Laser Diagnostic in a Plasma Display Panel Discharge Cell

Young Wook Choi
Korea Electrotechnology Research Institute, P.O. BOX 20, Changwon, 641-600, Korea

Abstract

Laser diagnostic method in a plasma display discharge cell was introduced. The information of electric field, potential and electron temperature *et al.* in the surface of plasma display panel can be measured using laser induced fluorescence spectroscopy. However, because of the very small discharge dimension of ~ 100 μm, the measurement attempt has almost not been performed. In this paper, the direct measurement possibility of the parameters and the recent work of electric field measurement are demonstrated in the plasma display panel.

Introduction

In recent years, laser spectroscopic techniques have been applied to make measurements of electric fields in gas discharges. These techniques make use of the Stark effect, [1-3] which is the well-known phenomenon where the internal energy levels of atoms or molecules are altered by an electric field. In order to detect this effect, various techniques have been developed, in which laser radiation is absorbed by particles in the discharge and the effect of this laser excitation is detected. Two main techniques for the detection have been used: laser opto-galvanic (LOG) spectroscopy, in which the change of the impedance of the discharge due to the laser absorption is measured; and laser-induced fluorescence (LIF) spectroscopy, in which fluorescence light emission from the absorbed particles is monitored.

Until now, electric field measurements have been made by detecting Stark effects in a very limited number of kinds of atoms and molecules. Booth *et al.*[4] have reported a LIF method for hydrogen atoms which uses multi-photon excitation of ground state atoms. Gottscho *et al.*[5-7] made a series of LIF measurements in dc and radio frequency (RF) discharges by detecting the electric field induced state-mixing between rotational levels of opposite parity in the diatomic BCl radical, which is present in discharges produced with BCl_3 gas. The largest set of electric field measurements, however, have been made in helium discharges, because the Stark structure of Rydberg atoms is readily calculated and therefore the measured results can be directly used to determine the electric field.

Rydberg atoms are excited-state atoms in which one electron is in a very high energy level, so that the electron is far from the nucleus and the atom is therefore hydrogen-like. This kind of atom is particularly susceptible to Stark effects because of the large size of the electron orbit in the atom and the small energy gap between levels of opposite parity. Initially, this technique was developed by Lawler *et al.*,[8] who made measurements in helium dc discharges. In these experiments, Rydberg states were excited by laser excitation from low lying metastable levels and the excitation spectrum was measured by LOG spectroscopy. The electric field was then determined from the excitation spectrum. A similar measurement technique using neon atoms was also demonstrated.[9-10] The same technique was also used by Ganguly *et al.*[11-12] to make measurements in dc and low frequency RF discharges. This LOG spectroscopy was extended by Greenberg and Hebner[13] who detected the excitation spectrum in a dc discharge by observing LIF signals.

As described above, there have been several developed methods which allow the electric field in discharge plasmas to be measured and measurements in several different kinds of discharges have been made. In this paper, the extension possibility of laser diagnostic in the plasma display panel was also surveyed.

Stark effect

Fig. 1 shows the typical LIF spectrum obtained in an rf discharge (rf power of 100 W) in helium at a pressure of 0.85 Torr and at a distance of 2.5 mm from the powered electrode. It is clear that an electric field can be determined from the separation of the peaks (Stark effect) in the spectrum.[14]

