Journal of Optoelectronics and Advanced Materials Vol. 4, No. 4, December 2002, p. 975 - 978

SHORT COMMUNICATION

DETERMINATION OF THE SCATTERING COEFFICIENT FOR n-GaAs FROM MAGNETORESISTANCE AND HALL MOBILITIES

V. Ciupina

Department of Physics, Ovidius University, Constanta, Romania

The scattering coefficient was determined experimentally for bulk-grown n-GaAs semiconductor. For this purpose the magnetoresistance mobility and Hall mobility are measured. The magnetoresistance measurements have been performed on <111> bulk-grown n-GaAs sandwich structures in low magnetic field, in order to determine the magnetoresistance mobility. The Hall mobility has been obtained using the van der Pauw method. The scattering coefficient is close to unity and practically independent of temperature in a large temperature interval.

(Received September 23, 2002; accepted October 31, 2002)

Keywords: Scattering coefficient, Magnetoresistance mobility, Hall mobility, Sandwich structure

In the case of GaAs-n crystals, at room temperature, the calculation of the scattering coefficient, ξ [1, 2] where

$$\xi = (<\tau^3><\tau>)/(\tau^2)^2$$

(τ = relaxation time) is not possible, because, due to the main scattering mechanism by optical phonons, it is not possible to write an expression for the optical phonons relaxation time in the temperature range T<400 K [3]. On the other hand, to evaluate the relaxation time at room temperature, it is necessary to take into account the scattering by acoustic phonon and by ionised impurities. [4, 5]

To avoid the difficulties which occur in the case of the theoretical evaluation of scattering coefficient ξ, we have calculated ξ in an experimental way, from relation [6],

$$\xi^{\frac{1}{2}} = \frac{\mu_m}{\mu_H} \quad (1)$$

where μ_m is the charge carrier magnetoresistance mobility, and μ_H the Hall mobility.

To obtain the magnetoresistance mobility μ_m we have measured the geometrical magnetoresistance, i.e the magnetoresistance which is a consequence of geometry of the sample [1], in the case of the sandwich structure (Fig. 1). Here the thickness d of the active layer of the sample is much smaller than the dimensions of the lateral surfaces, considerated to be infinitely extended on which the metallic contacts have been attached.

In the case of the structure shown in Fig. 1, the magnetoresistance mobility μ_m is defined by relation [1],

$$\frac{\Delta R}{R_p^0} = \left(\mu_m H\right)^2 \quad (2)$$

where R_p^0 is the resistance of the active layer in zero magnetic field, ΔR the variation of active layer resistance as a consequence of the application of H magnetic field, perpendicular to the direction of the electric field intensity $\vec{\varepsilon}$ (Fig. 1). The mobility μ_m is obtained from the slope of the straight line $\frac{\Delta R}{R_p^0} = f\left(H^2\right)$ for magnetic field values which are low enough to meet the requirement $\mu_m H << 1$. To ensure the necessary accuracy in determining the magnetoresistance mobility we have been considered only the values of $\frac{\Delta R}{R_p^0}$ for H < 6 kG.

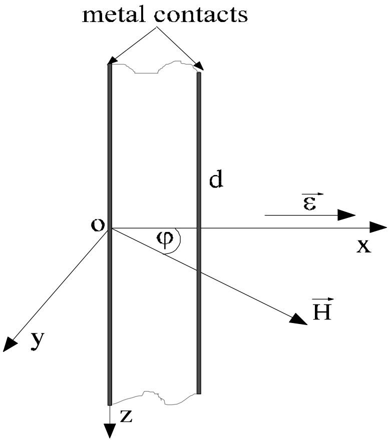

Fig. 1. Sandwich structure

The calculation of the magnetoresistance mobility requires the correct evaluation of the active layer resistance R_p^0; this must be separated from the metal-semiconductor contact resistance R_c which often influences decisively the measurement of the resistance in the magnetic field.

