UV 감지기로서 CCD어레이를 사용한 소형 디지털 광 오존모니터

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A New Small Size Digital Optical Ozone Monitor Using CCD Array as a UV Detector

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본 연구는 산업자원부의 지역혁신 인력양성사업의 연구결과로 수행되었음

요 약

UV기술에 기반한 오존모니터는 신호의 안정성 때문에 널리 활용되어오고 있다. 먼저 오존 발생기에서 나오는 오존농도를 실시간, 고정밀로 측정하기 위해서 저압 수은램프를 UV광원으로 하고, 광증배관을 UV 감지기로 하는 시스템을 구성하였다. 이 구조는 저비용의 고농도 오존의 계측에 유용한 시스템으로서 단순한 구조와 비교적 우수한 계측성능을 얻을 수 있었다. 제조된 시스템은 0.05~2wt.%의 측정 농도영역에서 좋은 선형성을 나타내었다. ppm 정도의 보다 정밀한 농도계측을 위해서는 UV광원으로서 고출력 펄스 크세논램프를 사용하고, CCD어레이를 광스펙트로메터로 사용하도록 시스템을 설계하였다. CCD출력으로 부터의 광신호는 우수한 반응성과 띄어난 광해상도를 가지고 디지털신호로 변환되고, 이 디지털신호는 PC의 스크린에 디스플레이되도록 설계되었다. 제작된 시스템은 10~10,000ppm 영역에서 선형적이고 우수한 감도를 보였으며 저농도의 오존을 측정하는 시스템으로서의 가능성을 보여주었다.

ABSTRACT

Ozone monitor based on UV techniques has been widely used due to their signal stability. The high concentration ozone monitor for real time ozone monitoring from ozone generator was composed of a low pressure mercury lamp as UV source and a photo multiplier tube as UV detector. The structure could be very useful for low price high concentration ozone monitor and showed good linearity to ozone in the concentration range between 0.05 and 2 wt %. For accurate ambient ozone monitoring, 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. The optical signal form the CCD array was converted to digital signal, and the digital signal was displayed on screen using PC interface. The developed system showed good linearity and sensitivity in relatively low measuring range between 10ppm and 10,000ppm, and showed some feasibility of high resolution ozone monitor using CCD array as a photodetecor.

키워드

Ozone monitor, Optical ozone monitor, CCD, Photomultiplier, UV detector

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Ⅰ. 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 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 NO2 production, the so-called photochemical smog. At present, commercially available O3 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 separately. 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 developed 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.

Ⅱ. 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.

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.

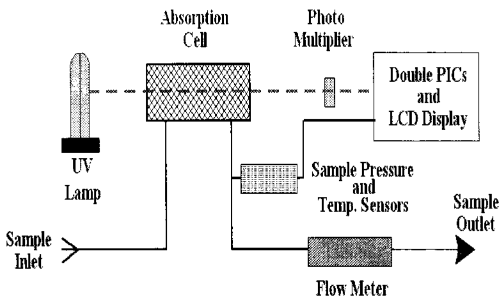

Fig. 1 The conceptive block diagram of high concentration ozone monitoring system.

To reduce optical loss, the distance between light source and photo multiplier was minimized as shown in Figure 3.

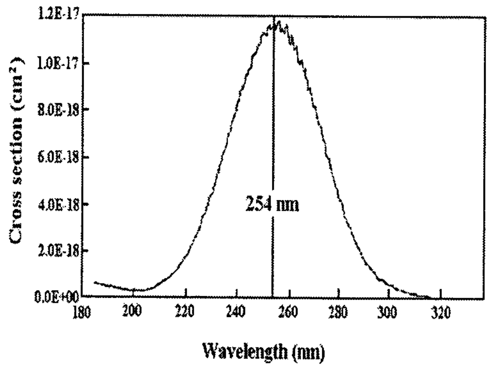

Fig. 2. Absorption cross sections of ozone in the ultraviolet.

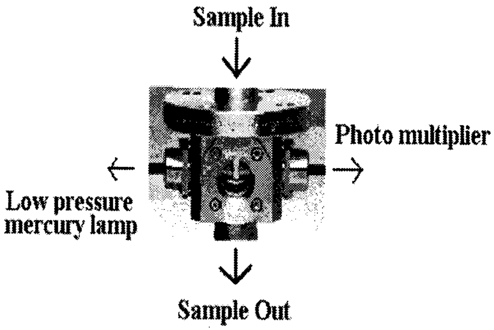

Fig. 3. The fabricated gas flow cell for high concentration ozone monitor.

