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A Study of the Change of Hall Effect as a Function of the V/III Ratio in n-GaAs compound Semiconductors

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In this study, the Hall effect has been studied in n-GaAs samples characterized by V/III growth ratios of 25, 50 and 100 and prepared by metal organic chemical vapor deposition. For the Hall effect measurements, the grown samples were cut to a size of 1×1 cm. The measurements were carried out at room temperature, using Indium contact metal at the four corners of the samples. According to the experimental results, the Schottky effect was not ovservation. Also for the n-GaAs sample of V/III 100 ratio the electron drift velocity was very high.

Keywords: n-GaAs, Electron carrier, sp3 hybridized orbital, Hall effect

1. INTRODUCTION

n-GaAs is a direct transition semiconductor which is useful for high speed active devices because of its high carrier mobility. In this paper the hall effect in this material is investigated and used to measure the carrier mobility as a function of the III-V compound ratio.

The n-GaAs crystal has the Zincblend structure, hybridized sp^3 orbitals and consists of two interpenetrating face-center cubic lattices each of which contains Ga and As atom, respectively. The n-GaAs crystal with electronic configurations of a Ga and As atom have the electronic stuctures $3d^{10}4s^24p^1$ and $3d^{10}4s^24p^3$, respectively[1].

Research on n-GaAs, a III-V compound semiconductor material has been carried since 1962 year particularly in the U.S.A at G.E with Hall, IBM with Nathan ans MIT with Suist. It has attracted attention both as an oscillator and semiconductor laser attention[2].

The samples studied in this paper were prepared using an by Axitron metal organic chemical vapor deposition system using organic metal TMGa and hybrid gas AsH_3.

2. THEORY

2.1 Mobility of the electron[3]

The electrical and optical properties of the material used for device fabrication are very important in the determination of the device performance. Mobility is one of these properties, which affects the carrier drift velocity and thus device speed and current handling capabilities under low electric field strengths is.

Since device speed depends strongly on the velocity of the carriers, high mobility is required to obtain a high-frequency response, Due to the low resistivity of high-mobility materials, devices fabricated from these materials can handle high current levels without excessive heating. High current levels are desirable in high-speed applications where the capacitances in the circuits need to be charged rapidly.

$$v = \mu E \tag{1}$$

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The carrier mobility is determined by a combination of scattering processes in the material and also depends on the temperature. In this study, the Hall effect has defined carrier mobility as the combination of mobilities due to different scattering mechanisms in the form

$$\frac{1}{\mu} = \sum_{i=1}^{j} \frac{1}{\mu_i} \tag{2}$$

Where j is the number of scattering mechanisms and μ_i is the mobility due to ionized impurity scattering which can be expressed by

$$\mu_i = \frac{64\sqrt{\pi\varepsilon_s^2}}{N_i q^3} \frac{(2kT)^{3/2}}{m^{*1/2}} \left\{ In\left[1 + \left(\frac{12\pi\varepsilon_s KT}{q^2 N_i^{1/3}} \right)^2 \right] \right\}^{-1} \tag{3}$$

Here N_i is the ionized impurity density, ε_s is the permittivity, T is the temperature, k is the Boltzmann constant and m^* is the effective mass, from we can see that μ_i is proportional to $(m^*)^{-1/2} N_1^{-1} T^{3/2}$. Therefore ionized impurity scattering is important in determining the mobility at low temperatures (low electron energy) and high ionized impurity densities.

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The mobility due to acoustic phonon scattering is given by

$$\mu_{AP} = \frac{\sqrt{2\pi c_{\ell} q h^4}}{D_A^2 m^{*5/2} (kT)^{3/2}} \tag{4}$$

where D_A is the acoustic deformation potential, h is Planck's constant and c_{ℓ} is the elastic constant, This expression is proportional to $(m^*)^{-5/2} T^{-3/2}$ which shows that the scattering mechanism is important at moderate of high temperatures.

In addition to these scattering mechanisms, optical phonon scattering is one of the dominant scattering mechanisms in polar semiconductors such as GaAs and alloy scattering is observed in alloy materials due to the random arrangement of the constituent atoms.

2.2 Hall measurement of the sample[3]

Hall measurements yield information about carrier concentration and mobility. Hall data also provide information on the electrically active impurities in a semiconductor. n-type semiconductor. With an electric field, E_x, applied in the x-direction and a magnetic field in the z-direction the Lorentz force on an electron in the y-direction is given by

$$F = qB_z v_x \tag{5}$$

Where q is the electronic charge and V_x is the electron velocity.

