Extended Abstracts of the 1991 International Conference on Solid State Devices and Materials, Yokohama, 1991, pp. 723-724 **PB8-L1**

A Possible New Structure for One-Dimensional Electron Gas Systems by Interface Bending of n-AlGaAs/u-GaAs Heterojunctions

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Recently, considerable attention has been paid to one-dimensional electron gas (1DEG) systems for possible applications to high-speed devices[1-3]. In this letter, we propose a new concept of achieving a 1DEG system by periodically bending the hetero interface of an n-AlGaAs/u-GaAs structure and show numerical evidence for the 1DEG structure using a device simulator based on the classical drift-diffusion model[4].

A saw-toothed n-AlGaAs/u-GaAs structure is shown in Fig.1 as an example of the bending interface structure. Here, $\lambda/\sqrt{2}$ is the period of the bending interface and the parameters used here are given in the figure caption. The depletion layer of n-AlGaAs is shown by the hatched area in Fig.1. The interface bending causes non-uniformity of the electron density because the depletion depth is shallower near point A and deeper near point B than that of the flat n-AlGaAs/u-GaAs interface, i.e., electrons in the n-AlGaAs near point B shift to the undoped GaAs near point A. Spatial distribution of the calculated electron density n(x,y) is shown in Fig.2 for λ=1200Å as an example. About double electron density near point A compared to that of the flat interface is produced by the bending of n-AlGaAs/u-GaAs interface. It does not appear in the conventional 1DEG structure by etching techniques[2,3]. The high density (near point A) of electrons will be applicable as a 1DEG channel for 1DEG-FETs.

In order to find the specific period of interface bending, regarding the accumulated electrons near point A as a 1DEG channel without a parastic 2DEG region, we introduce the local sheet density as $n_{local}(x)=\int^{y} n(x,y)dy$, and the averaged local sheet density as $n_{av} = \int^{\lambda} dx n_{local}(x)/(\lambda/\sqrt{2})$. Fig.3(a) shows the x dependence of $n_{local}(x)/n_{2D}$ for λ=1200, 2000 and 4000Å, where n_{2D} is the electron sheet density of the flat n-AlGaAs/u-GaAs interface. As λ decreases, the region of $n_{local}(x) \cong n_{2D}$ becomes small, i. e., the region of the parastic 2DEG behavior disappears and one dimensionality is enhanced. On the contrary, the λ dependence of n_{av}/n_{2D} in Fig.3(b) shows that n_{av} decreases as λ decreases. The large value of λ is suitable for FET applications. We define the specific λ_s to satisfy the inequality $n_{av} \geq n_{2D}$ and to assure one dimensionality. It means that λ_s keeps the nearly same number of electrons of the flat 2DEG structure. Therefore λ_s is estimated to be 1200Å from Fig.3(a) and (b). In this case the period of the bending interface of n-AlGaAs/u-GaAs is about 850Å, which is a realizable pitch by using the most advanced lithography[5].

A shape of an actual electron density n(x,y) near point A will be different from that of Fig.2 because of wave nature of confined electrons. However, the classically calculated sheet density of Fig.3(b) will reproduce actual sheet density n_{av} because n_{av} itself is determined by the surface integral over a closed surface of the normal component in the electric field.

A practical advantage of the proposed 1DEG structure is to keep the channel electrons as high as the flat 2DEG structure which comes from the densely packed 1DEG channel lines. The proposed 1DEG structure will open a new field for high-speed devices.

