# THE CURRENTS, LIMITED BY VOLUME CHARGE IN THE CHALCOGENIDE GLASSY SEMICONDUCTORS OF Se-Te SYSTEM

**S.I. MEKHTIEVA, A.L. ISAYEV, E.A. MAMEDOV, Z.A. AGAMALIYEV**
*Institute of Physics of National Academy of Sciences of Azerbaijan,*
*Az-1143, H. Javid av., 33*

In the stationary regime, the measurements of VAC of pure containing chlorine impurities (0,001; 0,005; 0,01; 0,1 at.%) of HGS system $Se_{100-x}Te_x$ (x = 0; 1; 2,5; 5; 10 at.%) in the structure of the type Te - $Se_{100-x}Te_x$ - Al , have been carried out. It is established, that in the given structure, the current going mechanism is caused by the currents, limited by space charge and definite parameters (concentration and activation energy), controlling the transfer of electric charges. It is also established, that the tellurium addition in the amorphous selenide, bigger than 2 at. %, causes the increase of the increase of density state of negatively charged defects *D*.

**Introduction.**

The complex investigation of optical and photoelectric properties of chalcogenide glassy semiconductors (HGS) of Se-Te system [1-3] showed that change of chemical composition and input of impurities of halogens strongly influences on the energy spectrum of electronic states near the boundary of permitted bands and in the chink of mobility also. It must influence on material properties connected with the electric charge transfer. The aim of the present work is the revealing of current going mechanism in (HGS) of Se-Te system. With this purpose the volt-ampere characteristics (VAC) of HGS of $Se_{100-x}Te_x$ ( x=0; 1; 2,5; 5; 10 at.%) system and HGS of $Se_{95}Te_5$ system also, containing the chlorine impurities (0,001; 0,005; 0,01; 0,1 at.%) have been measured.

**Experiment technique.**

The samples for measurements had structure by the type "sandwich" and presented themselves films, prepared by thermal evaporation in the vacuum at the residual pressure $10^{-6}$mm. of mercury. The polished glass substrates have been used on which the lower electrode from aluminum or $In_2O_3$ was applied. The upper electrode was film from tellurium, evaporated on the layer of the investigated material in the vacuum. The chemical composition of the film was the same, as in the suspended matter. The substrate temperature was controlled with the help of thermocouple.

VAC of the samples were measured on the direct current in the darkness. The polarity of applied voltage is "plus" on the tellurium electrode.

**Experimental results and their analysis.**

VAC of HGS samples of system ($Se_{100-x}Te_x$ (x = 0; 1; 5; 10 at.%) and HGS of $Se_{95}Te_5$ system, containing the impurities of chlorine (0,001; 0,005; 0,01; 0,1 at.%) correspondingly are given on the fig.1 and 2. Thicknesses of all samples are equal 10 mcm.

As it is seen, VAC contains from the several strongly expressed straight-line portions, corresponding to the degree dependence of current I on applied voltage *V* in the double logarithmic scale. The first portion corresponds to Ohm law (i.e. dependence $I \sim V^n$, where $n$=1). The quadratic dependence of the current on the voltage ($n$=1,8-2) is observed on the second portion and on the third portion the current increases with the voltage in the degree $n$>2. VAC of HGS samples of Se-Te system with the tellurium concentration about 2 -5 at.% have the two portions with quadratic and degree dependences of the current on the voltage, where $n$>2. VAC of HGS of $Se_{95}Te_5$ system at the different temperatures are shown in the fig.3. As it is seen from the figure, the voltage corresponding to VAC bending between ohmic and quadratic portions increases with the temperature increase.

