ISSN 1392-2114 ULTRAGARSAS, Nr.4(49). 2003.

Basic mechanisms of acoustoresistive effect

Ev. L. Garška, R. Giriūnienė

Vilnius University, Laboratory of Physical Acoustics,
Faculty of Physics, Sauletekio 9, 2040 Vilnius, LITHUANIA,
Phone:+370 2 33 60 83, E-mail:ramute.giriuniene@ff.vu.lt

Introduction

The problem of electrical conductivity of a medium when a high-frequency acoustic wave (AW) propagates in it is one of important problems of acoustoelectronic elements, which already for a long time has exceeded only physical interest and grows into practical, applied interest for implementation of sensors [1,2] and various phototransducers. The acoustoresistive effect (ARE), discovered nearly thirty years ago, has revived in sensors and it is still discovered in new materials such as gallium nitride [3]. This is the reason why the ARE and its mechanisms need to be reviewed. It is the purpose of this paper to analyze the basic mechanisms of the ARE and discourse its experimental investigations.

The (ARE) is a very exotic phenomenon: the variation of electrical resistance of medium under the action of an acoustic wave. From the first sight it seems difficult to find the motivation for the interaction between a system of charge carriers and varying elastic strain or particles velocity. However, there are some physical mechanisms determining a possibility of interaction between the elastic wave and the electrical system and forming the electrical conductivity of the medium. The origin of variable electrical fields reduces to a characteristic velocity of propagation v_b and peculiar behaviour of an absorption coefficient α. The characteristic property of such a wave is that its propagation is determined not only by the elastic constants: mass density, thermal conductivity, but also by the piezoelectric properties of material. The anisotropy of propagation of such a wave is caused by an anisotropy of elastic modulus c_{ik} and anisotropy of piezoelectric modulus d_{ijk}. It evident that in these conditions the acoustoelectric conductivity of the medium becomes anisotropic too. Acoustoelectric interaction changes the electrical conductivity. An increase of a drift velocity of carriers in the direction of the wave propagation reduces the electrical conductivity. However, grouping of the carriers into the bunches of inhomogeneous concentration propagating with a given velocity in the direction of the wave implies perturbations of processes of carrier capture by impurity levels, generation (both majority and minority charge carriers) and recombination. The capture in the acoustoelectric interaction is accounted for by introducing the capture factor *f,* which appears to be nonlinear depending not only on characteristic relaxation times, but also on the wave intensity.

Considering acoustoelectric interaction in an electrically inhomogeneous medium with potential barriers, one more variety of the medium resistance change due to perturbation of barriers by a field of a wave is observed. It is especially precisely exhibited in layered structures: piezoelectric and, for example, polycrystalline semiconducting layer.

The existence of acoustoelectric interaction in some crystals, especially in piezosemiconductors, and in various layered structures creates conditions for their strong acoustosensitivity. The acoustosensitivity, from a physical point of view, explains the series peculiarities of acoustoelectric interaction (AEI) at spatial-temporal modulation of potential fields of a lattice under the action of a wave. The acoustosensitivity is similar to the photosensitivity, however it is stipulated by completely other reasons. The acoustoresistive effect alongside with piezoresistive and strain sensitivity resistive effects envelops the whole class of related phenomenon: the ARE is possible to refer to a variety of the mentioned phenomena at high frequencies. The theory of the resistance variation under the action of AW is developed in works of Y. V. Gulyaev et. al. [4,5]. The various mechanisms of a possible conductivity variation (they called it as effect of acoustoconductivity) are considered, and it is shown, that the greatest value $\Delta R/R$ can be reached in the semiconductor with traps, where it can achieve several percent due to "eject out" (force out) of carriers from impurity centers at grouping.

1. Electron - phonon ARE

The acoustoelectric interaction at not so high frequencies is precisely described by the phenomenal approach not attracting a quantum nature of an acoustic wave. However, underlining the initial reason of the ARE as the interaction of a simple harmonic wave (stream of phonons) with other elementary excitations of the medium including charge carriers, proceeding from a generality of exposition of all frequency band (ultrasound, hypersound), was called an electron - phonon ARE.

From the beginning the problem of a possible change of electrical conductivity of the crystal was interesting for many of investigators. The research was subdivided into investigation of customary multivalley semiconductors, in basic germanium and silicon, in which AEI is called by a deformation potential, and piezosemiconductors, in basic cadmium sulphide, in which AEI is stipulated by piezoactivity of the medium.

