Optoelectronic Multi-Sensor of SO_2 and NO_2 Gases

Zinoviy Mykytyuk, Andriy Fechan, Vasyl Petryshak, Grygoriy Barylo, Oksana Boyko

Abstract – **In paper as the gas sensitive material of primary transducer of SO_2 and NO_2 optoelectronic multi-sensor the 5CB nematic liquid crystal (NLC) are used. The sensitivity of our sensitive element by means of adding to 5CB the cholesteric liquid crystal (CLC) was increased. The electrical realization of our multi-sensor was on ATmega 8 microcontroller.**

Keywords – **Optical Sensors, Liquid Crystal, Sulfur Dioxide, Nitrogen Dioxide.**

I. INTRODUCTION

Measurements of small concentrations of toxic gases is an important task in environmental protection and industrial process control. Currently semiconductor metal oxides are widely used as active materials for modern gas sensors [1-4]. However, besides of a number of advantages (low manufacturing cost, ease of design), semiconductor metal oxide sensors have some disadvantages such as low sensitivity and selectivity, the need for heating of the sensor material [5-6]. The sensitivity of such sensors is limited by fluctuations caused by the thermal motion of charges and defects, as the result, the high levels of noise are presented. Therefore the search for new materials to enhance the performance and of traditional gas sensors is an important task [2].

Optical gas sensors are the fastest type of sensors. Optical gas sensors also offer high sensitivity and selectivity, stability and long term stability of operation. The operation principle of many optical sensors is based on absorption of the gas by the sensing element of primary transducer resulting in the changes of its spectral characteristics [3].

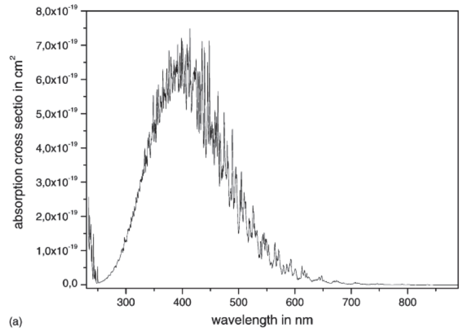
II. OBJECTS OF INVESTIGATION

We propose to use the 5CB NLC as a sensitive material of a primary transducer of SO_2 and NO_2 an optoelectronic multi-sensor.

Sulfur dioxide (SO_2) at normal conditions (room temperature and atmospheric pressure) is a colorless gas with a sharp suffocating odor. A concentration of sulfur dioxide of 400-500 mg/m^3 in the environment is life-threatening for human beings [1]. Sulfur dioxide has an intense absorption band at 300 nm in the ultraviolet (UV) region of spectrum [7].

Nitrogen dioxide (NO_2) is a gas with reddish-brown color and a characteristic pungent odor. In reaction with oxygen nitrogen dioxide forms a nitrogen oxide (NO). Nitrogen dioxide enters into the atmosphere mainly from exhaust gases of vehicles and has a characteristic absorption band around 400 nm.

Figure 1 a & b illustrate the above mentioned absorption peaks for NO_2 and SO_2 in the near UV range.



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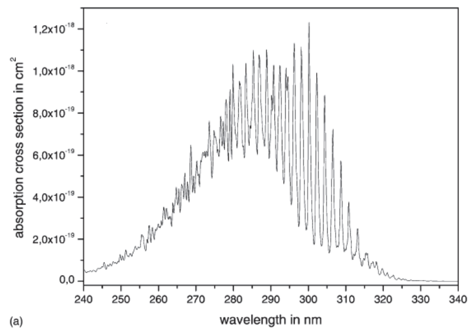

b)

Fig.1. Absorption spectra of a) – NO_2; b) – SO_2 [5]

III. EXPERIMENT

In this work we propose using the nematic liquid crystal material commonly known as 5CB as a primary transducer for an optical gas sensor of nitrogen dioxide and sulfur dioxide. The choice of the active material is due to the fact that its spectrum characterized by a peak absorption in the near ultraviolet region.

