Extended Abstracts of the 19th Conference on Solid State Devices and Materials, Tokyo, 1987, pp. 515-516

B-9-3 (LN)

Fabrication of Narrow Two-Dimensional Electron Gas Channels in GaAs/AlGaAs Sidewall Interfaces by Selective Growth

Hiromitsu Asai, Syoji Yamada, and Takashi Fukui
NTT Electrical Communications Laboratories,
3-9-11 Midori-cho, Musashino-shi, Tokyo 180, Japan

Recently, quantum well wires (QWWs) have been receiving considerable attention because of their favorable properties such as very high mobilities [1]. Experimental attempts to fabricate QWWs by combination of etching and regrowth techniques have been reported [2]. However, the regrowth-interface quality is degraded due to surface contamination and damage induced by the etching processes. We fabricated for the first time narrow two-dimensional electron gas (2DEG) channels on sidewall surfaces by selective growth using the metalorganic chemical vapor deposition (MOCVD) method. The great advantage of this method is that damage- and contamination-free interfaces can be formed and that 2DEG channel width can easily be controlled down to 10nm.

The sample structure fabricated in this work is shown in Fig.1. The fabrication processes are as follows. First, 500A-thick SiO_2 stripe masks (5 μm wide lines and spaces) are oriented toward the $[1\bar{1}0]$ direction on a (001) GaAs substrate. Next, undoped GaAs is selectively grown in a mesa shape by MOCVD under an arsenic partial pressure ($[AsH_3]$) of 1.8×10^{-3}atm, and then, a 100A-thick spacer layer of undoped $Al_{0.3}Ga_{0.7}As$ and a 750A-thick Si-doped $Al_{0.3}Ga_{0.7}As$ layer are preferentially grown on sidewalls in the mesa-shaped GaAs under an $[AsH_3]$ of 7.4×10^{-3}atm. The sidewalls of the mesa stripe GaAs are found to correspond to the {111}A face from the angle (55^0) of the facets with respect to the (001) surface. Thus, a 2DEG channel strucure having a 4 μm width can be formed in GaAs/AlGaAs interfaces at the (111)A and $(\bar{1}\bar{1}1)$A facets in the mesa. A key point in this fabrication method is to control the formation of facets in the selective growth by $[AsH_3]$, on the basis of MOCVD edge growth mechanisms [3].

In order to confirm the existence of 2DEG on {111}A facets, the dependence of Shubnikov-de Haas (SdH) oscillation on the angle (θ) between the magnetic field and [001] directions was measured for a mesa-shaped bar (1.5mm long). Typical SdH oscillations for $\theta=0^0$, 55^0, 90^0 are represented in Fig.2. Note that a clear SdH oscillation was observed even at $\theta=90^0$, corresponding to a magnetic field parallel to the substrate surface.

Figure 3 shows the peak magnetic fields in the SdH oscillations against θ. Theoretical curves, that is the cosine dependences for 2DEGs at the (111)A and $(\bar{1}\bar{1}1)$A facets, are also drawn as dashed lines in this figure. The $\theta=\pm 55^0$ corresponds to normal directions with respect to the (111)A and $(\bar{1}\bar{1}1)$A facets. All experimental data were in good agreement with the theoretical curves, but there was no SdH oscillation peak corresponding to the 2DEG on the (001) surface. This means that the 2DEG exists only on the (111)A and $(\bar{1}\bar{1}1)$A facets in the mesa bars and that the 2DEGs on both the facets have exactly the same electronic structure. The sheet electron density deduced from the oscillations at $\theta=\pm 55^0$ was $1.42 \times 10^{12} cm^{-2}$ which occupies up to the first excited subband.

We have demonstrated a new fabrication method for realizing narrow 2DEG channels on sidewall facets. The 2DEG channel width can easily be controlled down to 10nm by adjusting the SiO_2 opening width and the mesa height.

[1] H.Sakaki, Jpn.J.Appl.Phys. **19**, L735 (1980).
[2] P.M.Petroff, A.C.Gossard, R.A.Logan, and W.Wiegmann, Appl.Phys.Lett. **41**, 635 (1982).
[3] H.Asai, J.Cryst.Growth **80**, 425 (1987).

