FILM RADIOMETER BASED ON ELECTRICAL SUBSTITUTION FOR USE IN PHOTOMETRIC MEASUREMENTS

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The design of a nonselective radiometer that functions on the basis of the principle of electrical substitution is described. The assembled radiometer possesses high current−voltage sensitivity on the order of 10 V/W, time constant 7 sec, and error in measurement of the emissive power at most 0.3%. It is designed for exact photometric measurements in the visible and infrared bands of the spectrum.

Nonselective sensitive radiometers, which make it possible to maintain high measurement precision in measurements of optical power, are needed to carry out certain steps in photometric measurement, for example, the transmission of the scale of the energy and the spectral density of radiation (illumination and intensity of radiation) in the ultraviolet and infrared bands of the spectrum.

Absolute radiometers with electrical substitution are commonly used for these purposes. Among all the radiometers that have now been developed, absolute cryogenic radiometers [1-3] produce the highest measurement precision (at the 0.01% level). These types of radiometers are used to calibrate secondary receivers by means of stabilized He−Ne, krypton, and argon gas lasers that support the transmission of the unit of optical thickness at several wavelengths in the visible and near infrared bands of the spectrum.

A cryogenic radiometer is a rather complicated and expensive instrument, which, to a large extent, prevents it from being widely employed. Thus, it is extremely important to design a hollow radiometer based on the principle of electrical substitution that functions at room temperatures and maintains a measurement precision < 0.5% and high degree of sensitivity. Thermic receivers designed on the basis of thin-film technology [4-6] are the optimal instruments for this purpose. These types of receivers comprise a thin-film receiving site with absorbing coating on which a heating unit and thermopile are situated.

To improve the threshold sensitivity and equivalence of electrical substitution, the receiver is mounted in an evacuated chamber. To increase its absorption factor, the radiometer is placed in the center of a hemispherical mirror. The radiometers that have been previously described [4-6] possess a sensitivity on the order 0.3 V/W. Note that the insufficient current−voltage sensitivity of these radiometers to a large extent restricts their range of application in spectro-radiometric measurements whenever the strength of the measured signal does not exceed $10^{-6}$ W in the ultraviolet and visible bands of the spectrum.

Below we will consider an absolute radiometer we have designed. The current−voltage sensitivity of this radiometer exceeds, by a factor of ten or more, the sensitivity of existing radiometers based on thin-film technology.

Description. Calculations performed to optimize the characteristics of film receivers have demonstrated that it is possible to substantially increase (more than tenfold) the sensitivity of these types of receivers through improvements in the manufacturing technology. The need to maintain the necessary dimensions of the receiving site were taken into account in the calculations. Selection of thermoelectric materials for use as the thermocouple arms should aim to maximize the thermoelectric efficiency as well as make it possible to employ planar technology. The compounds Bi$_2$, Te$_3$, and BiSb are the most appropriate materials. It has been shown [7] that prior to condensation, Bi Te films produced by supercooling of the paired phase exhibit, by comparison with solid samples, a two- to threefold growth in thermoelectric efficiency as a result of the formation of potential barriers for the holes at the crystal boundaries. It should be noted that the thermoelectromotive force of a pair consisting of these materials depends only slightly on the mean temperature, allowing us to enlarge the temperature range over which the sensitive element may function. The identical values and nature of the dependence of the thermoelectromotive force

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and the electric conductivity for solid monocrystals and films indicate that the contribution of quantum effects is insignificant in the case of thicknesses greater than 0.05 μm.

A polyamide film serves as the heat-insulation material from which the thermocouple is created. This type of film possesses the required set of physical and mechanical properties. Moreover, it has no analogs among the well-known film materials with respect to all the important indicators, particularly at low and high temperatures. One of the most important properties of a polyamide film is its low heat conductivity. It is extremely important that the film not only possess high technical and electrical properties, but also retain these properties for lengthy periods of time.

Aluminum foil 25 μm thick serves as the heat-conducting base. A polyamide film 5 μm thick is created on the aluminum foil by means of imidization. Construction of the pattern of a thin-film thermopile is performed by means of photolithographic processes. Thin-film thermoelectric elements are created by means of vacuum evaporation. The reception site is drawn by means of thermal evaporation in a vacuum.

The assembly diagram of the radiometer is depicted in Fig. 1. Unlike the traditional construction of a hemispherical mirror, here we are using a spherical mirror. This enables us to improve the equivalence of substitution and to reduce the influence of thermal drift of the chamber's background radiation.

**Investigation of the Radiometer Characteristics.** In a receiver based on electrical substitution, the detected emissive power $W_e$ is determined on the basis of the measured electric power of substitution $P_{ab}$: