A3B5 photodiode sensors for low-temperature pyrometry

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ABSTRACT

Mid-infrared immersion lens photodiodes developed at the Ioffe Institute have high spectral selectivity ($\lambda max/\Delta\lambda \approx 0.1 \ldots 0.15$) at different wavelengths -2.9, 3.3, 4.2 and 4.7 microns, the response time (up to 10^{-9}s) and detectivity ($D^* \approx 10^9$-10^{11}, (cm√Hz)/W) being significantly higher than those of currently known detectors of thermal radiation[1].The analysis of the transfer function of the temperature sensors based on A3B5 photodiodes has shown that they permit implementing the methods of color and two-color pyrometry providing a significant decrease of the methodical error in optical temperature measurements associated with unknown values of object surface emissivity and uncontrollable changes in the environment transmission.

Keywords: Mid-infrared spectral range, A3B5 immersion lens photodiodes, two-color pyrometers, pyrometer transfer function

1. INTRODUCTION

The principal problems of low-temperature pyrometry are caused by the low level of thermal radiation of an object at temperature less than 300 °C and the shift of the radiation maximum into the far-infrared spectrum region. The detection of weak thermal radiation in commonly used pyrometers is solved by using a broadband (8-14 μm) radiation detector and by measuring the temperature on large parts of an object. The sighting coefficient of low-temperature pyrometers (the ratio between the size of a part on which the temperature is measured and the measuring distance) is usually small (about 1:10). This assumes temperature measurements on areas of the order of tens of cm^2 and sufficiently long measurement time (1 s and longer). The pyrometric methods are called as radiation methods in case broadband photodetectors are used. Radiation pyrometers are calibrated against the radiation of a black body, therefore measurement errors can be as high as 25-30% and more of the temperature being measured if the emissivity of a real object (ε) is unknown. The requirements for special (professional) pyrometers are considerably higher. As a rule, the sighting coefficient of such devices is not less than 1:50 and the measurement time can be limited to fractions of a second (for example, for the problem of checking the temperature of wheel boxes of a moving train). The accuracy and reproducibility of temperature measurements should be as high as several degrees or fractions of a degree and they should not depend on material, quality of treatment of an object surface and uncontrolled loss of light in an intermediate medium. At present, these parameters can be obtained in pyrometers designed for measuring the temperature higher than 3000C only. The availability of high-sensitive detectors of near-infrared and visible radiation allows the use of narrowband spectral filters and implement the methods of color pyrometry. Great practical interest is related to the two-color pyrometers implementing the ratio detector principle. Examples of industrial two-color pyrometers are: M90R1-3 by LUXTRON[2] (700-20000C, accuracy 0.7% of the readings, sighting coefficient 1:60, λ1=0.92 μm, λ2=0.98 μm), M770/M780 by MIKRON[2] (350-3500°C, accuracy 0.5% of the scale, sighting coefficient 1:90, near infrared region) and special pyrometers of the Modline R by IRCON[3] (700-1400°C, accuracy 0.75% of the scale, V=1:50, λ1=0.7-1.08 μm, λ2=1.08 μm) that record the temperature higher than 350 °C. The industrial color pyrometers designed for measuring the temperatures less than 300°C are produced by using the one-beam scheme only, for example, the pyrometer IRE 140/34 by IMPAC [2] (50-500°C, sighting coefficient 1:50, λ=3.43 μm).

The fabrication of low-temperature two-color pyrometers is possible only when using new photodetectors that have high detectivity within the mid-infrared region (λ = 2…6 μm). In this connection it is of interest to consider the mid-infrared photodiodes developed at the Ioffe Physical- Technical Institute of the Russian Academy of Sciences[4]. They have high spectral selectivity ($\Delta\lambda/\lambda max \approx 0.15$), and their operation speed (up to 10^{-9}s) and detectivity (10^9-10^{11}, cm√Hz/W) are

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Optical Sensors 2011; and Photonic Crystal Fibers V, edited by Francesco Baldini, Jiri Homola, Robert A. Lieberman, Kyriacos Kalli, Proc. of SPIE Vol. 8073, 80731A · © 2011 SPIE · CCC code: 0277-786X/11/$18 · doi: 10.1117/12.886309

considerably higher than those of the known nonselective detectors of thermal IR radiation. Earlier[5] we have already compared different types of mid-IR photodetectors and formulated their potential application for the creation of gas sensors based on nondispersive (NDIR) spectroscopy techniques . The present research considers their potential use for the low-temperature color and two-color pyrometers.