This force results in the piling up electrons in the y-direction at one side of the sample and an electric field E_y is produced in this direction. Since there is no current in the y-direction, E_y should balance the Lorentz force i.e.

$$qE_y = qB_z v_x \tag{6}$$

The current in the x-direction due to the applied field is given by

$$I_x = qwtnv_x \tag{7}$$

Using equation (7), (6) takes the form

$$qE_y = \frac{I_x B_z}{nwt} \tag{8}$$

The Hall coefficient R_H is defined by

$$R_H = \frac{wV_H}{I_x B_z} \tag{9}$$

Where V_H is the Hall voltage created in the y-direction due to E_y. Equations (8) and (9) give

$$R_H = -1/qn \tag{10}$$

3. EXPERIMENT AND MEASUREMENT

Metal organic chemical vapor deposition processes are widely used for the growth of n-GaAs compounds, In this research the homo epitaxy method was used to obtain 1.5 um thickness growths of n-GaAs on an undoped GaAs buffer wafers supplied by the Neosemitech company. The growth pressure and temperature were 160 mbare, and temperature 650.1°C respectively.

The growth high process was started after the reactor pressure had been at 995 mbar for tem minutes. After this time the scrubbing pump and connection pump by pass valves were opened and the reactor pressure fell to 990 mbar. During the metal organic chemical vapor deposition the gas flow velocity 10 m/s.

Three samples were produced with V/III compound ratios of 25, 50, 100, respectively and the n-type GaAs with doped SiH_2H_6 at a molecular concentration of 5×10^{18} cm^{-3} density.

The chemical reaction taking place in the GaAs growth is

$$\begin{aligned} &(C_2H_5)_3Ga + AsH_3 \rightarrow GaAs + 3C_2H_6 \\ &(CH_3)_3Ga + AsH_3 \rightarrow GaAs + 3CH_4 \end{aligned} \tag{11}$$

After the compound growth, the sample whose cross sectional dimensions were about 5 x 5 cm was cut to 1×1 cm for the purpose of the Hall effect measurements using the system shown in Fig. 1.

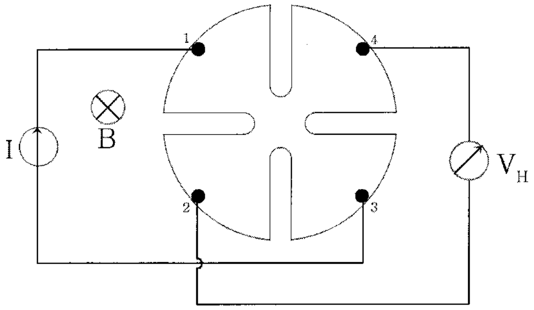

Fig. 1. Measurement method for the Hall effect.

4. RESULTS AND DISCUSSION

The Hall effect measurements are shown in Figs. 2, 3 and 4. In the graphs I-V curve data is presented both for contact point combinations 1,2 and 3,4. The sample with a V/III 25 growth ratio had the lowest Hall Mobility (853 cm^{2}Vsec).

One of the advantages of the I-V curve is that it can used for semiconductor device research.

Table 1. The dependence of Hall effect measurements in n-GaAs on the V/III ratio.

			V/III 25 ratio	V/III 50 ratio	V/III 100 ratio
Thickness of Sample			0.430 um	0.420 um	0.435 um
Hall effect	V-hall North	-24-	-2.95e-03	-3.37e-03	-6.49e-03
		+24+	+2.89e-03	+3.35e-03	+6.46e-03
		-13-	-2.97e-03	-3.32e-03	-6.00e-03
		+13+	+2.98e-03	+3.33e-03	+5.93e-03
	V-hall South	+24+	+2.91e-03	+3.24e-03	+5.83e-03
		-24-	-2.99e-03	-3.27e-03	-5.87e-03
		+13+	+2.89e-03	+3.28e-03	+6.31e-03
		-13-	+2.90e-03+	3.29e-03	6.40e-03
	Hall concentrated		-2.4 m^2/C	-3.07 m^2/C	-2 m^2/C
	Sheet concentrated		-2.604e+14 cm^{-2}	-2.036e+14 cm^{-2}	-3.127e+14 cm^{-2}
	Bulk concentrated		-6.055e+18 cm^3	-4.847e+18 cm^3	-7.188e+18 cm^3

