Amplification Stability of Channel Electron Multiplier for Residual Gas

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We investigated the amplification stability of a channel electron multiplier (CEM) after gas adsorption. As the adsorbed gases, we chose H_2, CO, CO_2 and CH_4, which are the main species in a typical UHV environment. The gas was introduced at $5x10^{-8}$Pa for 5min. After gas was adsorbed, we observed the intensity change of CEM for an input electron voltage of 80eV. The results showed that the H_2 and CO adsorbed on the CEM modified the CEM amplification but that the exposures of CO_2 and CH_4 did not affect the amplification. A higher voltage applied to the CEM reduced the modification of CEM amplification because of electron stimulated desorption (ESD).

1. Introduction

Channel electron multipliers (CEMs) and microchannel plates (MCPs) are widely used in surface analysis instruments because of their high gain, bakeable characteristic, and ability to be exposed in air. The amplification of a CEM can be easily controlled by applying a voltage to it, but there is no feedback system to stabilize the amplification. In contrast, other components of surface analysis instruments, such as the electron source or power supply for electrostatic analyzers, have such feedback systems. Therefore, the amplification stability of a CEM will dominate the stability of the whole system. Due to the important role of the CEM, many investigations studied the changes in CEM amplification with input energy, passage of time, applied voltage, and ionic state of input ion [1-5]. However, there have not been any reports about CEM amplification changes with environmental gas.

Since the CEM is usually installed in a vacuum chamber, its amplifying wall is always exposed to the residual gas existing in the chamber. The adsorption of the residual gas may change the secondary electron emitting yield of the amplifying wall, which could lead to changes in CEM amplification.

To investigate the CEM amplification changes after gas adsorption, we chose H_2, CO, CO_2 and CH_4 gases that are the main species in a typical UHV chamber. This paper investigates which gas species affects the change of CEM gain most significantly.

2. Experimental

We used a double-pass CMA (ULVAC-PHI 15-255GAR) that has a coaxial electron gun as shown in Fig. 1. A turbo molecular pump with pumping speed of 660 l/s evacuated the experimental chamber to a base pressure of $3x10^{-8}$ Pa. CH_4, CO, or CO_2 gas (purity 99.99%) was introduced through a variable leak valve. Hydrogen gas was introduced from a hydrogen purifier. The pressure of the introduced gas was measured with an ionization gauge (Varian UHV-24), and the relative sensitivity factor of the gas was 1.05 for CO, 1.5 for CH_4, 1.45 for CO_2, 0.43 for H_2, and 1 for N_2 [6]. To reduce the effect of

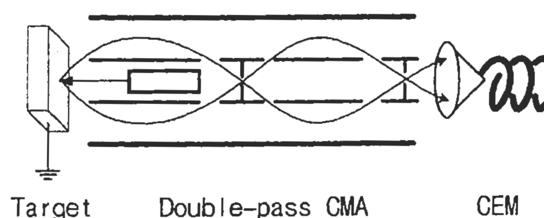

Fig. 1. Schematic view of experimental setup. Target was Au sample whose backside was heated to 300 °C.

adsorption, we chose a gold sample and mounted it on a PBN heater which was maintained at 300° C. The primary energy of the electron beam was 2 keV, and the fluctuation of the beam current was 2% during measurements. The spectra were taken in the pulse-counting mode, and the typical counting rate was 40 kcps (counts per second) at a pass energy of 80 eV.

The experimental procedure was as follows. During the aging of beam current for stabilization, the pass energy of the analyzer was set to zero and the output count rate was around 1 cps. After the aging, the gas was introduced up to a pressure of 5×10^{-6} Pa for 5min. After this, the gas was pumped out and the pressure was immediately restored to the previous pressure. The pumping of CO_2 needed the longest time (1 min) to achieve a pressure of slightly less than 7×10^{-8} Pa. After evacuation for 20 minutes, the pass energy was increased from 0eV to 80eV and the output intensity was recorded. To change the count rate, three different applied voltages were chosen and the above procedure was repeated.

3. Results and Discussions

Figure 2 shows the dependence of the CEM output on applied voltage. Between applied voltages of 1550V and 1850V, the output exhibited a plateau structure. We chose 1649V which was in the plateau region. Other

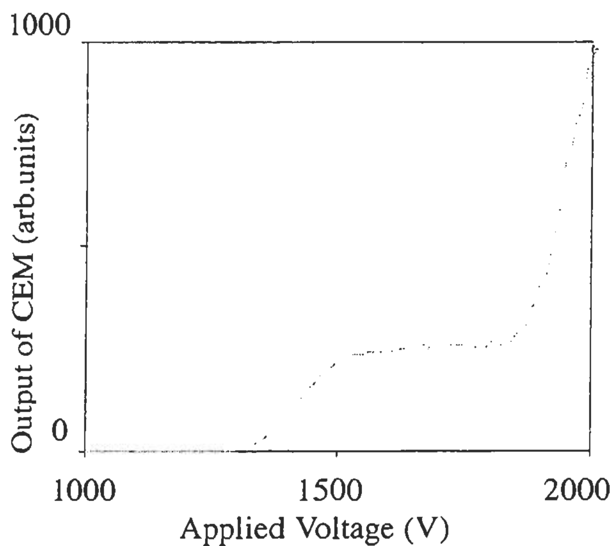

Fig. 2. Dependence of CEM output on applied voltage. Energy of input electron was 80 eV.

