OPTOELECTRONIC DEVICE FOR MEASURING THE HUMIDITY OF SILKWORTH COCOONS

Kuldashov G.O., Nabiev D.O.
Research Institute Physicists of semiconductors and microelectronics at the
National University of Uzbekistan

Annotation: The goal of this work was to create an optoelectronic device for measuring the humidity of silkworm cocoons based on mid-IR LEDs. An optoelectronic device has been developed for measuring the humidity of silkworm cocoons based on mid-IR LEDs, allowing measurements in real mode with an accuracy of 1.5%. In the optoelectronic device for measuring the humidity of silkworm cocoons, LEDs with emission spectra of 2.2 μm are used as a reference channel, and LEDs with emission spectra of 1.94 μm are used as a measuring channel. A scheme is proposed that ensures the main condition of two-wave optoelectronic devices, the temporal and temperature stability of the LED parameters and the equality of their initial reference, measuring radiation fluxes, which determine the measurement accuracy.

Keywords: silkworm cocoons, humidity, optoelectronics, LED, photodiode, device, emission spectra, measurement accuracy.

Introduction

One of the important parameters of many technological processes, by which the quality of the finished product is determined, is humidity. Work on the development of new instruments for measuring humidity is being carried out here in Uzbekistan and abroad. A wide range of research in the field of moisture measurement is stimulated by the practical demands of the national economy for express and highly sensitive methods and means of moisture measurement.

The most promising direction is optical moisture testing, which is based on the ability of water to absorb infrared radiation of a certain wavelength. The presence of absorption bands characteristic of water in the mid-IR optical range makes it possible to develop instruments for various materials in which it is necessary to measure moisture.

The operation of optical moisture meters is based on the selective absorption by moisture of infrared radiation of a certain wavelength reflected from the surface of the controlled object or passed through the substance.

Spectral characteristics of wet materials

During atomic polarization, the oxygen atoms that make up water undergo a complex movement, which is caused by the synthesis of three standard vibrations: absolutely symmetric angular, absolutely symmetric elastic, asymmetric elastic. The absorption bands of these vibrations are respectively 2.74; 6.27 and 2.66 μm. The absorption rates at these wavelengths are very high, however, due to the lack of stable LEDs and receivers of mid-IR radiation, these wavelengths are not used in the development of industrial devices. The mid-IR range is of greatest interest; the absorption spectrum of water in the mid-IR range consists, as shown in Table 1.1, of higher harmonics and combination components of standard vibrations [1-2]. The most optimal wavelength for practical use is 1.94 microns. Since the absorption of water in this range is in the nature of induced polarization accompanying atomic vibrations, this phenomenon is considered atomic polarization. Water entering a substance changes its spectrum. From the different spectral characteristics of dry matter (Fig. 1, curve 1) and at a humidity of 9% H2O (curve 2) it follows that at a wavelength of 1.94 μm water has significant absorption.

Table-1

ISSN 2349-7793 (online), Published by INTERNATIONAL JOURNAL OF RESEARCH IN COMMERCE, IT, ENGINEERING AND SOCIAL SCIENCES., under Volume: 18 Issue: 01 in January-2024
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Absorption spectrum of water

Wavelength, µm	Affiliation	Absorption rate, %
0,76	Higher harmonics	0.26
0,97	Same	0.46
1,19	Combination components	1.05
1,45	Same	26.0
1,94	Same	100

Consequently, if the controlled object is irradiated with IR radiation with such a wavelength and the power of the transmitted or reflected radiation flux is measured, then it will change depending on the humidity.

However, when measuring at only one wavelength, errors arise, the main sources of which, in addition to humidity, are the scattering of radiation by the substance being measured, its thickness, etc. To eliminate these errors, another radiation flux with a reference wavelength lying outside the band is used. moisture absorption.