The analytical description of optoelectronic pyrometric sensor with the help of the quasimonochrome transfer function was used to estimate the application potential of A3B5 photodiodes in low-temperature pyrometry. It takes into account the spectral and geometry characteristics of a pyrometer optical scheme, radiation characteristics of real objects, transmission of an intermediate medium and photodetector parameters. The analysis of the transfer function together with the noises of the photodetector and amplifier permits one to estimate the expected sensitivity and accuracy of the sensors within the entire range of measured temperatures for detectors with different features.

2. PRINCIPAL FEATURES OF MID-INFRARED PHOTODIODES

At the Ioffe Physical Technical Institute, studies have been carried out for some time on the creation, development and industrial production of mid-infrared photodiodes based on low-energy-gap semiconductor heterostructures $InAs_{1-x}Sb_x$ functioning without forced cooling. The main field of application for these diodes is the nondispersive analysis of liquids and gases that have strong absorption lines in the mid-infrared region. The sensitivity region of photodiodes PD29Sr corresponds to the absorption line of water in the region 2.9 µm, whereas the photodiodes PD34Sr, PD4.2Sr and PD4.7Sr are designed for the use as a detectors in the hydrocarbon gas sensors (absorption lines in the region 3.3 µm), carbon dioxide gas sensors (absorption line in the region 4.26 µm) and carbon monoxide gas sensors (absorption line in the region 4.7 µm).

Table 1 shows the main features of A3B5 photodiodes produced by the Ioffe Physical-Technical Institute[4] that are required for estimating the expected parameters of color pyrometer sensors based on them.

Table 1. Principal features of $InAs_{1-x}Sb_x$ mid-infrared photodiodes

Type	Optics	Response time, τ,ns	Current sensitivity, S_i A/W	Voltage sensitivity, S_V V/W	Detectivity, D*,@20^{0}C cm Hz$^{1/2}$/W	Spectral range, λmax ±Δλ/2, µm	NEP*, W/cmHz$^{1/2}$	NEP, d=3mm, W/ Hz$^{1/2}$	PhD noise e_n, nV/√Hz i_n, pA/√Hz
1	2	3	4	5	6	7	8	9	10
PD29Sr	Immersion .lens Acceptance angle ~30 deg Optical area d= 3mm	≤20	0.5	500	$2\cdot10^{10}$	2.9±0.15	$5\cdot10^{-11}$	$1.5\cdot10^{-11}$	4.5 nV/√Hz 7.5 pA/√Hz
PD34Sr			1	1500	10^{11}	3.4±0.2	10^{-11}	$3\cdot10^{-12}$	4.5 nV/√Hz 3 pA/√Hz
PD42Sr			1	90	10^{10}	4.15±0.22	10^{-10}	$3\cdot10^{-11}$	2.7 nV/√Hz 30 pA/√Hz
PD47Sr			1.5	10	$2\cdot10^{9}$	4.65±0. 25	$5\cdot10^{-10}$	$1.5\cdot10^{-10}$	1.5 nV/√Hz 225 pA/√Hz

When taking into account the equivalent values of self noises of photodiodes presented in the last column of Table 1, it is necessary to keep in mind the fact that the preamplifier noises can contribute considerably into the threshold sensitivity (detectivity) of the pyrometric sensor. Therefore the relation for the estimation of the minimum detectable power ΔPmin should be written as:

$$\Delta P\min = NEP_{PD+OP} = \frac{\sqrt{i_n^2 + i_{nOP}^2}}{S_i} = \frac{\sqrt{e_n^2 + e_{nOP}^2}}{S_v}, [W/\sqrt{Hz}] \quad (1)$$

where the amplifier noises are marked by ‘*op*’.

The typical values of input noises of the amplifier are of the order of 2 nV/√Hz. Therefore the values of the minimum detectable power ΔP_{min} in photodiode sensors PD42Sr and PD47Sr exceed the given NEP values (column 9th) by 1.5 and 2 times.

