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EFFECTIVE METHOD FOR PHOTOGRAPHIC RECORDING OF HEAT FIELDS OF OBJECTS AND LASER RADIATIONS BASED ON A GAS DISCHARGE CELL

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ABSTRACT

This paper describes the design of a semiconductor photographic ionization camera used for spatio-temporal diagnostics of thermal fields of objects in the infrared wavelength range up to 30 µm and beyond. The results of experimental studies of photo detectors made of silicon doped with platinum and sulfur in a semiconductor photographic ionization camera gas-discharge cell are presented. It is shown that high sensitivity of the photographic process is provided due to a new photographic effect, which is associated with the phenomenon of photoelectric hysteresis.

KEYWORDS: *Diagnostics, Thermal Field, Laser Radiation, Photographic Effect, Photoelectric Hysteresis.*

INTRODUCTION

Photographic methods of registration of thermal fields of objects and spatio-temporal diagnostics of infrared laser radiation is one of the promising directions of optical information recording [1-6]. In connection with the general intensive development of nanotechnological processes of creating photo detectors and their application in practical problems, the requirements for photographic registration of thermal fields of objects, as well as in the space-time diagnostics of laser radiation, have sharply increased. Among the numerous devices of infrared technology, a promising semiconductor photographic ionization camera [7, 8]. The use of the developed photo detectors in the semiconductor photographic ionization camera makes it possible to create a highly sensitive photographic system in the infrared region of the spectrum [9-12].

Experimental part

The experimental setup is assembled from a semiconductor photographic ionization camera (Fig. 1, a) and a video control device of the AMJEON PRO UZB type (made in Korea). The photographed and observed object was the slit of an infrared monochromator with a NaCl prism and a "globar with a ferrite rod" light source. The slit image was projected with a BaF_2 lens onto the receiving surface of the photo detectors in the gas-discharge cell. The intensity of the radiation incident on the photo detector was determined by direct measurements with a metrological thermal column of the LETI type with a sensitivity of 0.72 V/W. The sensitive (to infrared-radiation) electrode of the gas-discharge cell are semiconductor wafers made of silicon doped with platinum and sulfur – *p-Si*<*Pt*> и *n-Si*<*S*> using a special technology.

The input side of the semiconductor wafers is equipped with stable ohmic contacts. The recording element in the gas-discharge cell is a fiber-optic washer having a diameter of 36 mm and a length of 22 mm, provided with a conductive SnO_2 coating. The fiber optic washer, in turn, is connected to the input of an electronic optical converter of the EP-16 type (made in Russia), and the output of the latter is mated to the input of the video control device . The generated image on the EP-16 screen is transferred to the computer monitor through the video control device. Thus, computer processing of infrared images is provided.

The initial cooling of the semiconductor photographic ionization camera cooler to 80 K is provided by liquid nitrogen, a further decrease in temperature is achieved by supplying liquid helium through a copper tube.

A high voltage of about 1200 V is applied between the semiconductor wafer and the fiber optic washer. The residual air pressure in the gas discharge cell is about 0.2 Torr. At the output of the fiber-optic washer, the invisible image is amplified using the EP-16, and then the video control device converts it into a digital signal. Thus, the photographic installation of infrared images assembled by us has a modernized look with the use of modern devices.

However, to record the output photographic characteristics in the experimental setup, a photomultiplier tube of the PMT-19A type was used. The output brightness on the EP-16 screen or at the output of the fiber optic washer was measured using a photomultiplier. Thus, in characteristic curves, the brightness of the infrared image is expressed in relative units proportional to the photomultiplier tube current.