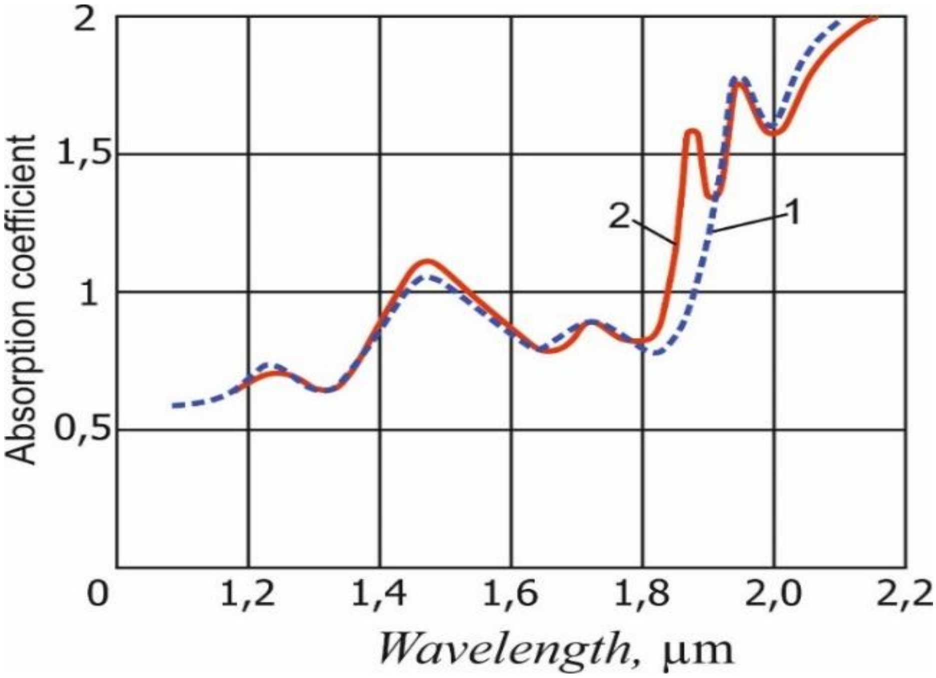

Fig.1. Spectral characteristics of dry (1) and wet (2) matter

Method for selecting the wavelength of analyzing radiation

The wavelengths of the measuring and reference flows can be selected optimally, taking into account the spectrum of the substance being measured, the humidity measurement range and other requirements. When constructing optoelectronic devices using semiconductor emitters, spectral

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characteristics are the basis on which the wavelengths of the measuring and reference radiation fluxes are selected.

To develop devices based on the use of optical radiation, the spectral characteristics of the cocoon (reflection spectra and transmission spectra of radiation) and the dependences of transmission, reflection and scattering of radiation are necessary.

The cocoon shell ultimately protects the pupa from cold and heat and creates favorable conditions for the living organism. Based on this, the cocoon shell allows radiation necessary for the life of the pupa to pass through and does not allow harmful radiation to pass through. That is, the shell of the cocoon reflects radiation with a wavelength harmful to the pupa, and transmits radiation with a wavelength necessary for the pupa [3]. In our case, knowledge of the reflection and transmission spectra is necessary to select a radiation source with the required wavelength.

Analysis of the results of studies of the optical properties of silkworm cocoons showed the feasibility of using IR radiation to control humidity. Of the optical characteristics, the greatest interest for monitoring the humidity of silkworm cocoons, infrared radiation, is transmittance, reflectance and absorptivity, and the ratio of the past. Reflected and absorbed IR radiation is characterized by corresponding coefficients depending on the wavelength and physical properties of silkworm cocoons. The effectiveness of using IR radiation to control humidity depends on the correct combination of the optical properties of the semiconductor emitter and the irradiated material.