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.

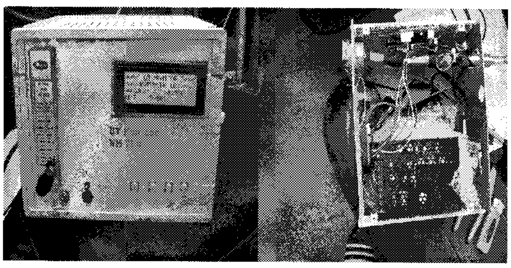

Fig. 4. The developed high concentration ozone monitor.

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 ㎛ 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.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 (86photons/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.

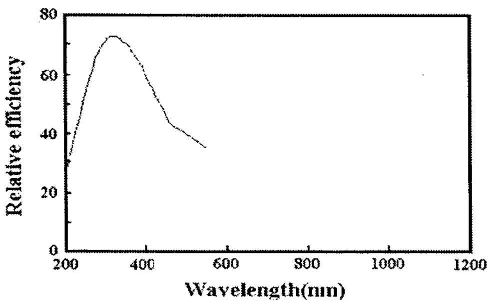

Fig. 5. Relative optical efficiency - Wavelength chart.

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:

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

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

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

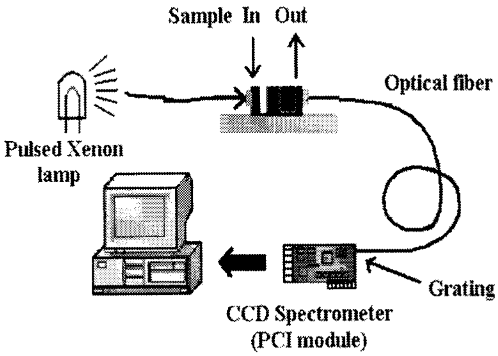

Fig. 6. Schematic model of the ambient ozone monitoring system.

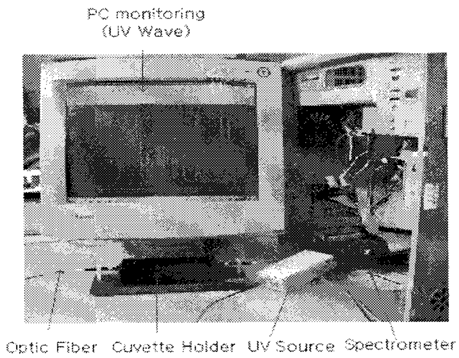

Fig. 7. Photograph of the developed ambient ozone monitoring system.

Ⅲ. 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.

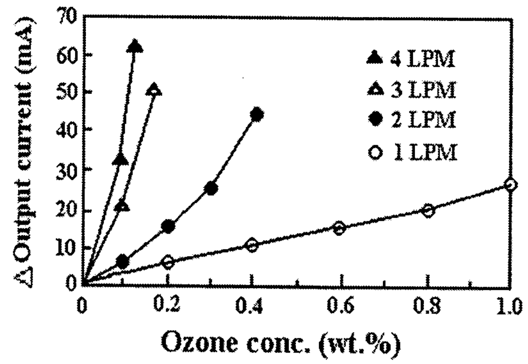

Fig. 8. Linearity of current output vs. ozone concentration.

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 has 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. The feasibility of CCD photodetector as a ambient ozone monitoring detector was confirmed in our experiment. Most sensitive CCD photodetector array should be developed for the system with much higher resolution for the lower ozone concentration measurement.

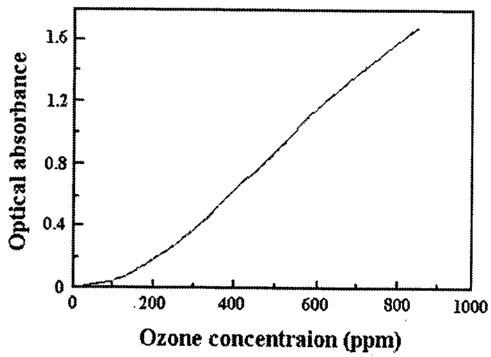

Fig. 9. Linearity of absorbance vs. ozone concentration

Ⅳ. CONCLUSION

An 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 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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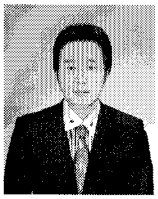

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