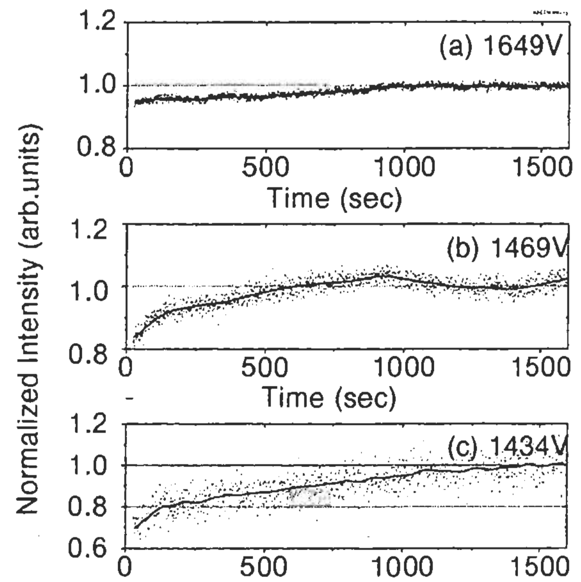

Fig.3. CEM output change after exposure of H_2 gas for CEM voltage of (a)1649 V, (b)1469 V and (c)1434 V. The intensity is normalized to the intensity at 1600 s.

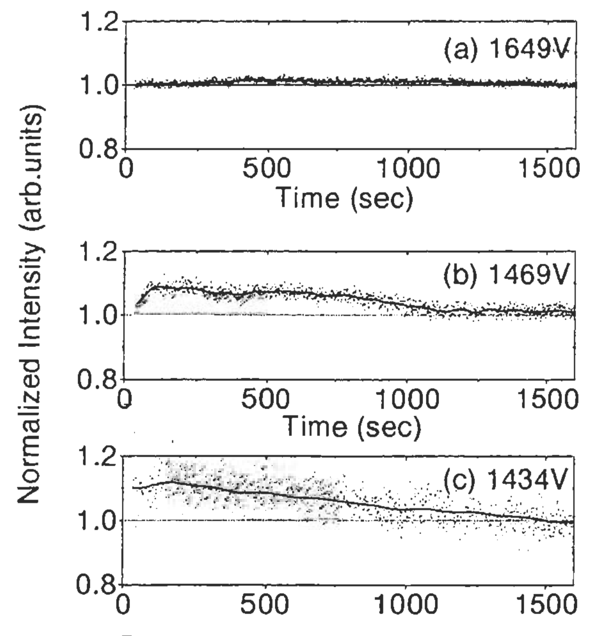

Fig.4. CEM output change after exposure of CO gas for CEM voltage of (a)1649 V, (b)1469 V and (c)1434 V. The intensity is normalized to the intensity at 1600 s.

voltages were 1434V and 1469V, which gave lower count rates. The typical count rates were 0.6kcps for 1434V, 4kcps for 1469V, and 25kcps for 1649V.

Figures 3 to 6 show the changes of the CEM output with time after the gas exposures. H_2 exposure reduced the output intensity, which then gradually recovered. The recovery was faster for higher applied voltages. CO exposure, however, led to an increment of the output intensity, which then gradually recovered. The recovery was also faster for higher applied voltages. In contrast, the exposures of CH_4 and CO_2 did not cause changes of the output intensity at any applied voltage.

We do not think that the gas was adsorbed on the sample surface because the long irradiation of the electron beam prevented adsorption. Furthermore, we do not think that the beam current was changed by the introduction of gases because the above tendency was also observed when measurements were made 60 minutes after the gas exposure was terminated, as shown in Fig. 7.

One of the most probable reasons for the change of output is the adsorption of gas onto the CEM wall, which subsequently caused the change of the secondary electron yield of the amplifying wall. When electrons arrive at the CEM, multiplied electrons bombard the adsorbed gas, and the amount of adsorbed gas gradually decreases because of electron stimulated desorption (ESD). ESD then leads to the recovery of output intensity. The higher

