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RESEARCH OF PHOTOELECTRIC PROPERTIES OF A GAS DISCHARGE CELL WITH PHOTOELECTRODES BASED ON GALLIUM ARSENIDE AND SILICON WITH PLASMA CONTACTS

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Abstract. *The effects of gas-discharge plasma contacts on the properties of semiconductor electrodes of a gas-discharge cell are investigated. Moreover, the gallium arsenide electrode has plasma contacts on both sides, and the silicon photoelectrode has ohmic and plasma contacts. On the current-voltage characteristic of the gas discharge cell, a region with negative differential resistance (NDR) based on a gallium arsenide electrode with two plasma contacts is observed. The results of theoretical and experimental studies satisfactorily coincide in the area with the NDR.*

Keywords: *gas discharge cell, silicon, gallium arsenide, plasma contact, photoelectric hysteresis.*

It is known that a flat gas-discharge cell with a semiconductor photosensitive electrode is the main element in a semiconductor photographic ionization chamber (SPIC) [1].

The passage of direct current in such a system is accompanied by a number of peculiar phenomena leading to the stabilization of the gas-discharge current, the possibility of controlling the magnitude of the latter and the spatial distribution over the discharge cross-section by modulating the conductivity of the semiconductor electrode. The variety of factors that determine the semiconductor stabilization of the discharge and their nonlinear functional relationships make this problem rather complicated. In this case, the damping properties of a semiconductor photodetector in the form of a uniform resistance play a special role. Only a high-resistance electrode in the form of a uniform distributed resistance provides stabilization of the gas discharge over the cross-sectional area [2].

In [3], the features of stabilization of a gas discharge in a wide range of gas pressures and the resistance of a photodetector with semiconductor electrodes made of chromium-compensated gallium arsenide (GaAs) at room temperature and silicon doped with platinum (Si <Pt>) at liquid nitrogen temperature were studied. With a semiconductor resistance of $10^7 \div 1.3\ 10^8$ Ohm, there is a wide range of stabilization at wide ranges of gas pressures. In addition, it was found that when the resistance of the semiconductor is below 10^6 Ohm, the discharge combustion in the cell does not stabilize. For this reason, a semiconductor wafer made of silicon doped with sulfur (Si <S>) [4] cannot be used as a damping electrode in a gas-discharge cell at a constant current, since even at a liquid nitrogen temperature its resistance is no higher than 10^6 Ohm. However, the Si <S> semiconductor wafer provides photographic registration and spatial diagnostics of laser radiation up to 11 μm.

The aim of this work is to create conditions for stable combustion of a gas discharge for direct current with a damping cell for semiconductor electrodes in a gas-discharge cell and thereby provide photographic recording in the far infrared region of the spectrum in the standby mode of the SPIC operation.

Below are the results of studies of the stabilization of discharge combustion in a cell with Si <S> and GaAs electrodes with plasma contacts; in the discussion, the theoretical and experimental results are compared.

The experiments were carried out at SPIC. The main part of the SPIC is a gas-discharge cell, which consists of a photodetector and a counter-electrode. The counter electrode is made of a fiber optic washer with a transparent conductive SnO_2 coating. When an infrared (IR) image of an object is projected onto the surface of a photodetector, a distribution of photoconductivity arises in it, a repeating intensity of the incident IR radiation. The formed image on the transparent counter-electrode in the form of visible and ultraviolet radiation is transmitted to the output of the device using a fiber-optic element.

The experiments were carried out with two types of configuration of semiconductor and transparent counter electrodes located in a gas-discharge cell. A chromium-compensated gallium arsenide (GaAs) semiconductor wafer is positioned between the glass plate and the fiber-optic washer with conductive SnO_2 coatings through gas-discharge gaps on both sides up to 100 μm thick. In this case, the experiment was carried out at room temperature with white light illumination.

Plasma contacts in a gas discharge cell have special effects on the semiconductor surface. The effect of plasma current carriers (electrons and ions), as well as the flux of photons created by the bremsstrahlung of electrons on the semiconductor surface, together with the glow of a gas discharge, extends to the entire depth of the semiconductor.

The change in the concentration of nonequilibrium carriers n with time taking into account the effect of the gas-discharge plasma is described by the equation

$$\frac{dn}{dt} = F - \frac{n}{\tau} + \xi\mu nE, \qquad (1)$$

where F is the intensity of optical generation, τ is the lifetime of nonequilibrium carriers, μ is the carrier mobility in a semiconductor, n is the concentration of photocarriers, E is the electric field strength, ξ is the proportionality coefficient. The change in the gas-discharge cell current j after switching on the voltage is determined by the expression in the region $E < 1/\xi\eta\tau$

$$j = \frac{e\mu EF}{\frac{1}{\tau}-\xi\mu E}\left\{1 - \xi\mu E\tau exp\left[-t\left(\frac{1}{\tau}-\xi\mu E\right)\right]\right\}, \qquad (2)$$

and in the region $E < 1/\xi\eta\tau$ - by the expression

$$j = \frac{e\mu EF}{\frac{1}{\tau}-\xi\mu E}\left\{-\xi\mu E\tau exp\left[-t\left(\frac{1}{\tau}-\xi\mu E\right)\right]\right\}. \qquad (3)$$

Relaxation dependences for GaAs with two plasma contacts in a gas-discharge cell, as well as the characteristics of a gas-discharge cell with two semiconductor electrodes, Si <S> and GaAs, are investigated. They were set according to the electrode configuration described above. In the latter configuration, GaAs plays the role of a damper (stabilizes the combustion of the discharge across the cross section), and Si <S> provides photographic sensitivity to infrared radiation with a wavelength of up to 11 μm [5]. The current-voltage characteristics of the through current through both semiconductor electrodes in the gas-discharge cell for wavelengths of 6.9 μm were taken at different rates of voltage supply with different values of the resistivity of the GaAs damping electrode and for different values of the intensity of IR radiation at a constant rate of voltage supply. The characteristic curves (dependences of the photomultiplier current (I) on the exposure H = 1/S = 1/(J t), where t is the exposure time) of the gas-discharge cell without amplification of the discharge glow and with amplification on the EP-16 at a wavelength of 6, 9 μm, according to the above-described configuration of semiconductors made of Si <S> and GaAs.

The general character of the experimental relaxation curves agrees to a certain extent with theoretical calculations, including in the region of negative lifetime. Relaxation is strongly influenced by the illumination intensity and resistivity of the GaAs damping electrode.

Thus, in a gas-discharge cell with an additional damping cell separated from the photoelectrode by a mica spacer, the photodetecting electrode is a Si <S> plate. At high intensities of IR radiation, there is a positive feedback, a GaAs electrode with two plasma contacts provides a positive feedback and stabilizes the discharge burning in an ultrathin gas-discharge cell, and a Si <S> photodetector at the input part of the - photosensitivity.

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