3. TRANSFER FUNCTION AND FIGURES OF MERIT OF COLOR PYROMETRIC SENSORS BASED ON A3B5 PHOTODIODES

3.1 Transfer function of a one-color pyrometric sensor

The easiest way to estimate the technical parameters of optical sensors used in measurement equipment is to determine the sensor transfer function that relates its output signal and a measurable physical quantity. In our case, the measurable quantity is object (an object part) temperature of the area B that is determined indirectly from measuring the power of its thermal radiation recorded by the detector at some distance from the object. The photodiode is an 'ideal' detector of radiation, because its output current is linearly related to the incident radiation power through the values of its current sensitivity $S_I(\lambda)$. With taking into account the limited angle of the radiation collection depending on the sensor optical scheme, object emissivity ($\varepsilon(\lambda)$) and transmission of optical elements and intermediate medium ($\tau(\lambda)$), the general expression for the transfer function of the pyrometric sensor based on a photodiode with the current sensitivity spectral distribution $S_I(\lambda)$ is:

$$I_{\mathrm{PhD}}(\mathrm{T}) = k_P \cdot B \cdot \int_{-\infty}^{\infty} S_I(\lambda) \cdot \varepsilon(\lambda) \cdot \tau(\lambda) \cdot R_0(\lambda, T) d\lambda, \quad (2)$$

where kp = ¼ *(1-cos(α)) determines the efficiency of thermal radiation power collection in a solid angle α;
$R_0(T,\lambda)$, W/(cm^2 μm) is the specific spectral density of the black body (BB) thermal radiation power;
T is the object temperature in Kelvin.

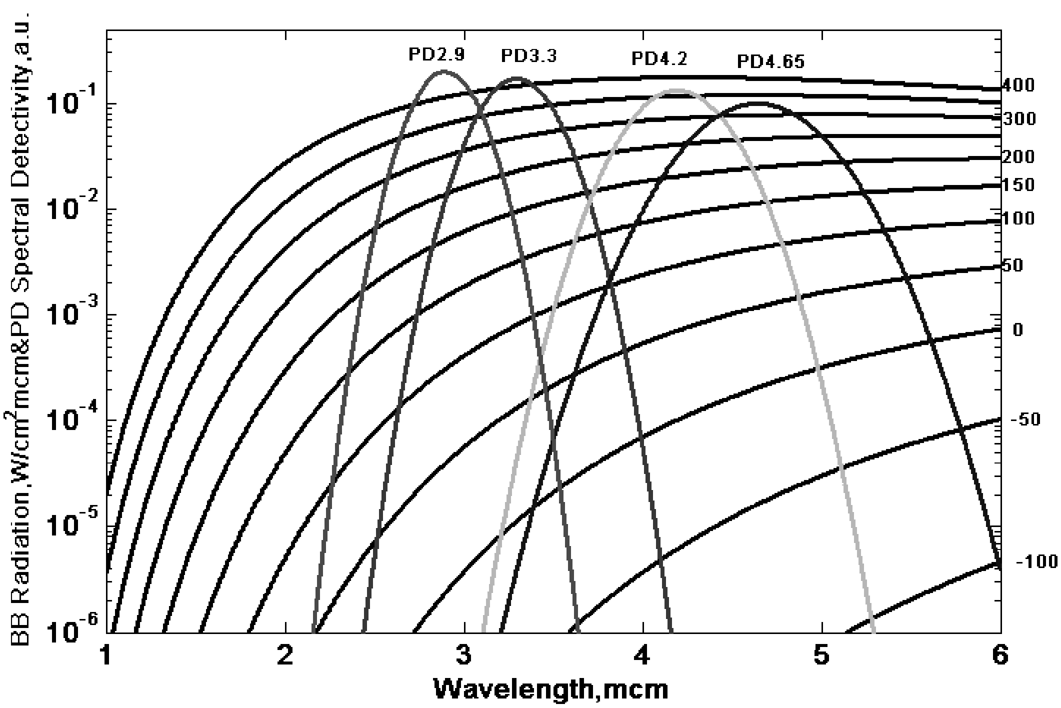

Figure 1. Spectral densities of the BB radiation at different temperatures and spectral distributions of sensitivity of A3B5 photodiodes (approximated by the Gaussian)

Figure1 demonstrates the specific spectral density of the black body radiation $R_0(\lambda,T)$ within the temperature range T= -100… 400°C together with the spectral characteristics of the sensitivity of the A3B5 photodiodes presented in Table 1. For preliminary estimations, the spectral sensitivity of these photodiodes can be approximated sufficiently well by the Gaussian function with parameters λmax and Δλ indicated in the 7th column of Table 1: $S_I(\lambda)= S_I(\lambda max)\cdot G(\lambda max,\Delta\lambda)$,

where G(λmax,Δλ) is the Gaussian function for which the normalization condition $\int_{-\infty}^{\infty} G(\lambda,\Delta\lambda)d\lambda = 1$ is fulfilled.

