Optical Ozone Monitor Using UV Source

Wan-Young Chung*

* School of Internet Engineering, Dongseo University, Busan, Korea
(Tel : +82-51-320-1756; E-mail: wychung@dongseo.ac.kr)

Abstract: Two types of ozone monitors using UV absorption method were tried in consideration of cost of the monitor and precision in measuring. The high concentration ozone monitor for high concentration real time ozone monitoring from ozone generator was composed of a low pressure mercury lamp as UV source, a photo multiplier tube as UV detector and signal processing unit for the most part. This structure could be very useful for low price high concentration ozone monitor due to simple system structure and fairly good monitoring characteristics. The developed system showed good linear output characteristics to ozone in the measuring concentration range of 0.05 and 2 wt.%. For accuracy ambient ozone monitoring in ambient in ppm level, the system composed of a high power pulsed xenon lamp as UV source, an optical spectrometer with a high sensitivity linear CCD array as UV detector and signal processing unit in brief speaking was proposed our study for the first time in the world. The developed system showed good linearity and sensitivity in relative low measuring range between 10ppm and 10,000ppm, and showed some feasibility of high resolution ozone monitor using CCD array as photodetector.

Keywords: Ozone monitor, UV, UV detector, Photo multiplier, CCD array

1. INTRODUCTION

Ozone generated from ozone generator has been used as strong clean oxidizing agents in the fields of disinfectant and deodorizing applications. Ozone cannot be stored at room temperature, and is commonly generated by electric discharge at a usage site. Since a generation efficiency of ozone by electric discharge is susceptible to various parameters [1], it is necessary to monitor the output ozone level of generators for reliable concentration control. The concentration of exhaust ozone from ozone generator should be monitored in real time for exact ozone generation.

On the other hand ozone in the ambient air is very harmful to human health. Rising concentrations of ozone in the ambient air due to increased traffic, which is the main factor leading to photochemical smog, but also in offices due to laserprinters and photocopiers lead to an increased interest in its measurement. It causes inflammation and congestion of the respiratory tracts and, in the case of severe exposures, it produces pulmonary edema, hemorrhage and death. Furthermore during sunlight, ozone is responsible for NO_2 production, the so-called photochemical smog.

At present, commercially available O_3 concentration measurement systems are mostly based on photometric, chemiluminescence and fluorescence technologies, iodide methods, passive sampling, as well as mass spectrometery[2~4]. Among them Ultraviolet light (UV) absorption method[5,6] may be the most widely-adopted method today. Ozone concentration measuring method based on UV techniques are very sensitive and stable for ozone concentration, and most widely used method for precise ozone measurement. In this method, the concentration of ozone can be measured basically by comparison of UV intensity of 254 nm wave length when UV pass through the transparent absorption cell with or without ozone. Major shortcoming of the method is cost due to complexity of the system and due to costs of individual parts.

In our study, two kinds of ozone monitors was developed for different objectives seperately. One ozone monitor which can measure the high concentration ozone from ozone generators for reliable exhaust concentration control in relatively low cost, and the other monitor was developeed to measure precisely low concentration ozone in ambient separately. High concentration ozone monitor was composed of a low pressure mercury lamp as UV source, a photo multiplier tube as UV detector and signal processing unit for the most part. Ambient concentration ozone monitoring system was mainly composed of a high power pulsed xenon lamp as UV source, an optical spectrometer with a high sensitivity linear CCD array as UV detector and signal processing unit.

This article describes the preparation procedure of the final camera-ready manuscript of the paper that was invited and/or accepted for ICCAS 2003. When authors submit their work to the ICCAS 2003 for publishing, they should strictly follow these instructions in order to maintain high standards of the proceedings. The aim of the style file "ICCAS_style.doc" is to allow authors of papers to prepare the final camera-ready manuscript with MS-WORD easily.

Each paper must be divided into two parts. The first part includes the title, authors' name, abstract and keywords. The second part is the main body of the paper.

