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DEVICES FOR REMOTE TEMPERATURE MEASUREMENT OF VARIOUS OBJECTS BASED ON *CdSb* ANISOTROPIC THERMOELEMENTS

The design, functioning principle, physical and technical parameters of the sensors of non-contact temperature measurement of various objects based on CdSb anisotropic thermoelements, are presented. The method of synthesis and growth of pure and structurally perfect CdSb single crystals to construct anisotropic thermoelements on them was developed.
Key words: temperature measurement, sensors, anisotropic elements.

Introduction

Many tracking systems, systems of measuring thermal signals and irradiance, technological and production processes, scientific studies and special equipment need and widely employ devices allowing signal measurement within the limits caused by a rather wide solid angle. This fact related to device design restricts considerably the equipment potential, complicates and elongates the research and measurement process, forces to supplement a design with rotary mechanisms for measuring unit, to install several such units in one system. The above mentioned requirements to design modification and complication reduce its precision and reliability, increase device dimensions and cost.

Design of measuring unit for recording of energy signals with 180° solid angle of measurement

Materials and methods

Numerous attempts are made to improve measuring systems, primarily increasing their precision and solid angle, enhancing the sensitivity and other device parameters.

In this work, the authors present a retrofit of a device for measurement of object irradiance, with the angle of coverage of measured signal increased to 180°.

Modernization of a device for irradiance measurement [1] led to expansion of viewing angle of thermal detector used in the device. Several design variants were considered with the use of a flat thermopile of anisotropic thermoelements based on cadmium antimonide known and currently used for this purpose in thermal detectors [2]. For the experimental determination of viewing angle, a measuring bench was developed and assembled (Fig. 1) which is an optical bench accommodating a stabilized source of thermal radiation 2; radiation cutoff screen 7; blinds 4 and light guide 3 restricting the diameter of thermal radiation bundle; rotation table with angle meter 5 accommodating thermal detector holder and thermal radiation detector 6; as well as voltage stabilizer of thermal radiator 8, and recording device 9.

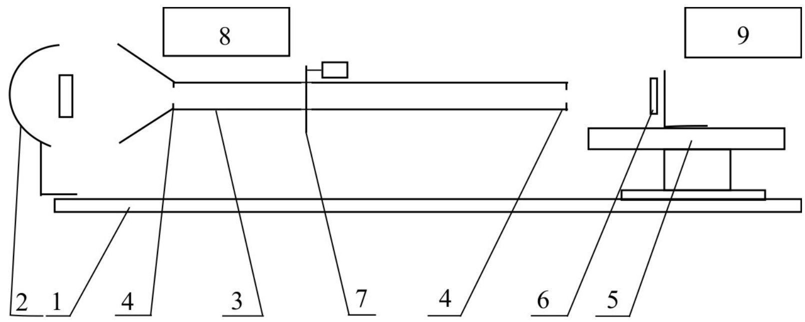

Fig. 1. Measuring bench.

The detector under test was placed into a holder in such a manner that the detector receiving pad was located on the optical axis of thermal bundle parallel to a beam. As a source of thermal radiation, an open nichrome spiral wound as a cone was used. The test was performed in natural heat exchange environment under normal conditions as follows. After switching and heating the installation for 2 min, the stable reading of detector recorder signal was recorded, which corresponded to background value of detector signal, then the shutter was opened for the time of exposition equal to 10 sec, the stable reading of detector recorder signal was recorded which corresponded to the measured heat flux value, following which the shutter was closed. The procedure was repeated seven times. Then the table with the thermal detector was rotated by the angle of 10° and a series of measurements was repeated for the newly set angle of receiving pad position with respect to incident heat flux. The results obtained were reduced to the average for each angular value and the respective indicatrix was built.

For further comparison and analysis the following thermal detector designs were considered for testing.

