Photostimulated excitation of current oscillations in a semiconductor structure

B. A. Malakhov and G. V. Stepanov
Institute of Radio Engineering and Electronics, Academy of Sciences of the USSR

(Submitted 20 December 1983)
Pis'ma Zh. Eksp. Teor. Fiz. **39**, No. 3, 138–140 (10 February 1984)

A tunneling-transparent insulating film is required at the contact of a metal with a semiconductor in order to explain the photostimulated excitation of current oscillations in the semiconductor structure.

Knab and Frolov[1] have recently reported observing relaxation current oscillations in a semiconductor structure which can be controlled by a voltage and also by the intensity and position of a light beam. The silicon semiconductor structure consisted of a heavily doped p-type substrate and a thin (10-μm), lightly doped n-type layer on whose surface rectifying contacts were fabricated. Knab and Frolov assumed that the feedback required for the current oscillations occurred through the n-type layer. They also assumed that important roles were played by the joining of the depleted region below the contact with the p-type layer and a modulation of the width of the n-type layer by the depleted region of the p–n junction.

We have used a similar semiconductor structure[2] to study the accumulation of minority carriers (holes) at a metal-semiconductor contact and to study the amplification of the injection of majority carriers from the metal. For the effect to be observed, there must be a thin, tunneling–transparent insulating layer between the metal and the

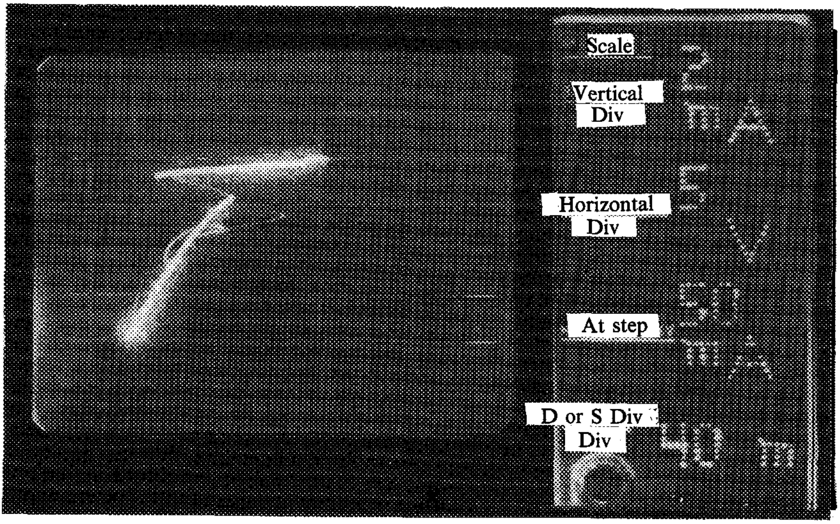

FIG. 1. I-V characteristic of a structure with a tunneling-transparent insulator as a voltage is applied between the metal and the p-type region.

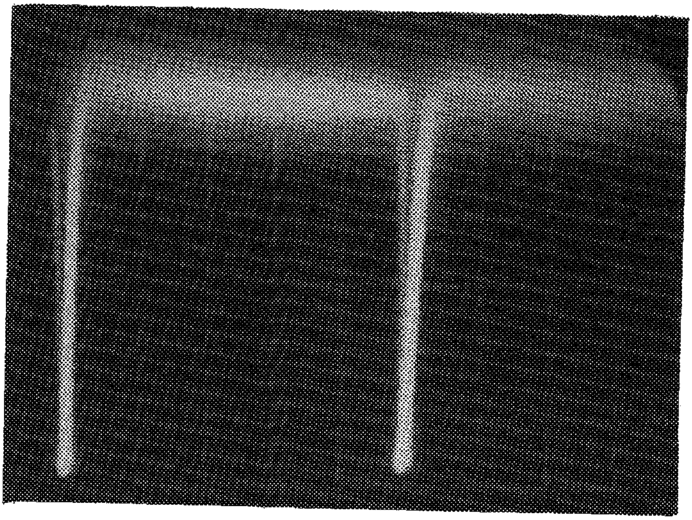

FIG. 2. Relaxation oscillations in a structure with a tunneling-transparent insulator. The scale along the x axis is 10 μs/div, and that along the y axis is 5 V/div.

n-type semiconductor. When a voltage is applied between the metal and the p-type substrate, the I-V characteristic of the stucture (Fig. 1) has a negative–resistance region when a negative potential is applied to the metal electrode. The particular voltage at which the negative–resistance region appears depends on several parameters, including the thickness of the insulating layer, the material from which the metal electrode is made, the thickness of the n-type layer, and the intensity of the illumination in the fundamental absorption region of silicon. The reasons for this behavior have been determined in detail in previous experiments.[2]

When a voltage is applied to two contacts with tunneling-transparent insulating layers, relaxation oscillations appear at some threshold voltage (Fig. 2). These oscillations are similar to those observed in Ref. 1. The amplitude and frequency of the oscillations depend in a similar way on the applied voltage and on the illumination intensity. The threshold voltages for the appearance of the current oscillations, like the threshold voltages for the appearance of the negative-resistance region, depend on the material from which the metal electrodes are made. Current oscillations are not observed in the same structures without the thin insulating layer between the metal and the semiconductor (the presence or absence of the insulating layer was determined from the presence or absence of the negative-resistance region on the I-V characteristic of each of the diodes).

In summary, the feedback required for the onset of current oscillations is provided by a tunneling-transparent insulating layer between the metal and the n-type semiconductor, by the accumulation of holes at this boundary, and by the intensification of electron injection from the metal into the n-type layer and the related amplification of the injection of holes from the p-n junction.

We wish to thank M. I. Elinson and L. L. Golik for a discussion of these results.

[1]O. D. Knab and V. D. Frolov, Pis'ma Zh. Eksp. Teor. Fiz. **38**, 244 (1983)[JETP Lett. **38**, 287 (1983)].
[2]B. A. Malakhov, V. I. Pokalyakin, and G. V. Stepanov, Mikroélektronika **9**, 241 (1980).

Translated by Dave Parsons
Edited by S. J. Amoretty