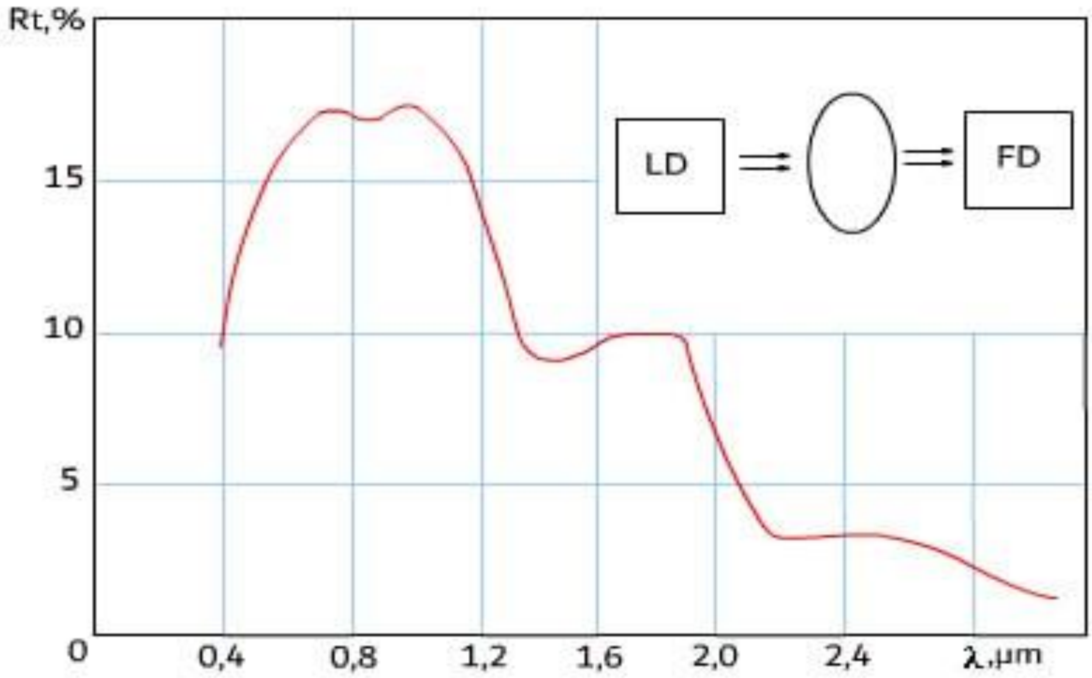

Fig. 2. Spectral characteristics of the transmission of infrared radiation of the cocoon

In Fig. Figures 2 and 3 show the experimentally obtained spectral characteristics of the cocoon. Analysis of the spectral characteristics shows that in the optical range of 0.4...1.2 μm the cocoon shell transmits radiation well.

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Radiation with a wavelength of 1...2 μm is well reflected by the cocoon shell [4-5]. These circumstances will be taken into account when choosing the wavelength of the emitter for the development of devices for determining process parameters. In the spectral region of 1.8-2.2 microns, the reflectivity is 85%, then drops to 14" at wavelengths of 3 microns. Transmission of radiation by the pupa in the spectral region of 0.4-10 μm was not detected.

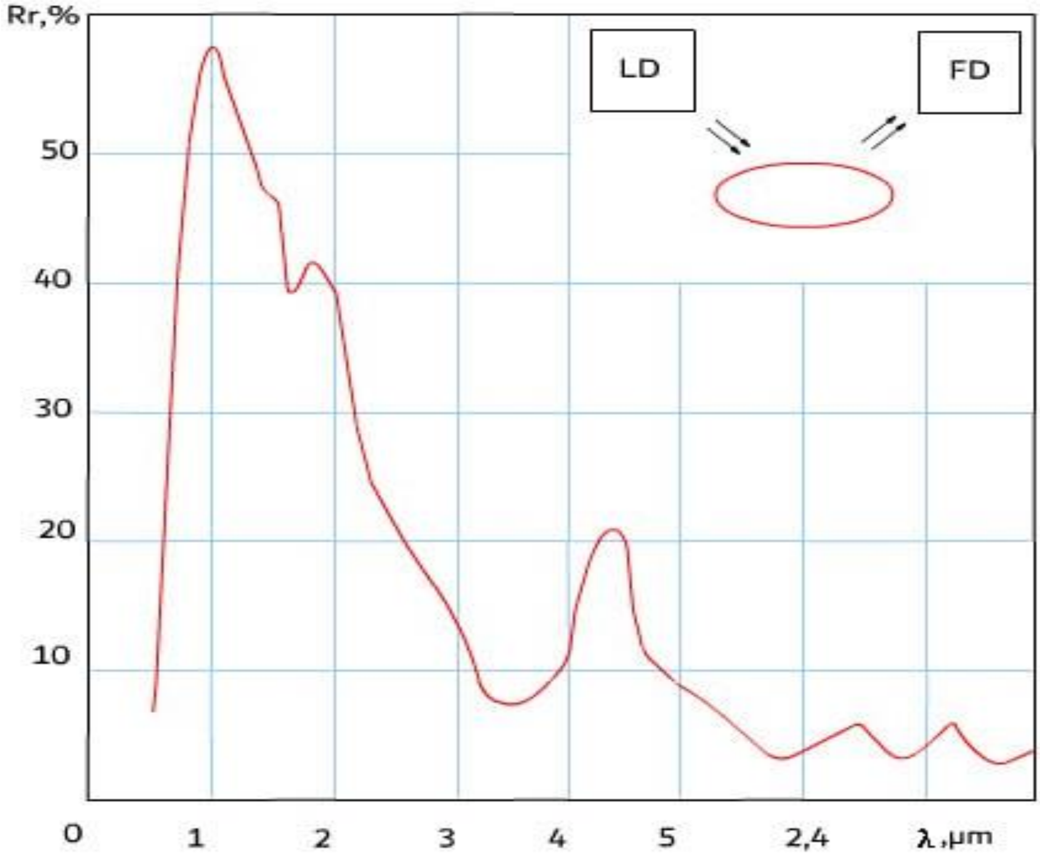

Fig.3. Spectral characteristics of the reflection of infrared radiation of the cocoon

Semiconductor optoelectronic devices can be composed according to the type of optical circuit of the sensor, the number of wavelengths of analyzing radiation, the principle of constructing a block diagram, as well as the principle of converting the controlled component into an electrical signal. Depending on the method of receiving optical radiation after interaction with a substance, four methods should be distinguished, based on the reception of radiation passed through the object and the reception of radiation reflected from the surface of the object.