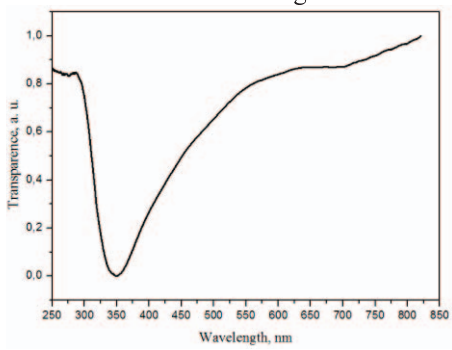

Fig. 2. Transmittance of 5CB NLC obtained experimentally

The absorption spectra of SO_2 and NO_2 are also in UV

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range of spectrum. The temperature range of 5CB is between 297 and 308 K and a positive dielectric anisotropy. Figure 2 shows experimentally measured absorption spectrum of 5CB. The absorption minimum is observed at 350 nm. We use the USB 2000 spectrophotometer and measurement are in 200-900 nm spectrum range. Also the Spectra Suite software was processed the experimental data.

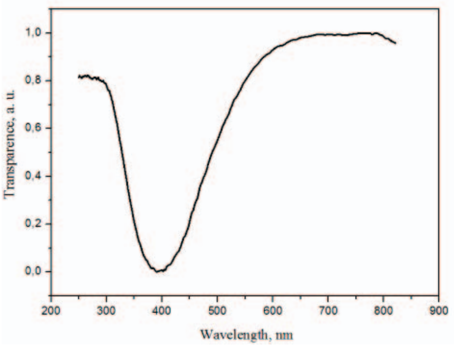
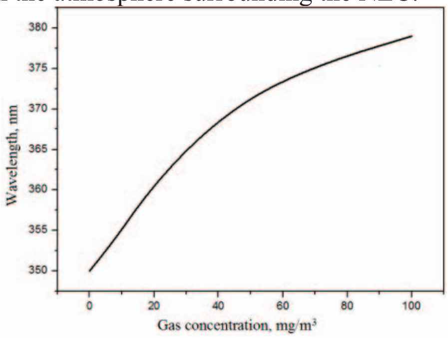


Fig. 3. Transmittance of NO_2 gas

Figure 3 illustrates transmission spectra of NO_2. It is observed that the transmittance minimum is at 398 nm and that an increase in the gas concentration leads to the increase in absorption at this wavelength.

Our studies showed that 5CB can be used for detection of SO_2 and NO_2 gases as the interaction of both SO_2 and NO_2 with the liquid crystal results in the changes of spectral absorption characteristics of the NLC which can be related to concentrations of these gases in the atmosphere surrounding the NLC.



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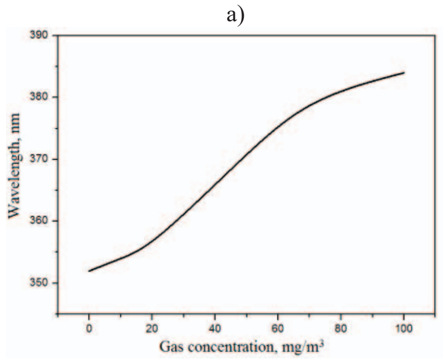


b)

Fig. 4. Transmittance of 5CB NLC under influence of gas: (a) – NO_2 and (b) – SO_2

Figure 4a shows the shift of the NLC transmittance minimum versus the concentration of NO_2 gas and Figure 4b shows the shift of the transmittance minimum versus SO_2 gas concentration. As can be seen from Figure 4, as the gases concentrations change from 0 to 100 mg/m^3 shifts of the transmittance minimum for NO_2 occurs in the range from 350 to 379 nm and in the range from 350 to 384 nm for SO_2.

Experimental results presented in Fig. 5 demonstrate that the sensitivity of the proposed material to the above gases can be increased with addition of cholesteric liquid crystal (CLC) (BLO-61) to the 5CB NLC.

