Absolute O Atom Density Measured in N₂/O₂ Surface-wave Plasma Using a VUVAS Method with a Calibration of Self-absorption of Light Source

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1. Introduction

The VUVAS technique is a well developed method for the absolute atom density measurement. For the VUVAS method, it's important to estimate the emission profile and the self-absorption of the light source, and the self-absorption should be reduced to negligible level for previous calculation theory of VUVAS. But sometimes the self-absorption can't be reduced to a reasonable level for the limit of the experimental conditions. Here, we have developed a new calculation method with the spectral analysis and the emission line profile correction, so that the light source with self-absorption can also be used for the VUVAS method.

In our previous work, surface-wave plasma (SWP) was used for sterilization of spores. The result showed the UV radiation is the most important lethal factor in N₂ and N₂/O₂ gas mixture plasma, but the neutral species, such as excited O atoms, also play a role in the inactivation of spores [1, 2]. In this study, with a compact low-pressure microwave plasma light source and the light probe at 130.49 nm, the absolute O atom density was measured with the developed VUVAS method. The effect of O atoms on the spores was investigated by the measured absolute atom density changed with different gas mixing ratio of N₂/O₂ low-pressure SWPs.

2. Experimental setup

The experimental setup consists of a stainless steel cylindrical vacuum chamber with a microwave launcher and 2.45 GHz microwave generator. The light source was installed on one side of the chamber and the VUV monochromator(Acton Research Corp., VM–502) was fixed at the opposite port. Two MgF₂ glass windows were inserted to separate it into three different pressure areas. The pressures both in the monochromator and processing chamber could be kept on 10^{-5} Torr by separated two-stage differential pumping systems.

3. Result and discussion



Fig.1. Specair fitting result of our best light source condition

Emission line intensity ratio within multiplets was used to evaluate the self-absorption of the light source. The best condition we got for our light source system was: Ar 5sccm, $O_2 0.1$ sccm, pressure 8.2 Pa, incident power 60 W. Then the emission profile of the best light source condition was fitted in the software of Specair to get a calculated discharge condition same to our light source. The result is shown in Fig.1. And then the ideal case without self-absorption was calculated by Specair with the calculated discharge conditions same to our light source, the result was shown in Fig.2. From Fig.2, the self-absorption of ours best light source condition was still obviously. In order to get accurate measurement results, it is necessary to calibrate the self-absorption of the light source.



Fig.2. The emission profile of our light source condition with self-absorption and the ideal condition without self-absorption.

A widely used empirical expression of the emission line without self-absorption from a low pressure light source can be given[3]:

$$E_{\nu} = C e^{-(\frac{\omega}{\alpha})^2}$$

Where α is emission line width/absorption line width, ω is the the normalized frequency. Then the real profile E_{ν} of the light probe we chose at 130.49nm was obtained with the calibration of the self-absorption based on theories related to the escape factor [4].

$$E_{v} = C e^{-\left(\frac{\omega}{\alpha}\right)^{2}} e^{\left(-k_{0}' l e^{-\left(\frac{\omega}{\alpha}\right)^{2}}\right)}$$

Where k_0' is the maximum absorption coefficient at emission line center, *l* is the discharge length of the light source. With the self-absorption calibrated of light source, the effect of O atoms on the spore-forming microorganisms will be investigated by the absolute atom density measured with the developed VUVAS method with different gas mixing ratio of N₂/O₂ low-pressure SWPs. The detail of the calibration of the light source self-absorption and the VUVAS measurement will be presented at the conference.

References

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 M.K. Singh, A. Ogino, M. Nagatsu, New J. Phys. 11 (2009) 15.
 Y. Zhao, M.K. Singh, A. Ogino, M. Nagatsu, Thin Solid Films 518 (2010) 3590-3594.

[3] A.C.Q. MITCHELL, M.W. ZEMANSKY, Resonance radiation and excited atoms, Cambridge University Press, 1961.
[4] L.M. Liao, J. He, Optik 125 (2014) 1602-1604.