For the sake of a historical validity it is necessary to specify, that the first who have tried theoretically to describe the change of crystal resistance were authors of the work [6], where the change of resistance is interpreted as influence of a deformation potential, and as piezoeffect;

the expressions of a relative modification of resistance $\Delta R/R$ at piezoelectric interaction $(\Delta R/R)_{\varphi}$, at the deformation potential $(\Delta R/R)_{\chi}$, and also due to the variation of concentration of charge carriers $(\Delta R/R)_{n}$, and also variation of their mobility $(\Delta R/R)_{\mu}$ are presented. Two reasons, under our judgment, are enveloped by essence of an appearance and consequently there is not absolutely clear a problem on the contribution of the first two reasons. Here we shall not develop the further controversy in this direction and we shall not present the obtained expressions due to their complication.

It would be desirable to mention work [7], in which an acoustic wave propagates along the piezoactive axes of a crystal and the external electric field E_i is applied at the same direction, the component of electric current density $I=I_0+I_{ae}+I_{\Delta\sigma}$, taking place in this direction are considered, here I_0 is the ohmic current density, I_{ae} is the acoustoelectric current density, $I_{\Delta\sigma}$ is the current density owing to a modification of electrical conductivity of a medium because of AEI:

$$I_{\Delta\sigma} = \frac{\alpha\mu^2 W}{v_b^2} E_i,$$

Here α is the electronic absorption coefficient of the wave, μ is the mobility of carriers of a current, W is the intensity of the wave, υ_b is the velocity of a wave. According to such expression the linear dependence of the electrical conductivity on the intensity of the wave W is obtained; the modification of electrical conductivity is determined, in basic, by modification of the electronic absorption factor α of an acoustic wave and its dependence on the strength of an external electrical field E_i. Such an acoustoresistive effect has a sharp anisotropy of the resistance and is determined by the tensor magnitude, which is defined by a wave type and piezoanisotropy. Contrarily from other types of the acoustoresistivity such ARE is called an electron – phonon ARE. Our experimental investigation completely confirmed analytical results [8]. However it is necessary to pay attention that such ARE is revealed in most perfect crystals from the point of acoustoelectric interaction, that is, the electronic absorption factor completely corresponds to its theoretically calculated magnitude.

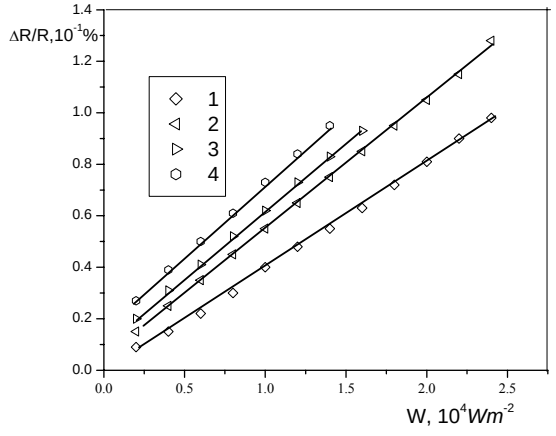

Fig. 1. **The dependence of the resistance relative variation $\Delta R/R$ on the acoustic wave intensity W: at $E_i=10^3$ V·m^{-1} of crystals CdS, at different frequencies: 1 - 10 MHz, 2 - 15 MHz, 3 - 25 MHz, 4 - 30 MHz**

In Fig.1 the dependences $\Delta R/R = f(W)$ are presented at different frequencies; in the given area (weak fields E_i) the modification of a resistance is minor and has only analytical meaning. The given appearance causes a decrease of the value of the resistance in comparison with the fixed one; that at the strong E_i (in the field of an amplification of the wave) it changes a sign due to a modification of a sign of factor α_e.

In consideration of an acoustoelectric current, the strong ARE in some CdS crystals we have observed [9]. The strong ARE links with a high photosensitivity of the crystals.

2. Acoustic quenching of photoconductivity

As AW propagates in a crystal, the modulation of an energy band gap, bottom of a conductivity band and ceiling of a valence band occurs. In the case of a crystal with strong piezoelectric properties the influence of a piezoeffect predominates over a deformation potential and the modulation of edges of a band gap occurs with an identical phase, and the depth of modulation ΔW is determined by a strain and the operating piezoconstant e_{ik}, then $\Delta W = qe_{ik}u_0 / \varepsilon_{ik}\varepsilon_o$, q is the elementary charge, ε_0 is the dielectric constant. At AW intensity of the order W/cm^2, the depth of modulation, for example, for crystals of cadmium sulphide can reach the order an electronvolt. Where the displacement is the function of the coordinate and time, it causes a heterogeneity of energy state of the crystal. At the presence of electron gas its thermodynamic equilibrium is breaked, the areas with the increased and reduced pressure of electron gas are created. At shielding by free carriers of interior fields and their grouping the modulation of quasi-Fermi level occurs, and its non-equilibrium part can be shown as a charge density wave. Then a modulated quasi-Fermi level is

