NON-LINEAR TRANSPORT PROPERTIES OF PbTe<Ga> SEMICONDUCTORS

A. Nikorich, V. Kantser, V. Nikorich*, D. Constantinescu**
International Laboratory HTSC SSE, Kishinev, Moldova
*Moldova State University, Kishinev, Moldova
**ICP "Electromecanica", Ploiesti, Romania

SUMMARY

The results of the I-V characteristics (IVC) investigation on PbTe<Ga> semiconductor samples in the temperature range 67-100 K are given. IVC was found to be N-shaped, and at temperatures below 77 K the electric current oscillations through the sample were observed.

1. INTRODUCTION

One of the ways to change the free charge carriers concentration in semiconductors is their doping with various impurities. However, the influence of doping with elements of the III group on compounds A^4B^6 leads not only to lowering of the background concentration, but also to appearance of qualitatively new properties. Thus, in particular, PbTe doped with Ga in a certain range of concentration shows high photosensitivity at temperatures $T<T_c \approx 80$ K, and photoconductivity has a long-time relaxation and very unusual kinetics. Besides, in the given samples non-linear transport properties are often observed. In the present work the non-ohmic behaviour of IVC of these bulk materials and the current instabilities revealing whereupon are studied.

2. EXPERIMENTAL RESULTS

The measurements of the IVC were performed on the samples n-PbTe<Ga> with the charge carrier concentration $n\sim(1\div3)\cdot10^{13}cm^{-3}$ and resistivity $\rho>10^4$Ohm·cm at 77 K.

The typical curves of IVC at the temperature 77 K are shown in Fig. 1. The characteristic is built in the coordinates voltage on the sample (U) - current through the sample (I). The significant feature of the ascending curve is that in a

0-7803-3223-7/96/$5,00 © 1996 IEEE

certain range of controlled current values the applied field is a multi-valued function of the current density, i. e. IVC is N-shaped. At the voltage descending with the same velocity the current value decreases, but the descending part of IVC does not repeat the form of the ascending one, indicating that we deal with the hysteresis effect. Thus, IVC is N-shaped at the voltage ascending and overlinear at its descending. At the increase of velocities of the voltage variation the IVC behaviour remains unchanged. It should be noted that the ohmic

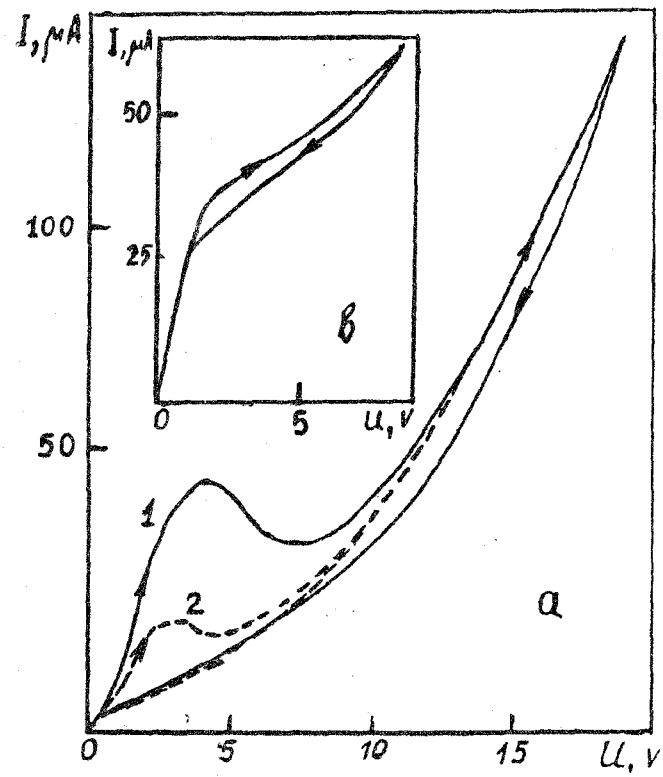


Fig. 1. IVC at the introduction and withdrawal of the voltage.
a) T=77 K, 1 -du/dt=0. 6 V/s; 2 -du/dt=0. 12 V/s;
b) T=100 K, du/dt=0. 6 V/s.

part of IVC curve at 77 K is observed only up to the voltage values U=0,25 V (E≃0,5 V/cm). With the temperature increase up to 100 K the ohmic part extends up to U≈ 0,8 V (E~1,5 V/cm) (Fig. 1b). At lower temperatures (T=67 K) the ohmic part of IVC curve practically disappears, however at the voltage more than 13 V on both ascending and descending curves of the IVC the current oscillations appear. Their amplitude increases

with the voltage increasing and at U=25 V one is about 4-5% of the monotonous part of the current (Fig. 2).