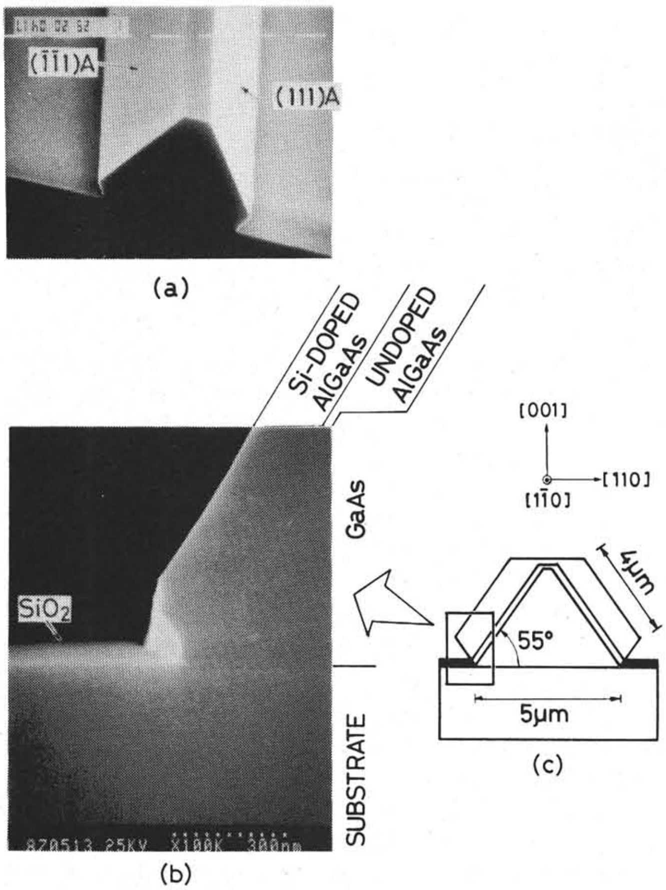

Fig.1 Sample structure: (a)SEM photogragh of a mesa bar (white bars denote 1 μm). (b)Enlarged SEM photogragh at the bar edge. (c)Schematic diagram of the bar structure.

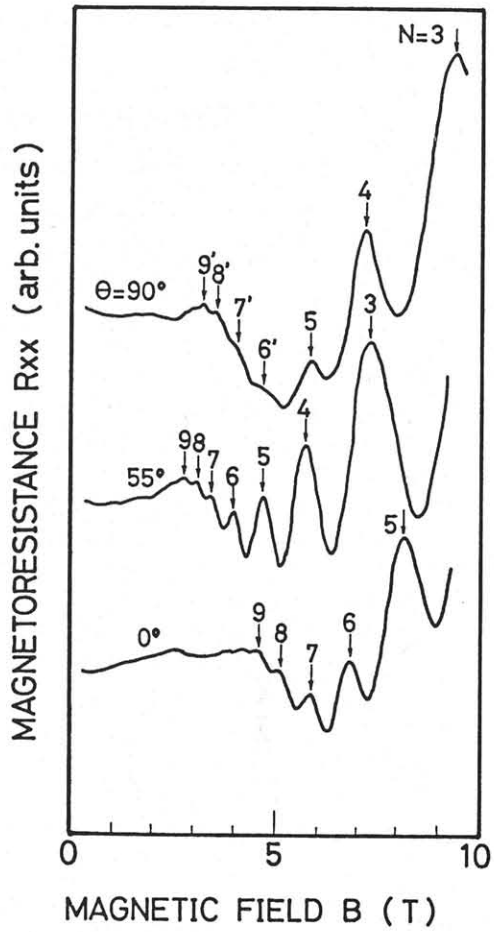

Fig.2 Longitudinal magnetoresistance as a function of magnetic field (SdH oscillation) for a mesa bar. θ denotes the angle of the magnetic field with respect to the [001] direction. Primed and non-primed Landau numbers, respectively, correspond to the oscillations of 2DEGs in the ($\bar{1}\bar{1}$1)A and (111)A facet interfaces (see Fig.1).

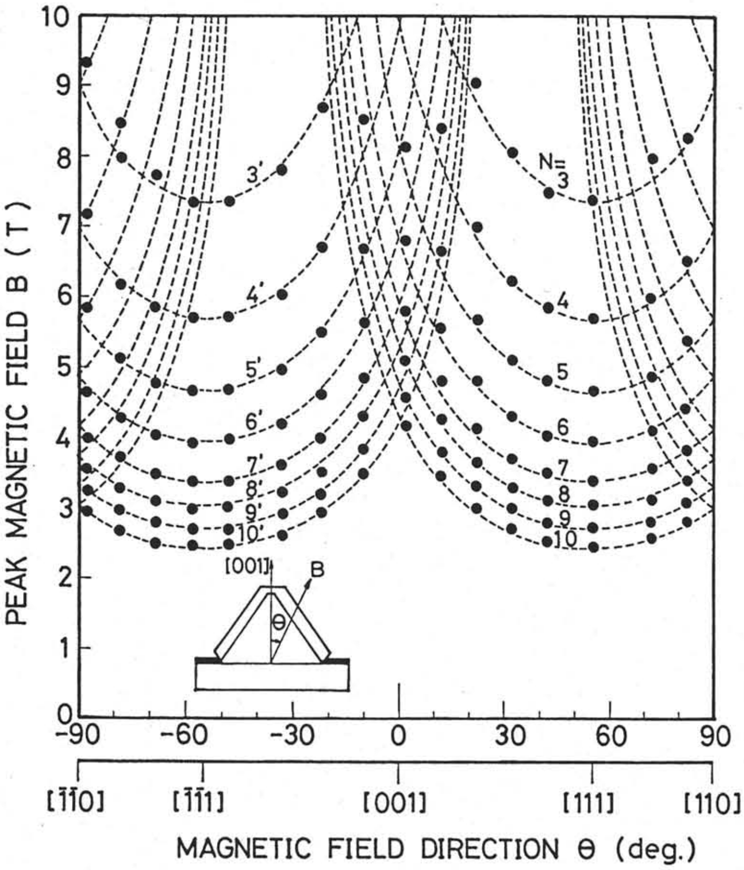

Fig.3 Peak magnetic fields of SdH oscillations as a function of the angle θ of the magnetic field with respect to the [001] direction, as shown in the inset. Dashed lines are the theoretical cosine dependences of the peak magnetic fields for 2DEGs at the (111)A and ($\bar{1}\bar{1}$1)A interfaces ($\theta = \pm 55^0$).