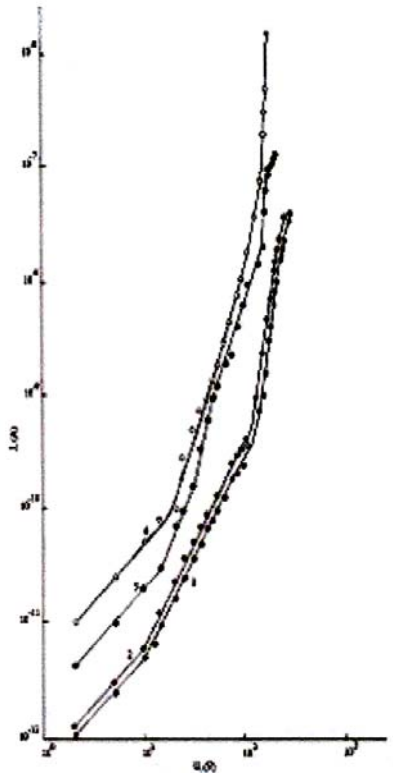

*Fig.1.* The volt-ampere characteristics of Se-Te system at the room temperature for the compositions 1 - Se; 2 - $Se_{99}Te_1$; $Se_{95}Te_5$; $Se_{90}Te_{10}$.

Such VAC behaviour is characteristic for the currents, limited by volume charge (CLVC), at the presence of the levels of hole attachment, situated lower than Fermi $F_0$ level, i.e. the condition $(F_0-E_t)/kT>1$ is fulfilled. The observable peculiarities of VAC prove that energy position and concentration of attachment levels depend on the chemical composition and on the concentration of inputted atoms of chorine impurities.

In a particular, in HGS of $Se_{95}Te_5$ system the observable peculiarities of VAC testify the existence of the two groups of trap centers, located between ceiling of valence band and Fermi level. In the frameworks of CLVC theory, the attempt, in order to explain the given peculiarities VAC has been done.

At the small values of the voltage applied of the sample the charge carrier injection from electrode is small and layer

conductivity stays ohmic because of the presence some quantity of the equilibrium charge carriers. Using the following obtained value

$$I=\mu e n_V/L \quad (1)$$

$$n = N_v exp( - (F_0 - E_v )/kT). \quad (2)$$

of concentration of the equilibrium holes n from formula(1) the position of Fermi level ($F_0$ - $F_v$) with the help of the formula (2) is obtained

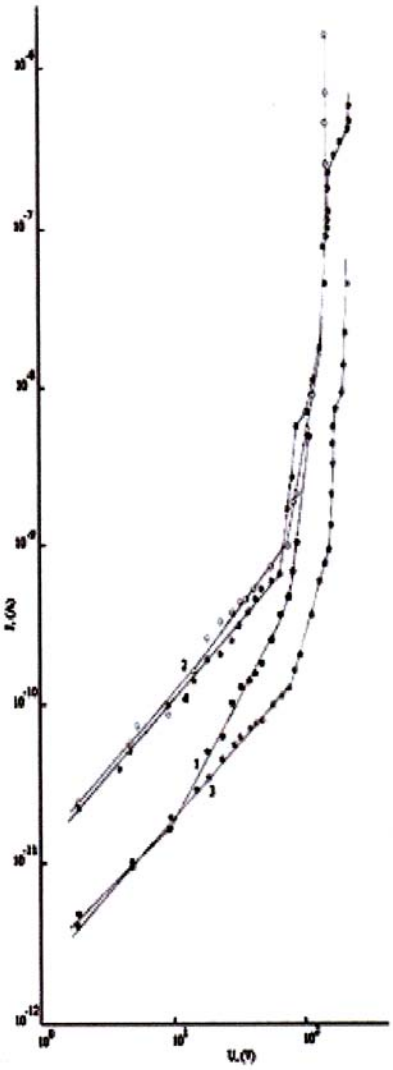

*Fig.2.* The volt-ampere characteristics of формула composition with chlorine impurity: 1- $Se_{95}Te_5Cl_{0,001}$; 2- $Se_{95}Te_5Cl_{o,005}$; 3- $Se_{95}Te_5Cl_{0,01}$; 4- $Se_{95}Te_5Cl_{0,1}$.

. Here $\mu$ is hole mobility; $e$ is elementary charge, $L$ is distance between electrodes, $V$ is applied voltage, $I$ is current density, $Nv$ is effective density of the states in the valence band, $kT$ is heat energy. The obtained values for the all samples are presented in the table.

