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# Contribution to the Experimental Methods of Deep Level Acoustic Transient Spectroscopy

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Since 1964 the interaction between a surface wave in piezoelectric material and an adjacent semiconducting layer has been intensively studied. Different approaches have been used to explain the transverse acoustoelectric voltage (TAV) observed in the semiconducting layer. Detailed scope and critic of different theoretical treatments were done by Fritz /1/.

Recently the transverse acoustic field produced by surface acoustic waves in semiconductors was used to the spectroscopic study of energy levels of MOS structures /2/. In these experiments the electromagnetic field of the surface acoustic wave (SAW) penetrates the small windows in the metallic waveguide to the studied semiconducting layer. TAV was measured as a function of both a bias voltage superimposed on the semiconductor and an illumination, respectively.

From the analysis given by Fritz /1/ one can see that the intensity of the electric field created in the semiconductor by the accompanying SAW can be described by an equation with two fundamental terms

$$E = E_0 + E_1 \exp(i(\omega t - kz)) \ . \tag{1}$$

The first dc term with label zero is obviously called acoustoelectric term and the second one labelled as $E_1$ is the high frequency term. Both are proportional to the amplitude of the excitation wave and the carrier concentration, too. Second-order terms at frequency $2\omega$ are not included in the analysis of the TAV signal, but that could be significant at sufficiently large input signal.

In our experiments we have used the rf component of the TAV and it has been demonstrated that in the case of rapid change of the bias voltage relaxation of the rf signal can occur in specific geometrical arrangements.

Two identical transducers were prepared on the polished surface, i.e. Y-Z-$LiNbO_3$ (Fig. 1). The width of the finger and width of the gap were the same. The generating transducer creates a SAW which proceeds in the Z-direction and is accompanied by a two-dimensional electric field. The second transducer has two series of fingers shorted out and grounded and serves as a periodic space filter for the rf signal. The electromagnetic wave produced by the SAW penetrates through

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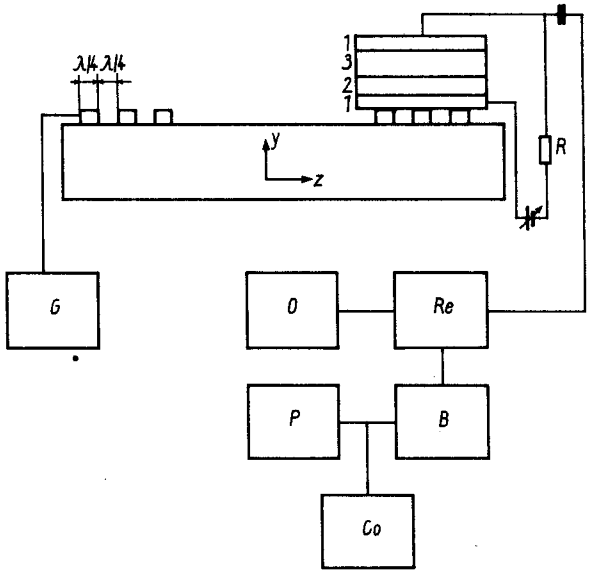


Fig. 1. Experimental arrangement: 1 metal, 2 oxide, 3 p-Si, C capacity, R resistor, G generator, O oscilloscope, Re rf receiver, B box-car, P plotter, Co computer

even or odd numbers of "windows" and creates an rf TAW signal. The rf acoustoelectric signal is given by the integral

$$U_{AC} = \int_{0}^{d=vt} E_1^y \sin(\omega t - kz)dz$$

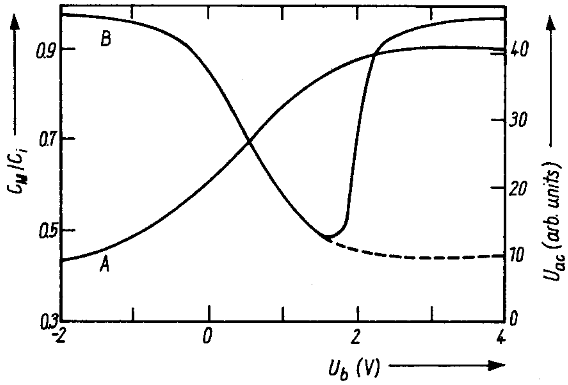


Fig. 2. Dependence of the acoustic rf signal on bias voltage (A). Dependence of the capacity of the MOS structure on bias voltage (B)

