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THE ELECTRICAL MEMORY SWITCHING EFFECT IN $MnIn_2S_4$ SINGLE CRYSTALS

O.B. TAGIEV, N.N. MUSAYEVA, R.B. JABBAROV
Institute of Physics of Academy of Sciences of Azerbaijan
370143, Baku, G.Javid pr., 33

For the first time the switching effect is detected in $MnIn_2S_4$ single crystals. The $MnIn_2S_4$ single crystals are obtained by a gas transport method, have a cubic structure with space group Fd3m and lattice parameter a=10.71Å. It is established, that in the temperature interval 77-190 K the electronic mechanism of switching takes place mainly, i.e. at result of the decrease of the scattering power the thermal breakdown at low temperatures transforms in the electronic one. In the temperature interval 190-300 K the thermal switching mechanism takes place.

The parameters of switching properties depending on temperature and thickness of sample are changed in intervals: threshold voltage 15-400 V, on-state current $2.5\cdot10^{-6}$- $8\cdot10^{-5}$ A, off-state current $1\text{-}10^{-3}$ A, residual voltage 0.2-1.5 V.

The switching effect arising in strong electric fields, is one of the interesting phenomena from practical and scientific points of view. In switching process the active material concluded between two metallic electrodes at certain applied voltage value transforms from a high-resistance state into law-resistance one and its volt-ampere characteristic (VAC) have the $S\,(N)$ -figurative form. Single crystals are obtained by the chemical transport reaction method.

The optimum temperature mode for obtaining single crystals from a gas phase is a temperature interval 850-750°C. Amount of iodine and duration of experiments are constants and equal to 5 mg/cm^3 and 5 days accordingly.

The electrical memory switching effect is detected by us at the research of electrical properties in the region of strong electric fields in the crystals $MnIn_2S_4$. The parameters, which characterize switching effect, are investigated in dependence on temperature, thickness of active region, wavelength and light intensity.

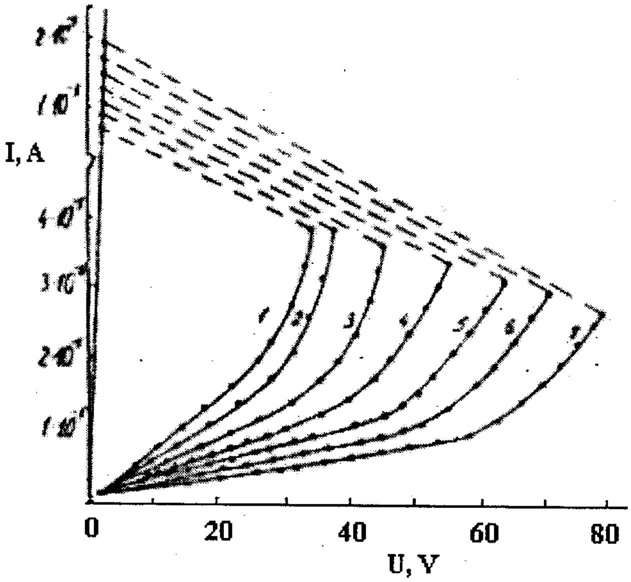

Fig.1. VAC of structures In- $MnIn_2S_4$ -In at various temperatures (K): 1-360, 2-346, 3-320, 4-287, 5-239, 6-125, 7-77.

Typical VAC of structures $MnIn_2S_4$ at various temperatures 77-360 K are represented on fig.1. On VAC the following sections are selected: linear, quadratic, region of growth of a current, region of a negative differential resistance (NDR) of a S-type.

After switching of the sample the resistance of a structure decreases almost on 3 order and it is observed long memory, i.e. in law-resistance state the sample can be a significant time. Returning of crystal in a high-resistance state (the erasing of electrical memory) can be realized by applying of short-term electric pulse with any polarity or by means of thermal effect on it.

The measurement shows, that with a decrease of temperature the threshold voltage increases and the threshold current of switching and multiple switching field decrease, but parameters of a structure In- $MnIn_2S_4$ –In change very small.

On the basis of experimental data represented on fig.1 the dependence of threshold voltage (U_{thr}) on inverse temperature in coordinates lgU from $10^3/T$ (fig.2) is constructed. On this dependence three characteristic sections are observed.

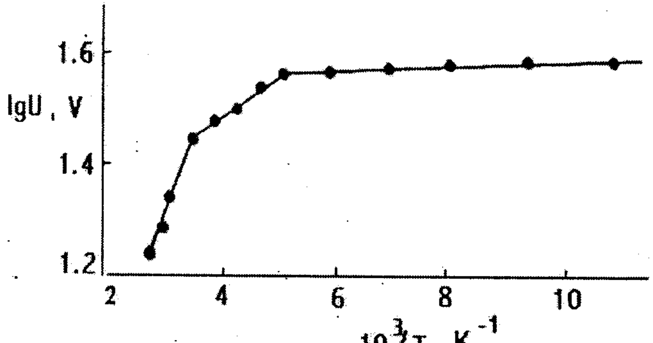

Fig.2. Dependence of threshold voltage on return value of temperature.

At relatively high temperatures the threshold voltage stronger depends on temperature, and the following decrease of temperature insignificantly increases the switching threshold voltage. The weak dependence of threshold voltage on temperature shows that in the temperature interval 77-190 K the switching electronic mechanism takes place mainly, i.e. at result of the decrease of the scattering power the thermal breakdown at low temperatures transforms into the electronic one [1,2]. In the temperature interval 190-360 K the switching thermal mechanism takes place mainly. On inclination of dependence $lgU=f\,(10^3/T)$ (fig.2) in the temperature interval 190-360 K the activation energy of traps responsible for switching are obtained, that are 0,11 and 0,063 eV. In many semiconductors, in which the switching effect is observed the formation of law-resistance state is connect with the appearance in the channel of the thermodynamically stable phase of the same composition that high-resistance initial substance has [3]. Sometimes the law-resistance state is characterized by a new phase distinguishing from an initial material, which can have half-metallic [4] or metallic conduction [5].

