A RADIATION METHOD OF STUDYING THERMAL REGIMES IN ELEMENTS OF SEMICONDUCTOR RADIOELECTRONICS

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A brief description is provided of the measuring installation by means of which it is possible to analyze the temperature fields of elements 5×5 mm^2 in size, with a resolution on the order of 50 μm in the temperature interval 50–120° C. The measurement results carried out on transistors are given.

The breakdown of circuits and elements in transistorized equipment, in the overwhelming majority of cases, is a result of intensive thermal operational regimes or of undetected defects in the equipment, which lead to local overheating and, finally, to the breakdown of the unit or to a reduction of its useful service life. To locate these defects and to establish the levels of reliability for small-scale elements in semiconductor equipment, the study of the temperature fields in operational devices by the method of radiation pyrometry should be looked upon as promising. Published material in this connection has recently appeared both here and abroad [1–5].

The measuring installation being described in this article permits us to obtain thermal photographs of objects 5×5 mm^2 in size, as well as to measure the temperature on a portion of that object, having a linear dimension on the order of 50 μm.

Figure 1 shows a schematic drawing of the installation, indicating its basic functional units. The conversion of the thermal image of the object into one that is visible is accomplished in the unit in the following manner. Flat and spherical mirrors are used to project the image of the object onto the plane of the radiation receiver. The mechanically modulated radiation from the segment of the object projected onto the receiver is converted by the latter into a variable electrical signal. After passing through the measuring amplifier, the signal is applied to the brightness modulator of a cathode-ray tube. An S1-4 oscilloscope was used as the indicator unit in our work. The entire object is examined by rocking the flat mirror, thus shifting the image of the object relative to the receiver in the horizontal direction (line scanning), and slowly shifting the table holding the object in the vertical direction, thus scanning the frame. The movement of the table and the rocking of the mirror are accomplished with two electric motors by means of a cam system which provides for the uniform shifting of the image over the surface of the radiation receiver in the forward direction, with a relatively rapid return motion. The synchronous frame motion of the beam on the oscilloscope screen is achieved by applying a voltage from a circular linear potentiometer onto the vertical amplifier of the oscilloscope, with the indicator of the potentiometer rigidly connected to the rotating lift cam of the table on which the object has been placed. Line synchronization is achieved by shaping the trigger pulse of the driven oscilloscope sweep at the instant of the initial position of the flat scanning mirror. The sweep time of the electron beam of the oscilloscope is set equal to the time of the forward motion of the scanning mirror. Thus a television-type raster is formed on the oscilloscope screen. The total time required for the formation of the image of the object on the screen of the oscilloscope is 60 sec.

The energy-brightness distribution pattern from the crystal of a p29A-type transistor without a protective cover—obtained by means of the installation described here—is shown in Fig. 2. The lighter spots on the photograph correspond to the greater energy brightness of the object. The light center spot corresponds to the indium over the emitter junction. The four facets of the crystal are also visible in the photograph. The hot ring-shaped crystal holder and its welded base lead can also be seen, but these are weaker in intensity. The dark region surrounding the emitter indicates a germanium crystal which is a poor absorber in the wavelength interval picked up by

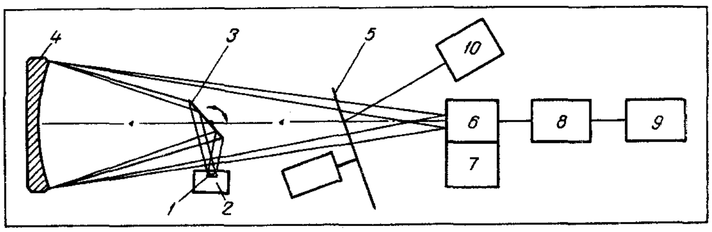

Fig. 1. Block diagram of measuring installation: 1) object under study; 2) lifting table; 3) flat mirror; 4) spherical mirror; 5) mechanical modulator; 6) radiation receiver; 7) light source; 8) narrow-strip measuring amplifier; 9) indicator unit; 10) standard radiation source.

the radiation receiver. The picture of the electrical heating of the P29A transistor was taken as current was passed through the collector-base circuit.