To obtain the metal-semiconductor contact resistance we have used the value of the sample resistance measured in a magnetic field, given by the relation, [1]

$$R_m(\varphi, H) = \frac{a(H)}{1 + b(H) \cdot \cos^2 \varphi} + R_c \tag{3}$$

where, a(H) and b(H) are constants for a given value of the magnetic field H, φ the angle between electric and magnetic field, and R_c the metal-semiconductor contact resistance. Such a dependence is presented in Fig. 2, in the case of sample V9, for different values of the magnetic field, at room temperature.

By fiting the theoretical relation (3) with the experimental data, the constants a and b and the metal-semiconductor resistance R_c can be obtained. The resistance of the active layer R_p^0 is obtained by subtracting the metal-semiconductor contact resistance R_c from the resistance of the structure in zero magnetic field R_m^0, i.e,

$$R_p^0 = R_m^0 - R_c \tag{4}$$

The Hall mobility μ_H in obtained using the van der Pauw method [7] on samples obtained from the same 250 μm material slice used for magnetoresistance measurements.

The experimental measurements of transport properties in n-GaAs were carried out according to [8].

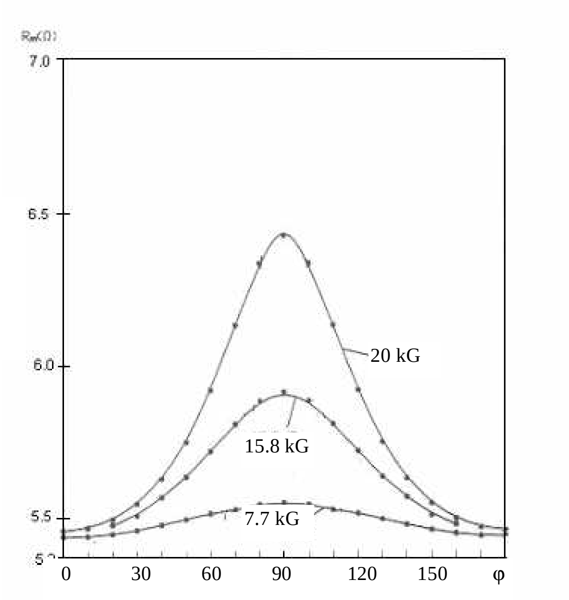

Fig. 2. The metal-semiconductor contact resistance versus the angle between electric and magnetic field.

The investigation was carried out on bulk-grown n-GaAs sample (V1, V2, ...) obtained from slices of n-type material 250 μm thick, cut beforehand in the direction <111>. Plates with an area of $\approx 1\text{cm}^2$ were detached from these slices. These plates were degresed by washing in an ultrasonic bath, in trichlorethylene and acetone of electronic purity, successively; the slices were then cleaned for 30 seconds in a sulphuric acid solution, oxygenated and bidistilled water at the ratio 3:1:1. After this chemical processing, an alloy of Au-12 % Ge-3% Ni was deposited by evaporation in vacuum of $\approx 10^{-5}$ torr on the surfaces of the slices; the depositing process was followed by a process of syntering for 2 min. at 450 ^{o}C. The surface area of the samples was situated between 0.25 mm^2 and 1.17 mm^2. Thin golden wires with a diameter of ≈30 μm were attached by thermocompresion.

The theory presented for a sample with an infinite surface is applicable in the case of real samples, with finite surfaces, only if the ratio between the thickness of the active layer and any of the linear dimensions of the contact surfaces is smaller then 0.39. The magnetoresistance mobility was obtained for the magnetoresistance sample by applying a corresponding correction for the finite area of the sample.

The sample used in the van der Pauw measurements has surface area of ≈ 12 mm^2. Before attaching the small contacts, the sample was chemically treated, as described above. The contacts have been obtain by diffusing tin on GaAs at temperatures between 450 and 500 ^{o}C, in pure argon atmosphere. The ohmic character of the contacts was also checked based on their volt-ampere characteristic. The resistance of the structures has been measured by the compensation method.

The values of the magnetoresistance mobility, the Hall mobility and the scattering coefficient ξ in the case of the sample denoted V19 at various temperatures, are presented in Table 1.

