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Formaldehyde concentration measuring system: An optoelectronic device

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The paper describes development of an optoelectronics system, which involves the use of ultra-bright yellow LED (λ, 583nm) as light source. BPW21 photodiode (relative spectral sensitivity, < 90 %, 500–600nm) is used as detector for measurement of formaldehyde concentration. The system is based on the reaction of formaldehyde with chromotropic acid in acidic medium. Violet colour, produced after the reaction, is used to measure the concentration (0.5 - 10 ±0.02 ppm) in water.

Keywords: Optoelectronic system, LED, Photo detector, Log amplifier, Formaldehyde
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Introduction

The methods used in absorption spectroscopy for analysis of formaldehyde are: colorimeter photoelectric photometer, spectrophotometer, and optoelectronics method[1,2]. Spectrophotometer involves the use of UV or visible spectrum, which in turn makes use of bulky optics such as lamp, filter, lenses, and gratings. This paper reports the use of LED, by which the intensity can be varied in such a way that the light passing through the blank (distilled water) gives 100 per cent transmittance.

The light of same intensity, when passes through sample (violet coloured) solution, gives the direct display of concentration of formaldehyde, which is highly allergenic and is carcinogen[3,4]. Formaldehyde, a toxic substance, reacts with chromotropic acid in presence of sulphuric acid[5] to yield violet colour.

Power Supply

Dual power supply of ±6V and 500mA was designed for the source, detector, and current to voltage converter. The system was calibrated in mV range, therefore, rechargeable batteries were used to make ripple free supply and to maintain portability of the system [Fig. 1(a)].

Light Source

Spectrophotometers available in the market generally use a tungsten lamp as light source, an optical filter, detector, and display system[2]. Light source used in this study was ultra-bright yellow LED (λ, 583nm; I_f =30mA; V_f =1.9V; Temp, –55° to +100°C). The light source was selected according to the application, keeping in mind the complementary colours. Use of LED's of desired wavelength, reduces size of the system as no filter/optics is required[3-5].

Photo Detector (BPW21)

A visible range photo detector[6] is selected with operating voltage (6V) and forward current of 1.3mA(typ) with maximum of 5mA, and output current being 50mA. It is ideal for low light level applications where a very high signal to noise ratio is important. The relative spectral sensitivity of BPW21 varies between 0.9-1.0 at a wavelength from 500-600nm, which is very close to human eye. Formaldehyde reacts with chromotropic acid in the presence of sulphuric acid to form violet coloured complex, which is measured by the portable formaldehyde measuring system based on Beer's Lamberts law at a wavelength of 583nm with a cuvette holder of an optical path of 1cm.

Log Amplifier

TL441 has been used as logarithmic amplifier[7], which contains four 30dB logarithmic stages. Gain in each stage is such that the output of each stage is proportional to the logarithm of the input voltage over the 30dB input voltage range. Each half of the circuit contains two of these 30dB stages summed together in one differential output, i.e., proportional to the sum of

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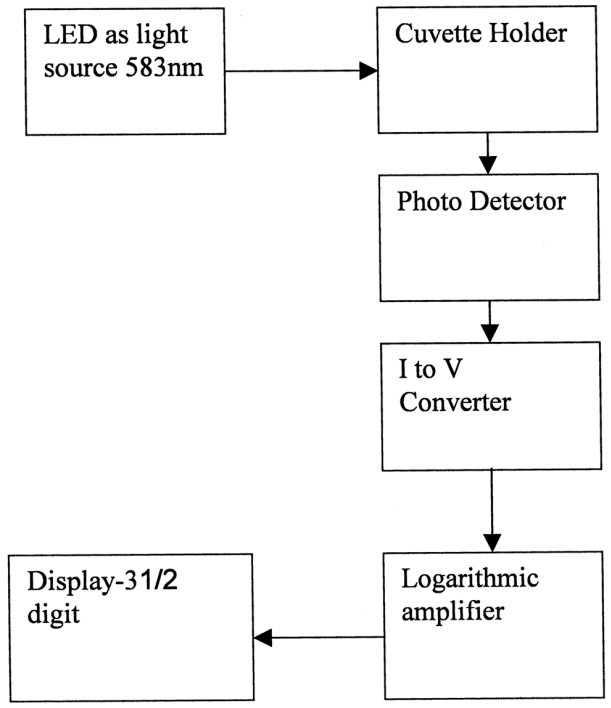

Fig. 1(a)—Block diagram of the optoelectronic system

Fig. 1(b)—Formaldehyde measuring system

the logarithms of input voltage of the two stages. The four stages may be interconnected to obtain a theoretical input voltage range of 120dB. In fact, this permits the input voltage range to be typically 80dB with log linearity of ±0.5dB. Bandwidth is from dc to 40MHz.

System Working

Formaldehyde reacts with chromotropic acid (10%) in presence of concentrated sulphuric acid to give violet coloured complex. To 1mL of sample solution was added 1mL of chromotropic acid (10%) and 5mL of concentrated sulphuric acid with continuous shaking. The mixture was stirred vigorously and heated at 100°C for 30 min. It was cooled to room temperature and read at 583nm against a reagent blank. A portable system [Fig. 1(b)] has been fabricated to measure the concentration of coloured compound.

The system is based on Lambert-Beer's law[1], which employs a light source; sample holding system, detector, and current to voltage converter, log amplifier, display-31/2 digit. A yellow LED (λ, 583nm) was used as light source. The cuvette holder was fabricated from Al alloy, which holds the cuvette of different path lengths (Maximum up to 1cm), which holds the LED at one end and Detector system at the other end. The test solution after colour development is added in the cuvette, which is placed inside the cuvette, holder. The absorption/transmittance related with concentration is detected by photodiode. Electronic card has been designed and fabricated to convert the current signal into mV using operational amplifiers. The mV generated are then supplied to the log stage where the logarithm ratio of the sample with respect to blank solution (distilled water) is taken which gives the absorbance directly and relates to concentration.

Results and Discussion

The LED (λ, 583nm) is specifically used to determine the concentration level of formaldehyde. The results obtained by using the ELICO SL-159 and the newly designed spectrophotometer are comparable (Table 1). The results obtained by the portable

Table 1— Comparison of results between available spectrophotometer and dedicated optoelectronic system

Sl No	ELICO SL-159 (ppm)	Dedicated optoelectronics system (ppm)
1	0.50	0.52
2	1.00	1.00
3	1.50	1.50
4	2.50	2.52
5	3.50	3.48
6	4.05	4.00

optoelectronic system are accurate and comparable with spectrophotometer. Use of LED has reduced size of the system restricting the use of lamps, grating, lenses, etc., hence making it a dedicated system. Formaldehyde vapours are highly toxic[8]. Passing the air through 50mL of water at the rate of 1 L/min gives 0.01mg concentration of formaldehyde in water. The colour is developed by the chromotropic acid method, which thus can measure formaldehyde in air.

Conclusions

The development of portable system using LED has resulted in a more compact reliable and efficient measurement of concentration level of formaldehyde. As the system is portable, it is suitable for field applications. The developed instrument can measure the vapour concentration by bubbling the air in water, as formaldehyde vapours are highly soluble in water.

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