$$W_{F'} = W_F + \Delta W_F = W_F + \Delta W_{F_0} \exp i(kx - \omega t),$$

here W_F is the Fermi energy. The value ΔW_{F_0} is determined by the non-equilibrium concentration, which is equal to the local concentration of grouped carriers.

Thus in a semiconductor with impurity levels (by analogy to sensitization of a photoconductor by light) "the acoustic" sensitization is possible. Naturally, acoustic sensitization is the peculiar harmonic (in a linear case) spatial-temporal inhomogeneity. On the base of the acoustic sensibilization it is possible to explain a series of developments of acoustoresistive effect in bulk and on a surface. It can be illustrated on the base of photosensitive crystal with a developed system of impurity levels in a forbidden band gap. Let here are available both small-sized (traps), and deep (recombination) levels. As AW propagates in the crystal and grouping of the carriers occurs, the demarcation level W_D, defining the character of levels, are modulated too. The depth of the modulation corresponds to the modulation depth of W_F, and the phase is turned (biased) on an integer π. If to suppose that in

conditions of acoustic modulation the previous capture cross-sections for electrons S_n and holes S_p are saved, then the demarcation level W_D is mirror map of W_F concerning a middle of zone of W_i (Fig. 2).

That's why the interval between W_F and W_D, defining the basic mass of recombination levels, is modulated from the point of view of impurity levels system in a forbidden band. The solution of a set of equations $\partial n / \partial t$ and $\partial n_t / \partial t$ for these conditions is difficult, therefore we shall limit ourselves by only qualitative consideration. Let's consider two cases: with one recombination level W_r (Fig.2) and with two levels W_{r1} and W_{r2} (Fig. 3). Let us assume that at the initial moment of consideration the quasi Fermi level $W_{F'}$ is closer to the conductivity band bottom, what corresponds to the increased local concentration of grouped together carriers.

At transition to the area with the reduced concentration, the quasi Fermi level $W'_{F'}$ is lowered, and the demarcation level $W'_{D'}$ is increased. The interval $W'_F - W'_\Delta$ is narrowed down, the level W_r goes out far from the bounds of this interval. The holes life time is $\tau_p = 1/N_r \nu_T S_p$, and at the enough large concentration

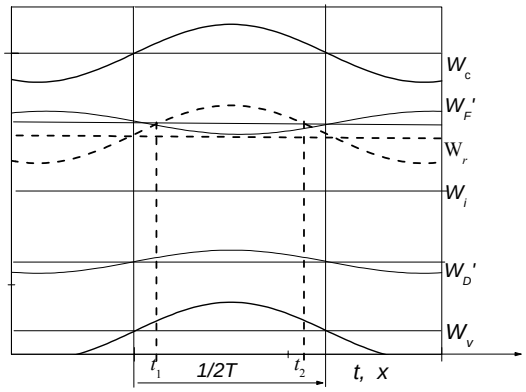

Fig. 2. **Modulation of power levels by an acoustic wave in photo sensing piezoelectric crystal**

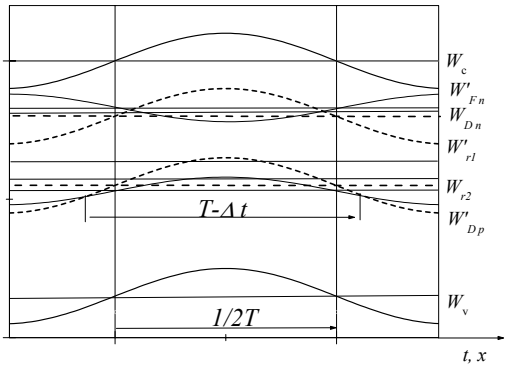

Fig. 3. **Modulation of a two-level structure by an acoustic wave**

p_r, and also n_r, the electrons life time $\tau_n = 1/p_r \nu_T S_n$ is increased, as the probability of a recombination through this level decreases:

$$1/\pi \sim \exp(-W_r/kT + W_{F'}/kT).$$

The average concentration of free carriers in zone is increased. Thus, we obtain an experimental outcome coinciding with analytical data obtained by Y. V. Gulyaev et. al. [4,5].