Figure 3a shows a photograph of a powerful P202-type transistor without a metal cover, whose collector junction exhibits a hidden defect resulting in local overheating on passage of current. The oscillograms of the signals corresponding to three scanning lines over the region of the crystal in which the local overheating is taking place are shown in Fig. 3b. The start of each line is shown in the photograph by a positive trigger pulse against the background of a bipolar signal. A third line passes directly through the segment with the elevated temperature. In Fig. 3a this point is marked with a white triangle. We used a point light source which could be placed in the position of the radiation receiver by means of a revolving system to determine that segment of the object whose signal at a given instant of time is incident on the receiver. The image of this light source—projected by the optical system of the measuring unit onto the object—indicates the point on the object which is projected onto the receiver at a given position of the scanning mirror and the object, when the receiver again returns to the location of the light source. It is object, when the receiver again returns to the location

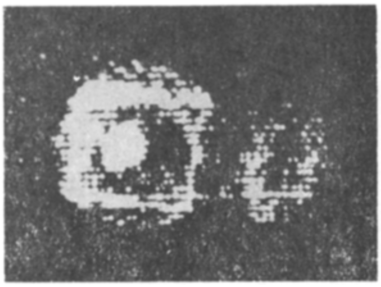

Fig. 2. Thermal picture of transistor P29A.

precisely this image which makes it possible to regulate proper focusing.

An uncooled lead-sulfide photoresistance was used as the radiation receiver. Its maximum spectral sensitivity varies from 2.2 to 2.4 μm, and its long-wave spectral sensitivity limit varies from 3.5 to 4.0 μm.

A regulated reference-radiation source—a comparison source—has been incorporated into the system being described here. The radiation from the comparison source impinges on the receiver and is reflected from the mirror surface of the vane of the mechanical modulator. The signal from the comparison source to the amplifier output turns out to have been shifted relative to the signal being studied through an angle of 180°. This radiation source is calibrated with respect to blackbody radiation.

To determine the temperature at a given spot on the surface of the object, after amplitude detection the signal from the amplifier ouput is applied to a pointer-type instrument. The minimum instrument reading corresponds to equality between the test and reference signals. In the course of the measurements, we must bear in mind that the optical characteristics of actual objects differ from the characteristics of a black body.

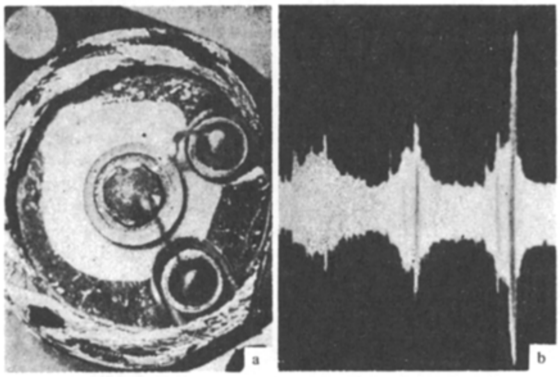

Fig. 3. Photograph of transistor with metal cylinder taken off (a) and distribution of output signal in the region of local overheating of the collector junction in transistor (b).

The signal on the radiation receiver as a function of the supplied electric power for P27A, P13, P401, and P101 transistors is shown in Fig. 4. The transistors were heated by means of the collector-base current. We recorded the radiation in the vicinity of the maximum heating of the surface of the crystal which was positioned above the collector junction. The irradiated region of the transistor crystals was first coated with kerosene carbon black.

For the specified supplied power it is possible to determine the surface temperature of the transistor crystal from the temperature scale shown in this graph. The temperature scale was obtained by measuring the signal on the receiver for various temperatures of a body with an emittance of 0.97–0.98. The graph shows that this installation makes it possible to record temperatures up to 50° C.

The installation described here thus makes it possible to monitor the thermal regimes of elements in

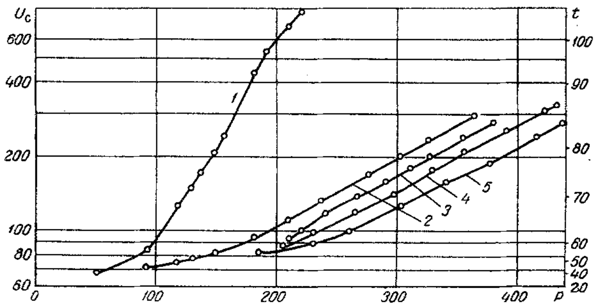

Fig. 4. Signal on radiation receiver (μV) and triode temperature (°C) versus supplied electric power (μW): 1) P27A; 2) P401; 3) P13; 4) P42B; 5) P101.

semiconductor equipment, to measure the thermal characteristics of these elements, and also to reveal hidden defects.

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