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Measurement Technique of Ozone Density by Using UV Sensor System

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Abstract

There are many studies and products using a test paper impregnated with chemical solution can react with ozone. The color of a test paper can indicate the concentration of ozone. The purpose of this research is to design and manufacture a system using ultraviolet light source to measure the ozone density. This new technique is based on the characteristic of decomposition from ozone into oxygen under ultraviolet light. We used two sources of ultraviolet light including UV lamp and UVLED to determine the decomposition of ozone. This system is built with the electronic components, sensors and sealed pump tube to measure the ozone density in units of g / cm^3,ppm,ppb.Inthispaper,, we present some initial results of measuring the ozone density from ozone generator after completing inspection for safety.

Key words: Ultraviolet, UVLED, UV lamp, Ozone density, Ozone decomposition.

I. Introduction

Ultraviolet (UV) light is the electromagnetic radiation. It has a shorter wavelength than visible light, and longer wavelength than X-rays. The energy per photon is about 3eV - 124 eV. The spectrum of ultraviolet can be subdivided into three types by wavelength range: Near- ultraviolet (380 - 200 nm), far-ultraviolet and vacuum ultraviolet (200 - 10 nm). Based on influences to human and environment, the electromagnetic spectrum of ultraviolet light can be subdivided into: UVA (380-315 nm) - long wave or black wave; UVB (315-280 nm) - medium wave; UVC (< 280 nm) - short wave [1]. Ozone or tri-oxygen is a pale blue gas with a distinctively pungent smell. At -112 °C, it condenses to form a dark blue liquid, and below -193 °C, it forms a violet - black solid. Ozone is a powerful oxidizing chemical, much stronger than O_2.Itisalsounstable,easilydecomposes into ordinary di-atomic oxygen. Ozone gas is ozone in gaseous status. In low concentration, it has no colour, and in high concentration, it is a light blue smoke [2]. Ozone is a powerful oxidant that has many applications, such as food hygiene, environment treatment: cleaning air, cleaning water, detoxifying vegetable, water sterilization equipment, medical equipment sterilization, aquaculture, etc

The sun emits UVA, UVB and UVC. They are mainly absorbed by the ozone layer of the Earth. 99% of ultraviolet light reaches the Earth's surface in the form of UVA [3]. The UV absorption

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characteristic of ozone is the basis for measuring the ozone density. When the ultraviolet gets through the environment containing ozone, its intensity decreases dramatically. We base on the attenuation of UV light to find the ozone density.

II. Experimental Methods

As mentioned above, ultraviolet (UV) is absorbed by ozone. We base on this characteristic to measure the ozone concentration by theory of Lambert Beer's law:

$$C_{O3} = \frac{1}{\sigma l} \ln\left(\frac{I_0}{I}\right) \quad (1)$$

In which:

C_{O3} : ozone density *(molecules/cm^3)*

σ : area blocked by a single molecule *(cm^2/ molecule)*

l : length of the detection cell *(cm)*

I_0 : light intensity when ozone is absent *(lumen)*

I : light intensity when ozone is available *(lumen)*

However, scientists often use the unit of ppm (part-per-million) or ppb (part-per-billion) to measure the value of the ozone concentration. It is defined as follows:

1*ppm*=1ofozonemolecule/10^6airmolecules

1*ppb*=1ofozonemolecule/10^9airmolecules

To convert from units of molecules / cm3 into the unit of ppb, ppm, we must use the formula of an ideal gas:

$$C_{air} = \frac{PN_A}{RT} \quad (2)$$

In which:

C_{air} :airconcentration*(molecules/cm^3)*

P : pressure in atmospheres *(atm)*

N_A :Avadrago's number (6,023.10^{23}*molecul1es/mole*)

R : gas constant *(82,06cm^{3}atm/Kmole)*

T : absolute temperature *(K)(^{0}C+273,15)*

From equation (2) we see that: In order to measure the density of the air, we need to measure two parameters of temperature and pressure. Then, by definition, we get:

$$ppm = \frac{C_{O3}}{C_{air}} x10^6 \, (3) \quad ppb = \frac{C_{O3}}{C_{air}} x10^9 \, (4)$$