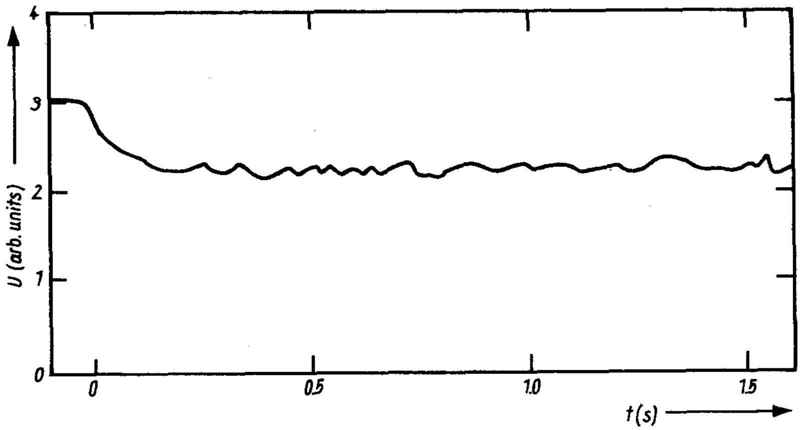


Fig. 3. Time dependence of the rf signal after step change of the bias voltage

and will be be periodically changed with the frequency $\omega$. Changing $E_1^y$ through the bias voltage, $U_{AC}$ is changed, too. The resulting effect will be the same as in case of one "window" of width $\lambda/2$. In the case of a thin oxide layer the following experimental arrangement is possible.

The surface of the studied MOS structure was metallised on the oxide side and placed on the shorted transducer, i.e. the whole surface of the oxide has the same potential. In such a situation the rf signal occurs as well. This fact can be explained by using capacity changes in that structure, which are plotted in Fig. 2. In the same figure the observed rf signal (with metallised oxide) versus bias voltage is plotted. The concentration of carriers for the theoretical capacity curve was $10^{23}$ $m^{-3}$ and for our sample $1.5 \times 10^{22}$ $m^{-3}$.

The layer thickness was the same and equal to 80 nm. It is clearly seen that by decreasing the capacity the rf signal becomes greater, i.e. the weakly coupled rf field of the SAW can produce a higher voltage.

The observed rf signal was also used for examining transient effects in MOS structures after step change of the bias voltage by using the experimental arrangement in Fig. 1. We have used the step change of the bias voltage from the state of accumulation to depletion on an n-type Si MOS structure.

The typical time dependence of the transient signal is shown Fig. 3. From the measured time dependences of the rf signal at different temperatures one can obtain the activation energies of energy levels, which are activated at definite temperatures (Fig. 4).

We have found two specific activation energies of 0.54 and 0.24 eV, respectively. These levels are known from /3/ and can be eventually attributed to the levels of gold and copper impurities.

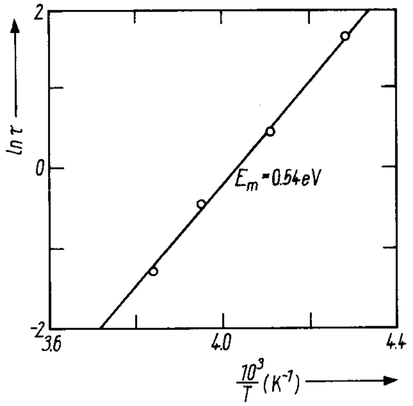


Fig. 4. Dependence of the relaxation time on 1/T

These results have been independently supported by Bury et al. /4/ using bulk acoustic waves.

Finally one can conclude that the rf signal obtained from MOS structures with metallised oxide gives similar transient curves as in the case of standard TAV techniques at rapid change of the bias voltage. The use of rf signals avoids the necessity to work with a broad-band dc amplifier. In the proposed configuration it is possible to test the complete MOS structure or the Schottky diodes.

References


/1/ I.J. FRITZ, J. appl. Phys. 52, 6740 (1981).

/2/ M. TABIB-AZAR, and P. DAS, Ultrasonic Symp. IEEE, 1985 (p. 1016).

/3/ M. TABIB-AZAR, M. DAS, and F. HAJJAR, IEEE Trans. Electron Devices 36, 1189 (1989).

/3/ S.D. BROTHERTON, P. BRADLEY, and J. BICKNELL, J. appl. Phys. 50, 3396 (1979).
D.V. LANG, H.G. GRIMMEISS, E. MEIJER, and M. JAROS, Phys. Rev. B 22, 3917 (1980).
N. TOYOMA, Solid State Electronics 26, 37 (1983).

/4/ P. BURY, I. JAMNICKÝ, and J. ĎURČEK, to be published.


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