This approximation has been experimentally proved when simulating characteristics of optical gas sensors based on these photodiodes[6]. It is seen in Figure1 that the spectral sensitivity of all photodiodes is close to the maximum of thermal radiation for the considered temperature range.

The values of the specific (from 1 cm² of the emitting surface) BB radiation power for normalized spectral distributions G(λmax,Δλ) $R_0(\lambda_{\max},\Delta\lambda,T) = \int_{-\infty}^{\infty} G(\lambda_{\max},\Delta\lambda)\cdot R_0(\lambda.T)d\lambda$ corresponding to PD29Sr, PD34Sr, PD42Sr, PD47Sr spectral sensitivity have been estimated . The obtained values for different object temperatures are shown in Figure 2 by points. The same Figure presents similar dependences (solid lines) of specific power of the BB radiation for the spectral lines 2.9, 3.3, 4.4 and 4.7μm.

The estimations demonstrate that the relative deviation of the values of the BB radiation specific power within the sensitivity band of photodiodes PD29Sr, PD34Sr, PD42Sr, PD47Sr from the ideal monochrome dependence does not exceed 0.1- 1% at the temperatures higher than 0 °C. This fact permits one to consider the above-mentioned detectors with their spectral characteristics as quasimonochrome and to use the monochrome approximation for recording the transfer function of pyrometric sensors based on A3B5 photodiodes:

$$I_{\text{PhD}}(\text{T}) = k_P\cdot\varepsilon(\lambda_{\max})\cdot\tau(\lambda_{\max})\cdot S_I(\lambda_{\max})\cdot\Delta\lambda\cdot B\cdot R_0(\lambda_{\max},T) = \\ = k_P\cdot\varepsilon(\lambda_{\max})\cdot\tau(\lambda_{\max})\cdot S_i(\lambda_{\max})\cdot\Delta\lambda\cdot B\frac{C1}{\lambda_{\max}^5\cdot\exp(C2/\lambda_{\max}\cdot T)}, \quad (3)$$

where C1 and C2 are the radiation constants in the Planck formula.
The sensitivity of the sensors to temperature changes is determined from the differentiation of transfer function (3):

$$\frac{dI_{\text{PhD}}}{dT} = S_T\left(\lambda_{\max},\Delta\lambda,k_P,B,\varepsilon,\tau,T\right) = -\frac{C2}{\lambda_{\max}\cdot T^2}I_{PhD}(T) \quad (4)$$

Expression (4) allows calculating the methodical error of temperature determination in case quasimonochrome approximation (3) is used for the pyrometric sensors based on the A3B5 photodiodes. The calculations show that the deviation of the transfer function of diode sensors from the ideal monochrome dependence within the limits 0.1- 1% leads to an insignificant additional error (ΔT/T) that does not exceed 0.1% of the value being measured at the temperatures higher than 0 °C.

3.2 Temperature detection limit

The detection limit, or the minimum measurable temperature determined with the confidence probability 0.95 can be estimated from the condition: $I_{PhD}(T_{min})= 3\cdot dI_{min} =3\cdot S_I(\lambda_{max})\cdot NEP$. By substituting this value in the left side of relation (3) we obtain the equation for the determination of the blackbody specific threshold detectable radiation power $R_0(\lambda_{max},T_{min})_{min}$:

$$R_0(\lambda_{\max},T_{\min})_{\min} = \frac{3\cdot NEP}{\Delta\lambda\cdot k_P\cdot B\cdot\varepsilon(\lambda)\cdot\tau(\lambda)} \quad (5)$$