At the voltage increase, because of the charge carrier injection from electrode, the hole concentration increases, and when they become bigger, than concentration of equilibrium holes, then the current subordinates to the law [4]:

$$I = \varepsilon \mu V^2/L^3 \quad , \quad (3)$$

where $\varepsilon$ is statical dielectric constant of the material.

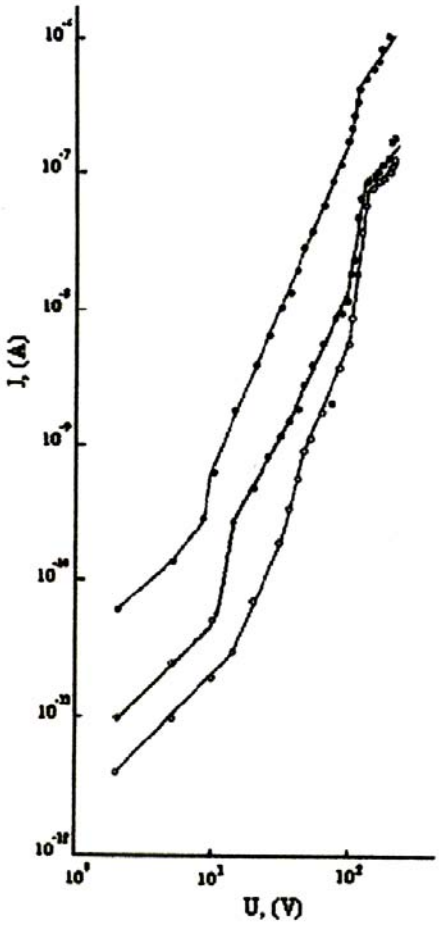


*Fig.3.* The volt-ampere characteristics of $Se_{95}Te_5$ composition at the room temperatures 20K, 35K, and 55K, correspondingly (from bottom to top)

In the case, when traps are existed, the parameter $\theta$ is input, defining the part of free charge carriers on the total charges:

$$\theta = N_v/N_t \, exp(- E_t/kT ), \quad (4)$$

where $N_t$ is concentration of small traps, $E_T$ is activation energy of the traps.

In this case VAC are described by the equation (3), but for $\mu$ it is need to use expression $\mu=\theta\mu_o$, where $\mu_o$ is mobility of free charge carriers.

The transversal voltage between portions, subordinating to ohmic and quadratic laws, is defined by the expression:

$$V_1 = e n_t L^2/2\varepsilon \, , \quad (5)$$

where $n_t$ is thermal equilibrium concentration of charge carriers. At $V>V_1$ , the traps gradually fill up and at the defined voltage value become totally filled. According to CLSC theory, voltage, at which the total trap filling begins, is defined by the expression

$$V_2 = e N_t L^2/2\varepsilon \, . \quad (6).$$

With the help of the equation (6), the concentration $N_t$ of traps, which is $10^{13}$–$10^{14}$cm$^{-3}$ has been calculated. The trap parameters (concentration and activation energy) were

calculated b by the formula(6), and also from the temperature dependence of $\theta$. The obtained results are presented in the table 1.

Table 1.

The traps parameters of HGS of Se-Te system.

| Material | $F_0 - E_v$,eV | $E_{t1}$, eV | $N_{t1}$, $cm^{-3}$ | $E_{t2}$, eV | $N_{t2}$, $cm^{-3}$ |
|---|---|---|---|---|---|
| Se | 1,09 | 0,87 | $2\times10^{13}$ | — | — |
| $Se_{99}Te_1$ | 1,08 | 0,81 | $5\times10^{15}$ | — | — |
| $Se_{98,5}Te_{1,5}$ | 1,05 | 0,80 | $2\times10^{17}$ | — | — |
| $Se_{95}Te_5$ | 1,05 | 0,84 | $2\times10^{16}$ | 0,67 | $5.\ 10^{18}$ |
| $Se_{90}Te_{10}$ | 1,02 | 0,82 | $1\times10^{16}$ | — | — |
| $Se_{95}Te_5Cl_{0,001}$ | 1,05 | 0,86 | $1\times10^{16}$ | 0,75 | $10^{18}$ |
| $Se_{95}Te_5Cl_{0,005}$ | 1,05 | 0,80 | $2\times10^{16}$ | 0,70 | $10^{18}$ |
| $Se_{95}Te_5Cl_{0,01}$ | 1,05 | 0,80 | $5\times10^{15}$ | — | — |
| $Se_{95}Te_5Cl_{0,1}$ | 1,05 | 0,80 | $2\times10^{15}$ | — | — |

