SPATIAL DISTRIBUTION OF CURRENT DENSITIES IN
AN INFRARED IMAGE CONVERTER

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Abstract. This work studies the spatial distribution pattern of the current density in an IR image converter with a GaAs photodetector. Transformation of the profile and amplitude of the current density of the filaments in the different regions of the CVC has been studied. This method of quantitative study of the non-uniform light emission distribution can be used only at relatively low current values and only when the Townsend discharge does not have a significant influence on the transport properties of the photodetector. The filamentation (i.e. an inhomogeneous distribution of the current density) was primary due to the formation of a space charge of positive ions in the discharge gap between photodetector and a transparent anode plate that changed the discharge from the Townsend to the glow type.

1 INTRODUCTION We investigated quantitatively the spatial distribution of the current density formed as a result of loss of stability of a homogeneous current state in high-resistivity GaAs cathode subjected to strong electric fields. The effect of such IR converter cell is based upon discharge formation in the gap between a planar transparent anode and a semiconductor cathode. Experimentally, the destabilisation of the homogeneous distribution of current density and formation of filamentation patterns in the IR image converter cell occurs when the transition from the Townsend to the glow mode of discharge takes place [1].

2 EXPERIMENTAL A scheme of the IR converter cell is shown in Fig.1. A Cr compensated GaAs (p~10\(^{17}\) Ωcm) plate was used as a semiconducting cathode. The diameter of the plate was 20 mm and the thickness is 1 mm. On the illuminated side of the GaAs a transparent conducting vacuum evaporated Ni-layer is coated. The anode was a disk of glass coated with a thin layer of a transparent conductor SnO\(_2\). The light of an incandescent lamp with an Si-filter in front illuminated the cathode uniformly. The size of the discharge gap \(d\) (80 μm) and the residual gas pressure \(p\) (100 Torr) are chosen to ensure a sufficiently bright light emission [2]. The assessment of the image formation was then based on analysis of the recorded through a transparent anode with the CVC.

3 RESULTS AND DISCUSSION The current density in the discharge can be controlled in a rather broad range, where the discharge operates in the Townsend regime, where it is also homogeneous, while increasing the supply voltage, the density of the charge is accompanied by the formation of the new breakdowns of the Townsend regime to the glow mode of discharge.

Figure 2 shows the change in the CVC resistance R. The CVC is very close to breakdown in the resistance of the cathode and the anode towards higher voltage. Visual observation and which current filaments are observed) also increases the critical current density.

Formation of patterns in the spatial distribution of light and the appearance of corresponding spatial structures, which were emitted by the discharge. The glow can be controlled there interactively by changing the intensity of IR light, which is radiated through the cathode.

The light emission distribution reflects nearly all cases the loss of stability of the discharge glow and consequently affects the filamentation in the discharge deteriorates the image. From Fig.3 that the filaments, which are similar with respect to the profile and the intensity.

Figure 4 shows one dimensional light emission emerging of a pattern which corresponds to partially and full filamentation (curve 3) states, respectively. The diameter of the discharge plane and p...
image formation was then based on analysis of the discharge light emission (330–460 nm), recorded through a transparent anode with spatial resolution via the corresponding light emission.

3 RESULTS AND DISCUSSION The discharge light emission, in particular the total current, can be controlled in a rather broad range. It includes quite low current densities \( j \leq 1.5 \mu A/cm^2 \), where the discharge operates in the Townsend regime. The light emission from the discharge is also homogeneous, while increasing total current by illuminating the cathode or increasing the supply voltage, the density of the charged carrier in the discharge gap increases. This is accompanied by the formation of the net space charge in the discharge gap, and gradually the transition from the Townsend regime to the glow regime takes place.

Figure 2 shows the change in the CVCs of the IR converter cell as a function of cathode resistance \( R \). The CVC is very close to being a linear curve for \( U > U_0 \) (curves 1 to 3). Clearly, a reduction in the resistance of the cathode shifts the super-linear part of the CVC (see points C, F and K) towards higher voltage. Visual observation demonstrates that the critical voltage (at which current filaments are observed) also increase; there is correspondingly greater increase in the critical current density.

