

CHARACTERIZATION OF THE ELECTRICAL TRANSPORT PROPERTIES OF GaAs-n DETERMINED BY MAGNETORESISTANCE MEASUREMENTS

V. Ciupina

Department of Physics, Ovidius University of Constantza, RO-8700, Constantza, Romania

The magnetoresistance measurements have been made on the bulk-grown GaAs-n "sandwich" structures and on Gunn diodes without magnetic cap. The magnetoresistance mobility has been determined by measuring the variation of the active layer resistance in a low magnetic field oriented perpendicular to the electric field direction. For this purpose the metal-semiconductor contact resistance, determined from the structure resistance vs. the magnetic field intensity and the angle between the magnetic field and the electric field, has been used. The resistivity has been obtained from the active layer resistance and the sample geometry. The concentration of charge carriers has been determined from the resistivity and the Hall mobility.

Keywords: Magnetoresistance, GaAs – n sandwich structure, Semiconductor, Gunn diode

1. Introduction

In the case of a sandwich structure, i. e. a structure that contains a semiconductor active layer of a thickness sufficiently small as against the dimensions of the big surfaces on which metal contacts are deposited (Fig. 1), for the measured structure resistance R_m in the magnetic field, can be written the relation [1], [2]

$$R_m - R_c = \frac{R_0 \frac{\sigma_0}{\sigma_{\perp}}}{1 + \left(\frac{\sigma_{\parallel}}{\sigma_{\perp}} - 1 \right) \cos^2 \phi} \quad (1)$$

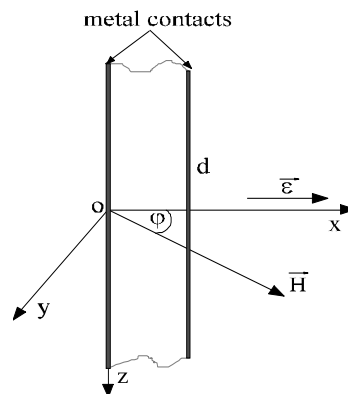


Fig. 1. "Sandwich" structure.

Here R_0 is the zero magnetic field active layer resistance, σ_0 the null magnetic field conductivity, σ_{\parallel} and σ_{\perp} the longitudinal and transversal magnetic field conductivity respectively ϕ the angle between the electric field and the magnetic field directions, and R_c the metal-semiconductor contact resistance independent of the direction and value of magnetic field intensity.

The relation (1) can be written in the form,

$$R_m(\phi, H) = \frac{A(H)}{1 + B(H)\cos^2\phi} + R_c \quad (1')$$

where there have been introduced $A(H) = R_0 \frac{\sigma_0}{\sigma_\perp}$ and $B(H) = \frac{\sigma_H}{\sigma_\perp} - 1$ which are constants for a given value of the magnetic field intensity.

At small magnetic field oriented perpendicular to the electric field direction, so that the condition $\mu_H H \ll 1$ may be satisfied, μ_H being the Hall mobility and H the magnetic field intensity, the following relation is possible [2], [3], [4], [5], [6], [7]

$$\frac{\Delta R}{R_0} = (\mu_m H)^2 \quad (2)$$

Here ΔR is the variation of the structure resistance with the magnetic field and μ_m magnetoresistance mobility, correlated with the Hall mobility by the relation [2]

$$\mu_m = \xi^{1/2} \cdot \mu_H \quad (3)$$

where ξ is the scattering coefficient depending on the scattering mechanism of the charge carriers.

The resistance R_0 can be obtained from the relation,

$$R_0 = R_m^0 - R_c \quad (4)$$

in which R_m^0 is the null magnetic measured resistance of the structure.

Measuring the structure resistance R_m for the various angles ϕ at a constant magnetic field value, the constants A , B and R_c can be obtained from the relation (1'), applying a computer program.

In order to obtain the magnetoresistance mobility μ_m we utilise the variation $\Delta R = R_m - R_m^0$ of the measured structure resistance at different values of the magnetic field intensity according to the relation (2). Knowing the coefficient ξ , the Hall mobility is determined on the basis of relation (3).

In order to determine the scattering coefficient ξ we have made the separate measurements. For the bulk - grown GaAs-n we have determined the Hall mobility by the help of van der Paw method [6] and then the coefficient ξ from the ratio μ_m/μ_H . In the case of epitaxial GaAs-n we have been considered the scattering coefficient practically equal to the unity [2].

Measuring the geometrical dimensions of the structure, with the help of R_0 we can obtain the resistivity ρ .

Utilising the resistivity ρ and Hall mobility μ_H the carrier concentration n can be obtained i.e.,

$$n = \frac{1}{\rho \mu_H e} \quad (5)$$

On the other hand, on the basis of the constants A , B and R_c , the ratios $\sigma_0/\sigma_\parallel$ and $\sigma_\parallel/\sigma_\perp$ can be obtained, which the information on the crystal anisotropy can give.