At the calculations the following number values of parameters of the investigated materials, are used: $N_v$=9,5· $10^{19}cm^{-3}$ [5], $\varepsilon$=5,5·$10^{-11}$ F/m [6], $\mu_o$=$10^{-3}$ $m^2$/V sec. [7].

As it is seen from the table, at the addition of the tellurium in selenium, the concentration of local states strongly increases (bigger, than in 100 times), but if tellurium concentration 5 at.%, the second group of localized states, situated near to the ceiling of valence band, appears. From the work [8] it is known, that tellurium, inputted in selenium, destroys selenium chains, in the result of which they become shorter and concentration of broken bonds increases. Obviously, these broken bonds are traps for hales. It is established by us [1-2] that tellurium additions in the amorphous selenium bigger than 2 at.%, causes the increase of the state density of negatively charged defects D. The decrease of the trap concentrations at the addition of the electronegative chlorine impurity in HGS of Se-Te system allows us to proceed, that hole traps in the given HGS material connect with the negatively charged defects *D*.


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**S.İ. Mehdiyeva, A.İ. İsayev, G.A. Məmmedov, Z.A. Aqamaliyev**

## Se-Te XALKOQENİD ŞÜŞƏVARİ YARIMKEÇİRİCİ SİSTEMLƏRDƏ HƏCMLİ YÜKLƏ MƏHDUDLAŞDIRILMIŞ CƏRƏYANLAR

Stasionar rejimdə təmiz və xlor aşqarları (0,001; 0,005; 0,01; 0,1 at.%) əlavə edilmiş şüşəvari xalkogenid yarımkeçirici $Se_{100-x}Te_x$ sistemi əsasında hazırlanan Te - $Se_{100-x}Te_x$ - Al strukturunun volt-amper xarakteristikası tədqiq edilmişdir. Müəyyən edilmişdir ki, həmin strukturda yük daşıyıcıların köçürülmə mexanizmi həcmi yüklərlə məhdudlaşan cəryanlarla əlaqədardır, və köçürülmə prosesini idarə edən lokal halların parametrləri (konsentrasiyası və aktivləşmə enerjisi) təyin olunmuşdur. Həmçinin müəyyən olunmuşdur ki, amorf selenə əlavə edilmiş tellurun miqdarı 2%-dan böyük olduqda, mənfi yüklü defektlərin konsentrasiyası artır.

**С.И. Мехтиева, А.И. Исаев, Э.А. Мамедов, З.А. Агамалиев**

## ТОКИ, ОГРАНИЧЕННЫЕ ОБЪЕМНЫМ ЗАРЯДОМ, В ХАЛЬКОГЕНИДНЫХ СТЕКЛООБРАЗНЫХ ПОЛУПРОВОДНИКАХ СИСТЕМЫ Se – Te

В стационарном режиме были проведены измерения вольтамперных характеристик (ВАХ) чистых и содержащих примеси хлора (0,001; 0,005; 0,01; 0,1 ат.%) ХСП систем $Se_{100-x}Te_x$ (x = 0; 1; 2,5; 5; 10 ат.%) в структуре типа Te - $Se_{100-x}Te_x$ - Al. Установлено, что в указанной структуре механизм токопрохождения обусловлен токами, ограниченными объёмным зарядом, и определены параметры (концентрация и энергия активации), контролирующие перенос электрических зарядов. Также установлено, что добавка теллура в аморфный селен, превышающая 2 ат.% , способствует увеличению плотности состояний отрицательно заряженных дефектов $D^-$.

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