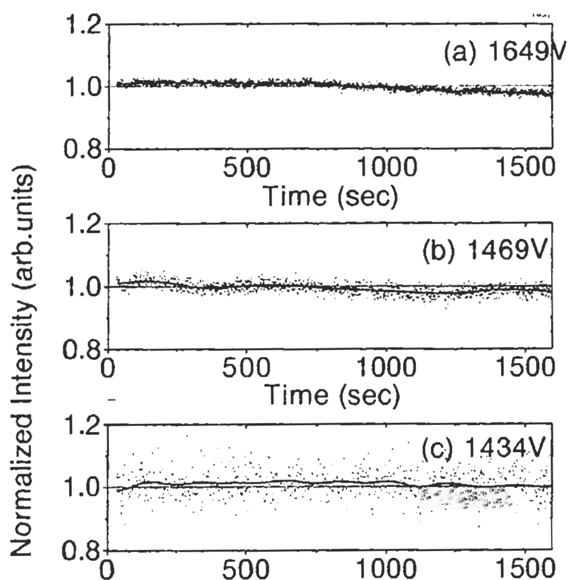

Fig. 5. CEM output change after exposure of CH_4 gas for CEM voltage of (a)1649 V, (b)1469 V and (c)1434 V. The intensity is normalized at the intensity at 1600 s.

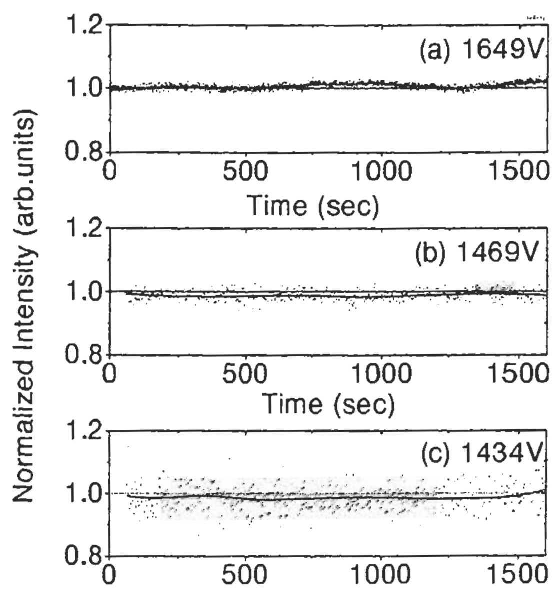

Fig.6. CEM output change after exposure of CO_2 gas for CEM voltage of (a)1649V, (b)1469V and (c)1434V. The intensity is normalized at the intensity at 1600Sec.

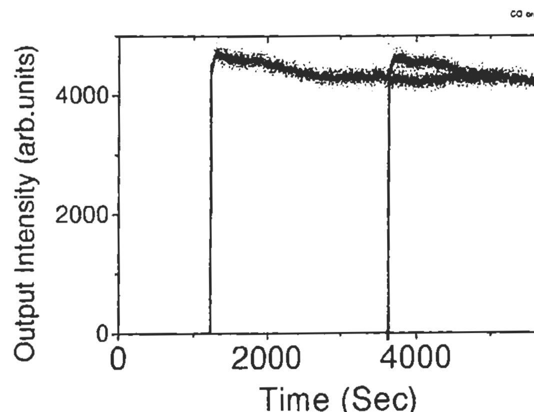

Fig.7. Intensity variation of the CEM output from gold surface after the inlet of CO gas with the pressures of $5x10^{-6}$ Pa for 5 min. After 20 min and 60 min the pass energy was set by 80 eV.

applied voltage leads to much more intense ESD because there were more amplified electrons, leading to the faster recovery of the output intensity.

There are several explanations for the CH_4 and CO_2 gases. The CH_4 and CO_2 exposures cause adsorption on the wall, but the adsorption does not change the secondary electron yield. Another possibility is that the sticking coefficients for CEMs wall are smaller than those of the other gases so the modification of the amplification was not observed in this experiment. Actually for titanium surface the initial sticking coefficients of the gas was 0.7 for CO, 0.06 for H_2, and 0 for CH_4 at 300K [7]. We still cannot determine the main reasons because the adsorption coefficient was not assigned for the CEM wall.

The results lead us to the following conclusions. When the CEM is operated with a high enough voltage, the amplification is stable because there is hardly any gas adsorption on the wall. However, when the pressure around the CEM is not low enough or there are too few input electrons, the amplification could be modified by adsorption of the gas. As a result, during the acquisition of a spectrum which has a large intensity variation, the output may not reflect the real spectrum because the amplification is modified in the weak intensity region. When a CEM is left for a long time without any input, the residual gas in the environment will be adsorbed, so the first spectrum may not reliable because of modified amplification.

4. Conclusions

We investigated the changes in CEM amplification with $5x10^{-8}$Pa, 5-min exposures of H_2, CO, CO_2 and CH_4, the main species in a typical UHV chamber. We concluded that the adsorption of H_2 and CO on CEM modified the CEM amplification. The exposures of CO_2 and CH_4 did not affect the amplification. Higher voltages applied to a CEM reduced the modification of CEM amplification because of ESD.

In this report, the input intensity to a CEM was held constant and the applied voltage was varied. To clarify the model in which the adsorbed gas was desorbed by ESD, it was necessary to apply a constant voltage and vary the input. Operating a CEM at a higher temperature is one method of avoiding the adsorption of residual gas.

5. References

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