2. The experimental technique

The studies have been made on the bulk-grown GaAs-n samples on the direction $\langle 111 \rangle$ cut, (PV1, PV2, etc.), and on the epitaxial GaAs-n Gunn diodes without magnetic cap (PEI, PEII, etc).

The ohmic character of the contacts results from the linearity of the volt-ampere characteristics. The resistance of the structure has been measured by the compensation method.

3. Experimental results and interpretation

The experimental results obtained for a part of the utilised samples at the room temperature are presented in the Table 1.

Table 1. The experimental results for a part of utilised samples.

Sample	PV4	PV6	PV7	PV8	PV9	PEI	PEII
$R_c(\Omega)$	1.56	1.26	2.871	1.20	3.20	9.420	0.50
$\rho(\Omega \text{ cm})$	0.0795	0.0796	0.079	0.0974	0.0815	85.847	45.768
$\mu_m(\text{cm}^2/\text{Vs})$	6393	6203	6107	6495	6150	4817	7059
ξ	1.038	1.021	1.014	1.028	1.028		
$n(\text{cm}^{-3}) \cdot 10^{13}$	1087	1259	1291.75	1292	1279	1.50	1.99

The temperature dependence of the above parameters in the case of one of the GaAs-n bulk-grown samples is presented in Fig. 2.

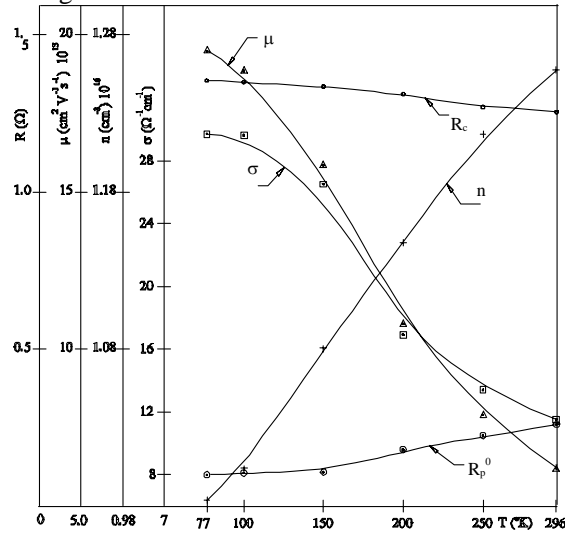


Fig. 2. The dependences $R_c=R_c(T)$, $R_p^0=R_p^0(T)$, $\sigma=\sigma(T)$, $\mu=\mu(T)$ and $n=n(T)$ in the case of bulk-grown GaAs-n sample PV7.

By determining the ratios $\sigma_0/\sigma_{||}$, σ_0/σ_{\perp} , and $\sigma_{||}/\sigma_{\perp}$ at different temperatures, the data presented in Fig. 3 have been obtained.

We can observe the fact that in the case of the bulk-grown samples the decrease of temperature determines the increase of the ratio $\sigma_0/\sigma_{||}$. In the case of the epitaxial samples this ratio is practically equal with the unity. Because the condition $\sigma_0 = \sigma_{||}$ is the complete isotropy condition and represents the proof of the sphericity of the conduction band minimum at $k=0$, we can conclude that the decrease of the temperature determine a apparent reduction of the symmetry of the crystal; this reduction can be correlated with the modification which appears in the structure of the Fermi surface [2].

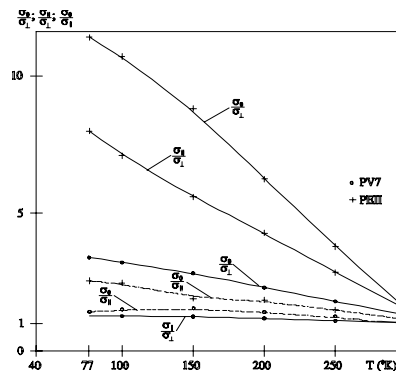


Fig. 3. Temperature dependencies $\sigma_0/\sigma_{||}$, σ_0/σ_{\perp} , and $\sigma_{||}/\sigma_{\perp}$ in the case of bulk-grown GaAs-n sample PV7 and epitaxial GaAs-n sample PEII.

4. Conclusions

- a) The geometrical magnetoresistance has been presented as a method of characterisation of some bulk-grown and epitaxial GaAs-n crystals, measuring the magnetoresistance mobility, Hall mobility and charge carrier concentration, in a wide temperature range.
- b) The ratios $\sigma_0/\sigma_{||}$, σ_0/σ_{\perp} , and $\sigma_{||}/\sigma_{\perp}$ have been determined between the liquid nitrogen temperature at the room temperature.
- c) On the basis of the temperature dependence of the ratio $\sigma_0/\sigma_{||}$, we conclude that the decrease of the temperature determines an apparent decrease of the crystal symmetric; this is interpreted as an effect of the modification which appears in the structure of the Fermi surface.

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