Formation of patterns in the spatial distribution of the current (see Fig. 3) was accompanied by the appearance of corresponding spatial distribution of the light emission in the visible range, which was emitted by the discharge. The essential feature of this pattern formation is that electric current can be controlled there interactively, by the amplitude of the feeding voltage and by the intensity of IR light, which irradiates the cathode, and thus governs its photoconductivity [3].

The light emission distribution reflects the lateral filament current density distribution. In nearly all cases the loss of stability of the current was coincident with the loss of uniformity of the discharge glow and consequently affected strongly by the resolution of the images. Filament formation in the discharge deteriorates the properties of dc-driven converter cell. It is evident from Fig. 3 that the filaments, which appeared in different parts of the structure, were quite similar with respect to the profile and the current that flowed through them.

Figure 4 shows one dimensional light emission density distributions in the case of the emerging of a pattern which correspond to homogeneous (curve 1), filamentation start (curve 2) and full filamentation (curve 3) states, respectively. The distributions have been measured along the diameter of the discharge plane and perpendicular to the pattern.
From the experimental point of view the underlying system evidently consists of two layers, which have quite different properties but are coupled electrically. This provides a starting point for a model describing this system. Various measurements at different parameter values show that the GaAs cathode has to be considered as a linear, weakly conductive material, whereas the discharge layer is the non-linear and therefore the active part of the sandwich structure. The non-linear properties of the system depend on experimental parameters (such as the values of pressure and gas discharge gap). The appearance of lateral pattern formation is related to some instability in the cathode, which presumably appears due to the process of charge carrier injection into the high Ohmic cathode at a high electric field, while the discharge layer serves as a display medium only [4,5].

When cathodes with a linear CVC were used in the cell structure a spatially uniform distribution of the current density was stable up to fairly high values of \( j \). This stability of the discharge in the presence of linear semiconductors is the operating principle of converter system. However, when cathodes with a super-linear CVC were used in the cell, a spatially non-uniform distribution of the current was observed frequently in the super-linearity region even at low values of \( j (<1 \text{ mA/cm}^2) \). Such non-uniform distribution was easily visualized from the distribution of the intensity of the light emitted by the gas in the discharge gap. We found that application of high feeding voltage to this cathode gave rise to non-uniform spatial distribution of the light emission, which disturbed the operation of the converter system. Visual observation indicated that, in the regions of the CVC, the system exhibits spatially non-uniform states of the current involving formation of multiple high-contracted filaments of the current. Generation of current filaments was accompanied by an increase in the total current through the investigated converter cell structure.

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References
in the cell structure a spatially uniform fairly high values of \( J \). This stability of the operating principle of converter system
were used in the cell, a spatially non-uniform in the super-linearity region even at low distribution was easily visualized from the gas in the discharge gap. We found that arise to non-uniform spatial distribution of the converter system. Visual observation exhibits spatially non-uniform states of the formed filaments of the current. Generation of the total current through the investigated

**Fig. 1** Schematic diagram of the ionization cell:
1. light source; 2. Si-filter; 3. conducting Ni layer;
4. GaAs cathode; 5. air gap; 6. transparent conductive SnOx; 7. disk of glass.

**Fig. 2** Typical set of CVCs of an ionization cell for different illumination intensities of the GaAs cathode. Curves 1 to 3 represent the CVCs for different resistance of semiconductor cathode and (a), (b) and (c) represent the homogeneous, filamentation start and full filamentation states.

**Fig. 3** 3-D patterns of light emission intensity distribution in an ionization cell with the radius of the cathode is \( r = 10 \) mm, the other parameters are \( p=100 \) Torr, \( d=80 \) \( \mu \)m; full filamentation state – feeding voltage \( U_f = 2.2 \) kV.

**Fig. 4** Light emission density distributions of a pattern at different feeding voltage for (a), (b) and (c) states, represent on Fig.2. For curve 1 to 3 \( U_f = 0.8 \) kV, 1.4 kV and 2.2 kV.