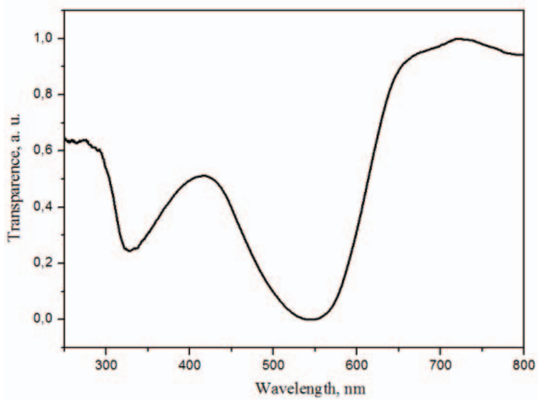
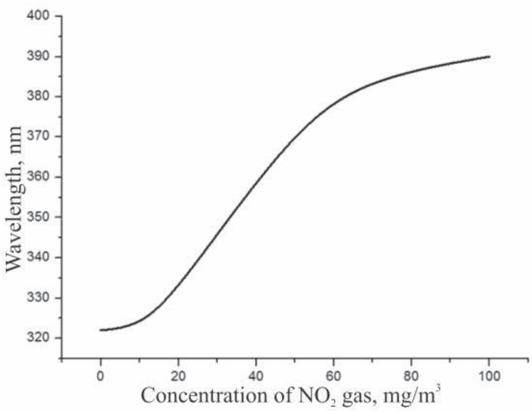


Fig. 5. Transmittance of the mixture on the basis of 5CB with 70 % of BLO-61

The transmittance minimum a pure BLO-61 CLC is at 556 nm. In this work several chiral mixtures were prepared with different concentrations of the BLO-61. The best experimental results in terms of the sensitivity to the above gases were achieved for the mixture with 30% of 5CB and 70 % of BLO-61 as shown in Fig. 5. The first transmittance minimum corresponds to the absorption by the NLC and the second minimum to the absorption by the CLC. It should be noted that addition of the CLC to the NLC material resulted in the shift of the NLC transmittance minimum from 350 to 323 nm.

The shift of the transmittance minimum under the influence of NO_2 is shown in Fig. 6 for the mixture on the basis of 30 % 5CB with 70 % of BLO-61. The NLC transmittance minimum shifts from 322 nm to 390 nm at the gas concentration changes from 0 to 100 mg/m^3.



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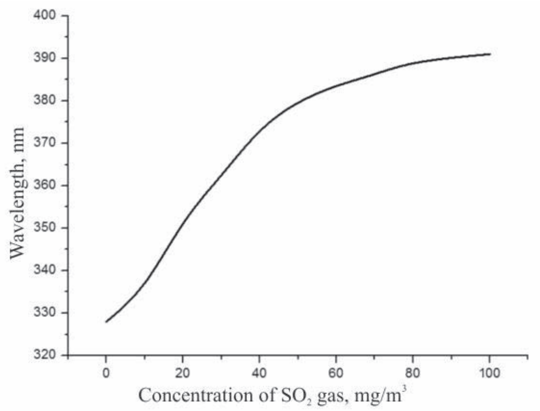

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Fig. 6. Dependency of the first transmittance minimum versus gas concentration: (a) – NO_2; (b) – SO_2 for mixture on the basis of 30% of 5CB with 70 % of BLO-61

The shift of the transmittance minimum under the influence of SO_2 is shown in Fig. 6b for the same mixture. The transmittance minimum shifts from 328 nm to 391 nm as the gas concentration increases from 0 to 100 mg/m^3.

The addition of BLO-61 to the NLC results in approximately two fold increase in the sensitivity to NO_2 gas, and in 1.85 times increase in the sensitivity to SO_2 gas compared with pure 5CB NLC.

It is also important to note that the time of reaction to gas is amounts up to 1 second and time of relaxation is up to 20 seconds.

Also we design the secondary transducer on the basis of ATmega 8 microcontroller. The functional scheme for the designed optoelectronic -gas sensor is shown on Fig. 7. The operation of the microcontroller is realized using external elements – quartz resonator and reset circuit.

During operation, the microcontroller generates the control pulses to an optical source (for example LED) through the corresponding transistor switch.

