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OPTICAL MOISTURE METER BASED ON GaInAsSb LED'S AND PHOTODIODES*

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Optoelectronic light-emitting diode – photodiode pairs based on multi component GaInAsSb have been researched and created dual – wavelength model of a new type optical moisture meter. Such pairs are able to detect absorption bands of water belonging to the spectral range 1.94–2.7 μm. Have been shown that, these pairs are very promising for new type optical sensors for ecology and environmental monitoring.

Key words: Optoelectronic LED–photodiode pairs, optical moisture meter, two operational amplifiers.

1. INTRODUCTION

In recent years a great attention is paid to research and develop sensors for purposes of ecology and environmental control, in particularly, optical sensors. The important components of the devices are sources and photo detectors operating in the mid – IR spectral range 1.8–5 μm to which belong basic absorption bands of water and many industrial gases (See Table 1).

Table 1

Absorption bands of water and some gases in the spectral range 1.6–4.8 μm

Substance	Maximum of absorption band, μm				
Water	H_2O	1.94	2.67		3.1
Methane	CH_2	1.65	2.32		3.32
Acetone	CH_3COCH_3		3.4		4.6
Ammonia	NH_3		2.94		
Nitrous oxide	N_2O		2.9	3.9	4.5
Carbon dioxide	CO_2		2.65		4.27
Carbon monoxide	CO		2.34		4.7
Sulfur dioxide	SO_2				4.1
Hydrogen fluoride	HF	1.29	2.45	2.58	

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At present several analyzers with sensors containing LED and lead salt photoresistors are graduating from research to development stage. However, slow photoresistor response, high noise and operating voltage as well as instability against temperature cycling do not allow the design of portable devices for measuring within the ppm region at room and higher temperatures. Photodiode-LED pairs operating at low or zero detector bias are, therefore, a good challenge for the above applications. At the same time, using semiconductor optoelectronic pairs LED – PD permit to create a qualitative new generation of optoelectronic sensors for the analysis of various liquids and gas mixture components [1].

We report the results of research and create dual – wavelength models of a new type optical moisture meter based on optoelectronic pairs operating in 1.8–2.2 μm spectral range.

2. OPTOELECTRONIC LED-PD PAIRS FOR THE 1.8–2.5 μm SPECTRAL RANGE

LED's and photodiodes for the 1.8–2.5 μm spectral range have been fabricated by LPE technology and based on GaInAsSb multicomponet alloys lattice matched to GaSb substrate. Changing the composition of the solid solution ($0 \le x \le 0.24$) the band gap of $Ga_{1-x}In_xAs_ySb_{1-y}$ can be chosen in the range of 0.8–0.5 eV which corresponds to the wavelength region of 1.8–2.5 μm [2].

Fig. 1 shows the emission spectra of some of GaInAsSb/GaSb LED's at room temperature. The LED's have a high quantum efficiency (1–4%) and can be used both in pulse and cw regime [3]. The output optical power is

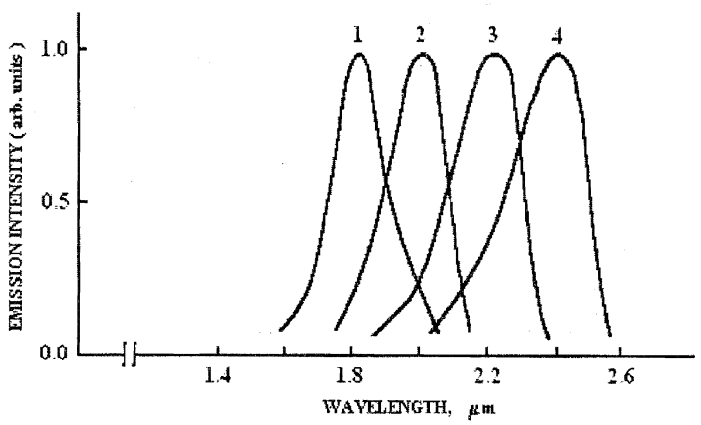


Fig. 1. – Spectra of emission intensity of GaInAsSb light-emitting diodes at room temperature.

P = 20–50 mW at operating currents 0.3–3 A, and P = 0.5–1 mW (I = 10–20 mA) in cw operating.

To detect the emission of the LED's we use hetero-photodiodes with GaInAsSb as active layer and GaAlAsSb as widebandgap "window" layer [4]. Sensitivity of GaInAsSb / GaAlAsSb photodiodes is about R = 1 A/Wt , and low dark current less than 0.1 μA was obtained at V = 0.5–1 V. The spectral characteristics of typical diode is shown in Fig. 2. The GaInAsSb/GaAlAsSb photodiode has a wide range of sensitivity from 1.3 to 2.4 μm. It allows to use one photodiode to detect emitting photon energy of several LED's with different maximum wavelength of emission. It will be noticed that an important advantage of the developed LED's and PD's have similar temperature dependence of the spectral characteristics because LED's and PD's are made from the same material. The temperature coefficient of band gap dependence is $\Delta E_g/\Delta T$ = = $3.5 \cdot 10^{-4}$ eV/K.

