ELECTRICAL PROPERTIES OF $FeGa_2S_4$

N.N.NIFTIEV, M.A.ALIDZHANOV, O.B.TAGIEV, M.B.MURADOV, F.M.MAMEDOV

Azerbaijan State Pedagogical University
(Az. 1000, Baku, Azerbaijan)

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Temperature dependence of the electrical conductivity and current-voltage characterictics (CVCs) of $FeGa_2S_4$ crystals have been studied. It has been shown that the current in the nonlinear range of CVCs is caused by the field effect. The activation energy of carriers and the trap concentrations have been determined.

At present, the interest has drastically arisen to semiconductors of the type $A^{II}B_2^{III}X_4^{VI}$ (A = Mn, Fe, Ni, Co; B = Ga, In; X = S, Se, Te) containing elements with unfilled d-shells [1—5]. This class of compounds constitutes a perspective basis for creating lasers, light modulators, photodetectors, and other functional devices controlled by a magnetic field. $FeGa_2S_4$ is attributed to the class concerned, the physical properties of which are little studied [6,7].

In the present work, the results are reported about the investigation of the temperature dependence of conductivity $\sigma(T)$ and of the current (J)—voltage (U) characterictics in $FeGa_2S_4$ crystals.

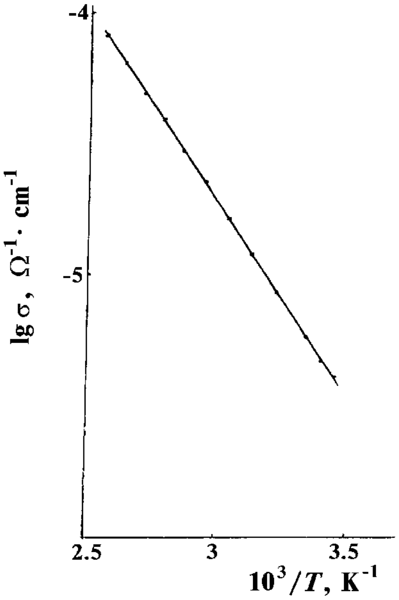

Fig. 1. Temperature dependence of the conductivity of $FeGa_2S_4$

$FeGa_2S_4$ crystals were produced by means of the direct mixing of elements with high degree of purity (99.99%) in stoichiometric proportion. Making use of the X-ray diffraction method, it was established that the $FeGa_2S_4$ crystals possess the rhombohedral structure of the type $ZnAl_2S_4$ with crystal lattice parameters $a = 12.89$ Å, $b = 7.51$ Å, and $c = 6.09$ Å [6].

The specimens were produced through the mechanical treatment of the ingot. The specimen contacts were created by the fusing of indium into the opposite surfaces. The interelectrode distance varied from 200 to 1000 μm.

In Fig. 1, the temperature dependence of the $FeGa_2S_4$ conductivity is shown. According to the slope of this dependence, the activation energy E_t was determined to be 0.29 eV.

Typical CVCs of the In—$FeGa_2S_4$—In junctions at various temperatures are depicted in Fig. 2. Two intervals of the CVC can be discerned, the ohmic one, where $J \sim U$, and the region of the accelerated current growth, where $J \sim U^n$ and $n > 1$.

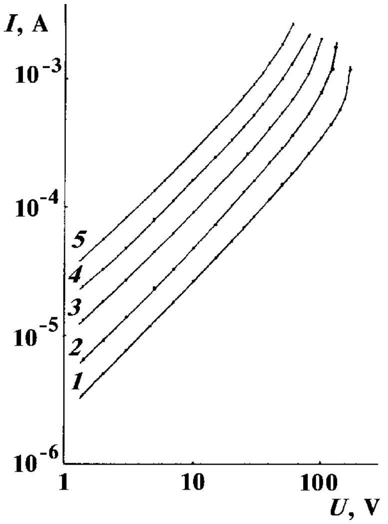

Fig. 2. Dark CVCs of the In—$FeGa_2S_4$—In junctions at various temperatures: *1* — T = 290 K, *2* — 310, *3* — 330, *4* — 350, *5* – 370

