LD-5-6

A TWO-DIMENSIONAL ELECTRON GAS IN A NEW TYPE OF HETEROSTRUCTURE, InP/n-AlInAs

M. Inoue and S. Nakajima*

Osaka Institute of Technology, Department of Electrical Engineering, Ohmiya 5-16-1, Asahi-ku, Osaka 535. *Osaka University, Department of Electrical Engineering, Suita, Osaka 565; present address: Sumitomo Electric Indus. Ltd.

abstract

Two-dimensional properties of the electron gas in an InP/n-AlInAs heterostructures are reported. Quantum transport measurements provided the evidence of two-dimensional character of electrons confined in the InP layer of the heterostructures grown by a simple LPE growth thehnique. This new 2DEG system has enormous potentialities as a fundamental structure for higher frequency applications alternative to GaAs devices.

1. Introduction

Special interest has been offered to InP for a long time as a host material for high frequency devices since better performances in transferred electron devices were demonstrated in early 1970's. An InP has higher potentialities than GaAs for high frequency devices, because of the higher peak and saturation velocities of hot electrons. Therefore, various types of field effect transistors with insulated gate materials have been demonstrated. Although many oxide materials have been tried to make InP MOSFET, electron mobility in a channel is limited by dominant scatterings near the interface as expected in conventional MOS structures.

The purpose of this paper is to report the first observation of 2DEG confined in a new heterostructure, the selectively-doped InP/n-AlInAs. Quantum oscillations of magnetoresistance and quantum Hall steps are presented as an evidence of two-dimensional character of electrons confined in the InP layer of this system.

2. Two-Dimensional Electrons in the Heterostructure

The new heterostructure consists of n-type $Al_{0.48}In_{0.52}As$ and semi-insulating InP substrate as shown in a schematic diagram of Fig.1. There have been no published data concerning the conduction band discontinuity of InP/AlInAs as far as we know. From the results studied in the different types of heterostructures and metal-InP junctions, we can roughly estimate that the conduction bandedge discontinuity is about 0.2 eV.

The heterostructures were prepared by conventional liquid-phase epitaxial growth of AlInAs lattice-matched to InP (1). The electron density of 2DEG in the heterostructures was controlled by doping of silicon donors into AlInAs. The thichness of AlInAs layer is about 0.3 µm.

Magneto-transport properties of InP/n-AlInAs were studied at low tempratures, 4.2 and 1.8 K. Typical recorder traces of ρ_{xx} and ρ_{xy} are shown in Fig.2.

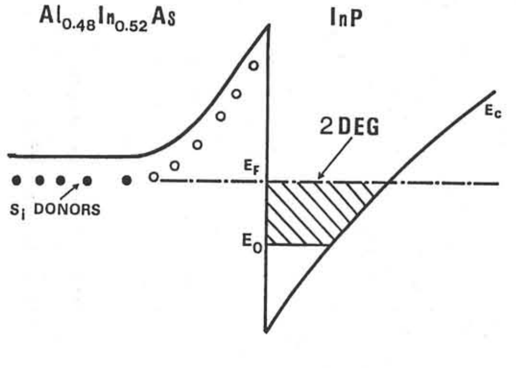

Fig.1 A schematic conduction band diagram of selectively-doped InP/n-$Al_{0.48}In_{0.52}As$.

High magnetic fields were applied perpendicular to the heterointerface. From the periodicity of the oscillating ρ_{xx} in 1/B, the sheet electron density is calculate to be $n_s=1.8 \times 10^{11}$ cm^{-2}. Assuming the relevant effective mass of InP ($m^*=0.080\ m_0$), we can obtain Fermi energy $E_F=5.4$ meV.

When a Landau level is completely filled, the diagonal conductivity σ_{xx} reaches zero at T=0. The condition $\sigma_{xx}=0$ $\rho_{xy}\neq 0$, implies that the 2D electron system is in a zero-resistance state, that is $\rho_{xx}=0$, at T=0 (2,3). The present data still shows somewhat resistivity of ρ_{xx} at the minima. The off-diagonal Hall resistivity is given by $\rho_{xy}=h/i \cdot e^2$, where i is the number of filled Landau levels(2). Figure 2 shows that ρ_{xy} becomes nearly constant around the magnetic field of 3.1T where ρ_{xx} reaches a minimum resistance. We can obtain the experimental resistivity for i=2, $\rho_{xy}=12.8\pm 0.2$ kΩ from a terraced structure of the trace shown in Fig.2. These experimental data are in good agreement with the theoretical values determined from the above relation whitin an experimental error. This indicates the distinctive characteristic of 2DEG in the heterostructure. Two-dimensional character of the system was also confirmed on magneto-transport measurements using the angle-dependence between magnetic fields and the heterointerface.

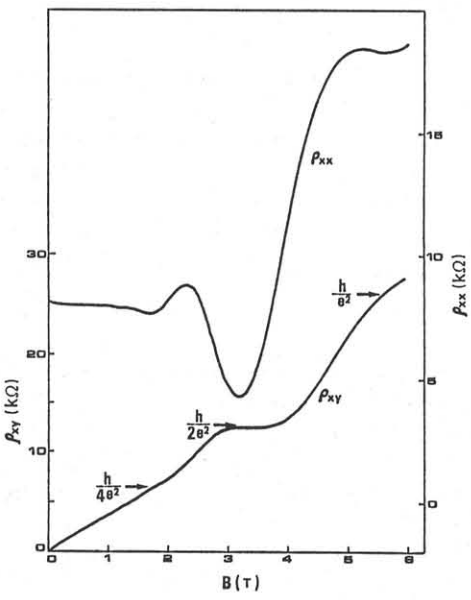

Fig.2 Plots of ρ_{xx} and ρ_{xy} as a function of magnetic field. The theoretical values of ρ_{xy} are also shown.

In comparison with the related data on prominent selectively-doped GaAs/n-AlGaAs(4), we can estimate electron mobility of the 2DEG in InP/n-AlInAs. We have observed much larger amplitude of quantum oscillations in the present experiment than that of oscillations measureed in the GaAs/n-AlGaAs grown by the same LPE technique (5,6). The averaged mobility of the heterostructure was higher than 10^4 $cm^2/V\cdot s$ at low temperatures,77 and 4.2 K. In addition, it should be noted that the present results were obtained by using the simple growth technique and much higher mobility may be achieved in specimens grown by a refined crystal growth technique.

3. Summary

We have reported the fundamental magneto-transport properties of the new heterostructure, InP/n-AlInAs, grown by the simple LPE method. Quantum oscillations of manetoresistance and quantum Hall steps were also presented as an evidence of the confinement of 2DEG in the heterostructure.

This system has enormous potentialities as a fundamental structure which will be widely used for high speed devices, such as HEMT, heterostructure bipolar transistor and opto-electronic devices.

References

1) K. Nakajima et al.Appl. Phys. Lett. 41, 194 (1982). 2) K. v.Klitzing et al. Phys. Rev. Lett. 45, 494 (1980). 3) H. Aoki et al. Solid State Commun. 38, 1079 (1981). 4) M. Inoue et al. Jap. J. Appl. Phys. 2, 357 (1982). 5) H. Hida et al. Techno. Rept. Osaka Univ. 32, 285 (1982). 6) D.C. Tsui et al. Appl. Phys. Lett. 35, 2 (1979).

Acknowledgement-We are grateful to Profs. Y.Inuishi and J.Shirafuji for their invariable supports over the past years. We are also indebted to Drs. H.Hayashi and K.Kikuchi of Sumitomo Electric Industries, Ltd. for kind supply of InP.