Replacing (1) and (2) into (3) and (4), we get the formula to calculate the ozone density in the atmosphere in units of ppm and ppb:

$$ppm = \frac{RTx10^6}{PN_A \sigma l} ln\left(\frac{I_o}{I}\right) (5)$$

$$ppb = \frac{RTx10^9}{PN_A \sigma l} ln\left(\frac{I_o}{I}\right) (6)$$

Thus, from equation (5) and (6) we have concluded that, in order to measure the concentration of ozone in the air, we need to measure: P (*atm*), T(*K*), I_0/I(*lumen/lumen, ampe/ampe or volt/votl*), and R, N_A, σ, l are constants corresponding to the certain measurement system.

III. Experiment and results

1. Designing measurement system and electronic circuit

Block diagram of the equipment is described as shown in *Fig1.* When ozone is pumped through a pump and volume meter, the electronic circuit controls the intensity and the time of UV light in one sealed chamber. UV light is absorbed by ozone when it decomposes into oxygen, and UV intensity decreases rapidly. UV sensor measures this data and transmits to the processor which is programmed. Then, it turns into the computer for processing. Thereby, we have the eventual ozone density.

In order to increase the accuracy of the measurement equipment, we choose the length of the sealed chamber containing ozone is 15cm, and diameter cylinder is 9 cm. We use one sensor inside the sealed chamber to determine the internal

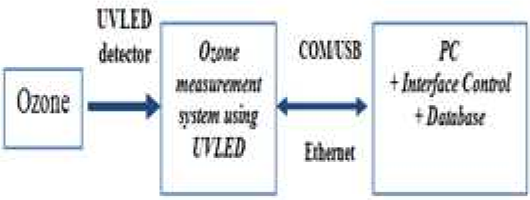

Fig 1. Block diagram for ozone measurement system using UVLED.

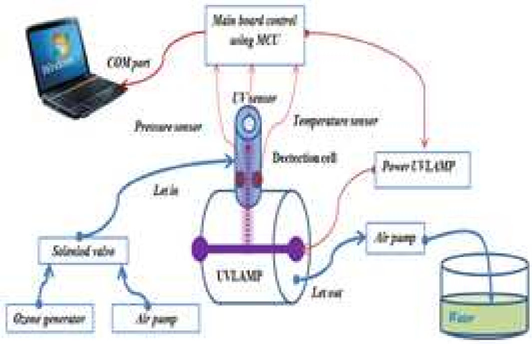

Fig 2. Structure of ozone measurement system using UVLED/UVLAMP.

temperature of the UV source. After finishing one measurement, the remaining oxygen and ozone are injected into the one the water bowl as described as Fig 2.

2. Manufacturing and testing

Fig 3. Ozone measurement system using UVLAMP

1. Ozone generator HO2

2. MCU control board using ATMEL128

3. LCD display

4. Air pump

5. Adapter UV Lamp

6. UV detector

7. UV Lamp 254nm

8. Detection cell

9. Ozone out into water

We use self-designed electronic components and two UV sources which are UVLED and UV lamp. We also complete the experimental systems to evaluate the operation of the UV source and the sensitivity of sensors. Details of these parts of equipment as described Fig 3.

3. Testing system & PC interface for analyzing

System is placed in a black box. The size of black box is 32cm x 45cm x 12cm. This black box ensures no external light but the UV light can affect the measurement results. In addition, our device is also tested for radiation safety at the Institute of Environmental Protection with the safety standards of the Ministry of Health.

Fig 4. System structure using UVLED

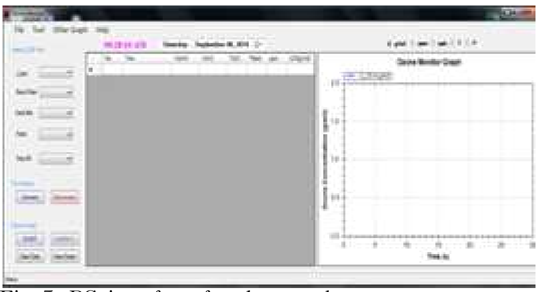

Fig 5. PC interface for data analyzer

Fig. 4 is the structure of the device, including the flow meter which adjusts air flowing into the chamber, the LED indicator for status of sensors and power supply. The LCD screen displays information and measurement results. COM port allows us to connect a system with computer via data acquisition software designed by our team.