The more complicated picture is observed for a photosensitive crystal possessing two recombination levels. Let us assume that the part of impurities is compensated. In such a crystal the levels for electrons W_{F_n}, W_{D_n} and for holes W_{F_p}, W_{D_p} are various; for everyone W_r exists two demarcation levels. It is possible to accept, that the intervals $W_{F_n} - W_{D_n}$ and $W_{F_p} - W_{D_p}$ are approximately equal among themselves and are modulated in the dependence on the local concentration n and p:

$$W_{F_n} - W_{D_n} = W_{F_n} - W_{F_n} + kT\ln(nS_n/pS_p) = W_{F_p} - W_{D_p}.$$

The interval of the recombination levels $W'_{D_n} - W'_{D_p}$ becomes modulated too. Lets to the levels W_{r1} and W_{r2} there correspond concentrations N_{r1} and N_{r2}, and N_{r2} even by one order are higher than N_{r1}, the cuts $S_{n2} << S_{n1} = S_{p1} = S_{p2}$. Let without of AW, the levels W_{r2} are located close to the level W_{D_p} and are closer to a middle of a forbidden band gap; such a location can be chosen by illumination. In these conditions the recombination occurs, in basic, through W_{r2}, as $n_{r2} << n_{r1}$. In the case of modulated levels (Fig. 3) W'_F and W'_D (in a Fig. 3 modulations W_{F_p} and W_{D_n} are not represented, $\Delta W_{F_p} < \Delta W_{F_n}$) the role of centers W_{r2} varies: at defined time interval $T - \Delta t$ the centers W_{r2} appear as sensitization centers, but in the remaining time they fall outside the limits W_D and play a role of usual trapping centers for holes. If $\tau < T$, at this time the filling of centers W_{r2} by holes slows down, $p'_{r2} < p_{r2}$. The filling of the centers W_{r1} by holes is increased. The resettlement holes from W_{r2} on W_{r1} (through the band W_V) reduces in increase of a role of a recombination through W_{r1}: the process reduces sensitization and decreases life time τ_n of the majority carriers and increases the photoresistivity.

It was repeatedly confirmed experimentally; in such crystals we observed the strong acoustosensitivity. The presented model is illustrated by the dependences of resistance modification on illumination of CdS or CdSe crystals, when the regulating of a position of non-equilibrium Fermi level realizes the greatest acoustosensitivity: the curve ΔR (Fig. 4) possesses an expressed extremum. The model becomes some complicated by the account of trapping levels. The significant role in a release of traps can be played by tunneling through a barrier; when the equilibrium carriers almost are absent and the bending of band is the greatest, AW can exhibit itself similarly to a long wavelength

illumination. At grouping, as repeatedly was shown, the traps are liberated too.

Both these phenomena govern increase of concentration both basic (from donor), and minority (from acceptor) carriers. But the increase of not basic carriers in two-center model sharply intensifies the recombination rate. Acoustoexitation of impurity we observed experimentally in the darkened out CdS or CdSe crystals. The complicated pulse - transient characteristic of a resistance (Fig. 5) was observed. In its initial part the fast decrease of a resistance with the duration time of order of μs was observed. Further the resistance begins to increase, reaching a fixed value. Here the relaxation time is some tens of μs. It can be explained by acoustoexitation of minority carriers, amplification of a recombination rate with switching of a channel on one faster and decrease of life time of basic carriers. In this experiment even a weak illumination of a crystal by a long wavelength light cut-off the curve peaks in direction of resistance decrease.

Basically a similar situation is realized on a surface. Thus the transversal component of acousto-emf creates a homogeneous charge carrier depletion or enrichment of a surface, displacing a surface Fermi level. The non-equilibrium bending of the quasi Fermi level near the surface breaks an absorption equilibrium and interchanging between a surface and environment. In the mentioned crystals on a surface the slow traps predominate and the equilibrium is reached slowly. The acoustoelectro-adsorption effect is determined by conditions of acoustoelectric interaction on a surface. The considerable modification of a resistance was revealed by us in strongly photosensitive cadmium sulphide crystals [10], and later