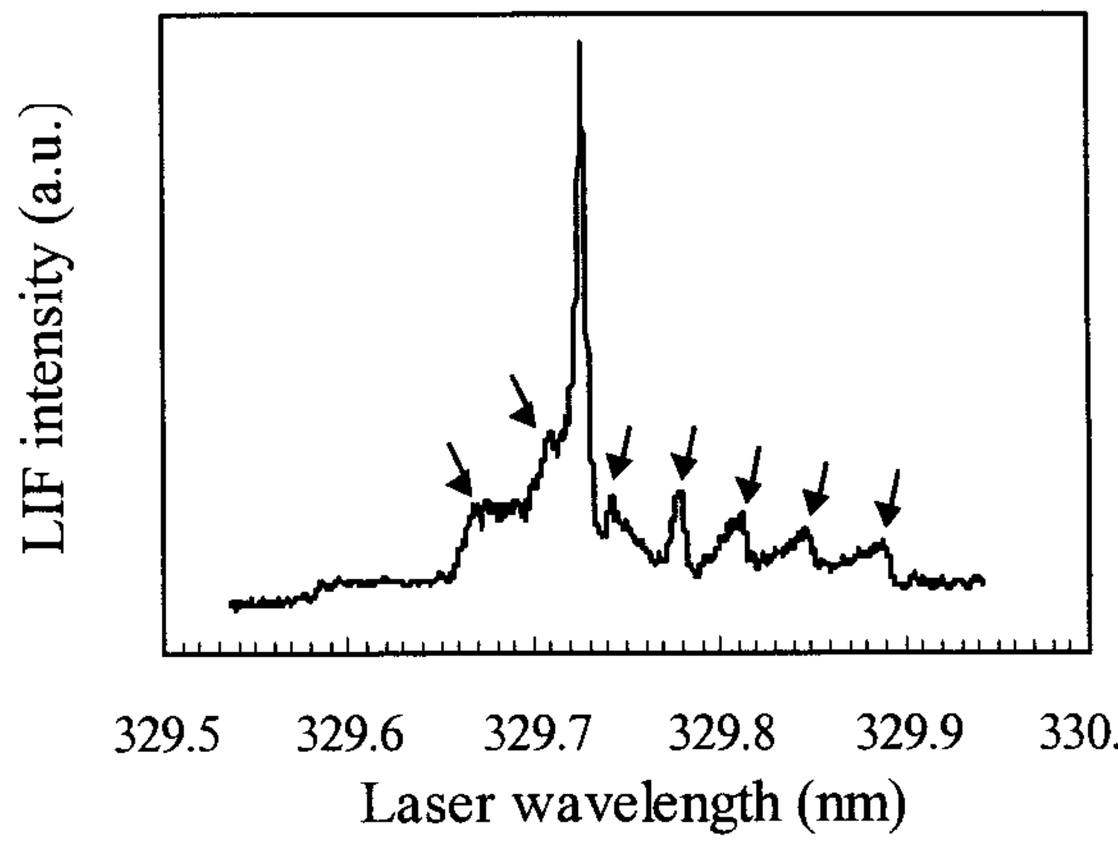

Fig. 1 LIF spectrum in rf discharge with He excitation energy n = 8 ($1s2s\,^1S \rightarrow 1s8p\,^1P$, 329.6 nm)

Fig. 2 shows the recently measured LIF spectrum in the plasma display panel.[15] Though the measured spectrum is not clear like Fig.1, the electric field can be obtained from the Stark broadening and the simulated spectrum. This is the first LIF spectrum in the plasma display panel. This result also illustrated the possibility of the electric field measurement application in the plasma display panel using *LIF technique*.

spectroscopy of atomic hydrogen," Appl. Phys. Lett., Vol. 65, No. 7, pp. 819 - 821 (1994).

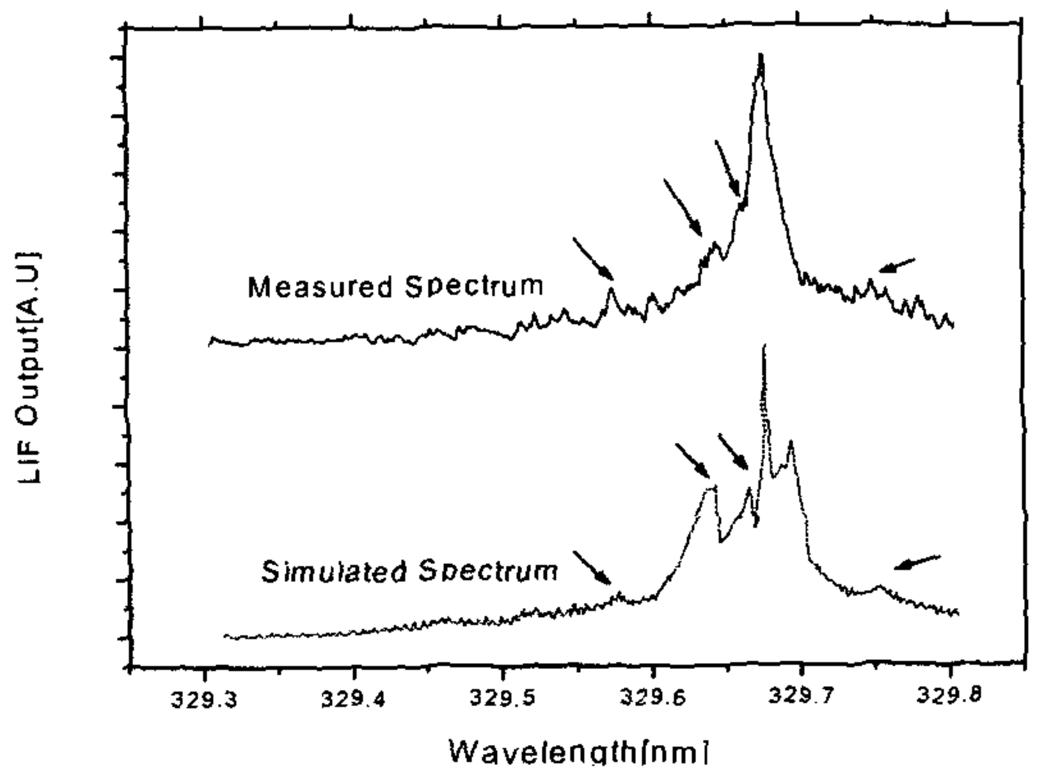

Fig. 2 Measured and simulated LIF spectrum in the plasma display panel with He excitation energy n = 8, [15]

Thomson Scattering

Thomson scattering of a high power pulsed laser can provide reliable and absolute measurements of the electron temperature Te and electron density Ne in plasma. The width of the Thomson spectrum is used to calculate the electron temperature and its intensity is used to calculate the electron density. There has been conducted the Thomson scattering to analyze in the processing of silicon wafers for the production of semiconductor devices. [16] When the information of electron temperature, electron density and neutral density in the plasma display panel can be obtained from Thomson scattering technique, it will become a big progress to understand the discharge characteristic in the plasma display panel.