The obtained data on the optical properties of the shell of silkworm cocoons made it possible to use the principle of reflection to control humidity, because at wavelengths of 1.95 and 2.22 μm, where there are maxima and minima of water absorption, the shell of silkworm cocoons transmits little IR radiation, but at these wavelengths it has good reflectivity, so it is necessary to use the principle of reflection of IR radiation.

To control the humidity of silkworm cocoons, we use an LED with a maximum at a wavelength of 2.2 μm (LED22) as a reference signal, and as a measuring signal we use an LED with a maximum at a wavelength of 1.94 µm (LED19). To record signals, we use a PD24 photodiode with a wide sensitivity range of 1.5 - 2.4 µm. Figure 4 shows the main spectral characteristics of LED19, LED22 and photodiode PD24.

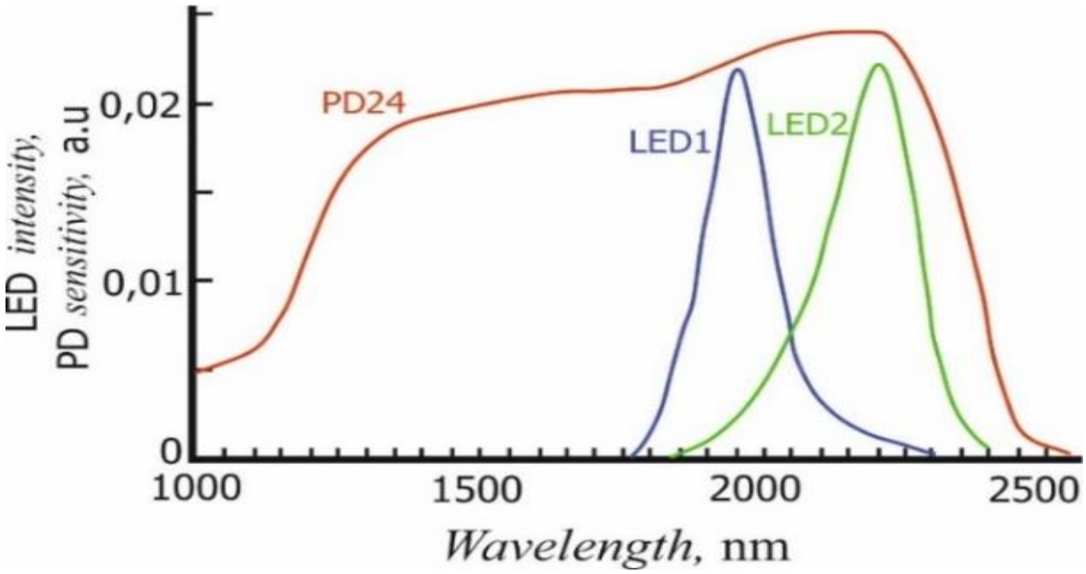

Fig. 4. Emission spectra of LEDs LED19, LED22 and spectral sensitivity of photodiode PD24.

Optoelectronic device for measuring the humidity of silkworm cocoons

An optoelectronic method and device have been proposed, which is designed to measure the humidity of silkworm cocoons, the operating principle of which is as follows: silkworm cocoons are irradiated with two streams F_0λ1 and F_0λ2 at the reference (λ = 2.22 µm) and measuring (λ = 1.94 µm) wavelengths, respectively.

The reflected flow from the managed object is described by the expression:

$$\begin{cases} F_{\lambda1=\gamma_{\lambda1}} . F_{0\lambda1} \\ F_{\lambda2=\gamma_{\lambda2}} . F_{0\lambda2} \cdot e^{-km} \end{cases}$$

where: $\gamma\lambda1$, $\gamma\lambda2$ – transmittance coefficients of the reference and measuring wavelengths, k – absorption coefficient, m – moisture mass.

Let $F_{\lambda1=A\cdot e^{-t/\tau}}$ then $\begin{cases} F_{\lambda1=\gamma_{\lambda2}\cdot A\cdot e^{-t/\tau}} \\ F_{\lambda1} = \gamma_{\lambda2} \cdot F_{0\lambda2} \cdot e^{-km} \end{cases}$

At the moment of comparing the fluxes of the reference and measuring wavelengths, i.e. $F_{\lambda1} = F_{\lambda2}$ or $\gamma_{\lambda1} \cdot A \cdot e^{-t/\tau} = \gamma_{\lambda2} \cdot F_{0\lambda2} \cdot e^{-km}$, usually $\gamma_{\lambda1} = \gamma_{\lambda2}$, then $m = -\frac{1}{K\cdot\tau}$, i.e. the mass of moisture of the cocoons is proportional to the comparison of time intervals.