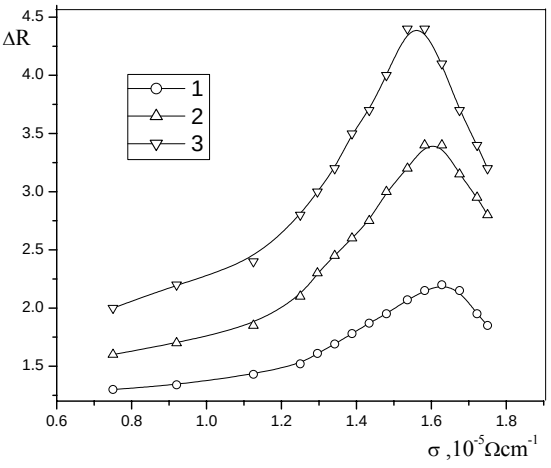

Fig. 4. **The dependence of acoustoresistivity on illumination**

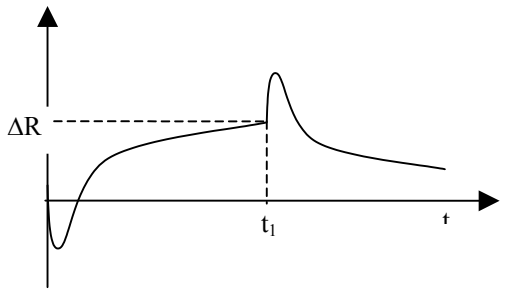

Fig. 5. **The resistance relaxation at acoustoexitation of the impurities**

for cadmium selenide. It has appeared that in such ARE a basic role is played by perturbation of recombination processes in sensitizing photoconductors.

3. Acoustoresistivity of thin films

We experimentally realized the significant ARE in a monolithic layered structure of piezoelectric - lithium niobate and a photo semiconductor - cadmium sulphide [10]. The layer of cadmium sulphide was made by a special process engineering, had photosensitivity and was of polycrystalline structure (small-sized monocrystalline grains oriented chaotically). In such layers the nonlinear electrical conductivity in a medium with an infinite amount of heterogeneities of potential barriers between crystallites was assumed. Taking into account such the intercrystalline nonlinearity is possible to assume ARE existence, based on perturbation of potential barriers by an electrical field of the wave. Really, the high-frequency electric field of an acoustic wave in a piezoelectric material modulates an intercrystalline field, that is, locally modulates a height of a barrier.

If to present the layer as an infinite circuit of series equivalent resistors, in the areas of increase of barriers the value of these resistors at action of a high-frequency electric field of the wave remains the large and almost does not influence the initial value of a resistance of the layer; in areas where there is a barrier, it decreases, the injection of not basic carriers intensifies and value of resistors considerably decreases. The high-frequency field stimulates the current: combined action of an external *dc* and high-frequency fields of the wave causes transition of an enlarged density electric current through the complex of potential barriers in polycrystal during propagation of an acoustic impulse. The short (in a comparison with the earlier discussed) relaxation time of the current indicates a simple injection mechanism. It is known that it is possible to reduce influence of barriers by illumination on passage of a current in a polycrystalline sample. In the considered ARE mechanism, increasing the layer conductivity by illumination it is possible to reduce a change of $\Delta R/R$.

At such consideration it is necessary to take into account that in photoconductive cadmium sulphide in to electrons a defined role play not basic carriers - holes, especially at small conductivity. The holes concentration can be close to the electrons concentration. Taking into account the holes in a barrier area, the current through barriers increases. Probably, to recombine the carriers have no time (radiation by a crystal it isn't observed). Further, both majority and minority carriers participate in transfer of the current through the crystal.

In Fig.6 the basic results of ARE in a structure with a polycrystalline film CdS are presented; the similar results were obtained for CdSe film [11]. The significant negative modification of a resistance ΔR is noticed. On the electrodes AB an acoustoelectric voltage U_{ae} is observed; we carefully investigated its influence to summarized voltage. The voltage U_{ae} is proportional to the intensity W of a wave, $W \sim U_t^2$. The voltage U_{ae} is dependent on an electronic absorption coefficient α_e, which has an extremum in the range 10^6 Ω of a resistance (Fig.6, curve

3), that is, the value U_{ae} was not constant in all resistance range of the layer. The contribution of the voltage U_{ae} is not constant at representation of data in a scale U_t.

According to experimental results the contribution of the voltage U_{ae} to the total voltage drop ΔU across the resistance R_H is unimportant and it is much lower than the voltage U_{ARE} , $U_{ae} << U_{ARE}$. We had not separated it from the total voltage ΔU. We have investigated $\Delta R/R$ across the wave propagation direction. The dependence $\Delta R/R$ on an initial resistance R is shown in Fig. 7. The resistance R was controlled by optical illumination by a white light. According to data presented in Fig. 7 it is visible that the increase of the photo carriers concentration leads to a significant decrease of the ΔR: at large conductivities the ARE weakens. Also we conclude that at the low conductivity the barrier mechanism of ARE predominates. For the benefit of the barrier mechanism also present the data for $\Delta R/R=f(U_t)$ (Fig. 6): the increase of the voltage U between the electrodes AB, both in longitudinal and in transversal directions, homogenizes smoothing barriers of a film.

