ACOUSTIC INVESTIGATION OF OPTICALLY INDUCED DEEP CENTERS IN GaAs/AlGaAs HETEROSTRUCTURES

P. Bury [a], P. Hockicko [a] and V. W. Rampton [b]

[a] Department of Physics, Žilina University, 010 26 Žilina, Slovakia
[b] Department of Physics, Nottingham University, Nottingham, NG7 2RD, UK

Introduction Characterization of deep centers in GaAs/AlGaAs heterostructures based high mobility devices is extremely important since the presence of defects significantly affects device performance. The use of acoustoelectric interaction has recently proved valuable in the study of the deep centers in GaAs/AlGaAs heterostructures [1-3]. The acoustoelectric response signal (ARS) is observed at the heterojunction when a longitudinal acoustic wave propagates through the heterostructure. The ARS is extremely sensitive to any changes in the space charge distribution in the interface region due to the trapped charge after an injection pulse (optical or electrical) has been applied. So that their time development represents acoustoelectric transients which reflect relaxation processes associated with the thermal recombination of excited carriers moving towards their equilibrium state. By investigating the temperature dependence of the acoustoelectric transients characterizing the return to thermodynamic equilibrium, the deep center parameters can be determined by the acoustic deep-level transient spectroscopy (A-DLTS) technique [4,5]. Planar GaAs/AlGaAs heterostructures with both two dimensional electron system (2 DES) and two dimensional hole system (2 DHS) were investigated by optically induced acoustic deep-level transient spectroscopy (OI A-DLTS) using a method of computer evaluation of isothermal acoustoelectric transients. Several deep centers were found and their parameters are determined. A theoretical of the obtained results of acoustoelectric transient measurement has been also made.

Experiments and results The A-DLTS technique we used is based on the fact that the time development of the amplitude of the measured ARS after an injection optical pulse has been applied to the heterostructure is proportion to the nonequilibrium carrier density, so that the decay time constant associated with the relaxation of the acoustoelectric signal amplitude is a direct measure of the time constant associated with the relaxation processes of injected carriers.

The release of carriers from deep trap levels that leads to the thermal equilibrium on a new steady state has the dependence on time

$$\Delta n(t) = n_{t0} exp(-t/\tau), \tag{1}$$

where Δn_{t0} represents the variation in trap occupancy due to the acoustoelectric field and τ is the time constant associated with the release of the carriers from deep centers when illumination is turned off.

Using a method of computer evaluation of isothermal acoustoelectric transients by applying a data compression algorithm [5] in connection with the known relation expressing the temperature dependence of the relaxation time which characterizes the return to thermodynamic equilibrium, the activation energies and corresponding capture cross-sections can be determined form transient measurements of ARS. The experimental arrangement of A-DLTS technique has already been described [2,6].

We have investigated GaAs/AlGaAs heterostructure which has been grown by MBE in the form of planar structure with 2 DHS (NU 1323) and 2 DES (NU 1323) at heterojunction with two ohmic contacts reaching the heterojunction. For the optical excitation the IR-LED was used with the maximum in spectral characteristic of 900 nm and power density during used 200 ms wide pulse could reach 60 mW/Sr.

Representative A-DLTS spectrum of NU-1323 sample with 2 DHS recorded by applying an optical injection pulse contains one dominant peak (a) and four weaker ones (b-e). Using Arrhenius plots constructed from the positions of the maxima of the A-DLTS peaks, the following activation energies and corresponding capture cross-sections were determined: 1.29 eV (a); 0.33 eV (b); 0.73 eV (c); 0.61 eV (d); 0.56 eV (e) and $1.8 x 10^{-19}$ cm^2 (b); $9.2 x 10^{-12}$ cm^2 (c); $1.5 x 10^{-12}$ cm^2 (d); $1.3 x 10^{-12}$ cm^2 (e), respectively. The appearance of two broader peaks With some structure of smaller peaks is the characteristic feature of A-DLTS spectra obtained on NU 1787 sample containing 2 DES. The activation energies of 0.29 eV (1) and 0.10 eV (2) with corresponding cross-sections of $2.2 x 10^{-18}$ cm^2 (1) and $5.5 x 10^{-21}$ cm^2 (1), respectively were determined as parameters characterizing two broad peaks.

The obtained values are mostly in good agreement with the values found by both optically induced and other transient spectroscopy techniques [1,2,6-9] and attributed to DX centers or other defects. The experimental arrangement indicates that detected deep centers should be localized close to the two dimensional holes or electron system. However, some features found only by acoustic transient spectroscopy still remain unclear.

Conclusion In conclusion, the acoustoelectric investigation using the acoustic transient spectroscopy technique we present can be successfully used to study the deep centers in GaAs/AlGaAs heterostructures. Several deep centers attributed to the interface states in GaAs/AlGaAs heterostructures with both 2 DES and 2 DHS were discovered and their parameters were determined.

Acknowledgements The authors would like to thank Dr. M. Henini for growing the layers and Mr. F. Černobila for technical assistance. This work was partly supported by Grant No.1/8308/01 of Slovak Ministry of Education.

References

[1] Tabib-Azar M., Hajjar F.: IEEE Trans. Electron Dev. 36 (1989) 1189.
[2] Bury P., Jamnický I., Rampton V. W.: Physica B 263-264 (1999) 94.
[3] P. Bury, V. W. Rampton, P. J. A. Carter and K. B. McEnaney: Phys. Stal. Sol. (a) 133 (1992) 363.
[4] Jamnický I., Bury P.: Phys. Stat. Sol. (a), 139 (1993) K35.
[5] P. Bury, I. Jamnický: Acta Phys. Slovaca 46 (1996) 693.
[6] Bury P.: Proc. 16th Int. Congr. on Acoustics, Seattle, (1998), Vol. I, 431.
[7] As D. J., Eperlein P. W., Mooney P. M.: J. Appl. Phys. 64 (1988) 2408.
[8] Wang C. W., Wu C. H.: J. Appl. Phys. 74 (1993) 3921.
[9] Enriquez L., Duenas S., Barbola J., Izpura I., Muňoz E.: J. Appl. Phys. **72** (1992) 525.