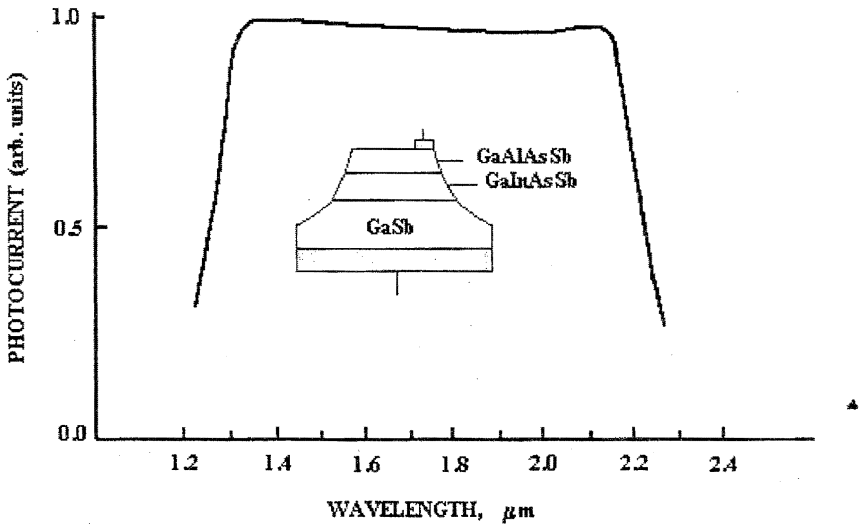


Fig. 2. – Spectral response of GaInAsSb/ GaAlAsSb photodiode at room temperature.

3. MEASUREMENTS AND RESULTS

We used some optoelectronic LED – PD pairs based on GaInAsSb to develop a new type small-dimension dual-wavelength optical moisture meter. To measure moisture content in paper we chose LED's with maximum emission wavelength λ_{meas} = 1.94 μm which is selectively absorbed by water in paper and λ_{ref} = 2.2 μm which can not been absorbed in paper. As a photodiode was chosen GaInAsSb/GaAlAsSb PD with a broad spectral characteristic.

For this goal, was created the two-wavelength IR moisture meter which consist of two parts: electrical and optical parts. The scheme of an electrical part is shown in Fig. 3.

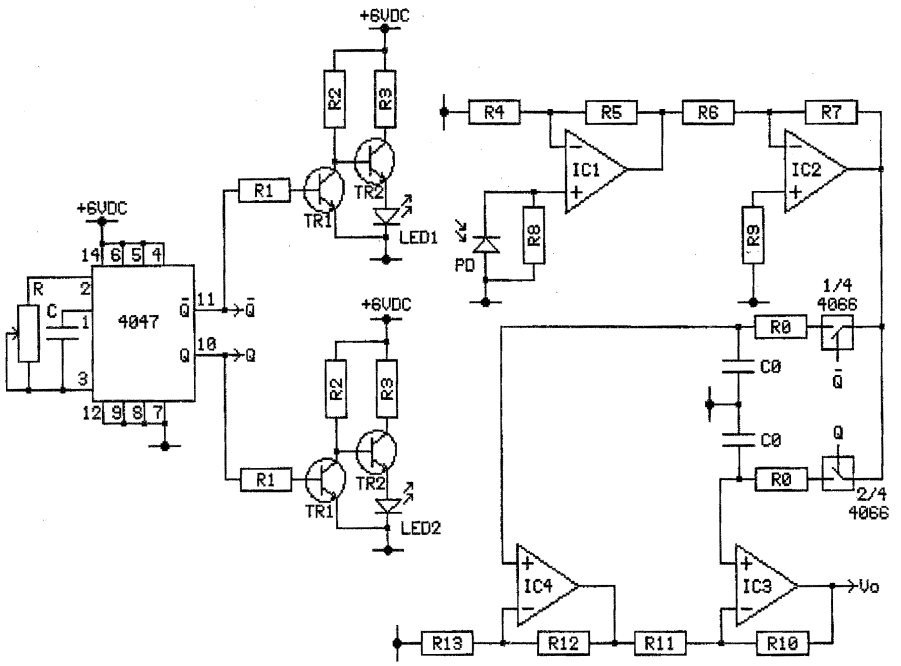


Fig. 3. – The electrical part of a dual-wavelength moisture meter.

In optical part we use two type optical reflectors (see Fig. 4): Parabolic (for measurements of a thick papers moisture) and Flat (for measurements of a thin papers moisture).

The circuit works as follows. The IC4047 has been working on the astable multivibrator mode. Working frequency is given with RC component values. The Q and ~ Q outputs of the vibrator supply IR LEDs of 1.94 μm and 2.2 μm from current drivers. These two IR LEDs act as transmitter.

