Report on Visit to SungKyunKwan University by International Training Program

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1. Introduction

I participated in the Long-term Placement Program of International Training Program (ITP) and did research activities under the guidance of Prof. Han in the Center for Advance Plasma Surface Technology (CAPST) of SungKyunKwan University.

I studying about the interlayer dielectric films etching and clarify the etching mechanism by experiment and simulation. The balance and composition of ions and radicals in plasma affect the etching performance. Because densities of the radicals are high, the radicals greatly influence the property of reactions in plasma and on surface. Therefore it is important to measure radicals in plasma for controlling the performances of plasma etching.

The research group of Prof. Han works on formation and control of properties and application of thin films using magnetron sputtering and plasma-enhanced chemical vapor deposition (PECVD). The setup for measurement of radicals in plasma contained SiH4 using vacuum ultra violet (VUV) light was constructed. I conducted a research on constructing VUV absorption spectroscopy (VUVAS) and measuring the radical densities in order to not only utilize my knowledge and experiences but also acquire new ones.

2. Research

Absorption spectroscopy is one of the methods of measuring radical density in plasma. The light thought plasma decay because of absorption. The density of species is calculated by the ratio of transmitted light intensity to incident light intensity. Figure 1 shows a schematic of absorption spectroscopy.

The relational expression between N_1, the atom density of lower level and $\kappa(\nu)$, absorption constant is

$$\int \kappa(\nu)d\nu = \frac{c^2}{8\pi\nu_0^2}\frac{g_u}{g_1}A_{u1}N_1 \qquad [1]$$

where c is light speed, ν_0 is center frequency of spectra, g_u and g_1 are statistical weight of upper and lower, A_{u1} is Einstein A coefficient of absorption spectra ,respectively. If parallel light go through plasma from light source, it is expressed using law of lambert

$$\kappa(\nu) = -\frac{1}{L}\ln\left[\frac{I_0(\nu)-I_A(\nu)}{I_0(\nu)}\right] \quad . [2]$$

Where $I_0(\nu)$ is intensity of transmitted light, $I_A(\nu)$ is intensity of incident light and L is absorption length respectively. Measured intensity is integrated on frequency and expressed

$$I_0 = \int e_0 f_0(\nu)d\nu \qquad [3]$$

$$I_A = \int e_0 f_0(\nu)\left[1-\exp\left\{-\kappa_0 f_A(\nu)L\right\}\right]d\nu \qquad [4]$$

Where $f_0(\nu)$ is line profile function of the light source. If the light is incoherent, $f_0(\nu)$ is Gaussian. $f_A(\nu)$ is line profile function of absorption by atom. Under the condition of low pressure, $f_A(\nu)$ is also Gaussian because the effect of Doppler broadening ascribable from thermal motion of atom is the larger. And e_0 light source intensity at the center frequency of $f_0(\nu)$, κ_0 is absorption coefficient at center frequency. By the equation [2] to [4],

$$\int \kappa(\nu)d\nu = \kappa_0 \int f_A(\nu)d\nu \qquad [5]$$

is obtained. By equation [1] and [5],

$$N_1 = \frac{8\pi\nu_c^2}{c^2}\frac{g_1}{g_u}\frac{\kappa_0}{A_{u1}}\int f_A(\nu)d\nu \qquad [6]$$

is obtained.

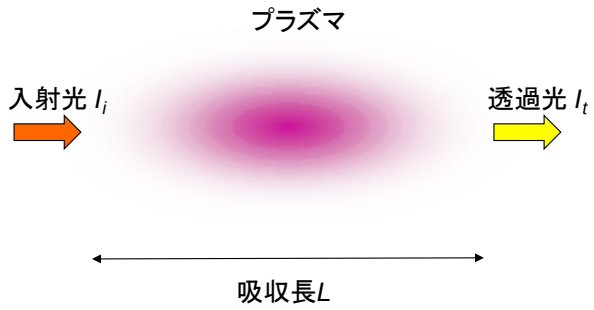


Figure 1. Absorption spectroscopy

In this study, Micro Hollow Cathode Lamp (MHCL) was used for VUV light source. Because the light from MHCL is incoherent, only absolute density is calculated if absorption profile and translational temperature are given. However setup composition using MHCL is simpler than using laser. Figure 2 shows the picture and schematic of VUVAS setup.