2. EXPERIMENTAL

2.1 High concentration ozone monitoring system

High concentration ozone monitoring system, that can monitor in the range of 0.01 and 10 wt.%, was developed using low price photo multiplier as a UV detector and very simple controlling unit that was composed of 2 PICs(Programmable IC with RISC like Architecture) as shown in Fig. 1.

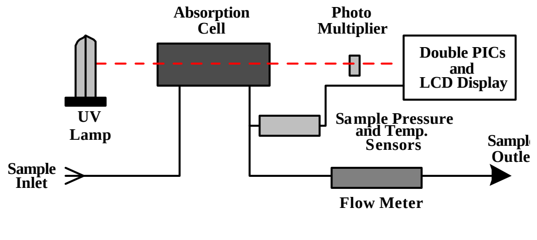

Fig.1 The conceptive block diagram of high concentration ozone monitoring system.

The ozone absorption cross section spectrum, as reported by Molina and Molina [7], is shown in Fig. 2. The concentration of ozone can be detected by comparison of UV intensity of 254 nm wavelength when air or oxygen flow pass through the absorption cell with or without ozone. An absorption cell was well designed considering repression of ozone concentration variation by irregularity of gas flow. To reduce optical loss, the distance between light source and photo multiplier was minimized as shown in Fig. 3.

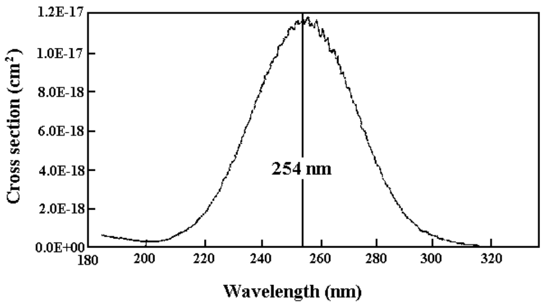

Fig.2 Absorption cross sections of ozone in the ultraviolet.

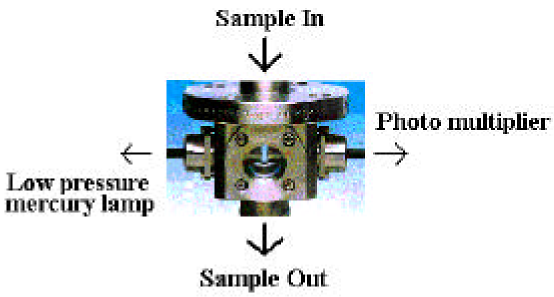

Fig.3 The fabricated gas flow cell for high concentration ozone monitor.

Figure 4 shows a photograph of the developed high concentration ozone monitor. This developed system have very simple structure and can be made by low cost.

2.2 Low concentration ozone monitoring system

To monitor ambient ozone, monitoring system should be able to measure between 0 and 100 ppm with ppb-level resolution. To increase the accuracy of the monitoring system, highly sensitive fiber optic spectrometer, which has a high sensitivity 2048-element linear CCD array detector.

A pulsed Xenon lamp with short-arc flashlamp for the UV between 220 and 750 nm in wavelength was used as a optical source with maximum pulse rate of 200Hz. The lamp produces high-energy pulses of brief duration and the flash rate could be controlled by software. In our study, a pulsed signal was used to reduce solarization that may occur below 260nm in many optical assemblies. Two pieces of 300 μm patch optical fibers were used in our experiment to reduce the optical loss. One was for illumination fiber between a light source and a sampling chamber, and the other was for connecting the optical signal from the chamber to the optical detector of the spectrometer. The light energy transmitted through single-strand optical fiber from a pulsed Xenon lamp was disperses via a fixed grating at the end of optical fiber.

Ozone concentration was detected by comparison of UV intensity in and around of 254 nm wave length when air or oxygen flow pass through the transparent absorption cell with and without ozone. A cell holder was designed for 10cm path length cell couples via optical fibers to the fiber optic spectrometer and light source for absorbance measurement of ozone. The holder had a pair of adjustable 5mm diameter quartz collimating lenses to improve the adsorption rate of the UV light. A quartz absorption cell with a pair of inlet and outlet for gas flow was designed also. The cell holder is covered with a black cover to eliminate ambient light.