References

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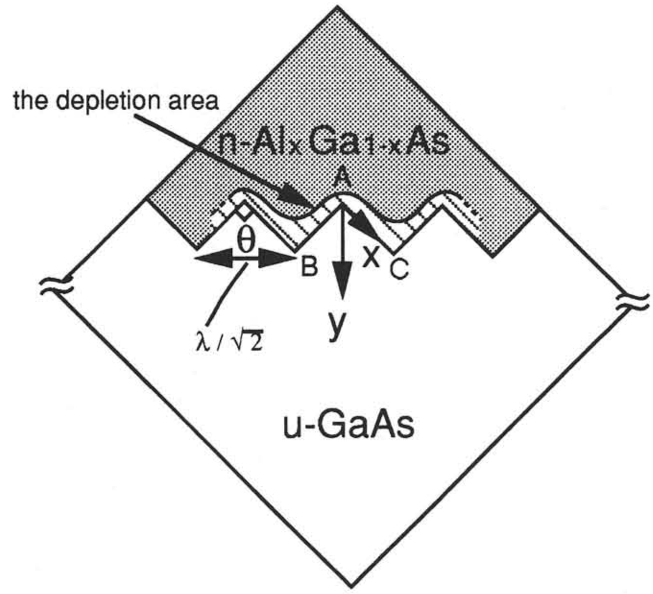

Fig.1 A cross sectional view of the calculated n-AlGaAs/u-GaAs bending interface structure. Doping concentration of n-$Al_xGa_{1-x}As$ is 1.0×10^{18} cm^{-3} and x=0.3. Concentration of p-GaAs is 1.0×10^{14} cm^{-3} and θ=90° The x and the y axes are along the line AC and perpendicular to the line BC, respectively. A side of the lozenge is 5μm.

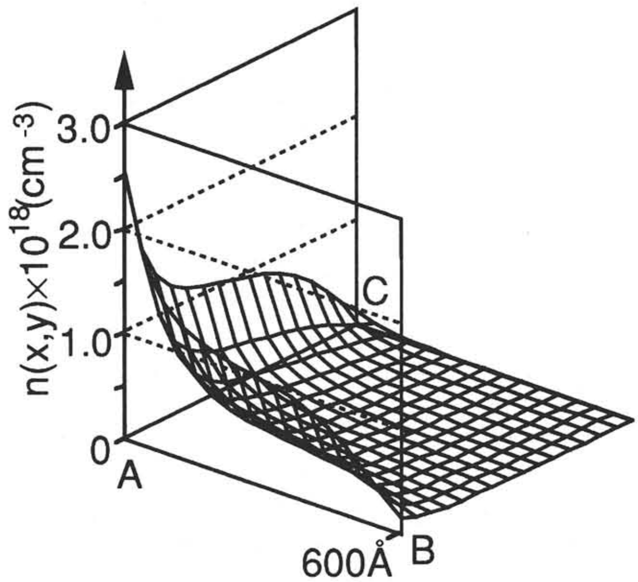

Fig.2 Distribution of the calculated electron density n(x,y) at the GaAs side of the bending of n-AlGaAs/u-GaAs interface for λ=1200Å.

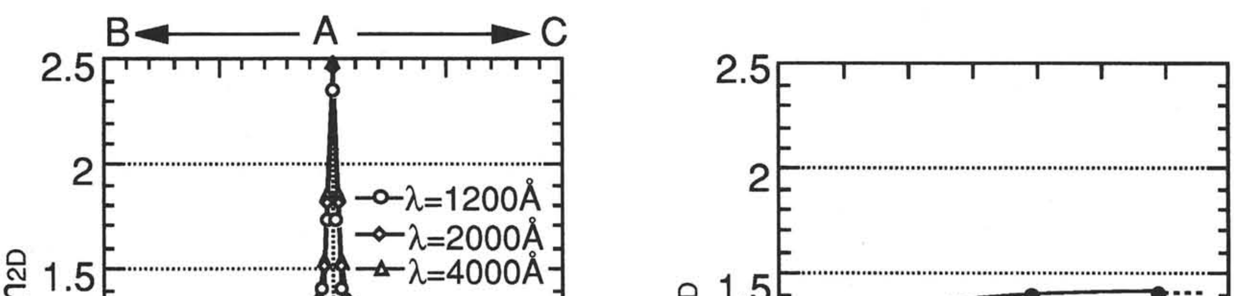

Fig.3 (a) x dependence of the local sheet density n_{local} for λ =1200, 2000, and 4000Å and (b) λ dependence of the averaged sheet density n_{av}, scaled by the sheet density n_{2D} of the flat n-AlGaAs/u-GaAs interface.