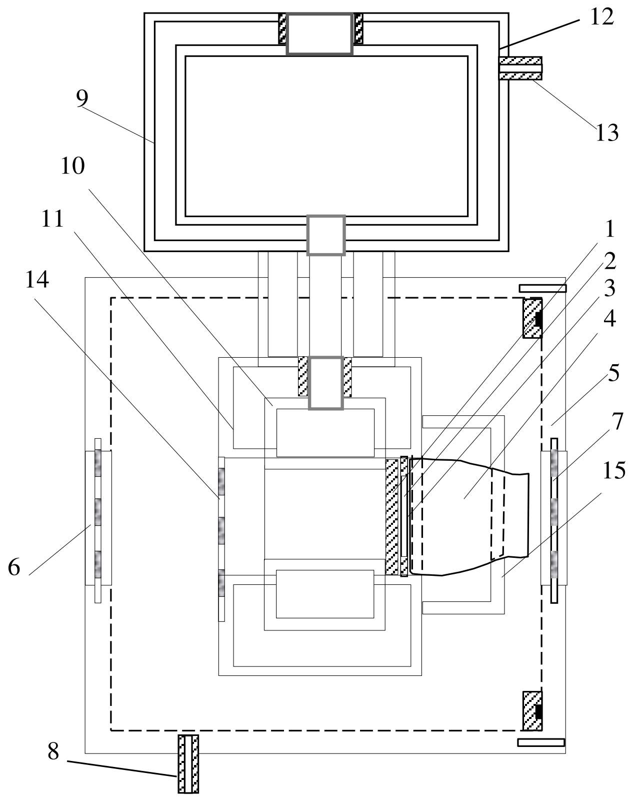

Fig. 1, a. Construction (schematically) of a semiconductor photographic ionization camera.

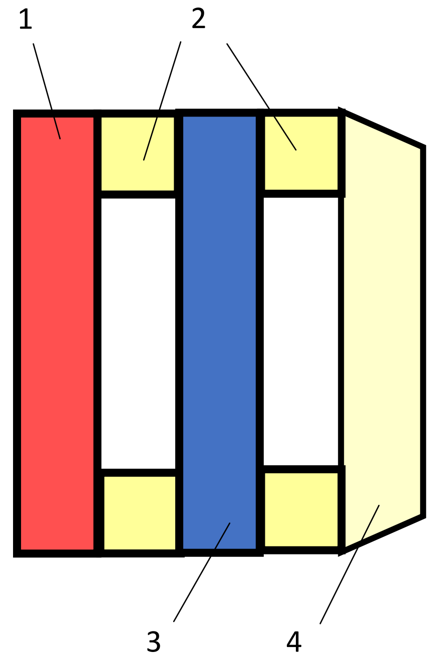

Fig.1, b. Gas discharge cell with *n-Si* <*S*> photodetector and GaAs damping electrode. 1 - *n-Si* <*S*> photodetector; 2 - mica plates with holes in the center; 3 - GaAs; 4 - fiber optic washer with SnO_2.

In fig. 1, and the following designations are adopted: 1 - annular cooler; 2 - gas-discharge cell (fig. 1, b); 3 - ohmic contact at the input of the fiber-optic washer made of SnO_2; 4 - fiber optic washer; 5 - cover for replacing the semiconductor photographic ionization camera tooling; 6 - semiconductor photographic ionization camera input window; 7 - semiconductor photographic ionization camera output window; 8 - valve for pumping out and letting in air; 9 - dewar vessel; 10 - cavity for liquid nitrogen; 11 - evacuated casing; 12 - protective casing of the dewar vessel; 13 - valve for air evacuation; 14 - inlet window of the evacuated casing; 15 - fiber optic washer holder.

RESULTS AND ITS DISCUSSIONS

To operate a photodetector made of *n-Si* <*S*> at liquid nitrogen temperature and direct current, we changed the configuration of the arrangement of the electrodes of the gas-discharge cell. In this case, an *n-Si* <*S*> was placed at the entrance of the gas-discharge cell, and then a GaAs electrode was placed through the gas gap and a fiber-optic washer was installed after the second gas gap (Fig. 1, b). In this configuration, GaAs plays the role of a damper (stabilizes the discharge combustion across the cross section), and *Si <S>* provides photographic sensitivity to infrared radiation with a wavelength of up to 11 μm [13].

The experimentally investigated temperature dependences of the dark and photocurrents in a gas-discharge cell with photo detectors made of *p-Si <Pt>* [10] and *n-Si <S>* [12], respectively, are shown in fig. 2, a and b.