Table 1. The magnetoresistance mobility μ_m Hall mobility μ_H and coefficient ξ at various temperatures, in the case of the sample V19.

T(^{o}K)	77	100	150	200	250	296	320	350	375	400	425	450
μ_m (cm^{2}V^{-1}s^{-1})	19346	18200	14900	11500	8250	6284	-	-	-	-	-	-
μ_H (cm^{2}V^{-1}s^{-1})	19216	17775	14000	10550	7910	5946	5344	4897	4581	4275	4053	3853
ξ	1.014	1.048	1.132	1.188	1.084	1.109	-	-	-	-	-	-

One observes that the scattering coefficient ξ is close to unity and practically is independent of temperature. Such a conclusion also results from Table 2, where the scattering coefficient at different temperatures in the case of various bulk-grown n-GaAs samples is presented,

Table 2. The scattering coefficient ξ in the case of four bulk-grown n-GaAs samples at different temperatures.

Sample **T(K)**	**77**	**100**	**150**	**200**	**250**	**296**	**320**	**350**	**375**	**400**	**425**	**450**
V15	-	-	-	-	-	1.022	1.040	1.038	1.034	1.040	1.032	1.034
V17	1.060	1.089	1.194	1.218	1.140	1.054	-	-	-	-	-	-
V18	0.990	1.002	1.058	1.028	1.022	1.117	-	-	-	-	-	-
V19	1.014	1.048	1.132	1.188	1.084	1.109	-	-	-	-	-	-

In order to characterize the scattering coefficient with a good precision, at room temperature, we have calculated the average value of this coefficient $\bar{\xi}$, taking into account the values in this case of six bulk-grown GaAs-n samples (Table 3).

Table 3. The coefficient ξ for bulk-grown n-GaAs at room temperature.

Sample	V14	V15	V16	V17	V18	V19	
ξ	1.077	1.022	1.042	1.054	1.117	1.109	$\bar{\xi}$ =1.070

The value of the ratio $\frac{\mu_m}{\mu_H}$, based on the $\bar{\xi}$ from Table 3, i.e., $\frac{\mu_m}{\mu_H} = \left(\bar{\xi}\right)^{\frac{1}{2}} = 1.03 \pm 0.004$, is in good agreement with the value from literature [9].

For the temperature T > 400 K, it is possible to define a relaxation time for optical phonon scattering mechanism, which depends on energy as $\tau \approx E^{\frac{1}{2}}$ [10]. In this case, It is possible to calculate the ratio $\frac{\mu_m}{\mu_H} = 1.04$. The value obtained, 1.04, is in very good agreement with our own values of ξ, from Table 2, in the case of the sample V15 in the temperature range T > 400 K.

The scattering coefficient ξ, for bulk-grown n-GaAs, was obtained experimentally from the ratio of the magnetoresistance mobility μ_m and the Hall mobility μ_H.

Its value is close to unity and practically independent of temperature between 77 K and 450 K in very good agreement with the data reported in the literature.

References

[1] V. Ciupina, Rev. Roum. de Phys. **26** (2), 211 (1980).
[2] T. R. Jervis, E. F. Johnson, Solid State Electronics **13**, 181 (1970).
[3] R. D. Larabee, A. J. Gebler, B. W. Smith, Trans. I.E.E.E., vol. ED-17, 271 (1970).
[4] V. Ciupina, Photovoltaic and Optoelectronic Processes, Bucharest, p. 116 (1984).
[5] V. Ciupina, Third Internat. Conf. Trends in Quantum Electronics, Bucharest, Romania, p. 508 (1988).
[6] V. Ciupina, Rom. Rep. Phys. **46** (10), 945 (1994).
[7] L. J. van der Paw, Phil. Res. **13**, 1 (1958).
[8] V. Ciupina, J. Optoelectron. Adv. Mater. **2** (5), 589 (2000)
[9] A. C. Beer, J. A. Armstrong, I. N. Greenberg, Phys. Rev. **107**, 1506, (1957).
[10] H. Ehrenreich, J. Appl. Phys. Supl. **32**, 2155 (1961).