Conclusion

To analyze the discharge characteristic in the plasma display panel cell, laser diagnostic is a powerful technique as a direct measurement method. From electric field measurement, we can obtain the potential distribution in the surface of plasma display panel at the condition of time varying and plasma on/off. From Thomson scattering, we will obtain electron temperature, electron density and neutral density. These two measurement methods will contribute to the accumulation of useful basic data in the plasma display panel application.

References

1. J. Stuart. Foster, "Application of Quantum Mechanics to the Stark Effect in Helium," Roy. Soc. Proc., A, Vol. 117, pp. 137-163 (1928).

2. H. A. Bethe and E. E. Salpeter, "Quantum Mechanics of One- and Two-Electron Atoms," Plenum Publishing Corporation, New York," (1977).

3. J. Stuart Foster, "Observations on the Stark Effect in Hydrogen and Helium," Phys. Rev. Vol. 23, No. 6, pp. 667 - 684 (1924).

4. J. P. Booth, M. Fadlallah, J. Derouard and N. Sadeghi, "Electric field measurements in discharges by 2+1 photon laser Stark spectroscopy of atomic hydrogen," Appl. Phys. Lett., Vol. 65, No. 7, pp. 819 - 821 (1994).

5. C. A. Moore, G. P. Davis and R. A. Gottscho, "Sensitive, Nonintrusive, *In-Situ* Measurement of Temporally and Spatially Resolved Plasma Electric Fields," Phys. Rev. Lett., Vol. 52, No. 7, pp. 538 - 541 (1984).

6. M. L. Mandich, C. E. Gaebe and R. A. Gottscho, "Time resolved fluorescence from parity mixed rotational energy levels: Collisions vs electric field effects," J. Chem. Phys. Vol. 83, No. 7, pp. 3349 - 3357 (1985).

7. R. A. Gottscho, "Glow-discharge sheath electric fields: Negative-ion, power, and frequency effects," Phys. Rev. A, Vol. 36, No. 5, pp. 2233 - 2242, (1987).

8. D. K. Doughty and J. E. Lawler, "Spatially resolved electric field measurements in the cathode fall using optogalvanic detection of Rydberg atoms," Appl. Phys. Lett., Vol. 45, No. 6, pp. 611 - 613 (1984).

9. D. K. Doughty, S. Salih and J. E. Lawler, "Two- step optogalvanic effect using intersecting laser beams: a pinpoint discharge diagnostic," Phys. Lett., Vol. 103A, No. 1,2, pp. 41 - 44 (1984).

10. K. C. Smyth and P. K. Schenck, "Opto-galvanic spectroscopy of a neon discharge: mechanism studies," Chem. Phys. Lett., Vol. 55, No. 3, pp. 466 - 472 (1978).

11. B. L. Preppernau and B. N. Ganguly, "Time-resolved electric field measurements in a 15 kHz helium glow discharge," Rev. Sci. Instrum. Vol. 64, No. 6, pp. 1414 – 1417 (1993).

12. B. N. Ganguly, J. R. Shoemaker, B. L. Preppernau, and A. Garscadden, "Rydberg state Stark spectroscopic measurement of electric-field profile in a glow discharge," J. Appl. Phys. Vol. 61, No. 8, pp. 2778 - 2783 (1987).

13. K. E. Greenberg and G. A. Hebner, "Electric-field measurements in 13.56 MHz helium discharges," Appl. Phys. Lett., Vol. 73, No. 24, pp. 3282 - 3284 (1993).

14. Y. W. Choi, M. D. Bowden and K. Muraoka, "Analysis of sheath electric fields in a radio frequency discharge in helium," Jpn. J. Appl. Phys. Vol. 35, No. 11A, pp. L1459 - L1461 (1996).

15. J. H. Kim, J. H. Lee, Y. W. Choi, J. H. Yang and K. W. Whang, "Wall voltage measurement in an AC PDP cell by Laser Induced Fluorescence," Proceedings of The Sixth International Display Workshops, Dec. 1-3, 1999, Sendai International Center Sendai, Japan, pp. 611-613

16. T. Hori, M.D Bowden, K. Uchino, K. Muraoka and M. Maeda, "Measurements of electron temperature, electron density, and neutral density in a radio-frequency inductively coupled plasma," J. Vac. Sci. Technol. A, Vol. 14, No. 1, pp. 144 - 151 (1996).