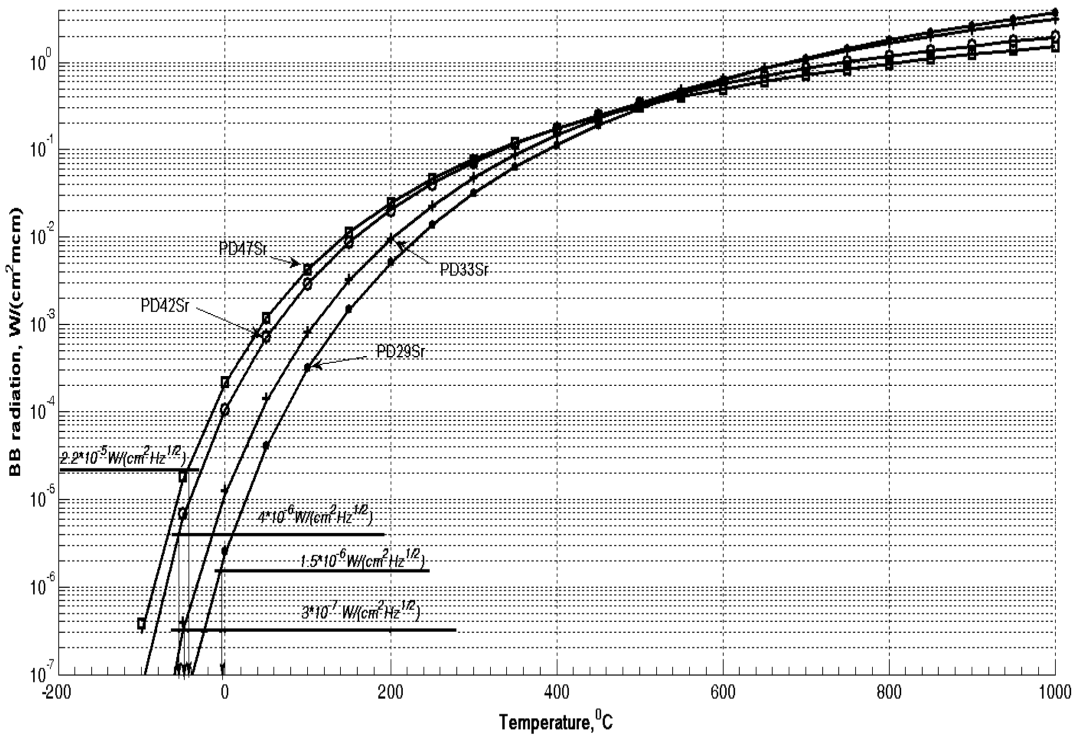

Figure 2. Dependences of specific thermal power of the BB radiation for spectral lines 2.9, 3.3, 4.2 and 4.7 μm in the monochrome approximation (solid lines) and in spectral ranges corresponding to the photodiodes PD29Sr, PD34Sr, PD42Sr, PD47Sr (points). The arrows indicate the thresholds of the temperature detection for these photodiodes for the measurement time 1 s, area of the measured surface B=1 cm^2 and angle of radiation collection $\alpha \approx 2.2^0$

The graphic solution of equation (5) determinates the threshold values of temperatures that can be measured by pyrometric sensors. . Let us perform estimations for loss-free sensors optical scheme ($\tau(\lambda)$=1) and objects with $\varepsilon(\lambda)$= 1, linear sizes of the region being measured $\sqrt{B}$=1cm, distance to the object is equal to 1 m which corresponds to the sighting coefficient 1:100 that is characteristic for professional measurement devices.

Table 2. Main parameters of pyrometric sensors based on A3B5 photodiodes

Type	Spectral range, λmax $\pm\Delta\lambda/2$, μm	ΔP_{min}, W/ $Hz^{1/2}$	$R_0(T_{min})$, W/cm^2 $Hz^{1/2}$	T_{min} °C	ΔT, °C		
					T=0^0C	T=50^0C	T=300^0C
1	2	3	4	5	6	7	8
PD29Sr	2.9±0.15	$1.5\cdot10^{-11}$	$1.5\cdot10^{-6}$	~0	10	0.7	$3\cdot10^{-3}$
PD34Sr	3.4±0.2	$3\cdot10^{-12}$	$3\cdot10^{-7}$	-50	5	0.05	$5\cdot10^{-4}$
PD42Sr	4.15±0.22	$4.5\cdot10^{-11}$	$4\cdot10^{-6}$	-55	9	0.2	0.05
PD47Sr	4.65±0. 25	$3\cdot10^{-10}$	$2.2\cdot10^{-5}$	-42	10	2.5	0.15
PD34Sr/ PD42Sr	3.4/4.15	$\sim4.5\cdot10^{-11}$	$4\cdot10^{-6}$	-55	10	2.5	0.07
PD34Sr/ PD47Sr	3.4/4.7	$\sim3\cdot10^{-10}$	$2.2\cdot10^{-5}$	-42	20	5	0.25

The main radiation losses are caused by a small angle of collection of object thermal radiation that propagates uniformly within the angle of π radian. The angle of radiation collection is determined by the pyrometer sensor optical scheme. It will be equal to $\alpha \approx 2.2^0$ if we take the input lens diameter equal to about 3.5 cm and the above-mentioned distance to the object (1 m). In this case the efficiency of thermal radiation collection will be equal to $k_p \approx 8.2*10^{-5}$. The values $R_0(\lambda_{max},T_{min})_{min}$ and the corresponding values of the minimum detectable temperature for the photodiodes under consideration are presented in Table 2(columns 4th and 5th).

