Spectroscopic and QMS Studies of DC-Glow Discharge with Reactive Cathode in N2/O2 Mixtures

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Abstract
A DC-glow discharge of N2, O2 and their mixtures are studied by the method of QMS and spectroscopy. A boron-compound lanthanum hexaboride (LaB6) material is applied for the cathode to investigate the effect of a cathode material on discharge gases.

1. Introduction
Glow discharge characteristics in N2, O2 and their mixtures by using reactive cathodes are studied experimentally. There are many problems to be solved in detail the basic mechanisms for a glow discharge in N2, O2 and their mixture gases. The interaction among mixed gases, electrode and chamber wall has complex characteristics.

In the experiment, we applied boron-compound materials such as BN, lanthanum hexaboride (LaB6) for the cathode. The application of boron-compound materials for the cathode was proposed previously to test a boron film deposition on a vacuum chamber wall [1][2][3].

In plasma confinement devices it is necessary to remove oxygen and water vapour impurities from a chamber wall to reduce radiation energy loss of the confined plasma column. A boronization, carbonization, beryllium coating and so on for a wall surface modification are usually applied in high temperature plasma devices. Experimental studies of a boron coating or boronization on the chamber wall have been carried out elsewhere. Many types of plasma sources for these purposes have thus far been investigated, in which the aim of experiments has been to coat effectively the desirable thin film on the metal wall. The glow discharge with a cold cathode is characterized by its working gas pressure, which is higher than that of other plasma sources. It is obvious that the cathode materials depend strongly on the created film properties and then gas conditions.

To investigate the effect of a cathode material on mixed gases of N2 and O2 gases during the discharge, elementary processes among molecules, excited species, sputtered particles from the cathode surface are examined by analyzing the dynamics of gas mixtures. Time analysis of partial pressures of mixed gas species are measured by using spectroscopy and particle methods of quadruple mass analyzer (QMA). For measurements of time variations of electron density and plasma potential, an electrostatic probe is also used.

Here, we investigate experimentally properties of partial pressures of working gases during discharge by a reactive cold cathode. For the purpose of the interaction study between mixed gases and the electrode, the reactive cathode of lanthanum hexaboride (LaB6) is applied for the cathode material on the basis of the preliminary study. The experiments showed that the
dynamics of partial pressures of residual gases is rema

parameters.

Fig 1 Discharge Chamber
C Cathode, P Probe

2. Experimental Device

Figure 1 shows the arrangement of the discharge electrodes. The glow discharge is done in the main vacuum chamber. The chamber is made of a stainless steel and has a diameter of 100 mm and is 300 mm in length. In the center of the main chamber the lanthanum hexaboride(LaB6) disk is arranged for the cathode electrode. The LaB6 disk of 50 mm in diameter with 5 mm thickness is used for the glow discharge experiment. The anode electrode is the stainless-steel wall surface of the discharge chamber. The glow discharge occurs between the LaB6 disk cathode and the chamber wall. The applied DC voltage is 300-2000 Volts. The experiments were carried out in pressures of 5-200 Pa. Figure 2 shows the simplified view of the measuring system of the experiment. The working gas is mainly N2 and O2. The discharge occurs in the main chamber and the discharge gases are introduced into the analysis chamber through a variable valve and an orifice. Then residual gases are analyzed by using a quadrupole mass analyzer(QMA). The vacuum system consists of two turbomolecular pumps(TMP), one has a pumping speed of 250 l/s and the other 50 l/s. Spectroscopic measurements of the visible light from the glow discharge are conducted by a monochrometer. The glow discharge parameters of the electrode voltage Vd and the total discharge current Id are monitored during the discharge. In the chamber, an elecro-static probe(Langmuir probe) for measurements of the plasma parameters is set and can be moved externally along the plasma region. From the probe measurements, local electron density, electron temperature and plasma space potential are also deduced. Correlation between QMS signals of partial pressures and light intensities of plasma parameters are analyzed by these measurements.

