Photostimulated generation of current oscillations in a semiconducting structure

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The basic characteristics of photostimulated free oscillations, observed by the authors in silicon structures with *p-n* junction and blocking contacts, are described. These include the following: characteristics excitation of oscillations by light and control of their frequency with the help of a light flux, disruption of generation at large light-flux intensities, memory, and coordinate sensitivity.

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We have discovered that oscillations are generated in the current controlled by a constant light flux over a wide range of frequencies. The objects studied consisted of epitaxial silicon structures with a *p-n* junction, formed by growing a thin (of the order of 10 μm), weakly doped *n*-type film on a strongly doped *p*-type substrate. The Au-Ni contacts with diameters ranging from several hundreds of microns to several millimeters were formed on the surface of the film. The distance between the contacts was about 10 mm. During the course of the experiments, the substrate remained insulated. The *p-n* junction was illuminated from the *n* side with the help of a GaAs infrared light-emitting diode with radiation wavelength $\lambda = 0.9$ μm. The dimensions of the

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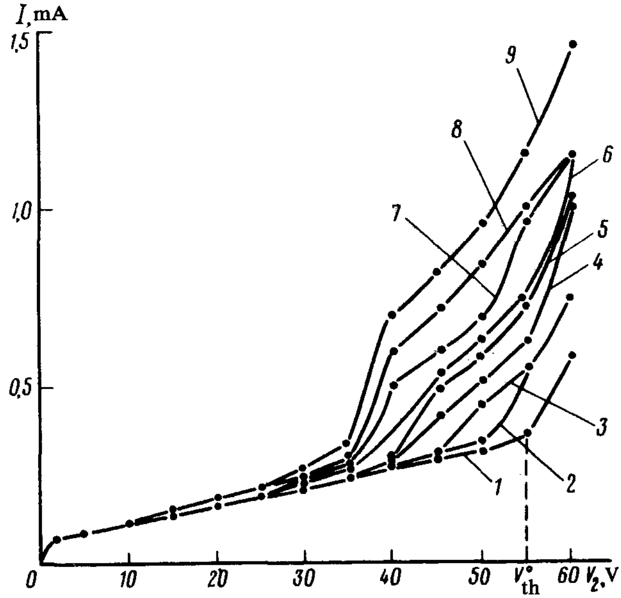

FIG. 1. *I-V* curves of structures with different levels of illumination: $1 - P = 0$, $2 - P = 80$ μW, $3 - P = 180$ μW, $4 - P = 340$ μW, $5 - P = 500$ μW, $6 - P = 620$ μW, $7 - P = 860$ μW, $8 - P = 1180$ μW, $9 - P = 1610$ μW.

crystals were in the range 0.5–12 cm^2. An alternating current was extracted from the contacts, to which a constant bias voltage V was applied, or from another pair of analogous contacts, likewise formed on the surface of the n-region of the structure.

The family of *I-V* curves for the structure described above, obtained with different levels of illumination, are illustrated in Fig. 1. The potential difference on the structure is plotted along the abscissa axis and the current is plotted along the ordinate axis. The intensities of the infrared radiation correspond to the light flux that fell on the specimen.

When there was no illumination and the potential difference V on the contacts exceeded some threshold magnitude V_{th}^{0}, the current I through the structure increases sharply (Fig. 1, curve 1). In the case examined, we have $V_{th}^{0} = 55$ V. Illumination appreciably changes the *I-V* curve: the ascending part of the curves is displaced toward lower values of the potential difference and, in addition, the displacement increases with increasing level of illumination (Fig. 1, curves 2–9).

In the region of the sharp increase in current, i.e., at $V \geqslant V_{th}^{0}$, the relaxation oscillations, whose amplitude increases linearly with the potential difference and reaches magnitudes of the order of several tens of volts (for example, $A = 37$ V with $V = 60$ V), occurred in the structure.

The frequency of the free oscillations depended on the potential difference on the structure, the level of illumination, and varied over a wide range for different specimens: from hundreds of hertz to several megahertz. Figure 2 shows the dependence of

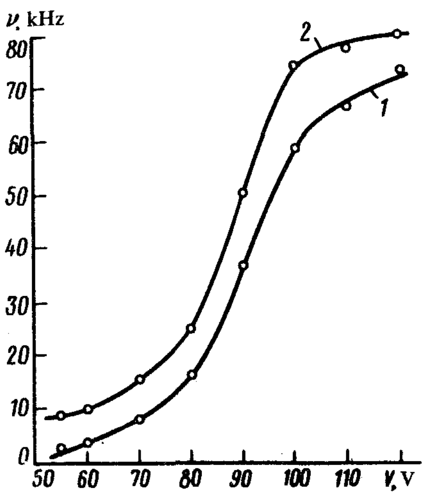

FIG. 2. Dependence of the frequency of free oscillations on the potential difference of the structure without illumination (curve 1) and with illumination (curve 2).

the frequency of the free oscillations on the potential difference with and without illumination obtained by us for one of the specimens. As is evident from the figure, illumination of the specimen appreciably increases the frequency of the oscillations for all values of the potential difference.

One of the characteristic properties of this effect is that self-excited oscillations can be generated in the structure by switching on the illumination when $V < V_{\text{th}}^{0}$. In this case, each level of illumination has its own threshold dependence of the potentials $V_{\text{th}}^{\text{free}}$ at which free oscillations appear. In the region $V_{\text{th}}^{\text{free}} < V < V_{\text{th}}^{0}$, the frequency of the free oscillations varies nearly linearly with increasing light flux intensity, while their amplitude remains constant in this case over a broad range of frequencies.

A high level of illumination leads to a break in the generation and a simultaneous jump in the current through the structure. A considerable decrease in the light flux was required to transform the structure from the conduction mode into the generation mode, which was manifested as hysteresis in the dependence of the current on the intensity of light incident on the structure.

We observed the coordinate sensitivity of the frequency of the photostimulated free oscillations of the current. We studied the latter on silicon structures with a diameter of 40 mm. The contacts to the n-region were formed at the center of the structures. Scanning the surface of such structures with a light spot 2 mm in diameter changed the frequency of free oscillations, which reached a maximum value when the contact region was illuminated and a minimum value when the edge of the plate was illuminated. The amplitude of the oscillations remained constant. The dependence of the frequency of free oscillations on the position of the light spot relative to the edge of the structure is shown in Fig. 3. We see that the scanning changed the frequency in the range 70–250 kHz.

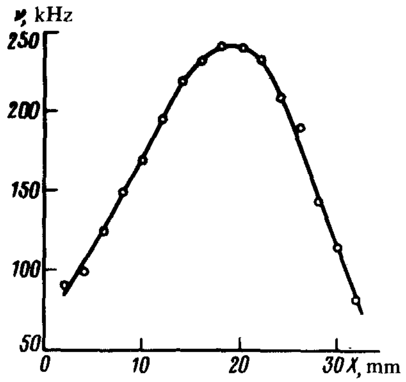

FIG. 3. Coordinate sensitivity of the frequency of photostimulated free oscillations.

We do not have sufficient experimental data to present in a final form the mechanism responsible for the phenomenon described above. However, our investigations suggest that feedback through the *n*-layer is realized in the structure during generation of the free oscillations. This is confirmed by the fact that the effect disappeared if the *n* region of the material between the contacts was separated by a groove, whose depth exceeded the depth of the *p-n* junction. The joint of the depleted region under one of the contacts with the *p*-layer and the modulation of the width of the *n*-layer by the space charge of the backward displaced *p-n* junction presumably play an important role in the generation mechanism.

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