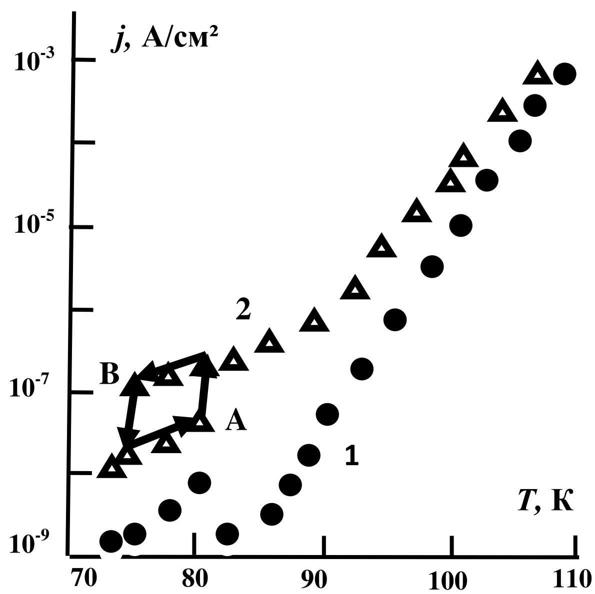

Fig. 2, a. Temperature dependences of the dark (curve 1 - black circles) and photocurrents (curve 2 - light triangles) in a semiconductor photographic ionization camera with a *Si <Pt>* photodetector.

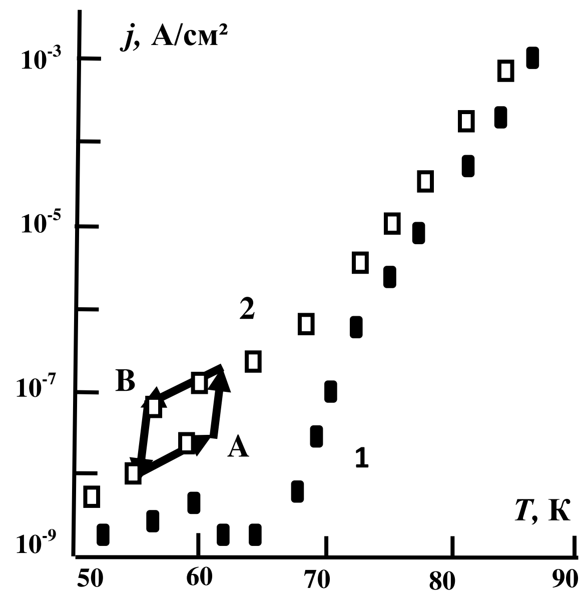

Fig. 2, b. Temperature dependences of the dark (curve 1 - black quadrilaterals) and photocurrents (curve 2 - light quadrilaterals) in a semiconductor photographic ionization camera with an *n-Si <S>* photodetector.

In the dependences of the dark and photocurrents, it was found that in the region of low temperatures (T = 80 ÷ 90 K for *p-Si <Pt>* and T = 60 ÷ 70 K for *n-Si <S>*), there is an abrupt change in currents, and the dependence the photocurrent is normal, and the dark current is abnormal (Fig. 2, a and b). As can be seen from these figures, there is a hysteresis in the temperature dependence of the photocurrent (a loop circled by black arrows), the so-called **photoelectric hysteresis** in a gas-discharge cell, which leads to a photographic effect.

The photocurrent (curves 2 in Fig. 2, *a* and *b*) in the temperature range of ~ 80 K has a jump up for a photo detector made of *p-Si <Pt>* and in the temperature range of ~ 60 K - for a photo detector made of *n-Si <S>*, this is is observed when the temperature rises along path **A**. When the temperature decreases along path **B**, that is, when the system is cooled, the photocurrent in the temperature range of ~ 75 K drops abruptly for a photo detector made of *p-Si <Pt>* and in the temperature range of ~ 55 K for a photo detector made of *n-Si <S>*. Thus, a photoelectric hysteresis associated with field emission is observed in a gas-discharge cell with a thickness of the order of 40 μm.

CONCLUSION

Note that the abrupt decrease in the dark current and the abrupt increase in the photocurrent are a new positive effect that affects the increase in contrast (multiplicity is the ratio of the photocurrent to the dark current), that is, the sensitivity of the semiconductor photographic ionization camera. The observation of a similar effect in different photodetectors and in different temperature ranges, apparently, has a natural character, which we call photoelectric hysteresis.

Thus, the effect of photoelectric hysteresis is a necessary condition for achieving high sensitivity of the photographic process in the semiconductor photographic ionization camera gas-discharge cell in the far-infrared region of the spectrum.

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