It is seen from Table 2 that the threshold of temperature being measured can be provided by the sensors based on photodiodes PD34Sr and PD42Sr (column 5th).

3.3 Instrumental error of a one-color sensors

The instrumental error determining the sensor resolution can be obtained for each of the considered sensors by differentiating relation (2). Then its value with the confidence probability 0.95 can be estimated according to:

$$\Delta T = \frac{3 \cdot dI}{S_T(T)} = \frac{\lambda_{max} \cdot T^2}{C_2} \cdot \frac{3 \cdot dI}{I_{PhD}(T)} = \frac{\lambda_{max} \cdot T^2}{C_2} \cdot \frac{3}{\Psi} \quad (6)$$

where ψ is the signal-to-noise ratio at the sensor output when measuring the current temperature T.

Dependences of instrumental errors of sensors using the above-considered photodiodes for the measurement time equal to 1 s are shown in Figure 3 (solid lines).

Columns 6 and 7 in Table 2 present the values of the instrumental errors at the temperatures 0°C, 50°C and 300 °C. As

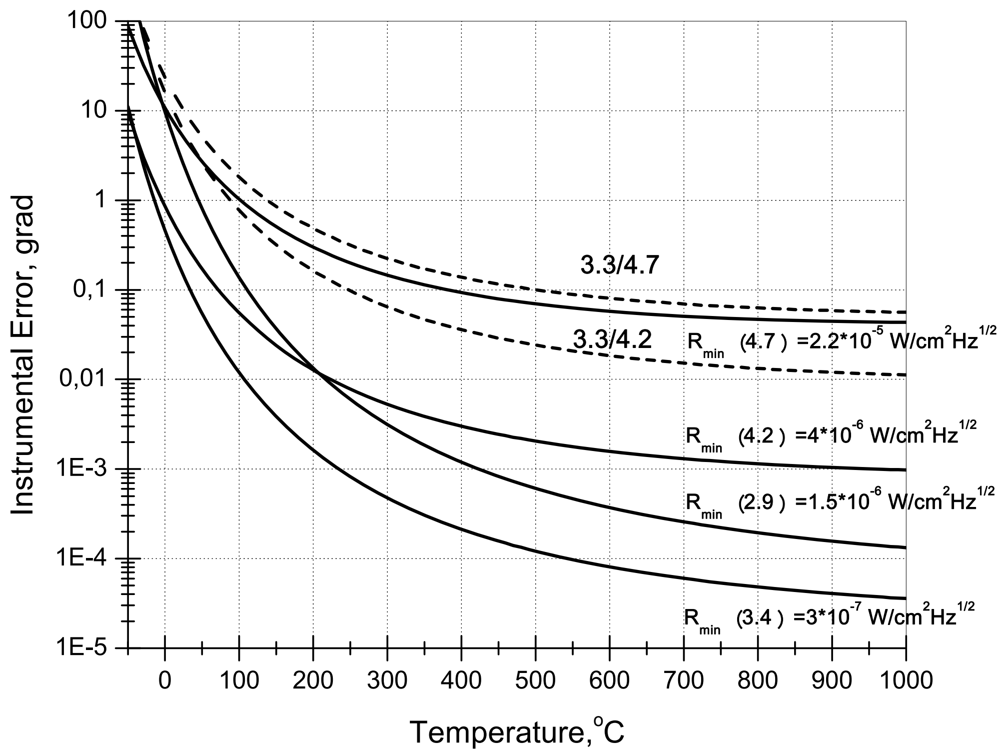

Figure3. Instrumental errors of one-color pyrometric sensors based on A3B5 photodiodes (solid lines) and two-color pyrometric sensors based on pairs of diodes (dotted lines). The time of measurement is equal to 1 s, the linear sizes of the object under measurement are equal to 1 cm, the sighting coefficient is equal to 1:100, the product ε(λ)τ(λ)=1.

one should expect, the minimum instrumental errors of the measurement of temperature are obtained in sensors whose level of photodetector self noise is less. It should be noted that this instrumental error of measurements in the sensors under consideration can be obtained only under the condition of precise determination of parameters ε(λ)·τ(λ) or by sensor periodic calibration against characteristic temperature points of an object under study[7]. It is possible to perform such calibration because the operation of the sensor is described to satisfactory accuracy by the analytical expression (3).