In this films and also on a surface of CdS monocrystals the observation of positive ARE is possible; in all cases the sign ARE did not depend on propagation direction of a wave.

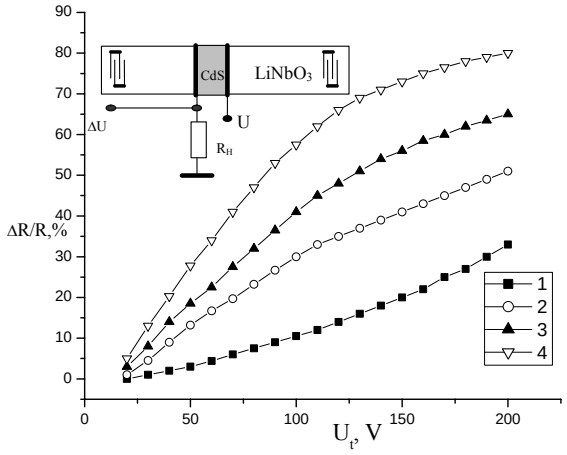

Fig. 6. **Scheme of experiment for investigation of the longitudinal ARE and the dependence of a relative resistance $\Delta R/R$ on the voltage U_S at the input SAW transducer at the measuring voltage on the electrodes AB U=100 V and different initial resistances R of CdS film: 1 – 10^8 Ω, 2 –1·10^7,Ω, 3 – 1·10^6,Ω, 4 – 6·10^5 Ω**

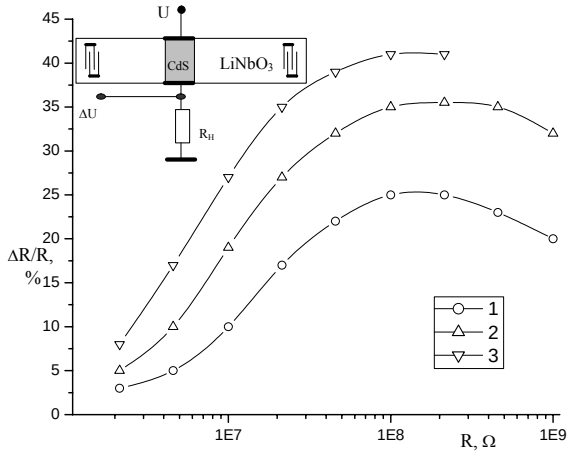

Fig. 7. **Scheme of experiment for investigation of the transversal ARE and the dependence of a relative resistance $\Delta R/R$ on an initial resistance R of CdS film (b) at different measuring voltages on the electrodes AB. U: 1 - 50 V, 2 - 200 V, 3 - 400** V

4. The influence of surface electrokinetic processes on ARE

Taking certain surface electrokinetic processes and also interaction of a surface with a various gas environment into account, it appears possible deriving ARE of both signs on the same substance.

In semiconductive polycrystalline films of tin oxide both the positive and the negative ARE are observed, when this film serves as a catalyst: if electron-acceptor heterogeneous reaction takes place on the surface of the film, the positive AR effect was observed and in the case of electron-donor heterogeneous reaction the negative ARE takes place [12]. In Fig.8 such a case is shown.

ARE effect observed in these films is used in sensors. The sensing is based on the SAW acoustoelectric interaction in semiconductor and the change of acoustoresistivity and measurements of the longitudinal acoustoelectric current. The main element of the sensor is the tin oxide film / lithium niobate layered structure. The structure is placed in a chamber, which can be filled with various gases or vented out. As a rule, semiconductor- type gas sensors have been fabricated mainly by sintering the tin oxide powder [13,14]. In our case the tin oxide film on the surface of lithium niobate was formed by acoustochemical oxidation of metal tin film in the oxygen atmosphere using the method developed by us [15]. Using such a method, it easy to control the properties of the film. The polycrystalline tin oxide film made by this method distinguishes in acoustoelectric interaction. An enormous acoustoresistive effect is observed in it too, and the film sensitively reacts to exterior influence including an ambient gas.

