A3B5 photodiode temperature sensors for low-temperature pyrometers

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The report considers the capabilities of low-temperature color (two-color) pyrometers with temperature sensors based on A3B5 immersion lens photodiodes in the spectral range 2-5 μm.

The main problems caused by low-temperature pyrometry are the low level of thermal radiation of the object when it temperature is below 300 ^{0}C and a shift of the radiation maximum to the infrared spectral region. The problem of detection of weak thermal radiation in industrial pyrometers is solved by using broadband (8-14 microns) radiation detectors and temperature measurements on large object areas. Usually, such pyrometers require initial calibration at the blackbody radiation, therefore the unknown emissivity of a real object can lead to methodical measurement error up to 25-30% or more. Methods of two-color pyrometry can resolve this methodological error but they can not be realized with broadband detectors and at the present time is suitable only for temperatures higher than 500^{0}C. Requirements for professional pyrometer: small size of the surface being measured, high speed, accuracy and repeatability of temperature measurements– are much higher than thous for industrially produced low-temperature pyrometers.

Mid-infrared immersion lens photodiodes developed at the Ioffe Institute have high spectral selectivity ($\lambda max/\Delta\lambda \approx 0.1 \ldots 0.15$); and as to the response time (up to 10^{-9}s) and detectivity ($D^* \approx 10^{-9}$-10^{-11}, cm√Hz/W) they are significantly higher than thous for currently known detectors of thermal radiation. To estimate the prospects of their application in low-temperature pyrometers we used an approach based on an analytic description of optical sensors using the transfer function with taking into account spectral and geometric characteristics of the pyrometer optical channel, radiation characteristics of real objects, the transmission of an intermediate medium, parameters of the detection and transmission of the electronic highway and the size of the surface under the analysis.

The relatively high spectral selectivity of photodiode temperature sensors allows the use of a fundamental Planck's radiation law to calculate the radiation power of the object at the $\lambda = \lambda max$ of the chosen photodiode.

The numeric differentiation of the transfer function with taking into account the noise of the photodiode with preamplifier circuits allowed us to evaluate the potential value of the pyrometer sensitivity and sensor instrumental errors within the entire range of measured temperatures at different wavelengths – 2.9, 3.3, 4.2 and 4.7 microns. Calculations showed that all the photodiodes provide high precision measurements: the absolute error of 0.01…1^{0}C at the temperature range 0-300^{0}C with the response time up to 10 mS.

The analysis of the transfer function of the temperature sensors based on A3B5 photodiodes also showed that they permit implementing the methods of the multicolor pyrometry, providing a significant decrease of the methodological error in the optical temperature measurements associated with unknown values of the object surface emissivity and uncontrollable changes in the environment transmission.

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