A block diagram of an optoelectronic device for measuring the humidity of silkworm cocoons is shown in Fig. 5.

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Optoelectronic device for measuring the humidity of silkworm cocoons (Fig. 5): master oscillator – 1, trigger – 2, first frequency divider – 3, second frequency divider – 4, second differentiating device – 5, first differentiating device – 6, third frequency divider – 7, first comparison circuit – 8, RS trigger – 9, second analog switch – 10, fifth differentiating device – 11, third differentiating device – 12, second logical element “NOT” – 13, exponential function generator – 14, first analog memory – 15, second analog memory – 16, second emitter follower – 17, first analog switch – 18, first logical element “NOT” – 19, logical element “OR” – 20, first emitter follower – 21, infrared radiation source emitting at reference wavelengths – 22, additional photodetector of infrared radiation – 23, source of infrared radiation emitting at analytical wavelengths – 24, cuvette for the analyzed sample – 25, photodetector of infrared radiation – 26, low-noise amplifier – 27, selective amplifier – 28, threshold device – 29, fourth differentiating device – 30, second comparison circuit – 31, counter – 32, decoder – 33, indicator – 34.

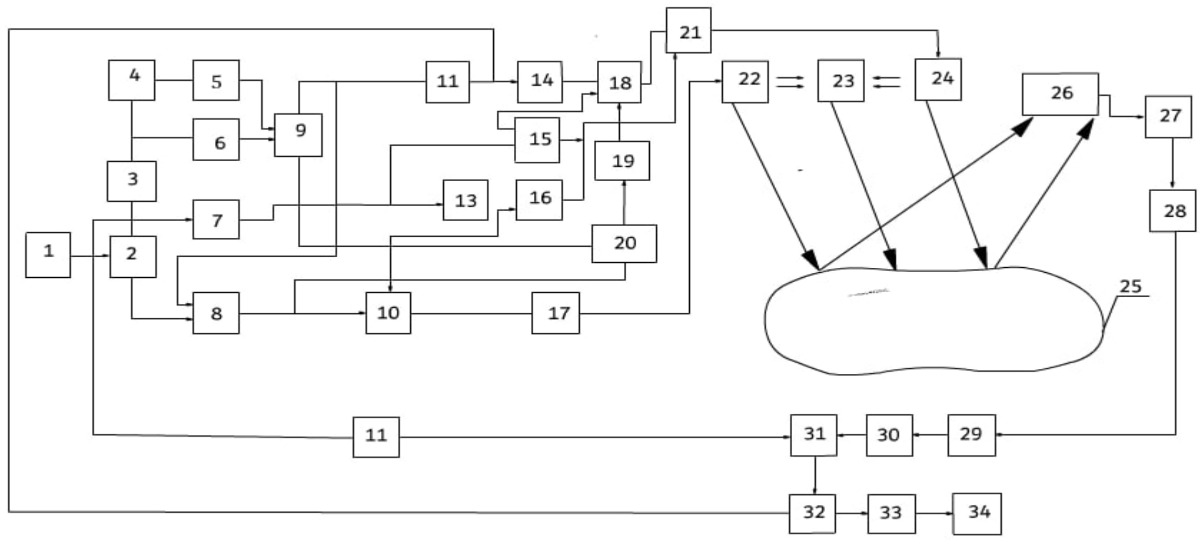

Fig.5. Block diagram of an optoelectronic device for measuring the humidity of silkworm cocoons

In order to increase the accuracy of the optoelectronic device for measuring the humidity of silkworm cocoons, an additional photodetector was introduced into the circuit, providing optical negative feedback to stabilize the parameters (radiation power, radiation intensity, radiation flux, maximum radiation spectrum, forward current, forward voltage) of mid-IR LEDs – areas.

Conclusion

An optoelectronic device has been developed for measuring the humidity of silkworm cocoons based on the selective optical absorption method using mid-infrared LEDs. A scheme is proposed that provides the main condition for two-wave optoelectronic devices, the temporal and temperature stability of the LED parameters and the equality of their initial reference, measuring radiation fluxes, which determine the measurement accuracy.

Based on the results obtained, it was made to measure the humidity of silkworm cocoons, allowing measurements in the range from 1 to 40% with an error of no more than 1.5%.

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