It is necessary to note, that in our experiments in dependence on a load resistance the value of a resistance of the active region the switching element in law-resistance state is changed from 10 up to 10^4 Ohm. A research of switching properties of samples of a various thickness has shown, that at samples of a thickness from 100-500 microns a resistance of active region in law-resistance state are equal to 10-50 Ohm. For explanation of a nature of memory in structures In-$MnIn_2S_4$-In also it is investigated temperature dependence of the resistance of these structures in law-resistance state. This dependence had the metallic character. For explanation of a nature of formation of metallic conduction, formed by the selection of a metallic component from the material, or diffusion from a metallic electrode, the different structures: In-$MnIn_2S_4$-In; Al-$MnIn_2S_4$-Al; Ag-$MnIn_2S_4$-Ag etc are investigated.

The temperature resistance coefficient (α) determined by the formula $R=R_0(1+\alpha t)$ is equal to $5.5\cdot10^{-3}$ deg.$^{-1}$. The obtained values of α correspond to temperature resistance coefficient of indium (α=$5.5\cdot10^{-3}$ deg.$^{-1}$). Therefore, it is possible to conclude, that the law-resistance state is stipulated by formation of the conducting channel of the selecting metallic phase from the used material (India).

It has allowed to make the supposition that the mechanism of memory and nature of law-resistance state in crystal $MnIn_2S_4$ of a thickness 100 micron and more are stipulated by selection of clusters In in a cord between electrodes, as well as in case of stratified compounds GaSe, at switching of which the metallic component Ga is selected [6].

This conducting channel is destroyed by impulse of a current of any polarity and the sample transforms into high-resistance state. A research of switching properties of samples of a thickness from 20 up to 100 microns has shown, that the resistance of active region in law-resistance state are equal to 10^3-10^4 Ohm, and the dependence of its resistance on temperature in law-resistance state has a semiconducting character. It is necessary to note, that in some cases in the certain temperatures interval (77-300 K) the dependence of a resistance on temperature in law-resistance state has a semiconducting character. It gives the basis to assume, that low temperature is insufficient for formation of the metallic channel of In. At the high temperatures, temperature of an environment and selection of heat at switching create conditions for formation of the metallic channel from India, which ensures preservation of memory. The temporary characteristics of switches are determined. Hold time, which passes from a beginning of submission of voltage up to sharp increase of a current on a load has significance of the order 10^{-9}- 10^{-7} s. The time of inclusion - own time necessary for transition for active region from a high-resistance state in low-resistance one changes in the interval 10^{-9}-10^{-7} s and time of restoring-returning of active region in an initial high-resistance state 10^{-6}-10^{-5} s.

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O.B. Tağıyev, N.N. Musayeva, R.B. Cabbarov

$MnIn_2S_4$ MONOKRİSTALINDA ELEKTRİK YADDAŞLI AŞIRMA EFFEKTİ

İlk dəfə olaraq $MnIn_2S_4$ monokristalında aşırma effekti müşahidə olunmuşdur. $MnIn_2S_4$ monokristalları kimyəvi qazköçürmə üsulu ilə alınmış a=10.71 Å qəfəs parametrinə və Fd3m faza quruluşuna malikdir.

Müəyyən olunmuşdur ki, 77-190 K temperatur intervalında aşırmanın elektron mexanizmi özünü göstərir, başqa sözlə paylanma gücünün azalması nəticəsində aşağı temperaturlarda istilik deşilməsi elektron deşilməsinə keçir. 190-300 K temperatur intervalında aşırmanın istilik mexanizmi özünü göstərir

Aşırma xassələrinin parametrləri temperaturdan və nümunənin qalınlığından asılı olaraq aşağıdakı tərtibdə dəyişir: hüdud gərginliyi 15-400 V, qoşulma gərginliyi $2.5\cdot10^{-6}$-$8\cdot10^{-5}$ A, ayırma gərginliyi $1\text{-}10^{-3}$ A, qalıq gərginliyi 0.2-1.5 V.

О.Б. Тагиев, Н.Н. Мусаева, Р.Б. Джаббаров

ЭФФЕКТ ПЕРЕКЛЮЧЕНИЯ С ЭЛЕКТРИЧЕСКОЙ ПАМЯТЬЮ В МОНОКРИСТАЛЛАХ $MnIn_2S_4$

Впервые в монокристаллах $MnIn_2S_4$ обнаружен эффект переключения. Монокристаллы $MnIn_2S_4$ получены методом газотранспортной реакции, обладают кубической структурой с пространственной группой Fd3m и параметром решетки a=10.71 Å.

Установлено, что в интервале температур 77-190 К имеет место преимущественно электронный механизм переключения, т.е. в результате уменьшения рассеиваемой мощности тепловой пробой при низких температурах переходит в электронный. В интервале температур 190-300 К имеет место тепловой механизм переключения.

Параметры переключающих свойств в зависимости от температуры и толщины образца изменялись в пределах: пороговое напряжение 15-400 V, ток включения $2.5\cdot10^{-6}$- $8\cdot10^{-5}$ A, ток выключения $1\text{-}10^{-3}$ A, остаточное напряжение 0.2-1.5 V.

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