1. Nonselective thermal radiation detector [3] which is a flat thermopile of anisotropic thermoelements based on cadmium antimonide arranged in a package with a flat cover. The input window in the cover is restricted by a diaphragm located at the distance of 0.5 from the receiving pad.
2. Nonselective thermal radiation detector similar to the first one and characterized in that the cover in this case is shaped as a mirrored hemisphere. The input window is covered by IR filter of cadmium telluride single crystal, which assures the transmission region from 0.8 to 20 microns. The filter geometry corresponded to geometry of cosine head, and the receiving pad of thermal detector was located in a diametrical plane of mirrored hemisphere.

3. Nonselective thermal radiation detector similar to the first one and characterized in that the detector lacks IR filter and certain structural modifications have been introduced.

All thermal radiation detectors exposed to testing have volt-watt sensitivity at least 0.4 V/W. All the detectors have the identical size of receiving pad which is 6×6 mm^2. The geometrical dimensions of thermoelements and their number in all the cases were identical. Table 1 lists the values of output signal of a flat detector based on anisotropic thermoelements as a function of the intensity of heat flux incident on the receiving pad.

Table 1

The values of flat detector output signal as a function of heat flux intensity

Heat flux intensity [W/mm ^{2}]	0.015	0.084	0.179	0.340	0.612	0.787	0.982	1.187
Output signal [V]	0.0026	0.0210	0.0646	0.1159	0.1802	0.2256	0.2118	0.3058

Fig. 2 shows the external view of one of the samples of detectors on anisotropic thermoelements for measuring heat flux intensity presented for testing.

Fig. 2. External view of a detector based on anisotropic thermoelements (overall dimensions 16 × 16 mm).

The results of comparative test are listed in Table 2. For convenience of analysis and comparison of characteristics, the measured data are represented in a normalized form (as a percentage ratio of electrical signal depending on the direction angle of thermal beam and maximum signal corresponding to a normal to receiving pad).

Table 2

Results of measuring signal values as a function of measurement angle

Normalized value of detector electrical signal										
Angle °	0	10	20	30	40	50	60	70	80	90
Sample 1	0	0	0	1.2	6.6	19.2	41.4	68.9	94.8	100.0
Sample 2	0.1	0.8	1.3	3.9	7.0	21.7	35.9	67.6	83.8	100.0
Sample 3	2.7	12.2	24.0	37.2	48.7	64.5	78.1	88.1	96.8	100.0

The measuring head design developed and proposed by the authors has demonstrated high performance characteristics, the possibility of measurement in a wide coverage solid angle of 180°, which is not provided for by the first two detector designs. The design occupies very small space and its commercial version can be considerably reduced.

Devices for distance temperature measurement of various objects based on *CdSb* anisotropic thermoelements

Heat flux sensors based on anisotropic thermoelements whose analogs were used to perform experimental studies of aperture angle, served the basis for creation of a variety of control and measuring instruments and systems of automatic regulation of technological processes. Examples of some of these devices are shown below.

Fig. 3 represents a measuring head of a specialized information-diagnostic complex for medical diagnostics which is based on the use of dynamic heat flow metering: noncontact remote observation of changes in thermal radiation within a certain period of time. Table 3 represents the main specifications of the elaborated measuring equipment.

Fig. 3. Measuring head of a specialized information-diagnostic complex.

Table 3

Specifications of information-measuring equipment

№	Parameter	Measuring units	value
1	IR radiation detector, uncooled, based on anisotropic thermoelements, resolution, at least	V/W	0.2 – 0.4
2	Digital scale division value, at least	°C	0.05
3	Temperature of object under study	°C	20 – 42
4	Time of one exposure	sec	1

Table 3 (continued)

5	Time to reach the mode, not more	min	30
6	Time of continuous operation, not less	hour	8
7	Ambient temperature	°C	10 – 35
8	Relative air humidity at 25°C, not more	%	80
9	Work spectral domain	μm	2 ÷ 16

The elaborated equipment and method of its use are intended for tooling backup of dynamic heat metering method. The equipment allows noncontact information reading from each point of object under study. With its aid, for instance, one can get information on the function disturbance of any organ even before the morphological changes take place, i.e. at the earliest stage.

Fig. 4. Portable radiometer.