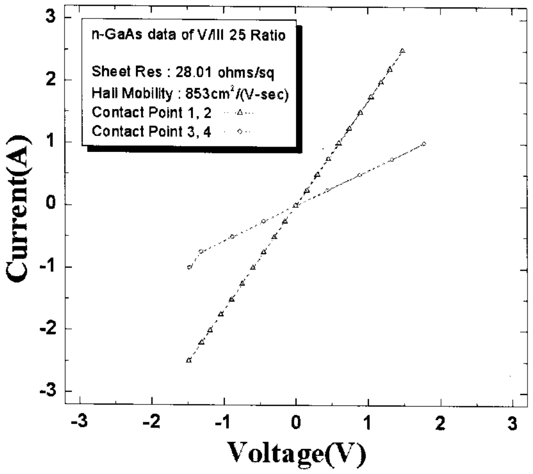

Fig. 2. The I-V Curve for the n-GaAs sample having a V/III ratio of 25.

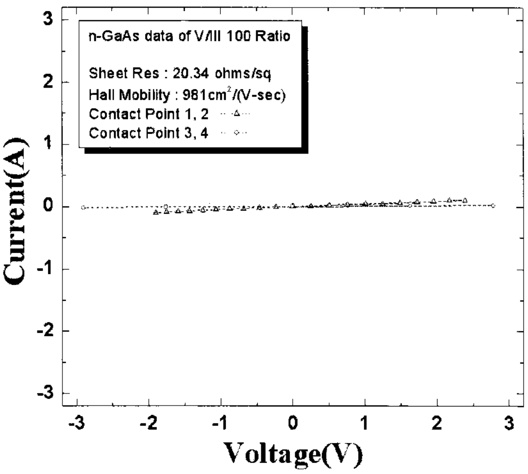

Fig. 4. The I-V Curve for the n-GaAs sample having a V/III ratio of 50.

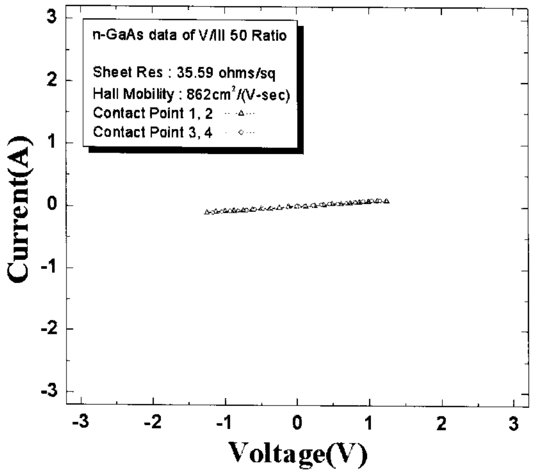

Fig. 3. The I-V Curve for the n-GaAs sample having a V/III ratio of 50.

I have been researched to the growth on the chance of n-GaAs semiconductor, electron movement, The ratio of growth with change electron have observation. The Fig. 2 graph have been showed. In the graph current (A) and Voltage(V) are plotted for the rectilinear sector. Also for the Fig. 3 and Fig. 4 graph at V/III 50 and V/III 100 ratio have been showed which V/III ratio on the GaAs sample respectively.

The energy band gap of the n-GaAs semiconductor is 1.53 Ev and 1.35 Ev at 0 K and 300 K respectively[4].

In this paper, the GaAs semiconductor V/III, which is sort of III-V, is analyzed for the effect of Hall by the ratios of 25, 50, 100. It is put in the operation of doping to intrinsic the semiconductor, which has the multi electronic carriers with the regular ration of Si_2H_6 to dope the properties of n-Type. Therefore, 3samples of semiconductor have the same consistency.

A recent study indicates that movement of carriers is faster when the ration of V/III grows. The gradient is higher when the ration of V/III decreases, but the graph had an angle of a gentle slope when the ration of V/III grows. Following the study of the Hall Effect, at the moment of t=0, which is the electric current that is sanctioned in the vertical way, sanctions an amperemeter.

The process of sanction occurs when an electron is moved though the amperemeter. The semiconductor GaAs, which is grown by the ration of V/III, gives an effect to the movement of carriers. The ration of V/III was set up differently when the semiconductor GaAs grows but in this time, there is no change in doping of the foreign matter of Si_2H_6. Therefore, the electrical characteristics are shown in the movement of the carriers in the semiconductor GaAs space according to the change in the movement of carriers and the change of the space lattice. Also, 3 of the semiconductor, GaAs, are grown by each ration of V/III, and it shows different thicknesses. That means the inner structure of the space lattice is changed by the ratio of V/III.

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