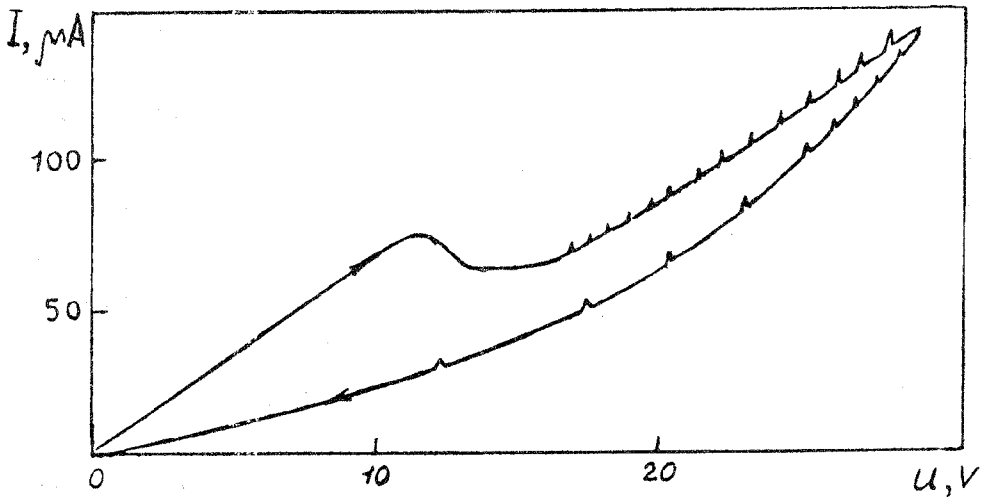


Fig. 2. The current oscillations on the IVC curve.
T=67 K; du/dt=0.3 V/s.

3. DISCUSSION

The complex form of the ascending branch of IVC may be caused by the influence of several mechanisms, one of which is the monopolar injection of electrons, trapping taken into account. The existence of the trapping processes is confirmed by the fact that at the fixed voltage the current through the sample decreases slowly in time. This mechanism determines mostly the dark conductivity at temperatures below 77 K when the ohmic section of IVC is practically absent. The ohmic contribution of free charge carriers to conductivity increases as the temperature rises.

The nature of the N-shaped part of IVC seems to be connected with the fact that in a certain range of electric fields the processes of carriers trapping overvail the processes of carriers generation in the sample, and the free carriers concentration decreases with the electric field increase. This is possible, firstly, if the trapping occurs in the result of tunneling through the Coulomb barrier. It is obvious that the tunneling probability increases with the

increase of the electron energy. So, already in relatively weak fields, far from the breakdown range, the trapping coefficient will depend on the applied field and increases with increasing of the latter. In the region of rather strong fields the trapping coefficient increases slowly with the electric field because the considerable part of the carriers does not "feel" the Coulomb barrier action.

The current oscillation in a certain range of the electric field values we suppose to occur due to the formation and drift of electric domains along the sample resulting from the electrons redistribution between the band states and the trapping ones /1/. Really, if in some local region of the sample an instability appeared as a result of the increase of the electric field voltage, then such an increase leads to that of the trapping velocity, wherefore the free electron concentration in this region will decrease. This, in its turn, will lead to much larger growth of the field voltage, and as a result, to further decrease of the free electron concentration. At the same time near such a region, closer to the anode, there also forms a region with the bulk positive charge, as far as the electron influx to it from the cathode side out of the region with lowered concentration of electrons is less than the reflux to the anode side. As far as in the stationary state the electron influx from the cathode side corresponds to their reflux to the anode, the domain shifts to the side of the anode, that will result in the current spike at its teaching the anode.

CONCLUSION

IVC investigation in PbTe:Ga crystals shows that the formation of the latter is conditioned by the redistribution of electrons between the conduction band and the trapping centers, the electric field increase leading to the change of the trapping velocity.

REFERENCES

/1/. V. L. Bonch-Bruevich, I. P. Zvyagin, A. G. Mironov. Domain electric instability in semiconductors. Moscow, "Nauka", 1972. (in Russian).