

be very critical to realize the control of band offsets as theoretically predicted.

Si (0-1 ML) and AlAs (30 Å) layers were grown on As-stabilized and Ga-stabilized (100) (denoted by (100)Ga and (100)As, respectively), (110), and (311)A oriented GaAs substrates by molecular beam epitaxy. Apparent VBO, (ΔE_v), was evaluated by in-situ XPS measurements [3]. ΔE_v decreases monotonously by ~0.4 eV when d increases from 0 to ~0.5 ML and saturates at ΔE_v ~0 eV, almost independent of the orientation.

The results for the (100)As interface agree well with the results in [2] as well as with the theoretical prediction when $d \leq 0.5$ ML. However, the experimental results for the (100)Ga, (110) and (311)A orientations disagree with the theoretical prediction: theoretically the VBO should increase for the (100)Ga and remain unchanged for the (110) orientation, while the experimental data decreased monotonously until $d = 0.5$ ML as being the same as in the (100) orientation. This disagreement shows that the interface dipole is not effectively formed by the Si layer insertion. This change in ΔE_v can rather be explained by the band bending in the AlAs overgrown layer caused by ionized Si-donors which should be independent of the crystal orientation.

In order to clarify why the interface dipole is not formed in our samples, we calculated by the tight binding method the interface dipole potential formed by Si layers in the following two structures; One consists of Si layers which fully occupy an As layer and a Ga layer at an AlAs/GaAs interface (ideal case) and the other consists of Si atoms distributed in an interface group-III site and two As sites next to the interface (diffused-Si case). It is found that the interface dipole potential is ~1.6 eV for the ideal case and only ~0.2 eV for the diffused-Si case, showing that a precise site control of Si atoms is essential to form an ideal interface dipole and to change the band offset.

We also formed a GaAs/AlAs (311)A heterostructure with a p-type Si-doped GaAs layer and a Si δ -doped (n-type) layer to show a possibility to control a band offset, while suppressing a band bending. We have obtained an evidence of the band-offset change. The details will be presented at the conference.

- [1] A. Muoos et al. Phys. Rev. B 41, 2976 (1990).
- [2] L. Sorba et al. Phys. Rev. B 43, 2450 (1991).
- [3] Y. Hashimoto et al. Proc. ICPS (1992); Proc. Int. Symp. GaAs Related Compounds (1992).

Thursday, June 24, 1993, AM

Session F1: SiGe Electrical and Optical Properties

Room: Engineering II Conference Room

Session Chairman: Y.H. Xie, AT&T Bell Laboratories, 600 Mountain Ave., Murray Hill, NJ 07174

Co-Chairman: Meyerson, J. Watson Research Center, Post Office Box 218, Yorktown Heights, NY 10598

8:20 AM, F1+

Effect of Alloy Scattering on Low Temperature Mobilities of Two-dimensional Holes and Electrons in Si/Si_{1-x}Ge_x Heterostructures:
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There has been great interest recently in the study of two-dimensional electron and hole systems in Si/Si_{1-x}Ge_x modulation doped heterostructures. Although electron mobilities in strained Si have surpassed 100,000 cm²/V·s, the best hole mobilities in strained Si_{1-x}Ge_x reported so far are below 7000 cm²/V·s. Previous workers have attributed the low mobility of holes to either coulombic scattering from ionized impurities, higher effective masses, or interface scattering due to poor sample quality. However these mechanisms do not explain the big order of magnitude difference in electron and hole mobilities of similar samples. In this paper, we experimentally show that this difference is due to the fundamental effect of alloy scattering in the Si_{1-x}Ge_x and establish the first determination of the strength of the Si_{1-x}Ge_x alloy scattering potential in a 2-D system.

Both n-type modulation doped structures (on relaxed

Si_{0.65}Ge_{0.35} substrates) and p-type modulation doped structures (on silicon substrates) were fabricated using rapid thermal chemical vapor deposition. The germanium concentration in the channel was varied from 0 to 20% while fixing the other parameters of the structure. Temperature dependent Hall measurements confirm the presence of a degenerate two-dimensional carrier system in all samples. The electron mobilities at 10 K were determined to be 15000, 3000 and 2500 cm²/V·s for 0, 12 and 20% germanium channels, respectively. The strong decrease of the low temperature mobility with increasing germanium concentration in the channel clearly proves the strong effect of alloy scattering. Despite slightly lower in-plane effective masses, the electron mobilities are, however, lower than hole mobilities for the same germanium concentration because of the extra effect of strong intervalley scattering caused by the alloy disorder (an effect unique to electrons). By fitting the mobilities measured to the correct expression for alloy scattering in two-dimensional systems, we obtain an effective scattering potential of 0.55 eV. Using this value, we show that maximum hole mobilities in Si_{1-x}Ge_x channels cannot exceed 10,000 and 6000 cm²/V·s for $x=0.1$ and 0.2 respectively, consistent with our data and other published results, (6000 and 3500 cm²/V·s for electrons).

8:40 AM, F2+

Velocity-Field Characteristics and Alloy Scattering in Si_{1-x}Ge_x:S-H.
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Si_{1-x}Ge_x alloys and SiGe/Si heterostructures are currently of immense interest due to the potentially useful electron and optical properties and compatibility with existing Si technology. The built-in strain in pseudomorphic alloys alters the bandstructure and carrier transport properties. No report on the experimental determination of the high-field transport in these alloys has been made. We will describe our work on the theoretical and experimental determination of the velocity-field characteristics in relaxed and coherently strained n- and p-type Si_{1-x}Ge_x ($0.1 \leq x \leq 1.0$). The alloy scattering potential in the material has also been estimated.

Relaxed (1-2 μm thick) and coherently strained Si_{1-x}Ge_x/Si heterojunctions were grown on (001) Si substrates by molecular beam epitaxy using gaseous disilane and solid Ge as sources. The undoped SiGe was n- type and p-type doping was achieved with solid B. The velocity-field characteristics at room temperature were obtained from pulsed current-voltage measurements on planar H-devices. The velocity increases monotonically with Ge content for the same applied field. As an example, in relaxed Si_{0.7}Ge_{0.3}, the electron velocity is 5×10^6 cm/s and in coherently strained Si_{0.87}Ge_{0.13} at 3kV/cm the in-plane hole velocity is $\sim 2 \times 10^6$ cm/s at 3 kV/cm.

A Monte Carlo calculation is carried out to study the effect of alloying and strain on the velocity-field relations of electrons and holes in the strained and relaxed SiGe alloys. The hole transport involves (a) the use of a (6 x 6) k-p formalism to identify the bandstructure of the alloy valence band with inclusion of the deformation potential theory, and (b) a Monte Carlo calculation retaining the anisotropic nature of the valence band. The electron transport uses an anisotropic conduction band where the valley degeneracies are affected by the strain in the system. The theoretical work is compared with the experiments to identify the role of alloy scattering. An alloy scattering potential of 0.2 eV for the holes and 0.5 eV for electrons is found to provide a good agreement with the experiments.

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9:00 AM, F3

Luminescence Characterization of Gas-Source-Grown Strained Si_{1-x}Ge_x/Si Quantum Wells: S. FUKATSU, H. Sunamura, N. Usami, Y. Kato and Y. Shiraki Research Center for Advanced Science and Technology (RCAT), The University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153, Japan

Luminescence characterization of strained Si_{1-x}Ge_x/Si quantum wells (QWs) grown by gas source Si molecular beam epitaxy (Si MBE) is presented.

It is addressed that the selection of appropriate growth temperature,