Portable radiometer, Fig. 4, for temperature measurement on different coal mining plots. The radiometer is intended for measuring IR radiation energy density in the wavelength range of 1 ÷ 25 μm, for determination of temperature and temperature difference over a wide range:

– object temperature: -30 ÷ + 700°C;

– ambient temperature: from 5 to 60 °C;

– relative air humidity: not more than 90 %;

– atmospheric pressure: from 96 to 104 kPa (720 – 780 mm of mercury).

Accuracy of temperature difference measurement: at least ± 0.1°C.

Table 4

Radiometer specifications

1	Measurement range of thermal radiation density of objects.	10 – 25000 W/m^2
2	Limit of permissible basic relative error at ambient temperature deviation from fixed one within the operating temperature range	± 0.1 %
3	Radiometer current consumption	Not more than 50 mA
4	Radiometer supply voltage	9 V
5	Setting time: in discrete mode	10 s
6	Setting time: in tracking mode	1 s
7	Device weight	Not more than 0.6 kg
8	Overall dimensions	Not more than 190 × 90 × 50 mm^3

Use of device in coal mining industry allows determination of possible and real places of egress of carbon dioxide and gaseous hydrocarbons, places of geological heterogeneities in the mine face at penetrating, as well as localization of spontaneous fires in the mines.

Fig. 5. General appearance of radiometer.

Radiometer, Fig. 5, is intended for measurement of irradiance intensity in the wavelength range from 0.2 to 25 μm under normal climatic conditions:

– relative air humidity at 25 °C, not more than 80 %;

– atmospheric pressure, from 96 to 104 kPa (720 – 780 mm of mercury).

Filter supplied with the device provides for infrared (thermal radiation) transmission at the level of 62 % in the band of 0.8 ÷ 25 μm.

Table 5

Radiometer specifications

1	Irradiance measurement range	10 ÷ 25000 W/m^2
2	Limit of permissible basic relative error	Not more than ± 6 %
3	Limit of permissible basic relative error with the ambient temperature deviation from 20 °C, within the operating temperature range	± 0.3 %
4	Radiometer supply current	Not more than 50 mA
5	Radiometer supply voltage	9 V
6	Setting time	1 s
7	Device weight	Not more than 0.6 kg
8	Overall dimensions, not more	190 × 90 × 50 mm^3

Both the radiometer and devices based on this concept, can be used in engineering, medicine, agriculture and other fields to measure the density of thermal radiation flux from the heated objects; to measure heat losses in heat power engineering, machine building, construction industry, etc.

Conclusion

1. The use of device in coal mining industry permits to determine methane egress in a mine face at penetrating, to localize spontaneous fires in coal mines.
2. To use the device as noncontact temperature controller in technological processes:
   – at quenching of technical glass for the temperature level of 600 ÷ 700 °C, to an accuracy at least ± 0.5;
   – at packing of pills and capsules in pharmacological industry at 90 ÷ 200 °C, to an accuracy at least ± 0.2.
3. In the instrumentation and test equipment as the sensors of automatic control systems in the chambers: of solar radiation, heat and cold, humidity with the resolution at least 8 g of water in 1 m^3, rain and dropping effect from individual drops to tropical shower.
4. In agriculture:
   – in cattle breeding;
   – in greenhouse business.
5. In meteorology:

– rain intensity sensor;
– actinometers.

6. In medicine:
   – for the noninvasive noncontact functional diagnostics of kidneys, thyroid glad, lungs and other diseases;
   – determination of placenta function, healing of postsurgical and traumatic stitches, etc.;
   – localization of inflammatory processes, etc.
7. In construction industry:
   – to detect the areas of largest real heat losses through external walls and to measure the value of these heat losses in watts from one square meter of surface;
   – for quality control of thermal insulation of heat pipelines and for measuring the value of heat losses from the unit surface of heat pipelines in watts from one square meter of surface;
   – for quality control of heat-insulating materials and structural elements by their real heat-insulating properties in units of heat flux density, i.e. $W \cdot m^{-2}$, etc.
8. Besides the ones listed above, other specific application fields are possible that are solved by using thermal phenomena associated with the process or function.

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