4. TRANSFER FUNCTION AND EXPECTED PARAMETERS OF TWO-COLOR PYROMETERS BASED ON A3B5 PHOTODIODES

The application potential of A3B5 photodiodes sensors is related mainly with two-color pyrometry. Two-color pyrometers allow one to avoid methodical errors associated with the dependence of the sensor output signal on the accuracy of the determination of the value of the product ε(λ)·τ(λ). The transfer function of the two-color pyrometer in which two quasimonochrome photodiodes with spectral characteristics $S1_I$ ($\lambda1_{max}$, Δλ1) and $S2_I$ ($\lambda2_{max}$, Δλ2) are used (in this case, λ1 and λ2 are sufficiently close to each other, so that the equality $\varepsilon(\lambda1_{max})\cdot\tau(\lambda1_{max})=\varepsilon(\lambda2_{max})\cdot\tau(\lambda2_{max})$ is valid), will be written as:

$$S_{out}(T) = \frac{I_{\text{PhD}}1(\text{T})}{I_{\text{PhD}}2(\text{T})} = \frac{S1_i(\lambda 1)\cdot\Delta\lambda 1}{S2_i(\lambda 2)\cdot\Delta\lambda 2}\cdot\left(\frac{\lambda 2}{\lambda 1}\right)^5\cdot\exp\left(\frac{C2}{T}\cdot\left(\frac{1}{\lambda 2}-\frac{1}{\lambda 1}\right)\right) \quad (7)$$

In this case, the error of measurements of temperature will depend on the instrumental error that can be defined with the confidence probability 0.95 as:

$$\Delta T = \frac{3\cdot dS_{out}}{S_T(T)} = \frac{\Lambda\cdot T^2}{C_2}\cdot\frac{3\cdot dS_{out}}{S_{out}(T)} = \frac{\Lambda\cdot T^2}{C_2}\cdot 3\cdot\left(\frac{1}{\Psi 1}+\frac{1}{\Psi 2}\right) \quad (8)$$

where ψ1, ψ2 are the signal-to-noise ratios at the output of each spectral measuring channels when measuring the current temperature T,

$\frac{1}{\Lambda} = \left(\frac{1}{\lambda 2}-\frac{1}{\lambda 1}\right)$ is the effective wavelength of the two-color pyrometric sensor.

The last two rows of Table 2 present the estimated values of the following parameters of two-color pyrometers based on photodiode pairs PD34Sr/ PD42Sr and PD34Sr/ PD47Sr: the threshold temperature (column 5) and the instrumental error value at the measurable temperatures equal to 0°C, 50°C and 300°C (columns 6 , 7 and 8). It was found for the two-color pyrometer that the threshold of temperature detection is similar for one-channel pyrometers with higher threshold temperature.

Figure 3 demonstrates the estimated values of the measurement instrumental error of two-color pyrometric sensors PD34Sr /PD47Sr and PD34Sr /PD42Sr (dotted lines) under the above-considered conditions. As seen in Figure 3, in comparison with the pair PD34Sr/ PD47Sr, the pair of photodiodes PD34Sr/ PD42S ensures better technical characteristics of the pyrometer, which results in a considerably less value of the measurement error. This can be accounted for by better parameters of the photodiode PD42Sr as compared to those of PD47Sr. On the other hand, in some cases, the photodiode PD47Sr should preferably be chosen due to its insensitivity to carbon-dioxide gas. When carrying out measurements with the photodiode PD42Sr at relatively large distances from a radiation source, an appreciable concentration of CO2 in atmosphere may lead to strong uncontrolled absorption of object thermal radiation.

A big value of the instrumental error of measurements in two-color pyrometers as compared to that in one-channel sensors fabricated with using the same hardware components is compensated by the absence of the methodical error related to the inaccuracy of the estimation of the object emissivity or optical channel transmission. For example, when measuring the temperature in the range of about 300°C by the two-color pyrometer based on a pair of diodes PD34Sr/ PD42Sr, the instrumental error is about 0.1 °C. In one-channel pyrometers, the similar measurement error is achieved with the relative accuracy of the determination of the product ε(λ)·τ(λ) being not worse that 0.1%, which is not always realizable in practice.

5. EXPERIMENT

In order to check the above-presented estimations in experiment, a prototype model of the sensor based on PD47Sr photodiode (λ_{max} =4.65 μm) with the current detection scheme consisting of a low-noise operational amplifier ICL28190 was investigated. The photodiode and amplifier were positioned on a Peltier element by which the sensor self temperature was stabilized. The bottom of a metal container where hot water was poured served as an object of measurement. During the cooling of water, the object temperature changed from 90 to 0°C (with the addition of ice) and it was measured by a thermocouple. A method of calibration against temperature points of the object under study [7] was used for the sensor calibration. The points in Figure 4 indicate the experimental values of an output signal of the pyrometric sensor under study normalized against the values of the sensor signal at the calibration temperature equal to t=54.5°C. The linear size of the object region under measurement is about 2 cm, the time of measurement is about 10 s. The experimental value of the lowest measured temperature is equal to 5°C.