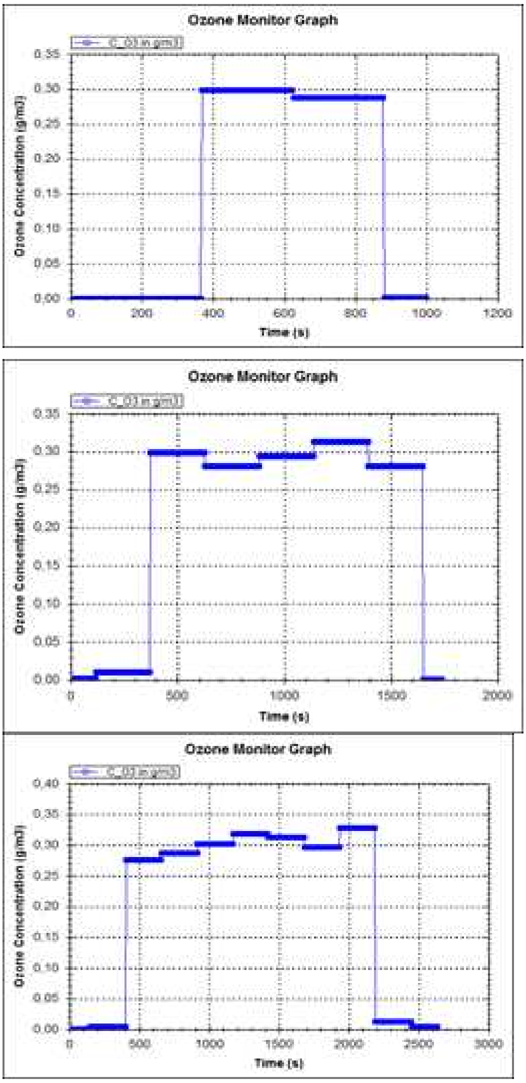

Fig 6. *Graph for data at 1,4l/min in 10', 20',30' with UV Lamp*

Estimate: Average value of ozone concentration is about 0,30 g/m^3.

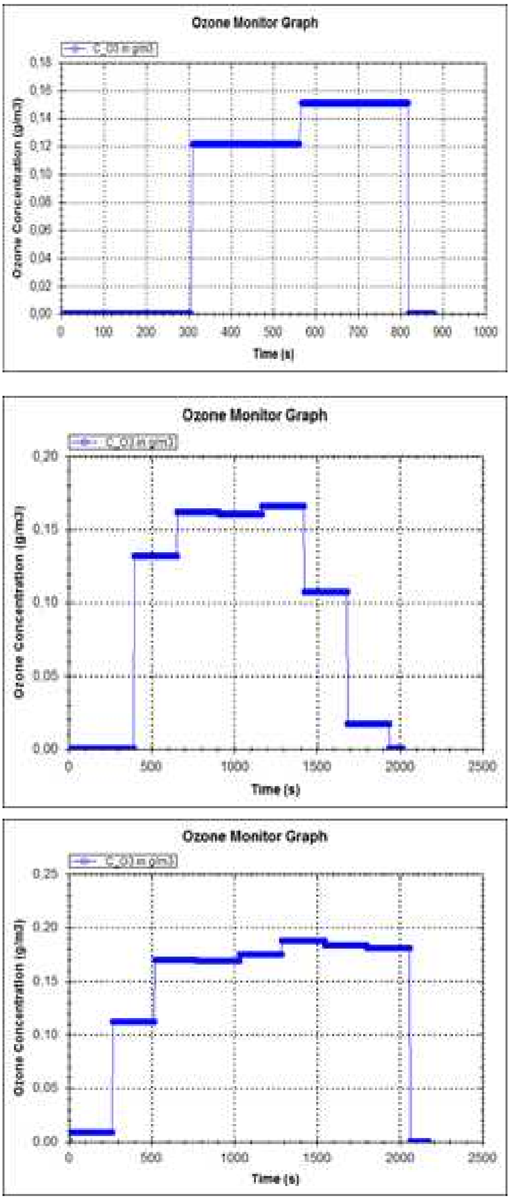

Fig 7. *Graph for data at 1,4l/min in 10', 20',30' with UVLED*

Estimate: Average value of ozone concentration is about 0,15 g/m^3.

