2 at atmospheric pressure

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The ion mobility of negative ions generated by photoelectrons in ultra high purity O_2 was measured at atmospheric pressure. The role of the influence of the trace constituents (impurities) on the value of the reduced ion mobility was studied. The reduced ion mobility reaches in ultra high purity O_2 a constant value of 2.39 $cm^2/V{\cdot}s$ in contrast to 2.31 $cm^2/V{\cdot}s$ in high purity O_2. The reduction of the ion mobility with increasing density of impurities was elucidated on the basis of formation of water cluster ions.

1. Introduction

Negative ions are important constituents of the discharge plasma and their properties were subjected to many fundamental studies. In our laboratory, our interest is focused on negative ion mobility measurements in O_2 at high pressure. The zero field mobility ($E/N \approx 2.83\times10^{-3}$ Td) in low purity O_2 (99.9%) has a value of 2.13 $cm^2/V{\cdot}s$ which was obtained by Norimoto et al [1]. In high purity O_2 (6.0 and 6.5 purity) the zero field mobility of O_2^- of 2.31 $cm^2/V{\cdot}s$ was determined [4]. However, it was observed that the ion mobility varied with impurities after exposing the apparatus to air. The low values of the ions mobilities for low purity O_2 and low values E/N is due to formation of cluster ions that are formed in drift tube as mentioned by McKnight[3] and Sabo et al. [4].

Thus, in the present work we have studied the influence of impurities contained in O_2 on the mobility of negative ions formed in this gas. We present the new value of negative ion mobility as determined in ultra high purity O_2.

2. Experiment

Fig. 1 shows a cross section of the apparatus and electrode system. G_1 is an ion drift space and G_2 is positive corona gap that acts as an ion detector. A mesh electrode M is a 200-mesh electrode made of stainless steel in 0.05 mm diameter, electrode C was manufactured of brass. The surface of electrodes C and M was covered with gold plating. The electrons were emitted from the surface of M and C by pulsed UV light generated by spark discharge between spherical electrodes in air. Negative ions were formed by electron attachment to O_2. The negative ions were detected using a point to plane discharge gap as an ion detector. In this experiment we used high purity O_2 of (99.99995% - 6.5 purity), in contrast to 6.0 O_2 (99.9999% purity) used in the previous experiments [2]. Moreover, we have used a gas defecator (MICROTORR: MC200-203FV) connected between gas cylinder and the chamber to remove the impurities. The information about the impurities in O_2 used in experiments is in Table 1.

Table 1 Impurities contained in the used oxygen

Impurities	99.9999% ([1])	99.99995%	Ultra high purity
N_2	< 0.2 ppm	< 0.2 ppm	< 0.2 ppm
CO	< 0.1 ppm	< 0.02 ppm	< 100 ppt
CO_2	< 0.1 ppm	< 0.02 ppm	< 100ppt
Ar	<0.1 ppm	< 0.05 ppm	< 0.05 ppm
THC	< 0.1 ppm	< 0.02 ppm	< 10 ppt
H_2O	< 0.522 ppm	< 0.522 ppm	< 100ppt

3. Results and Discussions

The vacuum chamber (CH) was exposed to atmosphere only prior the 1st measurement. Prior each set of measurement CH was evacuated by turbo-molecular pump over 24 hours and backed out in

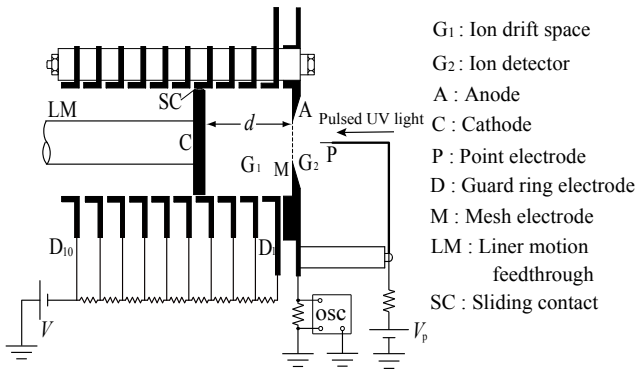

Fig. 1: Cross section of electrode system for negative ion mobility measurement.

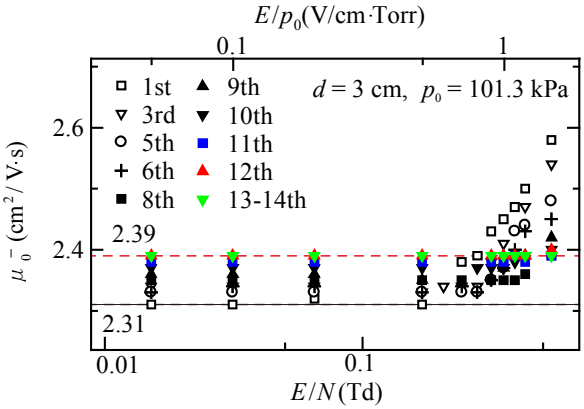

Fig. 2: Obtained mobility in O_2

order to improve the vacuum. The apparatus was filled with ultra high purity O_2 at atmospheric pressure and the ion mobility of the negative ions formed by photo electrons in O_2 measured. This procedure was repeated for several ten days. For low values of $E/N < 3.54\times10^{-1}$ Td, the initial value of reduced ion mobility was 2.31 $cm^2/V{\cdot}s$ and this value was gradually increasing (due to improving of the vacuum) with time up to value 2.39 $cm^2/V{\cdot}s$. This value is close to the values reported by Voshall et al[5], Rees[6] and Dutton and Howells[7].

The value of reduced ion mobility was increasing with increasing E/N. This increase was reduced with improving purity of the system and at the end a constant value of reduced ion mobility of 2.39 $cm^2/V{\cdot}s$ was obtained for $E/N > 3.54\times10^{-1}$ Td. This behavior we refer to the disappearance of impurity ions NO_3^-, NO_4^-, $N_2O_2^-$, CO_3^-, and CO_4^- formed from impurities [2] which are constituents of the atmosphere and adsorbed on the surfaces of the vacuum chamber. This behavior at $E/N < 3.54\times10^{-1}$ Td was never observed in our previous studies [2]. Therefore we believe that this effect is also associated with the improved purity of the gas.

We believe that the change of the reduced ion mobility at low values of E/N is mainly associated by the formation of $O_2^-.(H_2O)_n$ clusters. McKnight [3] measured the negative ion mobility with MS analysis of the ions in low pressure O_2 and reported the value of 2.18 $cm^2/V{\cdot}s$ for O_2^-. He reported observation of $O_2^-(H_2O)$. The low value of 2.18 $cm^2/V{\cdot}s$ resulted from trasport of equilibrium mixture of O_2^- and $O_2^-(H_2O)$ ions in the drift tube. The ion mobility is expected to increase in ultra high purity O_2 du to shift of the equilibrium in favor of O_2^- ions. Similar observation has been made by Sabo et al in case of air [4].

4. Conclusions

Negative ion mobility was measured in ultra high purity. The reduced ion mobility of negative ions reaches a constant value of 2.39 $cm^2/V{\cdot}s$ in wide range of E/N contrast to previous value of 2.31 $cm^2/V{\cdot}s$ in high purity O_2. This behaviour was assigned to the impurities in the gases (mainly H_2O) and formation of clusters ions.

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