3. Experimental Results

The fundamental properties of the glow discharge with the reactive cathode are examined by measurements of plasma parameters. The most characteristic point of this experiment is to
apply the LaB6 electrode for the discharge. The basic voltage-current properties of the glow discharge were examined prior to the cleaning experiment. The plasma parameters such as electron density,

**Fig.3 Electron Density Profile**

**Fig.4 Reduction of H2O Pressure**

electron temperature and space potential of the discharge were measured by Langmuir probe along the plasma column and near the cathode region. Figure 3 shows the space distributions of plasma parameters between discharge electrodes. The LaB6 cathode is positioned at the left side (r=0).

The figure indicates the electron density distributions which is deduced from the saturation current Is shown in the figure and the profiles of the electron temperature is also shown. The discharge conditions of the initial argon pressure is P=10 Pa. The discharge parameters obtained here are Vd=0.9-1.2 kV, discharge current Id=30-70 mA. The electron density near the cathode is estimated to be (3-5)x10^9 particles/cm$^3$. The electron temperature is 3-5 eV and is not affected remarkably by the discharge conditions. Correlations between partial pressures and plasma parameters are studied. Figure 4 shows the time dependences of the partial pressure of H2O (m/e=18) for various plasma densities. The previous experiments showed the discharge using a Cu electrode showed no rapid reduction of H2O vapor was observed and the discharge voltage and its total current were almost constant during the
discharge.

The experimental result showed that the boron films created on the metal vacuum wall can affect effectively on O₂ gases. It is recognized from the figure that the partial pressure of water vapor is reduced with the constant reduction rate for every plasma density. After the discharge is stopped, the time variations of H₂O becomes constant. The outgassing rate of the water vapor is recognized to be about constant without plasma conditions. Figure 5 shows the mass spectrum of m/e=2, 14, 18, 28, 32. The pattern indicates the result during the discharge. It is clear from the figure that H₂O is reduced remarkably by the LaB₆ sputter discharge. Figure 6 shows also the time histories of various gases during the discharge. The experimental results of spectroscopic measurements Fig.2 Measuring System are shown in Fig.7 and 8. The intensities of N and O₂ for wave length are shown in Fig.7. The results of correlations between light intensities and discharge current are shown in Fig.8.

![Fig.7 Spectrum of N and O₂](image)

![Fig.8 Light Intensities vs. Discharge Current](image)

4. Discussion
We investigate briefly the action of the created boron like films for residual gases. The experiment shows that the glow plasma by using reactive material electrodes is apparently effective to change the amount of oxygen gases in N₂/O₂ mixtures during the sputter glow discharge. The basic properties of the glow discharge with LaB₆ cathode is that the cold cathode is sputtered strongly by the ions. Then the discharge parameters are determined by the interaction between the cathode and gases. The time histories of mass
number of m/e=2, 18, 28, 32, 44 are monitored by QMS. In order to confirm the amount ratio of the gas, the spectroscopic spectrum is also detected simultaneously. The experiment showed that the glow plasma by using reactive electrodes is apparently effective to change the ratio of mixed gases and indicate a decomposition of NOx like gases.

5. Conclusion

Experiments on plasma parameters of density, temperature and sputtered film characteristic in a glow discharge are studied experimentally. To control Oxygen for processing plasma, lanthanum hexaboride (LaB6) is applied for the cathode material of the glow discharge. The application of LaB6 for the cathode was proposed to obtain a low outgassing wall for a plasma vacuum chamber. The experiment is performed in a stainless vacuum chamber with a volume of 2.4 liters. A disk of 50 mm in diameter of LaB6 is used for the cathode and is arranged in the center of the cylindrical anode of the chamber wall. The chamber is connected to the differential pumping system, in which QMS measurements of the partial pressures are made. The properties of the discharge plasma parameters are studied by measurements of spectroscopy and a voltage-current characteristics, electron densities and temperature of the plasma. The experiments show that the LaB6 coating by the glow discharge with LaB6 on a stainless steel wall is apparently effective to reduce the N2 and O2 composition.

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References