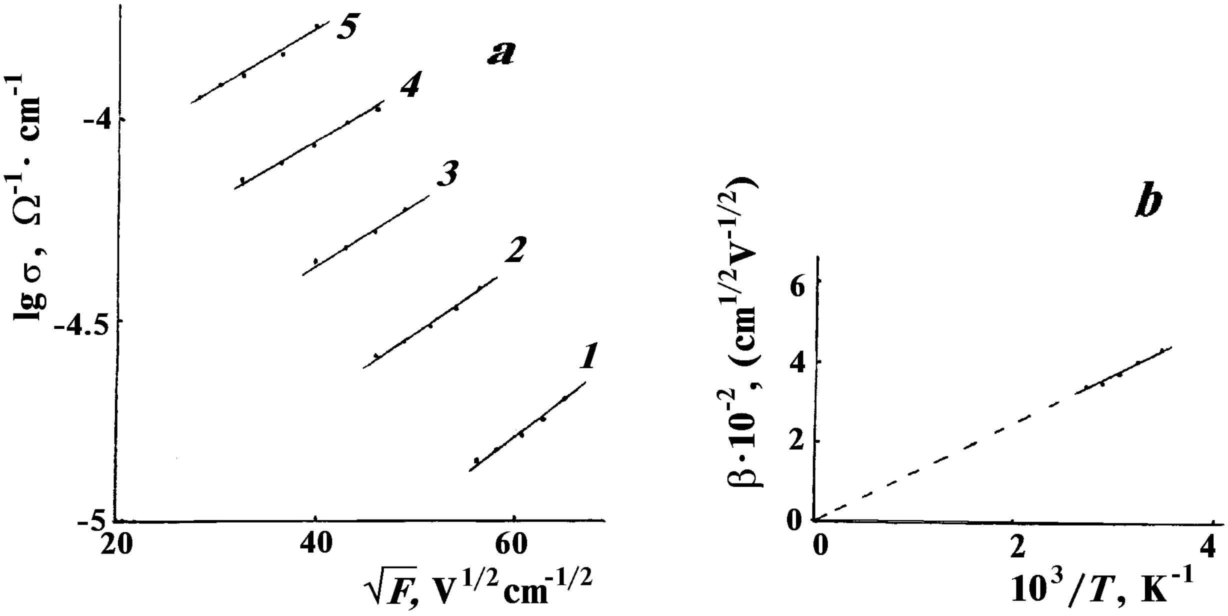

Fig. 3. *a* — dependences of the conductivity of the In—FeGa$_2$S$_4$ crystals on the external field strength F at temperatures: *1* — $T = 290$ K, *2* — 310, *3* — 330, *4* — 350, *5* — 370. *b* — temperature dependence of the Frenkel coefficient β

For the region of the accelerated current growth, the dependences of the conductivity on the external electric field F at various temperatures are presented in Fig. 3,*a* in the coordinates lg σ vs. $\sqrt{F}$. It is known that the theory of the exponential conductivity growth has been put forward first by Frenkel [7]:

$$\sigma = \sigma_0 \exp\left(\beta\sqrt{F}\right), \tag{1}$$

where

$$\beta = \frac{\sqrt{e^3}}{KT\sqrt{\pi\varepsilon\varepsilon_0}} \tag{2}$$

is the Frenkel coefficient, e is the electron charge, ε is the dielectric permittivity of the crystal, K is the Boltzmann constant, and T is the absolute temperature. From the slopes of the straight lines in Fig. 3,*a*, the values of β at various temperatures were determined. They are bounded by the interval $(3 \div 5) \cdot 10^{-2}$ (cm/V)$^{1/2}$. The temperature dependence of β, evaluated from the dependences $\sigma(F^{1/2})$ at various temperatures, is shown in Fig. 3,*b*. As is seen, the increase in β with decrease in temperature is observed, the dependence $\beta \sim T^{-1}$ obeying fairly. Such a temperature variation of β is consistent with the Frenkel theory, and the extrapolation of the straight line $\beta(T^{-1})$ by Eq. (2) leads to the coordinate origin.

The correspondence between experimental data and the modified Frenkel theory developed by Hill makes it possible to estimate the concentration of ionized sites in FeGa$_2$S$_4$ [8]. For the trap concentration, the following expression has been derived by Hill:

$$N_t = \left(\frac{2t}{KT\beta}\sqrt{F_{\rm cr}}\right)^3, \tag{3}$$

where $F_{\rm cr}$ is defined from experiment, being the critical field where the Ohm law is violated. For the trap concentration, the value $N_t = 9 \cdot 10^{14}$ cm^{-3} has been obtained.

Thus, it was shown on the basis of the CVC and $\sigma(T)$-dependence studies that the current in the nonlinear range is stipulated by the field effect. The energy of the current carrier activation and the trap concentration have been determined.

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ЕЛЕКТРИЧНІ ВЛАСТИВОСТІ $FeGa_2S_4$

Н.Н. Ніфтієв, М.А. Аліджанов, О.Б. Тагієв,
М.Б. Мурадов, Ф.М. Мамедов

Резюме

Досліджено температурну залежність електропровідності та вольт-амперні характеристики (ВАХ) напівпровідників $FeGa_2S_4$. Показано, що струм у нелінійній ділянці ВАХ пов'язаний з польовим ефектом. Визначено енергії активації носіїв струму та концентрації пасток.