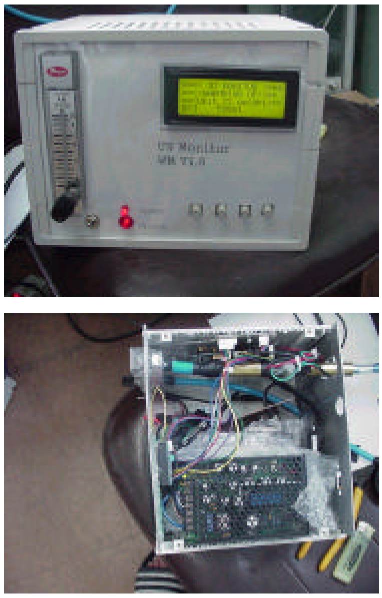

Fig.4 The developed high concentration monitor.

The spectrometer used in our study has a high sensitivity linear CCD array (2048 element linear silicon CCD array) that provides high response and good optical resolution (86 photons/count). Light transmitted via optical fiber from a absorption cell enters to the spectrometer. In the spectrometer, the divergent light emerging from the optical fiber is once collimated by a spherical mirror and the collimated light diffracted by a plane grating, the resulting diffracted light is focused by a second spherical mirror. And then the spectrum is projected onto a 1-dimensional linear CCD array, and the data is through an A/D card. Spectrometer system response depends on the grating, detector and other factors. The grating at the end of optical fiber in a spectrometer (ie. detector) yields the optimum wavelength range, optical resolution and signal for the special application. All ruled or holographically etched gratings optimize first-order spectra at certain wavelength regions. In our study, 600 lines/mm grating was etched for filtering the optical signal transmitted from optic fiber. The grating has a 650 nm spectral range as shown in Fig. 5, however is most efficient over a much narrower range from

200 and 575 nm. In this instance, wavelengths above 575nm will have lower intensity at the detector due to the reduced efficiency of the grating.

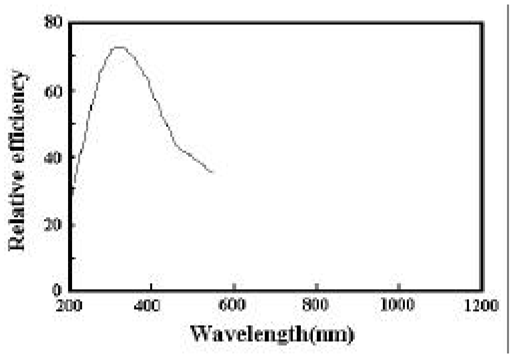

Fig.5 Relative optical efficiency – wavelength chart.

Absorbance spectra are a measure of how much light is absorbed by a sample gas. Absorbance is linearly related to the concentration of ozone. The absorbance could be calculated using the following equation:

$$A_\lambda = -\log_{10}\left(\frac{S_\lambda - D_\lambda}{R_\lambda - D_\lambda}\right) \quad (1)$$

Where S is ozone intensity at wavelength ë, D is the dark intensity at wavelength ë, R is th reference intensity at wavelength ë.

Fig. 6 and Fig. 7 show the schematic model of ambient ozone monitoring system and the assembled monitoring system.

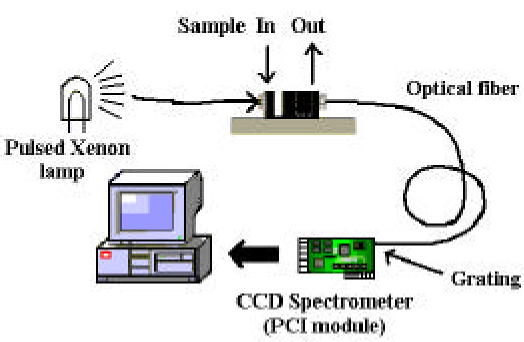

Fig.6 Schematic model of the ambient ozone monitoring system.