First two operational amplifiers on the receiver part of the circuit amplify the signal from photodiode. The amplifying signal has been applied of the switch circuit inputs which have been working with synchronous of the Q and ~ Q outputs. One of the obtained signals is absorbing other is transmitting signal. These two signals has been applied input of the differential amplifier. The output signal of the differential amplifier gives information about moisture content in sample.

The moisture of papers may be determined by following expression

$$W = \frac{m_m}{m_m + m_p} \%100 \qquad (1)$$

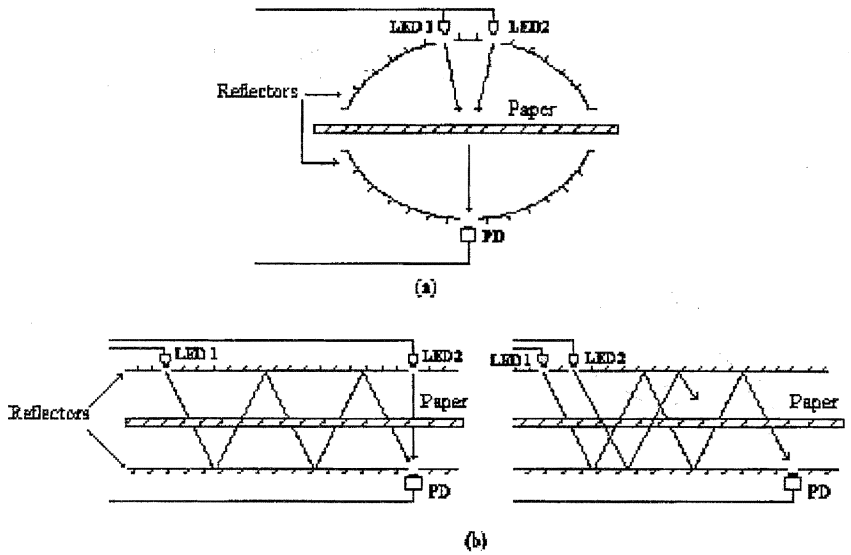


Fig. 4. – The optical part of a dual-wavelength moisture meter: (a) parabolic and (b) two type of a flat optical reflectors.

where W is moisture, m_P – mass of a dry paper, m_m – mass of moisture which content in paper. Magnitude of m_m expressing by magnitudes of reference and measurement signals, may be determined as follow:

$$m_m = \frac{1}{k_m \alpha_m} \ln \frac{V_r}{V_{out}} \tag{2}$$

where k_m is absorbing coefficient of light by moisture in the measurement wavelength and α_m is coefficient of nonlinearity. V_r and V_{out} are magnitudes of reference and measurement signals respectively.

Substituting Eq (2) in Eq (1) we obtaine

$$W = \frac{\ln \frac{V_r}{V_{out}}}{\ln \frac{V_r}{V_{out}} + k_m \alpha_m m_p} \%100 \tag{3}$$

In Fig. 5 shown the dependence of moisture content in paper on output signal obtaining with the different optical reflectors. One can see that, using a flat optical reflectors, we can get high sensitivity and good linear characteristics. The distinction between of results, obtaining by different reflectors is increase with increasing of papers moisture (see Fig. 5).

The output signal calibrated in moisture percentage is indicated by digital display. Optical moisture meter allows to measure moisture content in paper of 0.05–2 mm thick with accuracy less than 1% in the range of 0–35%.

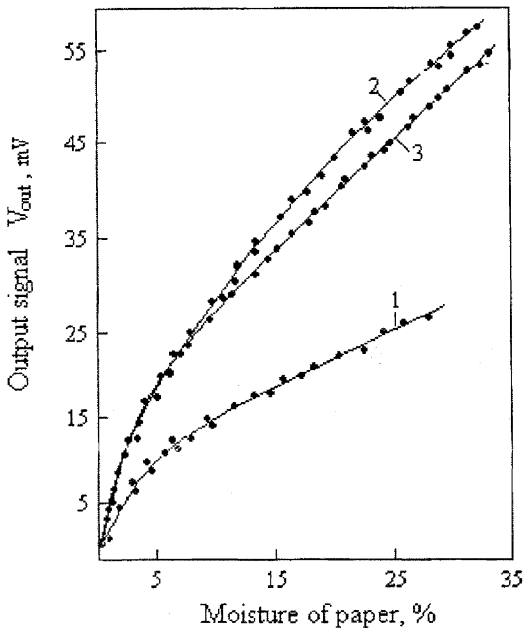


Fig. 5. – The dependence of moisture content in paper on output signal: with a parabolic (1) and a flat optical reflectors (2,3).

4. CONCLUSION

In conclusion, the optoelectronic LED – PD pairs based on multi component GaInAsSb alloy have been researched and created two – wavelength model of a new type optical moisture meter. These pairs are very promising for fabricating new type optical sensors for ecology, environmental monitoring, IR–spectroscopy, automatic control of technological processes, and some other tasks.

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