Tin oxide is the n-type semiconductor. The conduction electrons of tin oxide play a major role in gas sensing, since the concentration of the conduction electrons changes as the surface of polycrystalline tin oxide is exposed to the gas to be detected. Some gases are electron-accepting

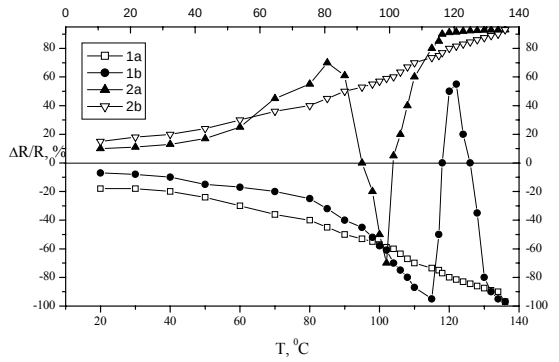

Fig. 8. **Acoustoresistivity as a function of the operating temperature in the oxygen atmosphere (curves 1a, 1b) and in air with hydrogen (hydrogen concentration 1000ppm, curves 2a, 2b)**

particles (for example, O_2) and are decreasing the conductivity, and some – electron-donoring (for example, H_2) and increasing the conductivity. For the polycrystalline film, the neck size connecting adjacent grains is also an important factor in determining the gas sensitivity. The neck size can not be simply controlled; since it can be changed by various experimental conditions such as the parameters of continuous mode SAW, the oxidation temperature and acoustoelectrochemical transition time. Polycrystalline thin films also seem to be suitable for gas sensing, because they have a large surface volume ratio and good possibilities of fast adsorption-desorption processes on their surfaces. Furthermore, the use of SAW in continuous mode increases the adsorption ability of the surface [16]. SAW propagating in the structure changes the parameters of surface states and creates new states [17] and it can change the adsorption equilibrium between solid and gas phase. SAW during wave period induces the additional charge δQ [18]:

$$\delta Q = \frac{seL_D|E_s|^2}{24\pi T},$$

so the relative surface adsorption ability will be:

$$\frac{\Delta N}{N} = (1-\eta_0)\left(\pm\kappa|E_s|^2 - 1 + \sqrt{o^2|E_s|^2 + 1}\right),$$

where $\kappa = \frac{seL_D}{48\pi TSN_0(1-\eta_0)}$; e is the electronic charge, ε is the dielectric constant of semiconductor, $|E_s|^2$ is the SAW electric field on the semiconductor surface, T is the temperature in energy units, S is the area of the film surface, $N = N_0(T,P)$ is the equilibrium concentration of adsorbed particles on the surface, L_D is the Debye screening length. The sign "+" corresponds to donor and "-" corresponds to acceptor particles adsorption.

Conclusion

The influence of acoustic waves on an electrical resistance of a material is determined by some physical mechanisms of interaction. The strong ARE reveals in thin films and layers. Both positive and negative ARE have been found by controlling the population of surface levels. In the presented paper the ARE of p-n junction and others inhomogeneous (heterogeneous) structures is not discussed.