4. Sample database

Data for one time measuring is 200 samples from sensors. Flow meter range is from 1,4l/min to 0,4 l/min & timer of ozone generator is 10', 20', 30'.

Fig 7 is the samples o f measurement data; the value is in average of all values collected from each value off low meter. In the next section, we will compare our results with an other system.

5. Comparing results with standard Ozone analyzer

Ozone Analyzer BMT 963 is one of products of BMT MESSTECHNIK GMBH Institute. We choose this to compare with our values.

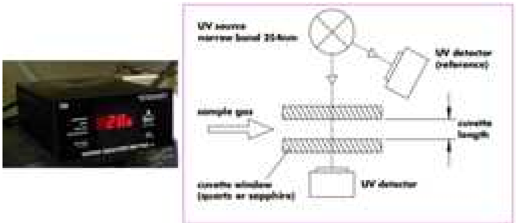

Fig 8. *Operation principle of Ozone Analyzer BMT963.*

From the data table and graph, we can see that measurement results of the system using UVLED is worse than the system using UV Lamp. The reason is that the intensity of UVLED is weaker than UV Lamp's. That is why UVLED changes less ozone into oxygen than UV Lamp. Moreover, the

Table 1. *Measurement data in average for UVLAMPUVLED & BMT963.*

Flow	UV Lamp(g/cm^3)	UVLED(g/cm^3)	BMT 963(g/cm^3)
2.6	0.25	0.10	…
1.4	0.3	0.15	0.35
1	0.33	0.20	0.40
0.6	0.34	0.25	0.5
0.4	0.35	0.25	0.60

difference between results of Ozone Analyzer BMT 963 system and my results can be explained as below:

First, the UV wavelength significantly affects to the

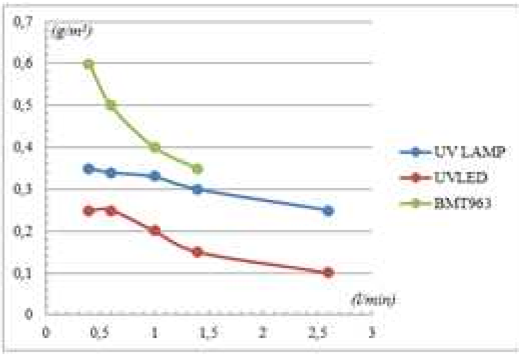

Fig 9. Comparing between UVLAMP, UVLED & BMT963.

decomposition of ozone. The assessment is better if we change into UVB or UVC source. The absorption is also much better at those wavelengths. System's detection is most sensitive at 254nm while we use the UV source at 355nm wavelength(UVA). That is reason why my result is not very stable.

Second, results depend mainly on the sensitivity of the UV sensor. In my experiment, the sensor is old model and my results could be less stable than results from the sensor of Ozone Analyzer BMT 963.

IV. Conclusions

The research is finished with both calculation and completed product. We measured the UV absorption of ozone from two different sources (UVLED and UV Lamp). The advantages are listed as follows.
The system can be used with lower cost than the others, especially when using UVLED with proper power and wavelength. The system is fully automatic. This can help users not to take time to control or record data into computer. System can be integrated with other types of sensor to measure more environment parameters, such as humidity, noise, dust, etc. This system is also faster than Ozone Analyzer BMT 963 . In addition, my system can be disconnected automatically when ozone level exceeds preinstalled value to protect the sensor.
However, the value of UVLED source system is not very stable because of using low power UVLED [4]. We must use the UVLEDs with higher performance

(high power and proper wavelength) to increase the stability. Moreover, in order to obtain the data, we need computer via COM port that would be sometimes inconvenient. To optimize this, the author added Bluetooth module, Wi-Fi or Gateway to get data transmission via Internet for measuring or memory card to store data. This is also the advantage that the Ozone Analyzer BMT 963 system does not possess.

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