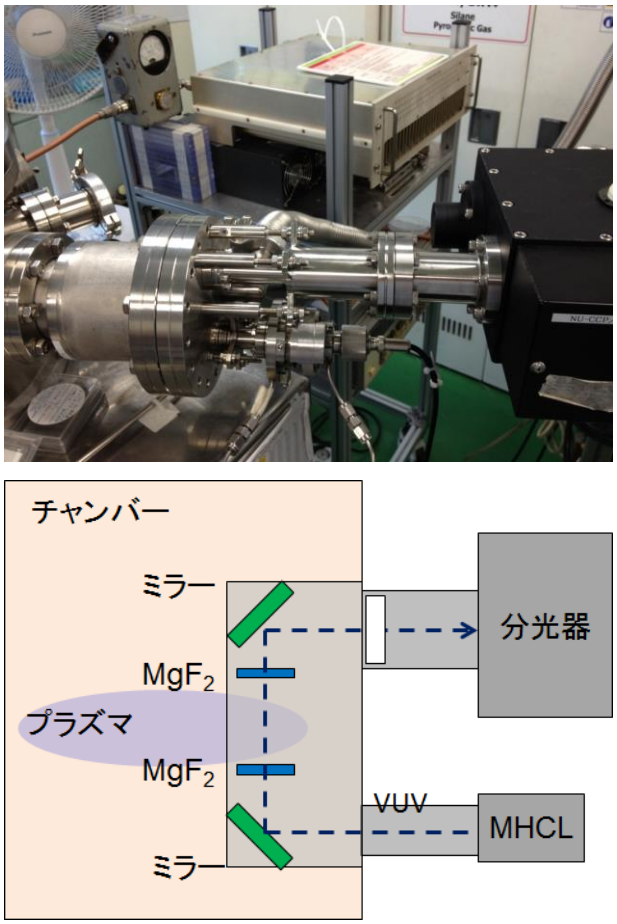


Figure 2. VUVAS

First of all, to collimate VUV, we adjusted the position of light source and spectroscope, and we gain the highest intensity in this time. The pressure of MHCL was atmosphere with He flow rate was 250 sccm and $He+O_2+H_2+N_2$ mixer gas flow rate was 2.5 sccm. Inlet voltage to MHCL was adjusted to control the current of MHCL was 10-12 mA. For intensity measurement, photo multiplier (PMT) fixed to spectroscope was used and voltage applied to PMT was -1200 V. The wavelength used to measure are 120.0 nm (N), 121.6 nm (H), 130.3 nm (O), 164.0 nm (He), 174.3 nm (N) and overall. However maximum signal intensity was only 4 mV. To measure radical density, it is necessary the signal intensity was 100 mV as the lowest. Therefore to look for the cause of low signal, we connected light source and spectroscope directly, and we check emission intensity of MHCL.

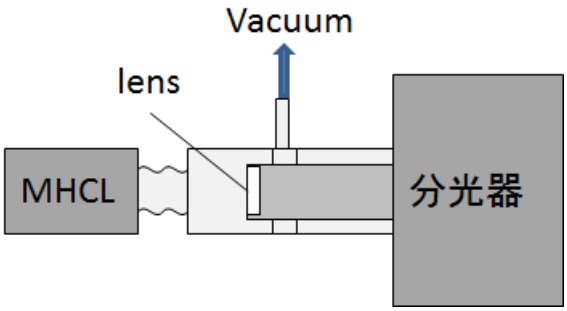


Figure 3. Directly connected of MHCL and spectroscope

After we connected MHCL and spectroscope directly and adjusted light axis, it was considered VUV was attenuated at MgF_2 window by lens of spectroscope because higher signal intensity was measured if MgF_2 was removed. The signal intensity of 121.6 nm was measured 260 mV without MgF_2 window, and it is enough to measure radical density. In this experiment, MgF_2 window did not negatively affect to experiment. Therefore we removed this MgF_2 window after this experiment.

Then we constructed VUVAS setup again and measured signal intensity. After we adjusted light axis and focus of lens, we measured the signal intensities as shown on table 1. Figure 4 shows measured signal intensity of 121.6 nm spectra.