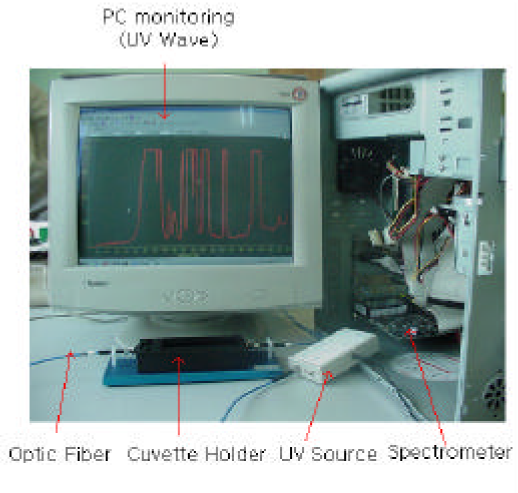

Fig.7 Photograph of the developed ambient ozone monitoring system.

3. RESULTS AND DISCUSSION

3.1 High concentration ozone monitor

The system using low pressure mercury lamp as UV lamp and photo multiplier tube as UV detector had a fairly good linearity and sensitivity in the measuring range of 0.01 and 1 wt.% as shown in Fig. 8. The developed system showed good linear output to ozone concentration of 0.05 and 2 wt.% at the different ozone mixed oxygen flow rate between 1 and 4 liter per min.(LPM). When the generated ozone flew faster, the absorption of optical signal of 254 nm became much bigger.

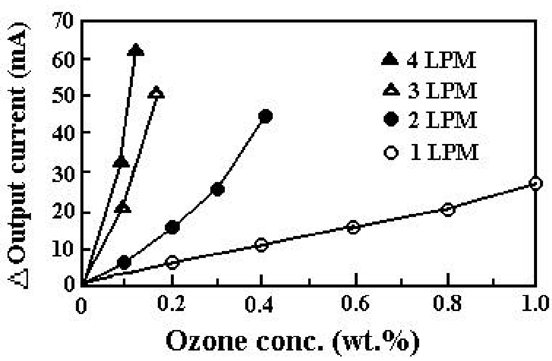

Fig. 8 Linearity of current output vs. ozone concentration.

3.2 Low concentration ozone monitor

The developed low concentration ozone monitoring system shows good linearity in the measuring range of between 10 ppm and 10,000ppm, as shown in Fig. 9. This system have better measurement resolution than high concentration ozone monitor, however the resolution should be improved more if this system can be used for ambient ozone monitoring system. For ambient ozone monitor, 0.1 ppm resolution will be wanted.

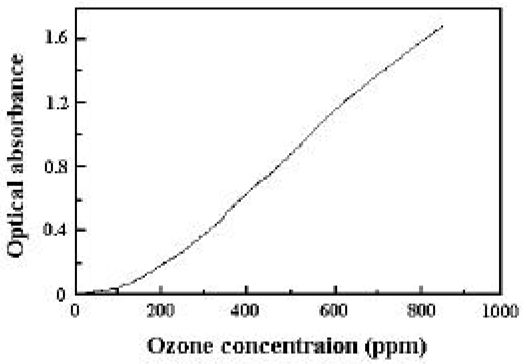

Fig.9 Linearity of absorbance vs. ozone concentration.

4. CONCLUSIONS

An low price ozone monitoring system that was composed of UV lamp (low pressure mercury lamp), photo multiplier tube as UV detector and signal processing unit composed of 2 PICs(Programmable IC with RISC like Architecture) was proved as a very useful system for high concentration ozone monitoring at low cost. The fabricated system can linearly monitor in the range of 0.01 and 10 wt.% of ozone.

An high precision ozone monitoring system using a high optical resolution linear CCD array as a absorbance detector was carried out to quantify ozone concentration firstly. The feasibility of this kind monitoring system, which used CCD photo detector and optical transmitting fiber, for ozone monitoring was proved. The optical fiber system have good linearity in the range of 10 and 10,000ppm, however the more efforts will be required in the near future to improve the sensitivity specially in the sub-ppm level.

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