The same Figure shows the theoretical dependence (solid line) of the sensor normalized output signal estimated according to the Planck radiation law for the spectral component λ_{max} =4.65 μm. One can see that there is a good

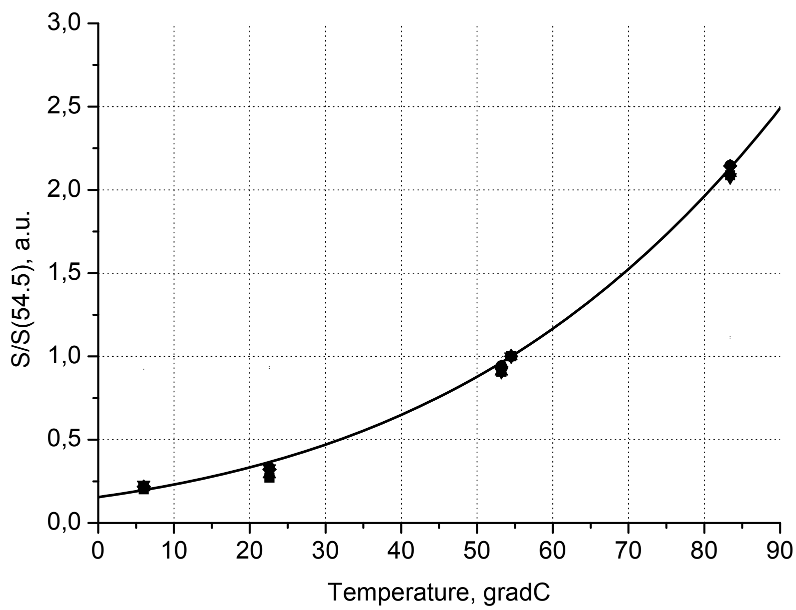

Figure 4. Experimental values of an output signal of the pyrometric sensor based on the PD47Sr (points), normalized against the values of the sensor signal at the calibration temperature t=54.5^{0}C and the corresponding theoretical curve for the monochrome approximation (solid line) for λ_{max}=4.65 μm. The measurement time is 10 s, the linear size of the object being measured is about 2 cm.

agreement of the theoretical dependence and experimental points, which indicates the validity of using analytical relation (3) for the description of sensor performance. The dispersion in the readings in the range 50°C corresponds to the error in the temperature measurement 2 °C when stabilizing its self temperature at the level 18 °C. This value is slightly less than that indicated in Table 2 because of greater measurement time and value of the object linear size (about 2 cm).

6. CONCLUSIONS

Color pyrometers based on mid-infrared photodiodes PD42Sr, PD47Sr and PD34Sr can provide parameters surpassing those of conventional present color pyrometers in the lower limit of temperature measurement, from 0 ^{o}C, with the high accuracy of measurements (not worse than 1%) within the wide range of temperature measurements, up to 800^{0}C.

The high sensitivity and relative narrowbandness of the photodiodes considered above make it possible to use them as a base when implementing professional two-color pyrometers operating within the temperature 0 -800 ^{o}C. Parameters of these pyrometers are: the accuracy is not worse than 1% of the scale at sighting coefficient about 1:100 and operation speed is within the range from milliseconds to 1 s. Moreover, they are insensitive to uncontrolled changes of object emissivity and intermediate medium transmission.

The validity of the presented estimations of temperature sensors based on the photodiodes A3B5 is proved by the results of the sensor (based on PD47Sr (λ_{max}=4.65 μm) specimen testing that have demonstrated a good agreement between the theoretical and experimental dependences. It confirms the validity of using the quasimonochrome approximation when describing the operation of the sensor. This allows the use of autocalibration methods of the temperature sensor for reducing the methodical error of measurements. The value of the lower measured temperature obtained from experiment is equal to 5 ^{o}C, the temperature resolution (sensitivity to temperature changes) is not worse than 2 ^{o}C within the temperature range 5-100 ^{o}C at the operation speed 10 s.

The authors are grateful to B..A. Matveev and M.A. Remennyi for their help in carrying out this study.

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