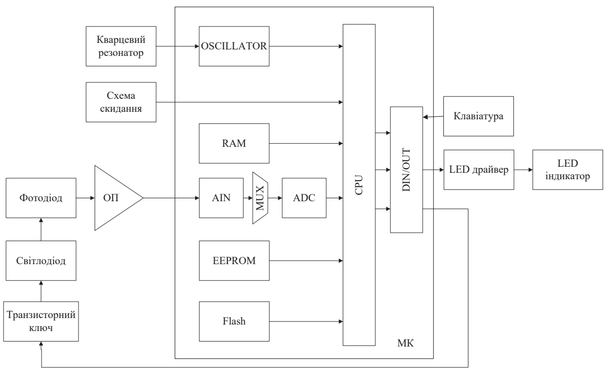

Fig.7. Functional diagram of the proposed optoelectronic gas muli-sensor

The input optical signal, which has passed through the LC material, is registered by the photodiode. The output voltage from the photodiode is amplified by the operational amplifier (OP) and is supplied to the analog input of the ATmega 8 microcontroller. A multiplexer (MUX) of the ATmega 8 microcontroller is connected with the integrated analogue-digital converter (ADC).

The generated digital codes are used for the analysis and processing in accordance with the algorithm embedded in the internal memory of the ATmega 8 microcontroller. By using of embedded software the conversion function of the optical signal is transformed into the values of gas concentration in the tested environment. The digital value obtained by the measurement, through the digital output ports DIN/OUT and LED driver appears on two digit display.

Operation of the sensor is carried out by means of the keyboard connected to digital input ports DIN/OUT of ATmega 8 microcontroller.

On the basis of the functional diagram an electrical circuit has been designed using the Proteus software (Fig. 8).

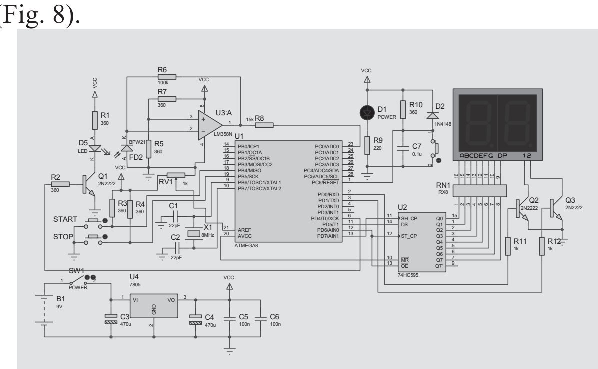

Fig. 8. Schematic diagram of designed optoelectronic gas multi-sensor

The proposed electric circuit implements the analog ATmega 8 microcontroller PC0/ADC0 input port, PB4-PB7 digital input ports and PD0-PD7 digital output ports. Operation of the light source is carried out through the PD4 port by using Q1 transistor key and operating current of the LED is set by R1 resistor. Optical signal passed through the active material is converted to electical by FD1 photodiode. Resulting electric voltage is amplified by the U2 operational amplifier, and then is supplied to the PC0/ADC0 analog input of ATmega 8 microcontroller.

The reset scheme provides restoration of the ATmega 8 microcontroller into its initial state and is implemented by the R9, R10, C7 elements and RESET button. The results of processing of the input information displayed on two discharge seven-segment displays by means of control signals formed on the PD0-PD7 digital output ports as the serial digital codes. Conversion of the code into the serial control signals of the display segments is carried out by means of the shift register, implemented on the basis of 74NS595 chip. To switch bits in dynamic display mode the Q2, Q3 transistors are used. Operation of the Q2, Q3 transistors is carried out by the PD0 and PD1 ports, respectively. Operation of the sensor is carried out by means of the START and STOP buttons. The developed sensor has a battery power source. The power source voltage is stabilized by U3 parametric stabilizer enabled by the circuit of C3, C4, C5 and C6 filter elements. Power is applied by the POWER tumbler.

During the implementation of the Proteus software environment simulation conducted basic modes of operation, based on what software debugged internal microcontroller.

III. Conclusion

The spectral characteristics of gas sensitive element of primary transducer of optoelectronic multi-sensor of SO_2 NO_2 gases was carried out. The 5CB was propose to use as sensitive material of primary transducer. The ATmega 8 microcontroller was use to design the secondary transducer. With aim to double the sensitivity of active element the cholesteric liquid crystal are proposed to use.

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