References

1. **Sato M., Yamamoto T., Meguro T., Yamanouchi K.** Sensitivity of an anodically oxidized aluminum film on a surface acoustic wave sensor to humidity. Sensors and Actuators. 1994. Vol. B.20**.** P.205-212.
2. **Reichert J., Coerdt W., Ache H.J.** Development of a surface acoustic wave sensor array for the detection of methanol in fuel vapours. Sensors and Actuators. 1993. Vol. B.13-14. P. 293-296.
3. **Rimeika R., Sereika A., Čiplys D., Shur M., Gaška R., Balakauskas S.** UV-induced acoustoresistive effect in GaN epitaksial layers. 35-oji jubiliejinė Lietuvos nacionalinė fizikos konferencija. Pranešimų tezės. Vilnius. 2003. P. 224.
4. **Гуляев Ю. В., Листвина Н. Н.** Изменение проводимости полупроводника под действием звука. ФТП. 1972. Т. 6. No 11. С.2169-2174.
5. **Гуляев Ю. В., Листвина Н. Н.** К нелинейной теории примесной акустопроводимости в полупроводниках. ФТП. 1976. Т. 10. No 6. С. 1148-1153.
6. **Сандомирский В. В., Коган Ш. М.** Акустоэлектричкские эффекты в пьезоэлектрических полупроводниках. ФТТ. 1963. No.5. P.1894-1899.
7. **Klein R., Rehwald W.** Combined effects of sound and electric fields upon the conduction electrons in solids. Phys. Rev. 1966. Vol.143. P.479-486.
8. **Гаршка Э., Брасджюнас П., Кунигелис В.** Электрон-фононный акусторезистивный эффект в CdS. Liet. Fiz. Rink. 1968. Vol. 9. No 2. P. 397-401.
9. **Брасджюнас П., Гаршка Э.** К вопросу об электронно-фононном взаимодействии в CdS. Liet. Fiz. Rink. 1967. Vol. 7. No.1. P. 131-136.
10. **Серейка А. П., Гаршка Э., Юцис А. И., Алишаускас А. В.** Акусторезистивный эффект в тонких поликристаллических пленках CdS. ФТТ. 1972. Т.14. Вып. 9. P. 2790-2792.
11. **Merilainen P., Luukkala M., Saarinen K.** Acoustoresistance of polycrystalline CdSe film on $LiNbO_3$ delay line. Wave Electronics. 1974/76. P. 231-245.
12. **Giriuniene R, Garshka E.** Acoustoelectric gas sensor with casserite film. Ultragarsas, Nr.2(35). 2000. P.27-29.
13. **Lalauze R., Pijolat C.** A new approach to selective detection of gas by a Sn_2O solid-state sensor. Sensors and Actuators. 1984. Vol.5. P.55-63.
14. **Coles G.S.V., Bond S.E., Willems G.** Selectivity studies and oxygen dependence of tin (IV) oxide –based gas sensors. Sensors and Actuators. 1991. Vol. B. 4**.** P. 485-491.
15. **Giriuniene R., Jucys A., Urbelionis V.** Acoustoelectrochemical Formation of Polycrystalline Casserite Films. 1987. Ultrasonics. Vol.19. P. 33-42.
16. **Giriuniene R., Jucys A.** Acoustoelectrostimulated Adsorption of Corbonics Acids on CdS Surface. J. Phys. Chem. (Soviet.). 1987. Vol. 61. P. 1844-1849.
17. **Giriuniene R., Jucys.A.** Acoustoelectrostimulated Catalysises on the Semiconductor Surface. J. Phys. Chem. (Soviet.). 1988. Vol. 62. P.2047-2052.
18. **Kalashnikov S. G., Fedosov V. I.** Nonlinear effects of highly-frequency field effect in semiconductors. Phys. Tech. of Semiconductors (Soviet.). 1975. Vol. 9. P. 2161-2170.

Ev. Garška, R. Giriūnienė

Pagrindiniai akustinio rezistyvumo mechanizmai

Reziumė

Sparčiai vystantis sensorikai ir jutiklių mikroschemose esant nuolatiniam naujų jautriųjų elementų poreikiui, medžiagų akustinis rezistyvumas įgauna tiesioginį techninį taikomąjį pobūdį. Darbe aptariami fizikiniai vyksmai, dėl kurių, sklindant didelio dažnio akustinei bangai, keičiasi medžiagos elektrinė varža. Nagrinėjamas pjezopuslaidininkinių medžiagų ir sluoksninių struktūrų akustinis rezistyvumas, kai aplinkoje laisvieji krūvininkai gali sąveikauti su sklindančia banga. Aptariami tūrinių bangų bei paviršinių bangų atvejai. Nurodoma, kad banga, sklindanti fotojautriame kristale, gali sukelti akustinį fotojautrumo slopinimą; pateikiami vieno ir dviejų pagavimo ir rekombinacijos lygmenų modeliai ir jų kintamas vaidmuo elektrokinetiniuose vyksmuose dėl energinių lygmenų akustinės moduliacijos. Vyksta ir paviršinių lygmenų moduliacija sluoksninėse struktūrose; polikristaliniame sluoksnyje sutrinka netiesinis barjerinis laidumas ir dėl to keičiasi sluoksnio laidumas.

Tuo atveju, kai su banga sąveikaujantis paviršius yra atviras dujinei aplinkai, dėl akustinės paviršinių lygmenų moduliacijos sutrinka elektroabsorbcinė pusiausvyra. Darbe aptariamas kasiterito (SnO_2) sluoksnio akustinis rezistyvumas; šioje medžiagoje galimas tiek teigiamasis, tiek neigiamasis akustinis rezistyvumas, sąlygojamas galimybės sukurti donorinio ar akceptorinio pobūdžio paviršius, esant skirtingai elektrokinetikos požiūriu dujų įgerčiai. Išnagrinėtas fizikinis mechanizmas, leidžiantis akustoelektrosorbcinį akustinį rezistyvumą panaudoti dujų jutikliuose.

Pateikta spaudai 2003 10 14