Table 1. Measured intensity

Wavelength [nm]	Intensity [mV]
全波長	160
120.0	4.8
121.6	240
130.3	44
164.0	20
174.3	11.2

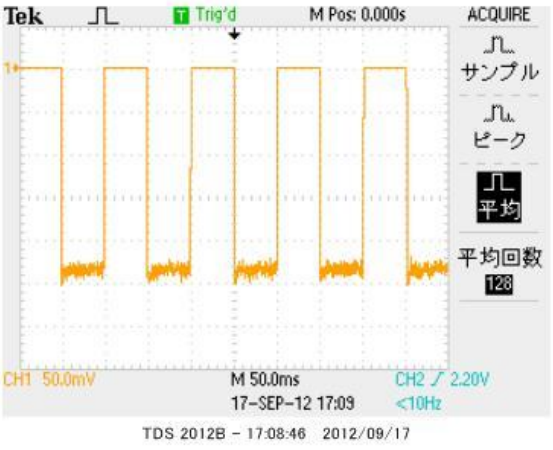
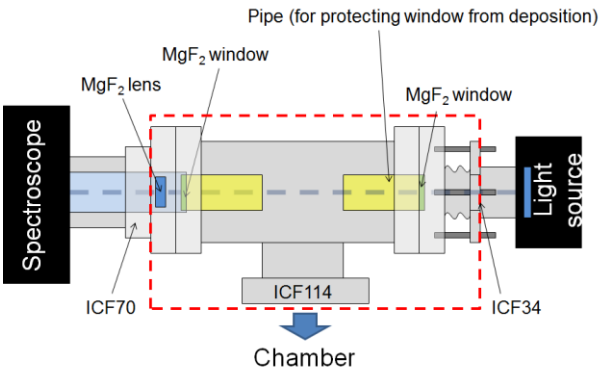


Figure 4. H signal

It was considered measured H signal intensity (121.6nm) was enough to do VUVAS measurement. However it was appeared N (120.0, 174.3 nm) and O (130.3 nm) signal intensity was not enough to do VUVAS measurement. To appear the cause of low signal intensity expects for H, we removed MgF_2 windows between chamber and measurement setup and measured signal intensity. However signal intensity did not change a lot with and without MgF_2 windows. Therefore it is considered VUV was attenuated at Al mirrors. Because the reflection rate of Al mirrors without MgF_2 coat is low (< 160 nm), it is assumed we used mirrors without MgF_2 coat.

Because H signal was enough to measure radical density, we measure the H radical density in H_2 plasma. We use a capacitively coupled plasma source and H_2 gas was applied with 1000 sccm flow rate. Pressure was 1 Torr. The VHF power was applied with 180 W and H2 plasma was produced. VUVAS setup was fixed at wall of chamber. We measured the change of intensity of 121.6 nm wavelength between with and without H_2 plasma. In the result of this measurement, signal intensity was 145 mV in the condition of only H2 gas without plasma and with H_2 plasma. It is assumed that H radical density was too low to measure because of long distance between plasma source and measurement position. If absorption was not enough to measure, we should change absorption length longer and absorption become larger. However absorption length of this setup was set 47 mm and was not changed. Therefore if we used this setup, we could not measure.

To resolve the problem of absorption length, we designed new setup we gain long absorption length. We asked company make some parts needed, however we did not get them and did not success VUVAS measurement. However, the knowledge and experience obtained from this study are expected to contribute strongly to future works on measurement the species in plasma and clarify etching mechanism.



Figuer 5 Straight type VUVAS setup

3. Life

I started to live in Korea at end of August when Japan-Korea relation became worse. Therefore I was afraid to live in Korea, before I attended ITP. However Prof. Han and other CAPST members made me welcome and support my stay, so I did not feel affect from Japan-Korea relation.

Regarding the food, I usually went to eat jjigae or other Korean food with CAPST members or went to buy bento to convenience store. There are basically a lot of spicy food as I could had imagined and some of them made me feel pain in stomachache after eating, but I am used to eating spicy food and enjoyed eating Korean foods fully. There is a station by the university and I could go to soul about a hour. So, I walked around the city and saw around traditional temples. I had a good chance to experience Korean custom.

I usually went laboratory on 9:00. In this time, some members already came to laboratory and did their works. So, I felt their good attitude for study. Mr. Shin, he did experiment with me, and I sometimes discussed and di experiment until 23:00. We communicated by English, but I often could not communicate well. I felt my English skill was worse than CAPST members and I felt attitude of activeness to world. I got a chance of attended a lecture. In this lecture, English was used in slides but presentation language was Korean. So I did not understand well, but I gained valuable experience.

4. Finaly

I'd like to thank Prof. Hori, Prof. Han, Prof. Sekine, Prof. Toyoda and ITP staffs for their help and support for my participation in this program. In addition, I really appreciate to Korean students for their support. I would like to take use of the experience obtained this time within the future work and life and go on to be an engineer or researcher who will be active internationally.