High-sensitivity temperature sensor with calibration on temperature of real object

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In the given work it is presented a spot pyrometer on the basis of a high-sensitivity photodiode sensor. The basic advantage of an offered pyrometer is realization in it of a calibration principle on the characteristic temperature points, inherent in object and received in situ on indirect measurements. The offered approach doesn't demand initial calibration of the device on the Black-Body temperature and allows to measure temperature from 400 ^{0}C on small spots of remote objects (3-5 mm on distance of 50 cm) in the conditions of unknown radiating ability (e) of real object ε (λ,) and uncontrollable change of the intermediate environment transmittance. The basic attention during device working out has been given for a sensor choice since its parameters define a range of measured temperatures, value of a tool error, response time and sensitivity of a pyrometer. In the developed spot pyrometer the high-sensitivity low-noise photodetector FI-1 created in Ioffe Institute is used. The photodetector represents microassemblage of the Si p-i-n photodiode with the electronic signal processing scheme using time-pulse modulation.

For a calibration possibility on the limited number of points (it is desirable, on one) it is necessary to have the analytical expression connecting the measuring object temperature and registered energy of it radiation. Only monochromatic methods of pyrometry allow to use for temperature calculations the analytical expression of the Planck's law o (approach of Wine for λT <3000 mcm*K). The condition of monochromaticity of a photodetector is reached by use of the narrow-band filter with λ max =0.95 mcm and Δλ =50 nm. The choice of a registered spectral line λ max =0.95 mcm has been caused by a problem of the real temperature control on the growing film surface on the different substrates (including GaAs, transparent for λ> 1mcm) during molecular-beam epitaxy (MBE).

Small noise (3*10-15) and high spectral sensitivity of a photodetector close to 0.95 mcm (0.55 A/W) allow to provide measurement of temperatures on small spots of object at high speed – up to 2-10 measurements per second..

Calibration process consists in definition of a photodiode current I_k corresponding to some known temperature of calibration T_k. Taking into account this procedure of calibration the equation for connection of the current value of a photodiode current (Ix) with the true temperature of object T_x will look like:

where A - constant depending on the registered spectral line λ max,

$$T_x{}^o, C = \frac{A}{\frac{A}{Tc + 273{,}3} - \ln\left(\frac{Ic - I_t}{I_0 - I_t}\right)} - 273{,}3$$

T_c - calibration temperature, in Celsius degrees;

I_x – current value of a photodiode current;

I_0 – the value of a photodiode current corresponding to the temperature of calibration $T_к$;

I_t – the value of the "dark" photodiode current.

The calibration principle on characteristic temperature points has been realized in a pyrometer intended for measurement of temperature of a substrate surface during MBE growth of the semiconductor heterostructures.

Device calibration was made directly during a work cycle on the temperature lying within a range of measurements and defined on physical points: the temperature of oxide evaporation for GaAs substrates (585^{+10} ^{O}C), accompanied by fast electron diffraction on reflection (detected visually from a change in the RHEED pattern), or the temperature of the beginning of Ga evaporation from a surface of a sapphire substrate (700^{+10} ^{O}C).

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